BRITISH STANDARD

BS EN 14500:2008

Blinds and shutters — Thermal and visual comfort — Test and calculation methods

ICS 91.060.50

British Standards

National foreword

This British Standard is the UK implementation of EN 14500:2008.

The UK participation in its preparation was entrusted by Technical Committee B/538, Doors, windows, shutters, hardware and curtain walling, to Subcommittee B/538/3, Domestic shutters and blinds.

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

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Abschlüsse - Thermischer und visueller Komfort - Prüf- und Berechnungsverfahren

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Contents

Foreword

This document (EN 14500:2008) has been prepared by Technical Committee CEN/TC 33 “Doors, windows, shutters, building hardware and curtain walling”, the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by November 2008, and conflicting national standards shall be withdrawn at the latest by November 2008.

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Introduction

This European Standard is part of a series of standards dealing with blinds and shutters for buildings as defined in EN 12216.

This European Standard is mainly based on the European work performed in CEN/TC 89 "Thermal performance of buildings and building components" relating to solar and light transmittance of solar protection devices combined with glazing, and the document CIE 130.

1 Scope

This European Standard defines test and calculation methods for the determination of the reflection and transmission characteristics to be used to determine the thermal and visual comfort performance classes of external blinds, internal blinds and shutters, as specified in EN 14501.

This European Standard also specifies the method to determine opacity characteristics of dim-out/black-out external blinds, internal blinds and shutters, as specified in EN 14501.

This European Standard applies to the whole range of shutters, awnings and blinds defined in EN 12216, described as solar protection devices in this European Standard. Some of the characteristics (e.g. g_{tot}) are not applicable when products are not parallel to the glazing (e.g. folding-arm awnings).

NOTE Informative Annex D presents an approach for the determination of characteristics in case of projectable products.

Products using fluorescent or retroreflecting materials are outside the scope of this European Standard.

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.

CIE 130:1998, *Practical methods for the measurement of reflectance and transmittance*

EN 410, *Glass in building – Determination of luminous and solar characteristics of glazing*

EN 12216:2002, *Shutters, external blinds, internal blinds – Terminology, glossary and definitions*

EN 13363-1, *Solar protection devices combined with glazing – Calculation of solar and light transmittance – Part 1: Simplified method*

EN 13363-2:2005, *Solar protection devices combined with glazing – Calculation of total solar energy transmittance and light transmittance – Part 2: Detailed calculation method*

EN 14501:2005, *Blinds and Shutters – Thermal and visual comfort – Performance characteristics and classification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12216:2002, EN 14501:2005 and the following apply.

3.1 Processes

3.1.1
reflection
process by which radiation is returned by a surface or medium, without change of frequency of its monochromatic components

The following sub-processes are defined herewith:

— Specular (or directional or regular) reflection: reflection in accordance with the laws of geometrical optics, without diffusion

— Diffuse reflection: reflection due to light scattering, in which, on the macroscopic scale, there is no specular reflection

— Direct-hemispherical (or mixed) reflection: partly specular and partly diffuse reflection. Direct-hemispherical reflection is the sum of the diffuse and specular reflection

— Isotropic diffuse reflection: diffuse reflection in which the spatial distribution of the reflected radiation is such that the radiance or luminance is the same in all directions in the hemisphere into which the radiation is reflected

3.1.2
transmission
passage of radiation through a medium without change of frequency of its monochromatic components

The following sub-processes are defined herewith:

— Directional (or direct-direct) transmission: transmission in accordance with the laws of geometrical optics, without diffusion or redirection

— Diffuse transmission: transmission due to light scattering, in which, on the macroscopic scale, there is no direct transmission

— Direct-hemispherical (or mixed or total) transmission: partly directional and partly diffuse transmission. The direct-hemispherical transmission is the sum of the diffuse and direct transmission

— Isotropic diffuse transmission: diffuse transmission in which the spatial distribution of the transmitted radiation is such that the radiance or luminance is the same in all directions in the hemisphere into which the radiation is transmitted

3.1.3
absorption
process by which radiant energy is converted to a different form of energy (e.g. heat) by interaction with matter

3.2 Characteristics

3.2.1
reflectance
ρ
ratio of the reflected flux to the incident flux

The following sub-characteristics are defined:

- Directional-directional (or direct-direct) reflectance: ratio of the specularly reflected flux to the directional incident flux
- Directional-diffuse reflectance: ratio of the diffusely reflected flux to the directional incident flux
- Directional-hemispherical (or total) reflectance: ratio of the total reflected flux to the directional incident flux
- Diffuse-hemispherical reflectance: ratio of the total reflected flux to the ideally diffuse incident flux. Ideally diffuse irradiation means that the radiance or the luminance is equal for the whole hemisphere of the incident irradiation

3.2.2
transmittance
τ
ratio of the transmitted flux to the incident flux

The following sub-characteristics are defined:

- Directional-directional transmittance: ratio of the directly transmitted flux to the directional incident flux
- Directional-diffuse transmittance: ratio of the diffusely transmitted flux to the directional incident flux
- Directional-hemispherical transmittance: ratio of the total transmitted flux to the directional incident flux
- Diffuse-hemispherical transmittance: ratio of the total transmitted flux to the ideally diffuse incident flux. Ideally diffuse irradiation means that the radiance or the luminance is equal for the whole hemisphere of the incident irradiation

3.2.3
absorptance
α
ratio of the absorbed flux to the incident flux

3.3 Angle definitions

3.3.1 General

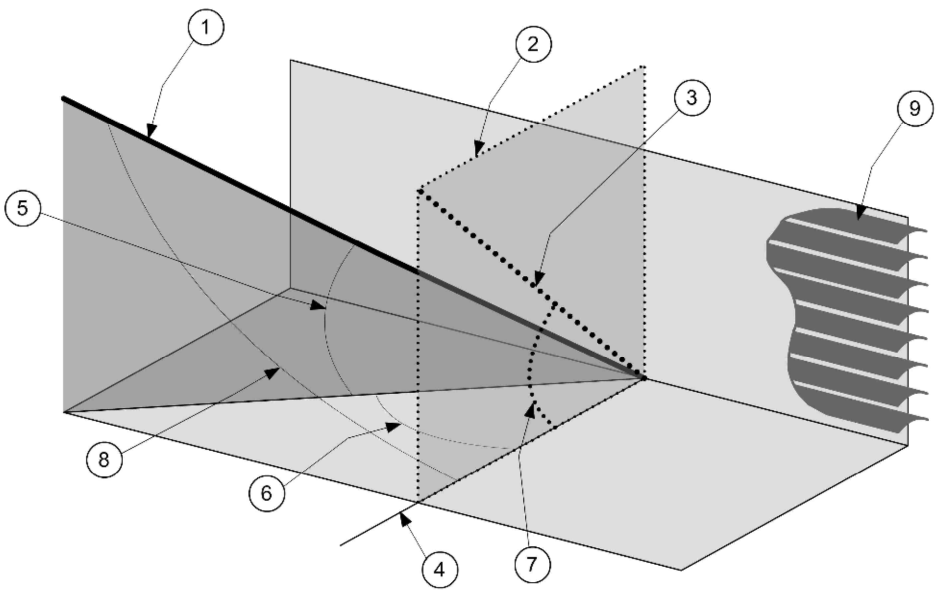
All the following angles are defined in a coordinate system which is fixed relative to the orientation of the solar protection device

3.3.2
angle of incidence
θ
angle between the normal to the plane of the solar protection device and the direction of the incident radiation (see Figure 1)

3.3.3
altitude angle
α_s
projection of the angle of incidence on the vertical plane which contains the direction of the incident radiation (see Figure 1)

3.3.4
azimuth angle
γ
projection of the angle of incidence on a plane which is normal to the plane of the solar protection device. The intersection of this projection plane and the plane of the solar protection device is horizontal (see Figure 1)

3.3.5
profile angle
α_p
projection of the altitude angle on a vertical plane which is perpendicular to the façade under consideration (see Figure 1). The profile angle is given by the following formula: tg α_p = tg θ / cos γ



Key

1	Direction of the incident radiation
2	Vertical plane normal to the solar protection device
3	Projected direction of the incident radiation
4	Direction normal to the solar protection device
5	Altitude angle (angle in the vertical plane)
6	Azimuth angle (angle in the horizontal plane)
7	Profile angle
8	Angle of incidence
9	Solar protection device

Figure 1 – Angle definitions

4 Notations used

4.1 General

For the purpose of this document, the optical factors τ (transmittance), ρ (reflectance) and α (absorptance) are labelled with subscripts which indicate:

— The visual or solar properties;

— The geometry of the incident and the transmitted or reflected radiation.

4.2 Visual or solar properties

According to the respective spectrum, the following subscripts are used:

— « $_e$ » solar (energetic) characteristics, given for the total solar spectrum (wavelengths λ from 300 nm to 2 500 nm), according to EN 410;

— « $_v$ » visual characteristics, given for the standard illuminant D_{65} weighted with the sensitivity of the human eye (wavelengths λ from 380 nm to 780 nm), according to EN 410.

4.3 Geometry of the radiation

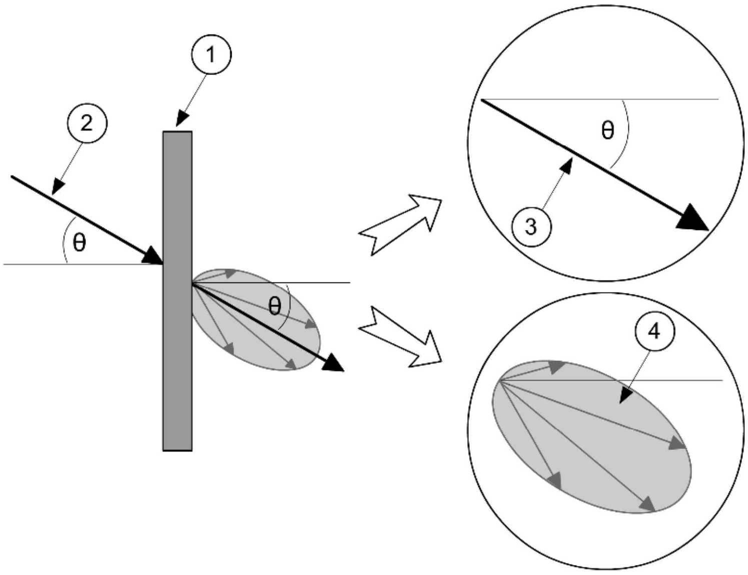
The following subscripts are used to indicate the geometry of the incident radiation and the geometry of the transmitted or reflected radiation (see Figure 2).

— « $_{dir}$ » for directional (fixed, but arbitrary direction θ);

— « $_n$ » for normal, or near normal in case of reflected radiation, the angle of incidence is $\theta = 0°$, or $\theta \leq 8°$ respectively;

— « $_h$ » for hemispherical (collected in the half space behind the sample plane);

— « $_{dif}$ » for diffuse.



Key

1 Solar protection device
2 Incident directional light or solar radiation
3 Transmitted direct component of light or solar radiation
4 Transmitted diffuse component of light or solar radiation

Figure 2 — Direct and diffuse components of transmitted radiation

4.4 Optical factors

The optical factors are designated as follows:

- $\tau_{e, n\text{-}n}$ normal-normal solar transmittance
- $\tau_{v, n\text{-}n}$ normal-normal light transmittance
- $\tau_{v, n\text{-}dif}$ normal-diffuse light transmittance
- $\tau_{v, n\text{-}h}$ normal-hemispherical light transmittance
- $\tau_{v, dir\text{-}h}$ direct-hemispherical light transmittance
- $\tau_{e, n\text{-}h}$ normal-hemispherical solar transmittance
- $\tau_{e, dir\text{-}h}$ direct-hemispherical solar transmittance
- $\rho_{v, n\text{-}h}$ normal-hemispherical light reflectance
- $\rho_{v, dir\text{-}h}$ direct-hemispherical light reflectance
- $\rho_{e, n\text{-}h}$ normal-hemispherical solar reflectance
- $\rho_{e, dir\text{-}h}$ direct-hemispherical solar reflectance
- $\tau_{v, dif\text{-}h}$ diffuse-hemispherical light transmittance

5 Test and calculation methods to be used according to product - Guidelines

5.1 General

The test methods described in this European Standard are intended to be used for testing the characteristics of the curtain elements of solar protection devices. Curtain elements are for example flat sheets of coated aluminium for slats for venetian blinds, fabric materials for roller blinds or glass slats with or without patterns for external glass venetian blinds. The properties of the whole product, which consists of one or more elements, are then calculated according to EN 13363-1 or EN 13363-2. Also a whole product may be tested, if the test equipment is sufficiently large so that the whole product fulfils the requirements of test samples as stated in Clause 6.3.

This European Standard characterises the product performance through the properties of the curtain (centre of product values). However, peripheral gaps and/or holes and the set-up can have a strong effect on the performance of the product under real conditions and shall be considered during set-up.

For all solar protection devices, it is assumed that the products are fully extended (not partially retracted) when solar protection or glare protection is required.

NOTE For building planning it can be useful to take into consideration partially retracted solar protection devices. The properties of the whole window can then be approximated from the properties of the window area with and without solar protection devices.

5.2 Venetian blinds

The solar and light characteristics of venetian blinds shall be:

- Either measured directly on a complete product according to Clause 7. The venetian blind shall in this case fulfil the requirements of test samples specified in Clause 6.3;
- or calculated using the properties of the individual slats. The slats characteristics shall be measured according to Clause 7 and the calculation method of Annex A of EN 13363-2:2005 shall be used. Additional information/requirements presented in Clause 8 shall be used.

NOTE If products cannot be appropriately characterised using EN 13363-2 (for example mirror finished and/or special shaped slats), a more detailed calculation method may be necessary.

The characteristics of the combination of a venetian blind with a glazing may be measured directly according to Clause 7 if the requirements of test sample specified in Clause 6.3 are fulfilled.

The different possibilities of determination of venetian blind characteristics are presented in Figure 3.

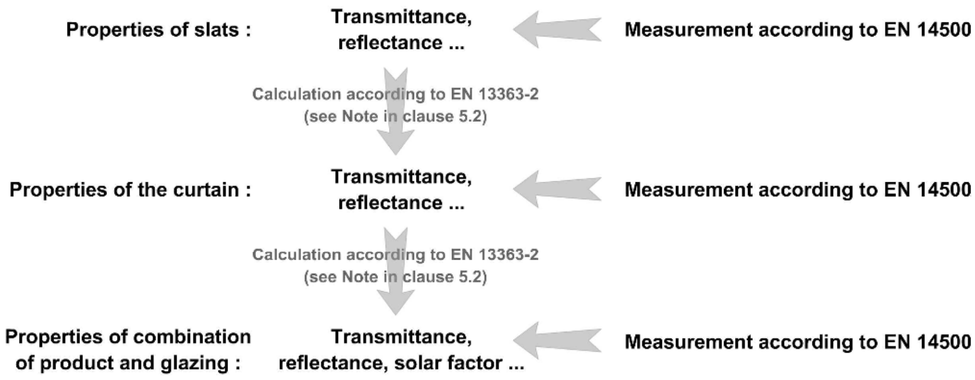


Figure 3 — Options for characterisation of venetian blinds

5.3 Roller blinds

The solar and light characteristics of roller blinds shall be:

— Either measured directly on a complete product according to Clause 7. The roller blind shall in this case fulfil the requirements of test sample specified in Clause 6.3;

— Or determined using the properties of the fabric. In this case, it is assumed that the properties of the complete product are the same as those of the fabric.

The characteristics of the combination of a roller blind with a glazing may be measured directly according to Clause 7 if the requirements of test samples specified in Clause 6.3 are fulfilled.

Opacity characteristics may be tested either on the curtain material or on a complete product if the test equipment is large enough. In all cases, it is essential to prevent any lateral losses through peripheral gaps.

The different possibilities of determination of roller blind characteristics are presented in Figure 4.

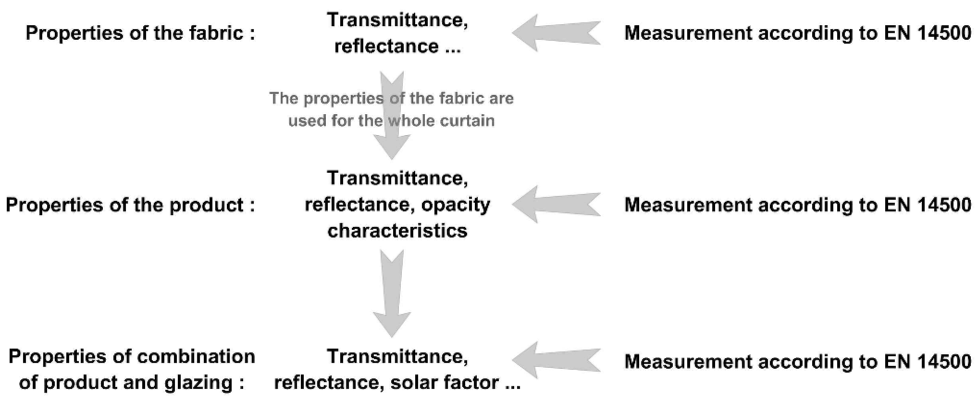


Figure 4 — Options for characterisation of roller blinds

5.4 Pleated blinds

As an approximation the properties of the fabric may be used as properties of the curtain in the same way as for roller blinds (see Clause 5.3).

When the measurement set-up is sufficiently large, the optical properties of the pleated curtain may be tested directly.

5.5 Projecting awnings

Fabric properties of projecting awnings may be determined according to Clause 7.

However, existing calculation methods being only applicable to products which are parallel to the glazing, it is not possible to characterise the performance of a whole product from its fabric properties only.

NOTE Informative Annex D presents an approach for the determination of characteristics in case of projecting awnings.

5.6 Vertical blinds

Properties of vertical blinds shall be determined according to Clause 8.3.

5.7 Shutters

The solar and light characteristics of shutters shall be:

- Either determined for the curtain material according to Clause 7;
- Or determined for the complete product according to Clause 8.4.

Opacity characteristics may be tested either on the curtain material or on a complete product if the test equipment is large enough. In all cases, it is essential to prevent any lateral losses through peripheral gaps.

6 Measurement set-up

6.1 Measurement principles

6.1.1 Spectral and integral characteristics

Any characteristic referring to optical properties of materials shall be determined under broad-band conditions with a specified illuminant (integral method) or spectrally for defined wavelengths λ (spectral method).

Spectral method

The relevant spectral characteristic (e.g. the normal-hemispherical spectral transmittance $\tau_{n\text{-}h}(\lambda)$) is measured as a function of the wavelength. Spectral measurements can be made either with monochromatic light or with a source having a broad spectrum and a spectroradiometer as detector. When a spectral characteristic of a sample is known, the corresponding integral characteristic can be calculated with the formula given in EN 410.

Integral method

The relevant weighted characteristic is measured directly, using a source with a standard spectral power distribution $S(\lambda)$ and a broad-band detector with the required relative spectral weighting function:

- For broad-band measurements of solar properties characteristic (e.g. the normal-hemispherical solar transmittance $\tau_{e,n\text{-}h}$), the detector system shall have a flat spectral response over the whole solar range and the spectral power distribution of the incident irradiation $S(\lambda)$ shall correspond to the EN 410 solar spectrum;
- For broad-band measurements of the light characteristics (e.g. the normal-hemispherical light transmittance $\tau_{v,n\text{-}h}$), the sensitivity of the detector shall correspond to the photopic spectral sensitivity

of the human eye V(λ) and the spectral power distribution $S_{D65}(\lambda)$ of the light source shall correspond with the standard illuminant D65 (according to EN 410);

— For broad band measurements of light characteristics it is also possible to use a light source with a spectral power distribution S(λ) that corresponds with the standard solar spectrum and to use a detector with a spectral sensitivity w(λ), so that $S(\lambda)w(\lambda) = S_{D65}(\lambda)V(\lambda)$.

Necessary accuracy: A broad-band light-source/detector system is accurate enough, when the solar or light characteristics for a solar control glazing with a selectivity of τ_v / τ_e > 1,5 and the results of a clear glass sample do not differ more than 4 % relatively from the results determined with a calibrated spectroradiometer with a relative accuracy of 2 % or better.

6.1.2 Absolute and relative methods (according to CIE 130)

Since they are defined as the ratio of two fluxes, reflectance and transmittance are, in themselves, relative characteristics, but, whenever their values are measured directly without the use of another material standard as a reference, the corresponding method is termed absolute.

Reflectance measurements are carried out with the help of a standard and are accordingly classified as relative methods.

NOTE 1 Absolute methods for reflectance measurements do exist, but they are outside the scope of this standard.

In the case of transmittance, similar considerations apply. Since the flux is transmitted through an unknown sample it is to be referred to the flux incident on it. This comparison with the incident flux does not, theoretically, require any standard. It is only necessary to leave a free passage for the flux. According to this principle, measurements of transmittance are classified as absolute measurements.

NOTE 2 Relative transmittance measurements can be more appropriate in the case of diffusing test samples. Then a diffusing reference sample can be more accurate.

6.2 Measuring equipment

6.2.1 General

An instrument for measuring the characteristics of materials consists of

— Equipment for irradiation (see Clause 6.2.2);

— Equipment for detection (see Clause 6.2.3);

— Reference samples (see Clause 6.2.4).

6.2.2 Equipment for irradiation

6.2.2.1 Single or double-beam instrument

Two methods of measurement are possible:

— Method A, using a single beam recording instrument;

— Method B, using a double-beam instrument. In double-beam instruments, the beam is switched between a path which has an incidence on the sample and one which does not.

Method B is recommended because of its inherent correction of drift in source brightness or amplifier gain.

6.2.2.2 Geometric conditions

The equipment for irradiation shall fulfil the following geometric requirements:

— In the case of test samples with directional features (e.g. slatted curtains and some single or multicoloured fabrics), the angular orientation of these features with respect to the plane of incidence or the plane of view shall be specified;

NOTE 1 The plane of incidence is the plane that contains the normal to the surface of the test sample and the direction of the incident radiation.

— In case of homogeneous samples without directional features, it is sufficient to characterise the direction of the incident irradiation with the angle of incidence θ. θ is the angle between the normal to the surface and the optical axis of the incident irradiation;

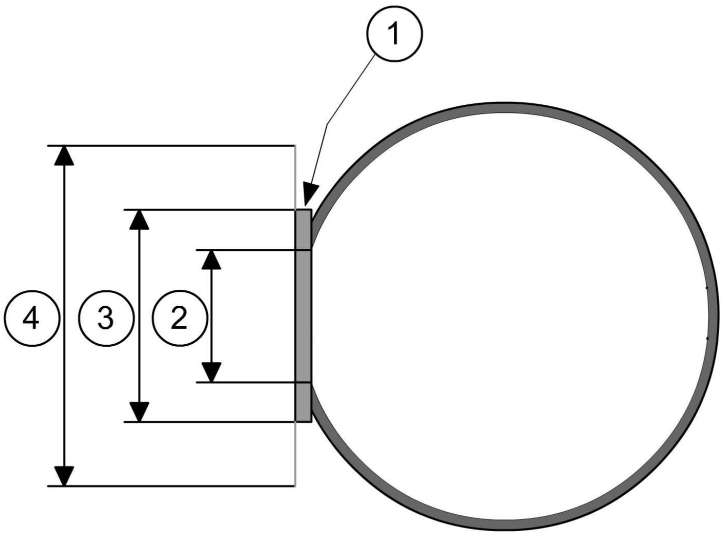
— The size of the irradiated/illuminated area of the sample shall be sufficiently large in comparison to the structure of the sample, so that the result is independent from the location of the incident beam on the sample. If this is not possible, the mean value of several measurements at different locations on the sample shall be used, weighted by the relative size of each area. The irradiance shall be nearly homogeneous on the relevant area.

NOTE 2 In the case of oblique irradiation/illumination, the size of the irradiated area increases with $1/\cos(\theta)$, where θ is the angle of incidence. For large angles θ, care shall be taken to satisfy the above requirements.

— Stray radiation outside the irradiated area of the sample shall be avoided;

— In the case of directional irradiation, the tolerance of the angle of incidence shall be ± 5° at every point of the relevant area. The size of the relevant area depends on the type of sample. The “thicker” the sample, the bigger the relevant area shall be. The definition of the relevant surface is presented in Figure 5. A definition of thick samples is given in Clause 6.3.2;

— In the case of diffuse irradiation, an integrating sphere shall be used as a light source.



Key

1 Sample
2 Diameter of the aperture
3 Diameter of the relevant area
4 Diameter of the incident beam

Figure 5 — Areas considered

6.2.2.3 Polarisation

The characteristics of solar protection devices or materials for non-normal incidence depend on the state of polarisation of the irradiating beam. Directional measurements can only be performed with unpolarised incident irradiation if no polarisation arises from the source or the deflecting or focusing optics (if present) and if the detector is insensitive to polarisation. Therefore, in general, for non-normal measurements, two separate measurements shall be made with the incident radiation fully linearly polarised in the plane perpendicular to the plane of incidence and in the plane parallel to the plane of incidence, respectively. The value of the characteristic for unpolarised irradiation shall then be calculated as the mathematical average of the two results.

NOTE 1 The reflected or transmitted radiation is usually partly polarised even if the incident radiation is unpolarised.

NOTE 2 The radiation emitted from a lamp is generally partially polarised. A beam entering an integrating sphere is depolarised by the multiple reflections inside the sphere.

6.2.3 Equipment for detection

6.2.3.1 General

Photometers, radiometers, spectroradiometers and spectrophotometers are used as detectors. For all types of detectors care shall be taken about sufficient linearity and low temperature dependence. A sufficient warm-up period shall be respected.

NOTE Errors may be caused by detectors with a sensitivity that depends on the position of the beam on the photosensitive area.

6.2.3.2 Integrating sphere

An Integrating (or Ulbricht) sphere is a hollow sphere whose internal surface is a diffuse white reflector. This optical device is used to collect flux either reflected or transmitted from a sample or to provide isotropic irradiation of a sample from a complete hemisphere. The hollow sphere has apertures for admitting and detecting flux and usually having additional apertures over which sample and reference specimen are placed.

An integrating sphere equipped with a radiometer, photometer and/or spectroradiometer is recommended for the measurement of:

— direct-hemispherical reflectance and transmittance,

— diffuse reflectance and transmittance.

The direct-direct components can then be obtained by subtracting one from the other.

NOTE 1 Special care has to be taken when the transmittance/reflectance of thick translucent samples (e.g. glass slats with printed patterns) is measured, because of possible lateral losses of transmitted/reflected light.

NOTE 2 Integrating spheres are not suitable for measuring luminescent materials.

NOTE 3 The higher the reflectance of the sphere coating is, the higher is the sensitivity of the detection equipment.

NOTE 4 Common materials for sphere coatings are $BaSO_4$ and pressed and low-density sintered PTFE.

NOTE 5 The basic idea behind integrating spheres is that the indirect illuminance/irradiance of the inner sphere wall is assumed to be proportional to the flux transmitted/reflected by the test specimen or reference sample. This is true for spheres with perfectly isotropic diffuse reflecting walls without openings. The illuminance/irradiance of directly irradiated parts of the sphere is not proportional to the flux. It is therefore necessary to equip the sphere with baffles as it is described in Clause 6.2.3.3.

6.2.3.3 Requirements

An integrating sphere together with the detectors shall fulfil the following requirements:

— All detector ports shall be equipped with additional baffle(s) in order to cut the line of sight between sample/reference port and detector(s). This ensures that the detector is not illuminated directly. The baffles shall be coated with a diffuse, spectrally non-selective coating with a very high reflectance (normal-hemispherical spectral reflectance > 92 %).

— Detectors shall either be:

  — Radiometers/photometers which are sensitive to light coming from all the different possible directions in the integrating sphere. Radiometers/photometers shall evaluate the incoming radiation according to the cosine law;

  — Radiance/luminance meters with a narrow viewing angle. In this case it is necessary to shield/baffle the (small) observed area of the sphere wall which is directly seen by the detector. No radiation other than that from the observed area shall be allowed to influence the reading of the detector.

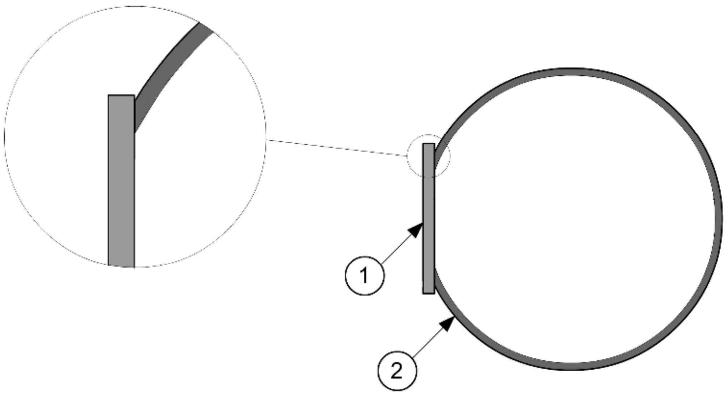
— The outside surface of the sphere shall be painted black in order to avoid inter-reflections between the sample and the outer surface of the sphere.

NOTE 1 Many matt samples (e.g. opal glass lamellae) are abrasive and may become contaminated if they are allowed to come into contact with black paint. For these materials a thin sheet of black paper surrounding the sample can prevent the sample from being contaminated.

— Ports:

— The total area of the sphere ports shall not exceed 1/10 of the internal reflecting sphere area. Unused ports which are closed and covered with the same coating as the rest of the inner walls of the sphere do not have to be taken into account;

— The wall surrounding the sample port shall have a sharp edge, so that there is no step between the inner sphere wall and the sample surface (see Figure 6);



Key

1 Sample
2 Integrating sphere

Figure 6 — Sharp edge on sample port of integrating sphere

NOTE 2 The number, position and diameter of the necessary sphere ports depend on the measurement method, the type of the sample and the characteristics to be measured. Since ports always disturb the operating conditions in the sphere, their number and diameter should be minimised.

— The diameter of the sample port shall not exceed 1/6 of the diameter of the sphere;

NOTE 3 A diameter of less than 1/10 is recommended.

— In the case of reflectance measurements, the diameter of the irradiating beam shall be smaller than the diameter of the entrance port for the irradiation.

NOTE 4 Ideally, the internal surface should be isotropic diffuse reflecting.

NOTE 5 For solar broadband measurements, $BaSO_4$ sphere coating is not appropriate because the spectral reflectance is too low above 1 600 nm. Therefore spectrally selective samples should be measured only spectrally when using $BaSO_4$ coatings.

NOTE 6 Properties of the coating of the inner walls in case of broad band measurements: the reflectance of the walls should be as non-selective as possible. A measure for the selectivity is $K(\lambda)_{rel}$ according to CIE 130:

$$K(\lambda)_{rel} = \frac{\rho_k(\lambda)(1-\rho_{k,max})}{\rho_{k,max}(1-\rho_k(\lambda))} \tag{1}$$

where $\rho_k(\lambda)$ is the normal-hemispherical spectral reflectance of the sphere coating. $\rho_{k,\,max}$ is the maximum of $\rho_k(\lambda)$.

NOTE 7 In case of broad band measurements, non-selectivity is more important than a high reflectance. It may be useful to use a coating with a normal-hemispherical reflectance of about 0,8 with very good non-selectivity instead of $BaSO_4$ with a maximum spectral normal-hemispherical reflectance of about 0,98.

NOTE 8 Sphere paints are available commercially for which the relative factor $K(\lambda)_{rel}$ is listed as a function of wavelength.

6.2.4 Reference samples

The reference samples shall be of sufficient size to prevent the possibility of light leakage at the edges of the entrance port. The size shall be compatible with the sample compartment of the instrument. Reference samples shall be clean and dry. The storage and the cleaning procedures stated by the manufacturer shall be followed.

Reference samples should have similar reflectance or transmittance properties as the test samples (e.g. diffuse reflecting reference sample for diffusely reflecting test sample). With the measurement of reference samples the following accuracies shall be proven:

— Diffuse reflecting reference samples (e.g. low-density sintered PTFE) with a reflectance between 0,85 and 1 shall be measured with an absolute accuracy of less or equal than 0,04;

— Specularly reflecting reference samples (mirrors) with a reflectance between 0,85 and 1 shall be measured with an absolute accuracy of less or equal than 0,03;

— Directly transmitting reference samples (e.g. glass sheets) with a transmittance between 0,75 and 1 shall be measured with an absolute accuracy of less or equal than 0,03.

Secondary reference samples calibrated by the laboratory itself are allowed, when the additional uncertainty is taken into account and when the accuracy is traceable.

6.3 Test samples

6.3.1 General

The test samples shall be of sufficient size to prevent the possibility of light leakage at the edges of the entrance port. The size shall be compatible with the sample compartment of the instrument. Test samples shall be clean and dry, unless otherwise specified. The storage and the cleaning procedures stated by the manufacturer shall be followed.

Test samples shall fulfil the following additional requirements:

— The irradiation equipment must be able to irradiate the sample according to the requirements stated in Clause 6.2.2;

— The detection equipment must be able to detect the total transmitted/reflected flux according to the requirements stated in Clause 6.2.3.

If these requirements are not fulfilled, the sample can not be tested with the test equipment under consideration.

6.3.2 Thick translucent samples

A translucent sample shall be regarded as thick when special procedures are required to prevent a significant fraction of the reflected or transmitted radiation from being not detected because of lateral losses. Special care shall be taken as specified in Clause 7.2.3.2.

If there is any doubt whether a sample has to be regarded as thick, then a test method suitable for thick samples shall be used.

NOTE 1 The physical dimensions of a sample are not much relevant for the distinction between thin and thick samples. It is more important whether a sample is strongly diffusing or not.

NOTE 2 When a clear glass with a diffusing surface (e.g. printed glass) has the same direct-diffuse transmittance as a glass with volume scattering, then it has higher lateral losses because the internal reflections can travel more easily.

NOTE 3 A visual inspection, made while irradiating the sample with a collimated beam, may be useful for the decision whether a sample has to be regarded as thick.

NOTE 4 This definition of “thick” samples is given in CIE 130.

7 Measurement procedure

7.1 General

If the measured transmittance and reflectance are spectral measurements, the solar and the light factors are calculated following the procedure described in EN 410.

If the measured transmittance and reflectance are broadband measurements, these measurements give directly the solar and the light factors. The spectrum of the light source and the spectral response of the system (sphere and detector) determine these factors.

7.2 Test method A – Single beam instrument (substitution method)

7.2.1 General

With the substitution method, test sample and reference sample are measured at the same sphere port one after another. As a result, the average reflectance of the walls changes between test and reference measurement when the two samples have different reflectance properties on the surface which is facing the inside of the sphere. This means that the sensitivity of the sphere/detector-equipment changes between sample and reference measurement in most cases. This effect shall be corrected with an auxiliary lamp or an auxiliary reflectance measurement as specified in Clause 7.2.2.

NOTE The effect could also be corrected using the auxiliary screen method. In this case the recommendations given in CIE 130 should be followed.

Measurements with an integrating sphere having a sample port which is large compared to the diameter of the sphere can only be carried out using the substitution method.

7.2.2 Test apparatus for the substitution method

For the test equipment for the substitution method the following additional recommendations are given:

- In the case of detectors which are sensitive to light coming from all the different possible directions in the sphere (radiometers/photometers), it is recommended to put the detector port as close as possible to the sample port in order to minimise the necessary size of the baffle;

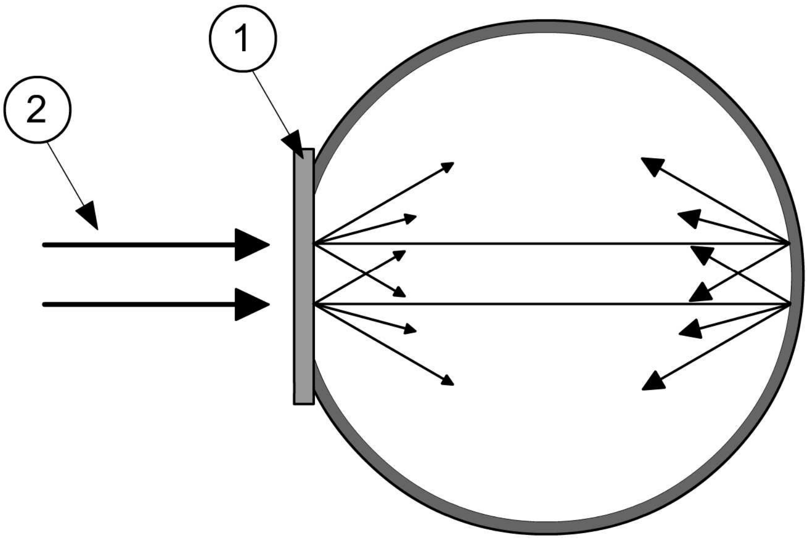
- In the case of detectors with a narrow viewing angle (e.g. radiance/luminance meters), the observed area shall be protected from being irradiated directly with baffles as stated in Clause 6.2.3.3. It is recommended to put the observed area as close as possible to the sample port in order to minimise the necessary size of the baffle for the observed area.

NOTE Figures 6 and 7 of CIE 130:1998 give examples of optimised locations of the detector which lead to minimised size of the baffle.

7.2.3 Direct-hemispherical transmittance mode

7.2.3.1 General case

Transmittance shall be determined with the incident beam being normal to the surface of the test sample. The test sample is mounted externally, its external side facing the incident beam (see Figure 7).



Key

1 Sample
2 Incident beam

Figure 7 — Integrating sphere for transmittance measurement

The direct-hemispherical transmittance $\tau_{dir\text{-}h}$ of the sample is the ratio of the detected flux ϕ with the sample in front of the sphere and the detected flux ϕ_o without the sample. The sensitivity of the detection system (integrating sphere plus detector) is strongly dependent on the total reflectance of the inner sphere wall, and this reflectance changes if the sample is in front of the sphere or not, or if a reference sample is used.

In order to correct the systematic error caused by the reflection of the back side of the sample which modifies the total reflection of the sphere wall, the successive steps of the measurement procedure shall be the following:

— Step 1: Measurement of flux ϕ_o without the sample or with reference sample and with an external source illuminated, the internal source being switched off;

— Step 2: Measurement of flux ϕ with the sample in front of the sphere and with an external incident beam illuminated, the internal source being switched off;

— Step 3: Measurement of flux ϕ_{od} without the sample or with reference sample and with an internal incident beam on the sphere wall illuminated, the external source being switched off;

— Step 4: Measurement of flux ϕ_d with the sample in front of the sphere and an internal incident beam on the sphere wall illuminated, the external source being switched off.

The explanation of each measurement is given in Table 1.

When no reference sample is used, τ_{ref} is equal to 1.

Table 1 — Procedure for measurement of transmittance

Step	Source	Sample	Measured flux
1	External	None (τ_{ref} = 1) or Reference sample	$\Phi_0 = K\,\Phi_i \frac{\rho_w}{1-\rho_s}\tau_{ref}$
2	External	In front of the sphere	$\Phi = K\,\Phi_i\,\tau_{dir-h}\frac{\rho_w}{1-\rho'_{s'}}$
3	Internal	None (τ_{ref} = 1) or Reference sample	$\Phi_{od} = K\,\Phi_s \frac{\rho_w}{1-\rho_s}$
4	Internal	In front of the sphere	$\Phi_d = K\,\Phi_s \frac{\rho_w}{1-\rho'_{s'}}$

With

K constant depending on the geometry of the sphere and the detector ports;

ϕ_i incident flux from external source;

ϕ_s incident flux from internal source;

ρ_w reflectance of the sphere wall;

ρ_s reflectance of the total inside surface of the sphere without the sample;

$\rho_{s'}$ reflectance of the total inside surface of the sphere with the sample in front of the sphere.

The constant K depends on

A_{det} detector port area;

A_e entry port area of the sphere;

Ω solid angle (field-of-view) seen by the detector.

$$K = \frac{A_{det}}{A_e} \cdot \frac{\Omega}{\pi} \quad (2)$$

The transmittance is given by the following formula:

$$\tau_{dir-h} = \frac{\Phi}{\Phi_0}\frac{\Phi_{od}}{\Phi_d}\tau_{ref} \quad (3)$$

Alternatively, when the spectral reflectance $\rho_{e,\,h\text{-}h}$, $\rho_{v,\,h\text{-}h}$ or $\rho_{\,h\text{-}h}(\lambda)$ of the sample and the throughput of the integrating sphere F_e, F_v or $F(\lambda)$ is known, the following formula may be used.

$$\tau_{dir-h} = \frac{\Phi}{\phi_0}(1 - F\rho'_{h-h}) \tag{4}$$

where F is

$$F = \frac{A_e}{A_s}\frac{1}{1-\rho_s} \tag{5}$$

The conventional throughput T of the sphere is defined as the incident flux on the detector related to the incident flux into the sphere:

$$T = \frac{\Phi_0}{\Phi_{in}} = K \cdot \frac{\rho_w}{1-\rho_s} \tag{6}$$

where ϕ_0 and ϕ_{in} are measured without sample (τ_{ref} = 1). ϕ_{in} has to be measured in the entry port. One possibility is to determine illuminance and multiply by entry port area.

To determine F, the luminance of the sphere will be measured and divided by the luminance of a sphere wall element positioned at the entry port. In the first measurement the flux incident on the detector with the field-of-view W is:

$$\Phi_{d,s} = \frac{A_{det}}{A_S} \cdot \frac{\Omega}{\pi} \cdot \frac{\rho_w}{1-\rho_s} \cdot \Phi_{in} = T \cdot \Phi_{in}$$

$$\Phi_{d,e} = A_{det} \cdot \Omega \cdot \rho_w \cdot \frac{\Phi_{in}}{A_e \cdot \pi}$$

resulting in

$$F = \frac{\Phi_{d,s}}{\Phi_{d,e}} = \frac{A_e}{A_s} \cdot \frac{1}{1-\rho_s} \tag{7}$$

Another possibility to determine F is to measure in Step 1 and Step 2 ϕ_0 and ϕ for calibration samples with known transmittance τ and hemispherical reflectance $\rho_{h\text{-}h}$. Then:

$$F = \frac{1 - \tau \cdot \dfrac{\Phi_0}{\Phi}}{\rho'_{h-h}} \tag{8}$$

NOTE Normally no reference samples are used for transmittance measurements, since the open sample port can be used as a reference, which leads to absolute transmittance measurements. For very accurate measurements with diffusing/light redirecting samples, it is better to use an additional diffusing reference sample or a reference sample with similar light distribution characteristics as the test sample also for transmittance measurements. In such a case two measurements should be performed with and without reference sample.

7.2.3.2 Specific case of thick translucent samples

In the case of thick translucent samples, lateral losses of light can lead to large measurement errors and shall therefore be minimised. Lateral losses can be minimised with one of the following two configurations:

— Configuration 1: Large beam/small sample port. The diameter of the irradiated area shall be bigger than at least two times the diameter of the sample port. The test and reference samples shall be bigger than the irradiated area. The influence of the thickness shall be assessed in order to reach a reasonably accurate measurement;

NOTE The idea behind this configuration is to compensate lateral losses with lateral gains.

— Configuration 2: Small beam/large sample port. The sample port is very big in comparison to the irradiated area on the sample so that most of the transmitted light can be captured in the integrating sphere. The influence of the thickness shall be assessed in order to reach a reasonably accurate measurement.

Nevertheless, it is recommended to use configuration 1, because configuration 2 theoretically never leads to the correct result since there are always losses of higher order reflection.

7.2.4 Direct-hemispherical reflectance mode

7.2.4.1 General

The direct-hemispherical reflectance can be determined with the following methods:

— Reflectance measurement with wall mounted sample (only “thin” samples) (see Figure 8);

— Reflectance measurement with centre-mounted sample with the test sample at the centre of the sphere and the sample being backed by a black opaque absorbent material (see Figure 9);

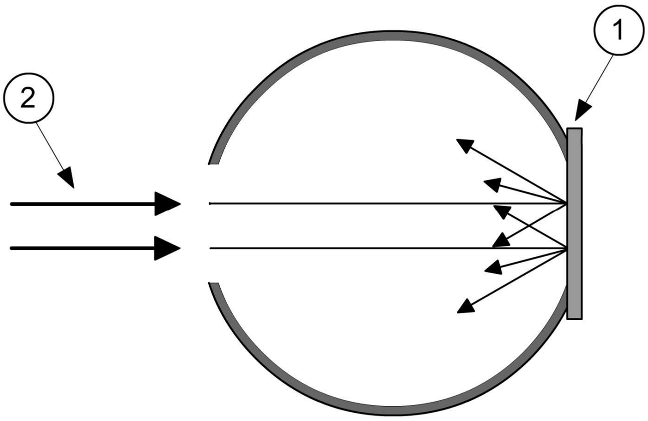
— Determination from absorptance measurement with centre-mounted sample (see Figure 10).

7.2.4.2 Reflectance measurement with wall- or centre-mounted sample

The test sample shall have its external side facing the incident beam and mounted, either at the centre (see Figure 9) or at the rear of the sphere (see Figure 8).

Wall-mounted samples shall only be used for “thin” samples.

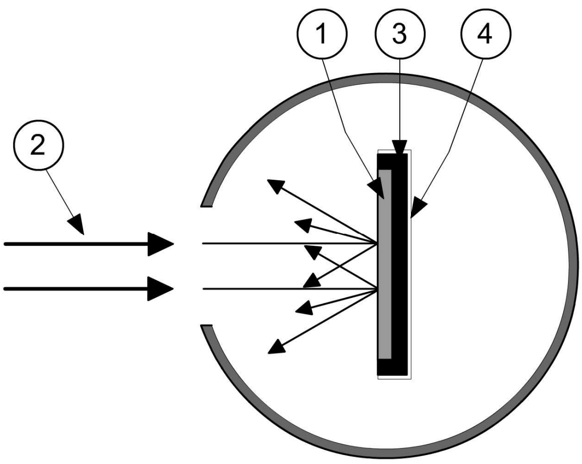
With the test sample at the centre of the sphere, the sample shall be backed by a black opaque absorbent material ($\rho_{e,\ n\text{-}h} \leq 0{,}02$ and $\rho_{v,\ n\text{-}h} \leq 0{,}02$), white on the reverse side in order to eliminate the transmitted flux from the measurement.



Key

1 Sample
2 Incident beam

Figure 8 — Integrating sphere for reflectance measurement with a wall mounted sample



Key

1 Sample
2 Incident beam
3 Black opaque absorbent material
4 White material

Figure 9 — Reflectance measurement with centre-mounted sample

The direct-hemispherical reflectance $\rho_{dir\text{-}h}$ of the sample is the ratio between the flux ϕ_s detected with the sample and the flux ϕ_{ref} detected with a reference sample multiplied by the reflectance of the reference sample.

In order to take into account surplus light, the dark line reading ϕ_{dark} has to be measured and taken into account according to the following formula:

$$\rho_{dir-h} = \frac{\phi_s - \phi_{dark}}{\phi_{ref} - \phi_{dark}} \rho_{ref} \quad (9)$$

An instruction for the different measurements is given in Table 2.

Table 2 — Procedure for reflectance measurement in case of wall- or centre-mounted sample

Flux to be measured	Set-up with samples at the rear or at the centre of the sphere	Meaning of the measured flux
ϕ_s	Flux recorded with the sample to be measured	$\Phi_s = K\,\Phi_i \frac{\rho_{dir-h}}{1-\rho_s}$
ϕ_{ref}	Flux recorded with the reference sample	$\Phi_{ref} = K\,\Phi_i \frac{\rho_{ref}}{1-\rho_s}$
ϕ_{dark}	Flux recorded without sample or with light trap sample	Φ_{dark}

With:

K constant dependent on the geometry of sphere, the detector ports;

ϕ_I external incident flux;

ρ_{ref} reflectance of the sphere wall or of the reference sample;

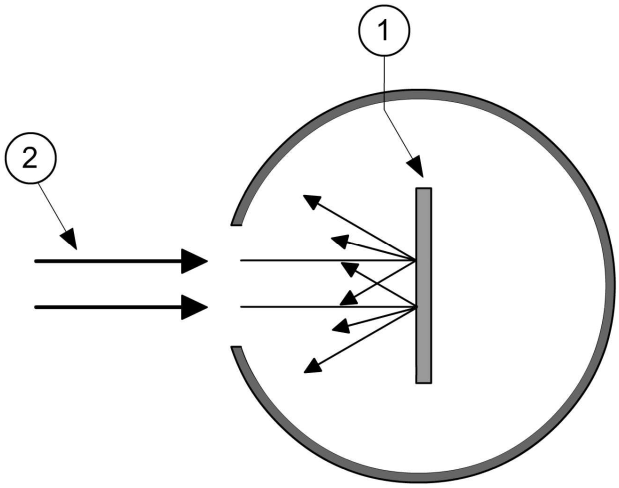
ρ_{dir-h} reflectance of the sample;

ρ_s reflectance of the total inside surface of the sphere with the sample in place.

7.2.4.3 Reflectance determination from absorptance measurement with centre-mounted sample

In this case the sample is not backed in order to measure the sum of transmittance and reflectance m = ($\tau + \rho$). With an additional transmittance measurement, the reflectance can be calculated from the formula:

$$\rho = 1 - \tau - (1 - m) \tag{10}$$



Key

1 Sample
2 Incident beam

Figure 10 — Integrating sphere for reflectance measurement for sample mounted at the centre of the sphere

NOTE In the case of thick samples with lateral losses, the edges of the sample should be covered with reflecting foils with a reflectance of more than 80 %.

7.2.5 Diffuse-hemispherical transmittance mode

The measurement is carried out in exactly the same way as the measurement of the direct-hemispherical transmittance (see Clause 7.2.3) with the only difference that the illumination is diffuse. Requirements on the equipment for irradiation are specified in Clause 6.2.2.

7.3 Test method B – Double beam spectrophotometer (comparison method)

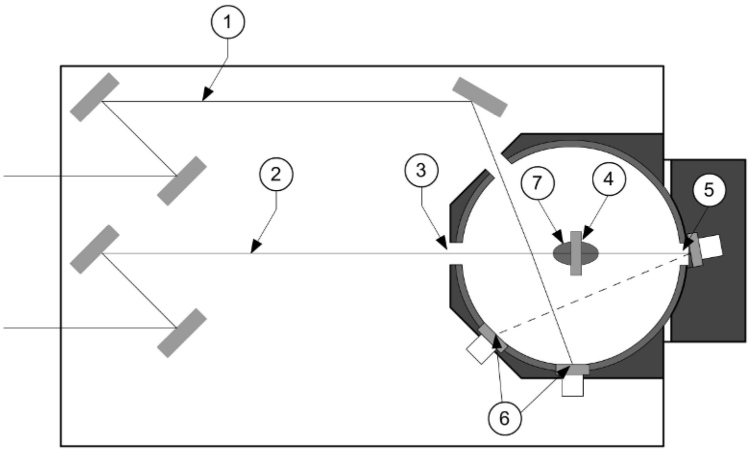
7.3.1 General

For direct-hemispherical measurements, the spectrophotometer shall be equipped with an integrating sphere with the following characteristics (see Figure 11):

— either a set-up with the sample at the front of the sphere: sample at port N°3, ports N°5 and N°6 closed, support N°4 removed (see Figure 12 a);

— or a set-up with the sample at the rear of the sphere: sample at port N°5, ports N°6 closed, support N°4 removed (see Figure 12 b);

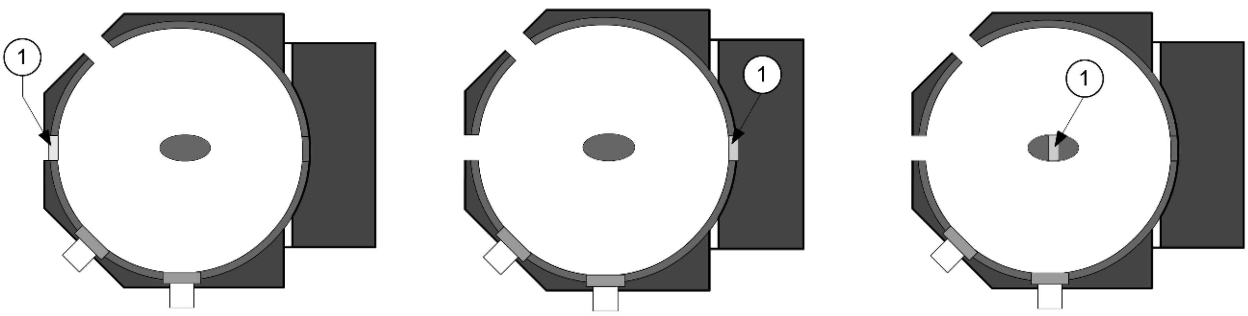
— or a set-up with the sample at the centre of the sphere: sample at support N°4, ports N°5 and N°6 closed (see Figure 12 c).



Key

1 Reference beam ϕ_r
2 Sample beam ϕ_s
3 Port N°3
4 Support N°4
5 Port N°5
6 Reference port
7 Detector (at the highest or the lowest point of the sphere)

Figure 11 — Schematic representation of a double beam spectrophotometer with an integrating sphere



a) Sample at the front b) Sample at the rear c) Sample at the centre

Key

1 Sample

Figure 12 — Different set-ups for direct-hemispherical measurements

7.3.2 Spectral direct-hemispherical transmittance mode

The transmittance shall be determined with the incident beam normal to the surface of the test sample. The test sample shall be mounted in front of the sphere (port N°3), its external side facing the incident beam.

Port N°5 shall be covered with a totally opaque material having the same coating and the same optical characteristics as the inner surface of the sphere.

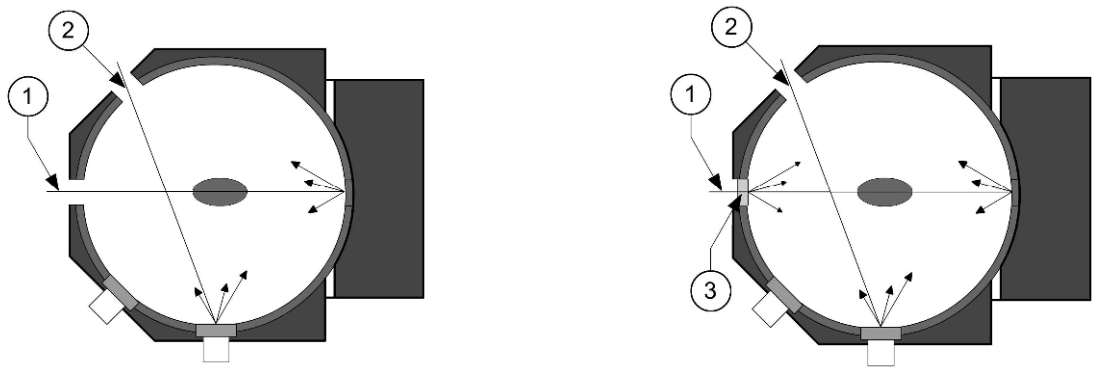
Since flux ϕ_s from the sample beam and flux ϕ_r from the reference beam are not exactly equal, the "substitution method" shall be used to measure the transmittance of the sample.

The operating procedure is as follows:

— Step 1: Measure the signal $S_1 = \phi_s / \phi_r$ without the sample: port N°3 free (see Figure 11);

— Step 2: Measure the signal $S_2 = \tau_{dir\text{-}h}\, \phi_s / \phi_r$ with the sample in front the sphere: sample on port N°3 (see Figure 11).

Figures 13 a, 13 b and Table 3 below show the two different configurations of the sphere.



a) Step 1: Measure without sample

b) Step 2: Measure with sample

Key

1 Sample beam ϕ_s
2 Reference beam ϕ_r
3 Sample

Figure 13 — Procedure for direct-hemispherical transmittance measurement

Table 3 — Procedure for transmittance measurement

Step	Sample	Flux of sample beam	Flux of reference beam	Measured signal
1	None	ϕ_s	ϕ_r	$S_1 = \frac{\phi_s}{\phi_r}$
2	On port N°3	$\tau_{dir\text{-}h}\, \phi_s$	ϕ_r	$S_2 = \frac{\tau_{dir\text{-}h}\phi_s}{\phi_r}$

The transmittance is given by the following formula:

$$\tau_{dir-h} = \frac{S_2}{S_1} \tag{11}$$

7.3.3 Spectral direct-diffuse transmittance mode

The direct-diffuse transmittance $\tau_{dir\text{-}diff}$ shall be determined with the same methodology than the direct-hemispherical transmittance $\tau_{dir\text{-}h}$ with the only difference that port 5 is opened (see Figure 11).

NOTE When port 5 is opened, the directly transmitted part of the radiation is captured in the light trap behind the port 5.

7.3.4 Direct-hemispherical reflectance mode

7.3.4.1 General

The direct-hemispherical reflectance may be determined with the following methods:

- Reflectance measurement with wall mounted sample (only “thin” samples) (see Figure 14),
- Reflectance measurement with centre-mounted sample with the test sample at the centre. The rear surface shall be covered by a black opaque absorbent material (see Figure 15),
- Determination from absorptance measurement with centre-mounted sample (see Figure 17).

7.3.4.2 Reflectance measurement with wall-mounted sample

The test sample shall be mounted at port N°5 of the sphere, with its external surface facing the incident beam.

When the test sample is at the rear of the sphere, the operating procedure shall be as follows:

- Step 1: Measure the signal $S_1 = \rho_{r,\ dir\text{-}h}\ \phi_s\ /\ \phi_r$ with reference sample on port N°5 (see Figure 11);
- Step 2: Measure the signal $S_2 = \rho_{s,\ dir\text{-}h}\ \phi_s\ /\ \phi_r$ with the test sample port N°5 (see Figure 11);

Figures 14 a, 14 b and Table 4 show the detail of the procedure to perform the reflectance measurement with wall-mounted sample.

a) Step 1: Measure with reference sample

b) Step 2: Measure with test sample

Key

1 Sample beam ϕ_s
2 Reference beam ϕ_r
3 Reference sample
4 Test sample

Figure 14 — Procedure for direct-hemispherical reflectance measurement – Wall-mounted sample

Table 4 — Procedure for reflectance measurement in case of wall-mounted sample (port N°5)

Step	Port N°5	Flux of sample beam	Flux of reference beam	Measured signal
1	Reference sample	$\rho_{r,\ dir\text{-}h}\ \phi_s$	ϕ_r	$S_1 = \frac{\Phi_s}{\Phi_r} \rho_{r,dir-h}$
2	Measured test sample	$\rho_{s,\ dir\text{-}h}\ \phi_s$	ϕ_r	$S_2 = \frac{\Phi_s}{\Phi_r} \rho_{s,dir-h}$

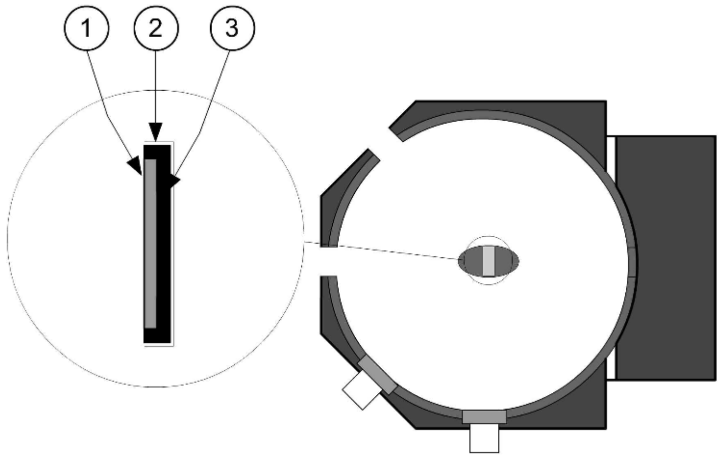
The reflectance is given by the following formula:

$$\rho_{s,dir-h} = \frac{S_2}{S_1} \rho_{r,dir-h} \qquad (12)$$

7.3.4.3 Reflectance measurement with centre-mounted sample

The test sample shall be placed at support C (at the centre of the sphere) with its external surface facing the incident beam. The back surface of transparent samples shall be covered by a black opaque absorbent material ($\rho_{e,\ n\text{-}h} \leq 0{,}02$ and $\rho_{v,\ n\text{-}h} \leq 0{,}02$). The back surface of support C shall be white and isotropically diffuse reflecting (see Figure 15).

NOTE In the case of thick samples with lateral losses, the edges of the sample should be covered with reflecting foils with a reflectance of more than 80 %.



Key

1 Sample
2 White material
3 Black opaque absorbent material

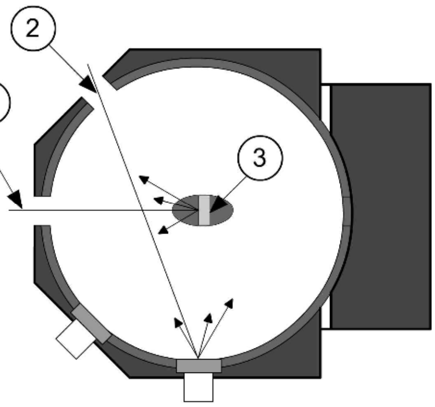
Figure 15 — Centre-mounted sample for direct-hemispherical reflectance measurement

The measurement procedure shall be as follows:

— Step 1: Measure the signal $S_1 = \rho_{r,\ dir\text{-}h}\ \phi_s\ /\ \phi_r$, with reference sample being in the incident beam on port N°5 (see Figure 11).

— Step 2: Measure the signal $S_2 = \rho_{s,\ dir\text{-}h}\ \phi_s\ /\ \phi_r$, with the test sample being in the incident beam on port N°5 (see Figure 11).

Figure 16 and Table 5 show the detail of the procedure to perform the reflectance measurement with centre-mounted sample.



Key

1 Sample beam ϕ_s
2 Reference beam ϕ_r
3 Test or reference sample

Figure 16 — Procedure for direct-hemispherical reflectance measurement – Centre-mounted sample

Table 5 — Procedure for reflectance measurement in case of centre-mounted sample

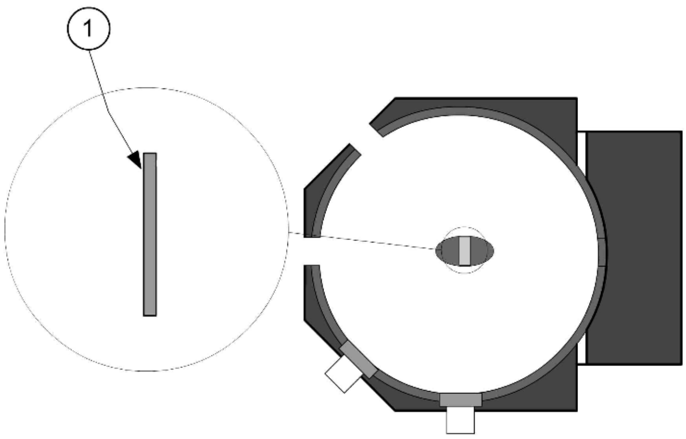
Step	Support N°4	Flux of sample beam	Flux of reference beam	Measured signal
1	Reference sample	$\rho_{r,\,dir\text{-}h}\,\phi_s$	ϕ_r	$S_1 = \frac{\Phi_s}{\Phi_r}\rho_{r,dir-h}$
2	Measured sample	$\rho_{s,\,dir\text{-}h}\,\phi_s$	ϕ_r	$S_2 = \frac{\Phi_s}{\Phi_r}\rho_{s,dir-h}$

The reflectance is given by the following formula:

$$\rho_{s,dir-h} = \frac{S_2}{S_1}\rho_{r,dir-h} \tag{13}$$

7.3.4.4 Reflectance determination from absorptance measurement with centre-mounted sample

In this case, the sample is not backed in order to measure the sum of transmittance and reflectance: $m = \tau + \rho$ (see Figure 17).



Key

1 Sample

Figure 17 — Centre-mounted sample for reflectance determination from absorptance measurement

With an additional transmittance measurement according to Clause 7.3.2, the reflectance can be calculated from the following formula:

$$\rho = 1 - \tau - (1 - m) \tag{14}$$

NOTE In the case of thick samples with lateral losses, the edges of the sample should be covered with reflecting foils with a reflectance of more than 80 %.

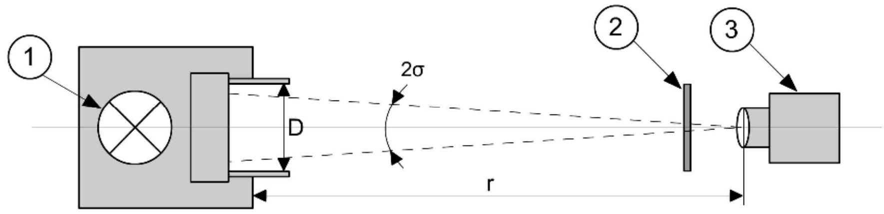
7.4 Determination of $\tau_{n\text{-}h}$ and $\rho_{n\text{-}h}$

Normal-hemispherical transmittance and reflectance shall be determined according to the procedures defined for measurement of direct-hemispherical transmittance and reflectance, with the beam at an angle of incidence $\theta = 0°$ in case of transmittance and $\theta \leq 8°$ in case of reflectance measurement.

7.5 Determination of $\tau_{n\text{-}n}$

7.5.1 General

The normal-normal transmittance $\tau_{n\text{-}n}$ of samples with mixed or specular transmission may be measured using the arrangement shown in Figure 18.



Key

1 Source
2 Sample
3 Detector
2σ Viewing angle of the detector
r Distance between diffuser and detector
D Diameter of diffuser, D > r.tg2 σ

Figure 18 — Measurement of $\tau_{n\text{-}n}$ of samples with regular or mixed transmission

The system consists of:

- a source with a diffuser providing a uniform radiance/luminance across the emitting area and with the prescribed spectral power distribution;
- a radiance/luminance meter with a viewing angle of $2\sigma = 10°$.

The diameter D of the emitting area of the diffuser shall be such that D > r.tg2σ, where 2σ is the viewing angle of the detector and r is the distance between the standard and the lens of the meter. The sample is positioned directly in front of the detector with an orientation normal to the beam.

7.5.2 Measurement of $\tau_{n\text{-}n}$

For the normal-normal transmittance $\tau_{n\text{-}n}$ measurement, the following radiance/luminance values shall be measured:

ϕ_X flux of beam source with the sample in the beam;

ϕ_N flux of beam source with no sample in the beam;

ϕ_o flux of the sample when the detector is turned by an angle of about 4σ about a vertical axis, so that the source is no longer within the field of view.

Then

$$\tau_{n-n} = \frac{(\phi_x - \phi_0)}{(\phi_N - \phi_0)} \tag{15}$$

7.5.3 Determination of τ_{n-n} from the measurement of τ_{n-dif}

The normal-normal transmittance may be obtained from τ_{n-h} and τ_{n-dif} using the following formula:

$$\tau_{n-n} = \tau_{n-h} - \tau_{n-dif} \tag{16}$$

7.6 Determination of τ_{dif-h}

7.6.1 General

τ_{dif-h} can be measured either directly (with diffuse irradiation) or calculated from several measurements of the direct hemispherical transmittance τ_{dir-h}.

7.6.2 Measurement

τ_{dif-h} shall be measured according to Clause 7.2.5.

7.6.3 Calculation

7.6.3.1 Fabrics and other products with rotationally symmetric transmittance

For many fabrics τ_{dir-h} depends only on the angle of incidence. This means that τ_{dir-h} does not change in case of a fixed angle of incidence when the relative orientation of the fabric to the incident irradiation is changed. For these types of samples, τ_{dif-h} can be calculated with the following formula:

$$\tau_{dif\text{-}h} = \sum_{k=0}^{6} a_k \; \tau_{dir\text{-}h}(15\,k) \tag{17}$$

where

a_0 = 0,0170 $\qquad$ a_4 = 0,2241

a_1 = 0,1294 $\qquad$ a_5 = 0,1294

a_2 = 0,2241 $\qquad$ a_6 = 0,0170

a_3 = 0,2588

NOTE 1 There are many fabrics with regular openings (e.g. transparent screens with Parallelogram-shaped holes) which can be treated as rotationally symmetric when the angle-dependent transmittance is averaged over different orientations of the fabric or if an orientation with intermediate transmittance is chosen for the measurements.

If the determination according to Formula 17 is not possible because of missing angular dependent transmission data, the following approximation can be used for fabrics:

$$\tau_{dif\text{-}h} \cong a\tau_{n\text{-}n} + b\tau_{n\text{-}dif} \tag{18}$$

where a = 0,73835 and b = 0,89050

NOTE 2 The Formula 18 has been derived from the measurement of 11 different fabrics. From these measurements, coefficients a and b have been determined by minimising the absolute error between the Formula 18 and the analytical Formula 17. The maximum absolute error found is less than or equal to 0,02.

NOTE 3 Being derived from measurements on fabrics, Formula 18 should not be used for other materials.

7.6.3.2 Venetian blinds and other products with transmittance with profile angle symmetry

For most venetian blinds without glazing, $\tau_{dir\text{-}h}$ depends only on the profile angle of the incident radiation. This means that $\tau_{dir\text{-}h}$ does not change in case of a fixed profile angle when the azimuth angle is varied. For this type of sample, $\tau_{dif\text{-}h}$ can be calculated with the following formula:

$$\tau_{dif\text{-}h} = b_0\ \tau_{dir\text{-}h}(0) + \sum_{k=1}^{6} b_k\ (\tau_{dir\text{-}h}(15\,k) + \tau_{dir\text{-}h}(-15\,k)) \tag{19}$$

where

b_0 = 0,1304	b_4 = 0,0653
b_1 = 0,1261	b_5 = 0,0338
b_2 = 0,1130	b_6 = 0,0043
b_3 = 0,0923	

7.7 Determination of opacity characteristics for dim-out and black out fabrics or products

7.7.1 General

The principle of the test is the following: surrounded by a light tight environment, an observer shall detect if light is perceptible through a fabric or product when this fabric or product is illuminated on the outer surface at different levels of illuminance.

For the level of accuracy of this standard, it has been assumed that human eyes are sensitive enough and therefore shall be used for the opacity characteristics determination. The observer shall have adequate light perception.

NOTE 1 The human eye is extremely sensitive in the dark adapted condition (scotopic vision).

NOTE 2 Determination of the opacity characteristics with an electronic eye:

Using an electronic eye is possible in very-well defined conditions and in particular, with high angle lens, with a high performance monochrome camera equipped with a Couple Charge Device (CCD) set up behind a scotopic filter (simulating human eye). Monitoring of the delay of aperture of this electronic eye (for example: 20 s or more) with an imaging card in relationship to a pictorial software provides a mean grey level value of the solar protection device when tested.

Calculation of the Optical Density (OD) from the minimum grey level (g_0) determined in dark conditions (without lighting on the opposite side of the solar protection device) and the mean grey level (g_{sample}) in light conditions (when tested) as follows: OD = $-\log_{10}[1 - g_{sample} / (N-1)]$ with N = 256 (in case of 8 bits imaging card), allows the assessment of the opacity characteristic. Afterwards, if the check is positive (CCD reaction to a hole in the curtain), an OD value of the solar protection device less than 0,0005 should be considered as no light is perceived when tested (see Clause 6.2.3 of EN 14501:2005).

The test may be performed for fabrics and/or complete products. Although the test procedure has been designed for both cases, some specific requirements are stated when differences applied between the two situations.

7.7.2 Samples

The minimum dimensions of the samples shall be the following:

— For fabrics: 200 mm x 200 mm;

— For products: 1 000 mm x 1 000 mm.

In case of products, the sample shall be mounted in accordance with the technical instructions of the manufacturer.

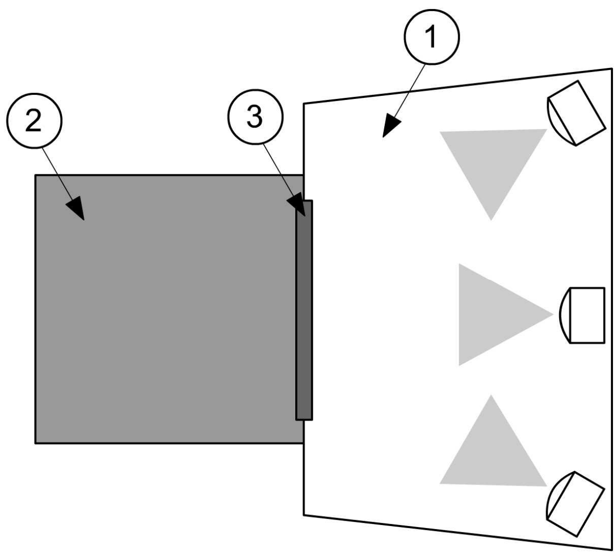
In case of fabrics, the mounting shall ensure that no light coming from the sample border will disturb the results. The fixing of the sample shall be light tight.

It may be possible for a manufacturer to validate a test for a range of fabrics or products. In this case, the sample shall be representative of the most unfavourable situation. In particular, the colour shall be the brightest colour of the range, the slats or laths shall be the thinnest of the range.

7.7.3 Test equipment

7.7.3.1 General

The test equipment shall consist of two different areas. One area (area 1) is used to light uniformly the sample and the other (area 2) is used to create a light tight environment in which the observer has to detect if light is perceptible. The test sample is installed in between the two areas (see Figure 19).



Key

1 Area 1 – Illumination of the sample
2 Area 2 – Observation of the sample
3 Sample

Figure 19 – Representation of the test principle

NOTE Annex A (informative) gives examples of test equipment which may be used.

7.7.3.2 Area 1 – Illumination of the sample

Area 1 shall fulfil the following requirements:

- One of the faces of area 1 shall be designed in order to allow the installation of the sample;
- Area 1 shall be equipped with lighting equipment (e.g. lamps) which allow to reach the level of illuminance specified in Clause 7.7.4;
- Both the design of area 1 and the lighting equipment shall allow the illuminance homogeneity level on the sample stated in Clause 7.7.4 to be achieved.

NOTE Colour and reflectance of the surface of area 1 and design of the lighting equipment influence the homogeneity of illuminance on the sample.

7.7.3.3 Area 2 – Observation of the sample

Area 2 shall fulfil the following requirements:

- The surfaces of area 2 shall be black (maximum reflectance ρ inferior to 0,1);
- The complete area 2 shall be light tight;
- One of the faces of area 2 shall be left opened in order to accept the sample;
- The opposite face shall be equipped in order to ensure that the observer's eyes are in a completely light tight environment. This may be achieved by the use of an observation mask (the observer body being out of area 2) or the observer may be completely inside area 2;
- The design of area 2 shall ensure that the observer's eyes are positioned on an axis passing through the centre of the sample;
- Area 2 shall be designed in order to ensure that the distance between the observer's eyes and the sample is :
  - For products testing: at 80 % ± 5 % of the smallest dimension of the sample (either width or height),
  - For fabric testing: at 250 % ± 10 % of the smallest dimension of the sample (either width or height);
- In case of very high illuminance, the area 2 shall be equipped with a removable safety device which will prevent any direct illumination of the observer's eyes by the lighting equipment.

NOTE Light tightness of area 2 may be verified carrying out the test with an opaque panel instead of a sample.

7.7.4 Test procedure

The sample is illuminated at the level chosen according to the type of test (fabric or product) and the class foreseen according to EN 14501 with the following condition: on the whole surface of the sample, the illuminance shall not be lower than the level of illuminance of the class and shall not exceed this level by more than 40 %.

Coloured lamps shall not be used for the test.

In case of illuminances over 75 000 Lux, the safety device shall be in place in order to prevent any direct view from the observer.

The homogeneity of the illuminance on the sample shall be checked with a luxmeter which has a measuring range of at least 0,1 to 100 000 Lux with an accuracy of ± 5 %.

In case the safety device is in place, it shall be removed after having controlled that the sample is in its fully extended or fully extended and closed position and that no direct view of the illumination is possible.

Once the homogeneity of illuminance is reached, the observer shall verify if light is perceptible through the sample for 5 minutes.

If no light is perceptible, the test is positive for the level of illuminance used.

This test shall be repeated with two different observers. If the results of the two observers are contradictory, the test shall be repeated with a third observer. The final result of the test is the one determined by the third observer.

According to the final result and the level of illuminance used, the fabric or the product is classified according to EN 14501.

7.7.5 Lighting using natural light

It is possible to use natural light to illuminate the sample. All the requirements in Clause 7.7 shall however be fulfilled. In particular, the same levels of illuminance shall be achieved and the homogeneity of the illuminance on the sample shall also be fulfilled and controlled before the test.

8 Additional calculation methods for transmittance and reflectance of products

8.1 General

This Clause applies to venetian blinds, vertical blinds and shutters.

8.2 Venetian blinds

8.2.1 General

The solar and light characteristics of venetian blinds shall be either measured directly – if the venetian blind as a whole fulfils the requirements of test samples - or calculated from the material properties of individual slats. The calculation of the product properties can be done with the approximate method given in Annex A of EN 13363-2:2005 or with more accurate methods.

NOTE 1 Annex A of EN 13363-2:2005 is intended to be used only for diffuse slats, it should not be used for specularly reflecting slats.

In Annex A.7 of EN 13363-2:2005 the view factors are only given for blinds with a spacing ration d/l = 1 and slats adjusted at 45° perpendicular to the solar beam, where “l” is the width of the uncurved slats and “d” the distance between the slats. The view factors given in the following tables shall be used for venetian blinds with a spacing ration of d/l = 72/80 or 43/50 or 22/25 or 14/16.

In every case there shall be no direct solar radiation transmitted through the blind and the slats shall be diffusely reflecting (maximum gloss level of the slats: 80 %). The following approximation is therefore valid: $\rho_{e,n\text{-}hem} = \rho_{e,n\text{-}dif}$ and $\tau_{e,n\text{-}hem} = \tau_{e,n\text{-}dif}$. So, if Annex A of EN 13363-2:2005 is used, $\rho_{e,n\text{-}hem} = \rho_{e,n\text{-}dif} = \rho_{S,D}$ and $\tau_{e,n\text{-}hem} = \tau_{e,n\text{-}dif} = \tau_{S,D}$.

NOTE 2 $\rho_{S,D}$ and $\tau_{S,D}$ are the notations used in EN 13363-2 whereas $\rho_{e,n\text{-}hem}$, $\rho_{e,n\text{-}dif}$, $\tau_{e,n\text{-}hem}$ and $\tau_{e,n\text{-}dif}$ are the notations used in EN 14501.

The assumptions made in this Clause on energy properties are also applicable to visual properties.

8.2.2 Ordinary venetian blind with incomplete closure, normal incidence

View factors Φ_{ij} for normal incidence and slats with a spacing ratio d/l = 0,87 ± 0,03 tilted at 65° (see Table 6):

Table 6 — Normal incidence and slats with a spacing ratio d/l =0,87 tilted at 65°

Φ_{ij}	*j*			
i	**1**	**2**	**3**	**4**
1	0,000	0,339	0,168	0,494
2	0,339	0,000	0,494	0,168
3	0,15	0,43	0,000	0,424
4	0,43	0,15	0,424	0,000
5	0,085	0,611	0,000	0,304
6	0,256	0,217	0,526	0,000

NOTE The assumed closing angle of 65° is not the worst case. There are venetian blinds on the market with smaller closing angles.

8.2.3 Ordinary venetian blind with slats tilted at 45°, 45° solar altitude, 0° azimuth

View factors Φ_{ij} for 45° solar altitude, 0° azimuth and slats with a spacing ratio d/l = 0,87 ± 0,03 tilted at 45° (see Table 7):

Table 7 — 45° solar altitude and slats with a spacing ratio d/l =0,87 tilted at 45°

Φ_{ij}	*j*			
i	**1**	**2**	**3**	**4**
1	0,000	0,261	0,081	0,658
2	0,261	0,000	0,658	0,081
3	0,07	0,57	0,000	0,357
4	0,57	0,07	0,357	0,000
5	0,049	0,707	0,000	0,244
6	0,444	0,089	0,467	0,000

8.2.4 Ordinary venetian blind with slats in “Cut-Off” position, 30° solar altitude, 0° azimuth

View factors Φ_{ij} for 30° solar altitude, 0° azimuth and slats with a spacing ratio d/l = 0,87 ± 0,03 tilted in cut-off position (see Table 8).

Table 8 — 30° solar altitude and slats with a spacing ratio d/l = 0,87 tilted in cut-off position

Φ_{ij}	*j*			
i	**1**	**2**	**3**	**4**
1	0,000	0,353	0,199	0,448
2	0,353	0,000	0,447	0,199
3	0,173	0,389	0,000	0,438
4	0,390	0,173	0,438	0,000
5	0,172	0,390	0,000	0,438
6	0,389	0,173	0,438	0,000

NOTE “Cut-off” position corresponds to the first position of the slats at which direct-direct transmittance is eliminated, when closing.

8.2.5 Ordinary venetian blind with slats in horizontal position, 60° solar altitude, 0° azimuth

View factors Φ_{ij} for 60° solar altitude, 0° azimuth and slats with a spacing ratio d/l = 0,87 ± 0,03 tilted in horizontal (see Table 9):

Table 9 — 60° solar altitude and slats with a spacing ratio d/l = 0,87 tilted in horizontal position

Φ_{ij}	*j*			
i	**1**	**2**	**3**	**4**
1	0,000	0,374	0,313	0,313
2	0,374	0,000	0,313	0,313
3	0,272	0,272	0,000	0,455
4	0,272	0,272	0,455	0,000
5	0,178	0,366	0,000	0,456
6	0,178	0,366	0,456	0,000

8.3 Vertical blinds

Vertical blinds shall be characterised with the same methodology as venetian blinds (see Clause 7).

NOTE The solar and visual properties of a vertical blind for an arbitrary but fixed azimuth angle of the sun can be considered to be independent from the altitude angle in most cases. (The altitude angle in case of vertical blinds corresponds with the profile angle in case of blinds with horizontal slats.) The assumption is not valid for vertical blinds with slats that have a strong angular variation of the reflectance/transmittance of the individual slats.

8.4 Shutters

The transmittance of a roller shutter is equal to the openness coefficient of the curtain in the case of laths made from opaque material. The transmittance through the holes is independent from the wavelength of the radiation. The solar and the light transmittance are therefore equal.

$$\tau = \frac{A_{holes}}{A_{total}} \qquad (20)$$

Where A_{total} is the total area of the curtain and A_{holes} is the total area of the holes.

The reflectance of a roller shutter is calculated from the properties of the slat material and the area of the holes with the following formula:

$$\rho = (1 - \tau)\rho_{n-h,lathmaterial} \qquad (21)$$

NOTE 1 When only some of the laths are perforated, then this has to be taken into account.

NOTE 2 In the case of laths made from non-opaque material, the transmittance through the curtain has to be taken into account.

NOTE 3 As a first approximation, the thermal resistance of the curtain may be ignored for solar factor (g_{tot}) calculation according to EN 13363-1 and EN 13363-2.

9 Test report

The test report shall contain as a minimum the following information:

a) Identification and description of the sample, including:

- Identification of the side of the sample which faced the incident irradiation,
- Total area of the sample and the measured area of the sample,
- Number of samples tested;

b) Identification and description of the reference sample, if used;

c) Identification and description of the equipment, including:

- Test method,
- Description of the geometry of the incident radiation,
- Description of the geometry of the detection equipment;

d) Results obtained.

Annex A
(informative)

Examples of test equipment for opacity characteristics determination

A.1 General

This Annex presents examples of test equipment which fulfil all the requirements stated in Clause 7.7 of this document and which may be used for the opacity characteristics determination of products or materials.

A.2 Example 1

The test equipment consists of two boxes: one white and the other black. The product or the material to be tested is installed in between.

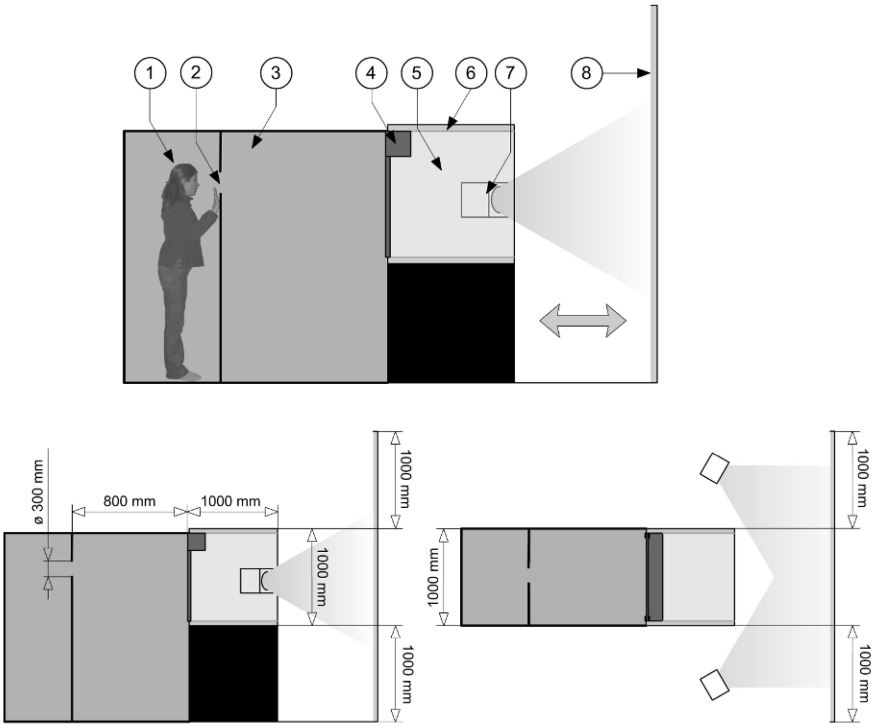
The white box is opened on one of its faces. A white wall is installed in front of this aperture. Both the white box and the black box are able to translate according to an axis perpendicular to the white wall. This movement of translation will allow the illuminance level on the sample surface to vary and therefore to reach all the levels defined for the classification of products or materials.

The lighting is indirect. The lamps light the white wall which reflects uniformly the radiation on the sample surface.

The black box is light tight. Its dimensions allow the observer to enter completely into it. Once inside, a surface determines the place where the observer has to stand during the observation. An aperture is created in that surface to allow the observation.

The test equipment is represented in Figure A.1.

Dimensions in millimetres



Key

1 Observer
2 Observation aperture
3 Black box
4 Sample
5 White box
6 Reflective material
7 Lamp
8 White wall

Figure A.1 – Representation of test equipment - Example N°1

NOTE Even if this test equipment may be used for products or materials, its dimensions make it more convenient for complete products opacity characteristics determination.

A.3 Example 2

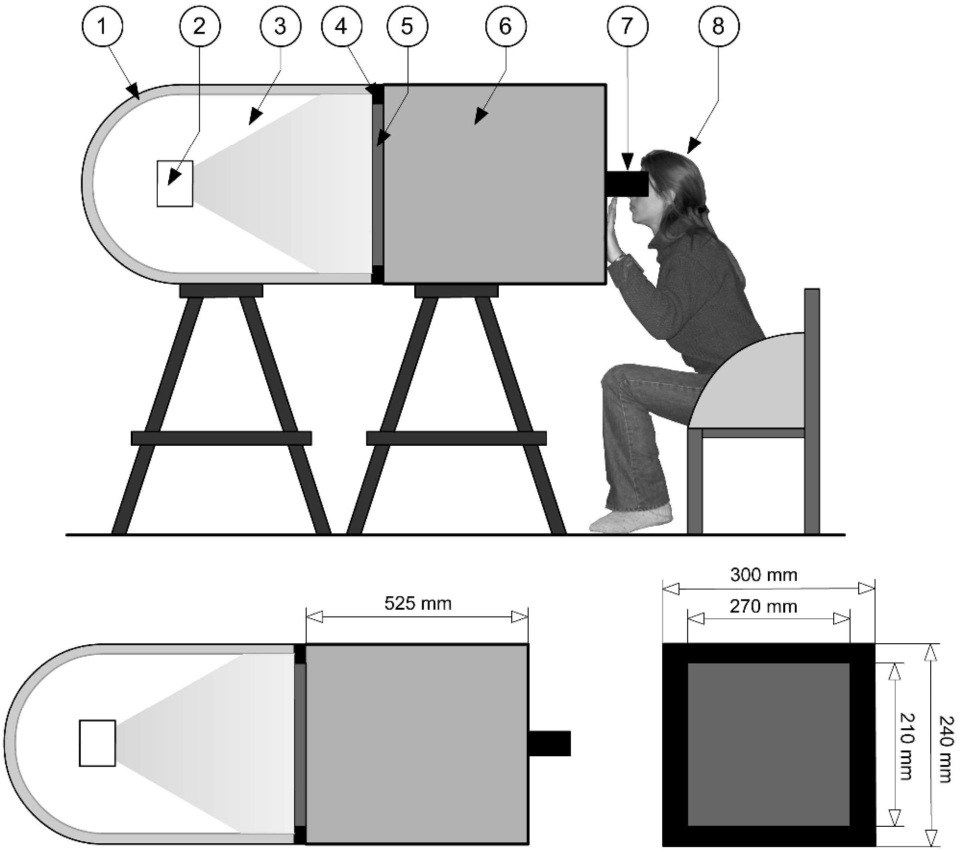
The test equipment consists of two boxes: one white and the other black. The product or the material to be tested is installed in between.

The white box is used to illuminate the sample. The test equipment is fixed and the uniform lighting is direct. The illuminance variation is achieved by a change of the lamp's intensity in order to reach all the levels of illuminance stated in the classification.

The black box is light tight. The observer is outside the box and looks into it through an observation mask which is also light tight.

The test equipment is represented in Figure A.2.

Dimensions in millimetres



Key

1 Reflective material
2 Lamp
3 White box
4 Sample support
5 Sample
6 Black box
7 Observation mask
8 Observer

Figure A.2 – Representation of test equipment - Example N°2

NOTE Even though this test equipment may be dimensioned for products opacity characteristics determination, it is usually used for materials testing which requires smaller dimensions.

Annex B
(informative)

Determination of openness coefficient

B.1 Method for fabrics made from opaque material

In relationship with the solar factor calculations using EN 13363-2, the openness coefficient plays a double role:

— Curtain openings, that allow an air flow through the blind,

— Infrared transmission through the solar protection device.

In case of fabrics made from opaque material, the openness coefficient C_o is the ratio between the area of the openings and the total area of the fabric.

It can be approximated by $C_o = \tau_{v, n\text{-}n}$ for normal incidence n.

NOTE For identical fabrics that differ only by the colour, the openness coefficient is considered as independent of the colour. The value of the openness coefficient should be measured for the darkest colour.

B.2 Method for venetian blinds

The value of the air permeability used in calculations of the solar factor according to EN 13363-2 through a partially open venetian blind is not yet perfectly solved.

According to the relatively minor effect of this parameter on the final result, i.e. the solar factor of a glazing combined with a blind, a first rough approximation could be to consider the Infrared transmittance value as the air permeability parameter value, in the same way it is used for a fabric made from opaque material with holes.

Annex C
(informative)

Determination of infrared properties

C.1 General

For the calculation of the solar factor according to EN 13363-2, the infrared transmittance and emissivity of the solar protection device are needed.

The emissivity ε, the infrared reflectance ρ_{IR} and infrared transmittance τ_{IR} are related by the Kirchhoff's law,

$$1 = \varepsilon + \rho_{IR} + \tau_{IR} \qquad (22)$$

The emissivity ε is defined as the ratio of the energy emitted by a given surface to that of a perfect emitter (black body) at the same temperature. At ambient temperature, the spectral range over which the irradiance of a black body is significant is 5 to 50 µm.

The equation (22) is valid at each wavelength and for the total (i.e. integrated over wavelengths) emissivity, transmittance and reflectance at any angle (e.g. normal incidence or 45°). It is also valid for the total hemispherical quantities (i.e. further integrated over all angles).

For materials that are opaque in the infrared, τ_{IR} = 0 and the sum of the emissivity and reflectance is equal to 1.

In the case of scattering materials that are opaque in the infrared, the normal-hemispherical emissivity can be obtained from measurements of the normal-hemispherical reflectance using equation (22) (with the transmittance τ_{IR} = 0) or from measurements of the angular emissivity followed by the integration over all angles. Both total and spectral measurements are possible. Spectral reflectance and emissivity values can be integrated to total values using the procedure described in the standards EN 673 (and EN 12898).

In the case of non-opaque materials, the infrared transmittance must be measured as well, in conjunction with the reflectance in order to determine the emissivity.

Concerning the infrared properties of solar protection devices, the following situations can be distinguished:

— plastic films (as polyester), where the material itself is transparent to IR radiation,

— holes in an opaque layer,

— multiple reflection (venetian blinds).

C.2 Determination

C.2.1 IR properties of transparent materials

The normal-hemispherical IR transmittance (resp. reflectance) of the non diffuse homogeneous material may be measured directly in the region of thermal radiation as the normal-normal transmittance (resp. reflectance).

The emissivity is calculated according to equation (22): $\varepsilon = 1 - \rho_{IR} - \tau_{IR}$

C.2.2 IR properties in the case of holes in an opaque layer

In the case of an opaque (in the infrared) layer perforated by holes, the infrared properties of the layer can be calculated on a simplified way on the basis of the infrared properties of the opaque material constituting the layer and the openness factor of the layer.

The IR properties of the layer perforated by holes can be approximated as follows:

- IR transmittance: $\tau_{IR} = f\,(C_o)$

NOTE 1 This function f depends on the type of material (thickness…)

- IR reflectance: $\rho_{IR} = (1 - C_o) \cdot \rho_{IR\ opaque\ material}$

- IR emissivity: $\varepsilon = 1 - \rho_{IR} - \tau_{IR}$

NOTE 2 The emissivity of painted surface can be assumed to be 0,9 in many cases. When this surface is opaque (τ_{IR} = 0), the infrared reflectance $\rho_{IR\ opaque\ material}$ of the surface (without holes) can be calculated according to equation (22) and therefore can be assumed to be 0,1.

C.2.3 IR properties of venetian blinds

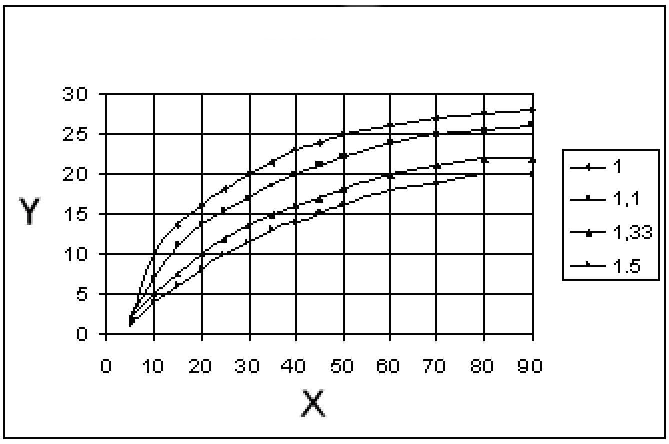
The procedure given in Annex A of EN 13363-2:2005 may be adapted to calculate the IR transmittance and reflectance of a partially opened venetian or vertical blind on the basis of the infrared properties of the slats.

The equations for a diffuse radiation are used, replacing the solar transmittance and reflectance of the slats by the infrared transmittance and reflectance.

The Figure C.1 gives the values of τ_{IR} (hemispherical-hemispherical IR transmittance) in function of the angle of aperture of the blind, for different d/l ratios, with non perforated slats with an emissivity of 0,9 (slats are supposed opaque in the infrared).

Where l = width of the slats

d = distance between slats axes



Key

X Aperture angle (°)

Y IR transmittance (%)

Ratio l/d

Figure C.1 – IR transmittance for venetian blinds with slats with an emissivity of 0,9

Annex D
(informative)

Approach in case of projecting solar protection devices

D.1 General

Projecting solar protection devices considered are projecting roller blinds, folding arms awnings, projecting shutters.

Three cases are distinguished according to the projection angle β towards the protected window:

a. Angle between 60 degrees and 90 degrees: the projecting solar protection device is considered as “horizontal” and is covered by this Annex;

b. Angle between 30 degrees and 60 degrees: the projecting solar protection device is considered as “oblique” and is covered by this Annex;

c. Angle between 0 degrees and 30 degrees: the projecting solar protection device is treated as vertical, parallel to the wall and is not covered by this Annex.

Note: In case of angle β between 0 degrees and 30 degrees, it is proposed that a calculation according to EN 13363-2 is made with gaps of 10 cm width at the lower and lateral part.

D.2 Detailed model

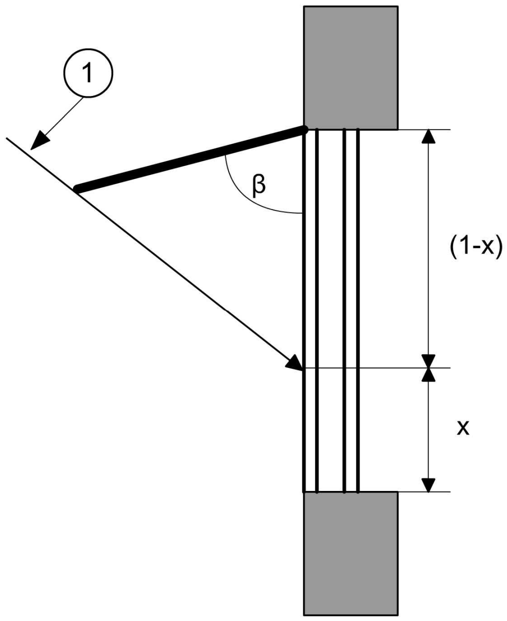
The building model used should allow the calculation of a ratio x, being the fraction of the glazing directly exposed to the sun at each time step (shaded part).

The solar radiation incident on the window is then handled considering that:

— the direct radiation is multiplied by a reduction factor F_{dir},

— the diffuse radiation coming either directly from the sky or reflected from the ground is multiplied by a reduction factor F_{dif}.

D.2.1 Reduction factor of direct radiation



Key

1 Solar radiation
(1-x) Shaded fraction of the glazing
x Exposed fraction of the glazing

Figure D.1 – Approach for projecting solar protection devices

— For a mainly direct-direct transmission of the blind (case of holes): $F_{dir} = x + (1\text{-}x)\tau_e$

— For a mainly direct-diffuse transmission of the blind: $F_{dir} = x + (1\text{-}x)C_{ard}.\tau_e$

With if horizontal ($60° < \beta \leq 90°$) $C_{ard} = 0{,}30$

if oblique ($30° < \beta \leq 60°$) $C_{ard} = 0{,}65$

D.2.2 Reduction factor for diffuse and reflected radiation

If $\beta = 90°$ $F_{dif} = 1$

If $\beta = 45°$ $F_{dif} = 0{,}5$

D.3 Simplified approach for summer

A global reduction factor F_{glo} is defined, for which the following default values are given.

This factor may be employed to correct the glazing solar factor, considering then the global incident radiation unchanged for building calculations.

Table D.1 – Reduction factor F_{glo} for solar protection devices at 45°

	North	Other façades
Solar protection device at 45°, opaque	0,45	0,25
Solar protection device at 45°, τ_e = 0,2	0,50	0,35

Table D.2 – Reduction factor F_{glo} for solar protection devices at 90°

	North	East, West	South
Solar protection device at 90°, opaque	0,90	0,60	0,45
Solar protection device at 90°, τ_e = 0,2 diffuse transmission	0,90	0,65	0,50
Solar protection device at 90°, τ_e = 0,2 direct transmission	0,90	0,70	0,60

D.4 Examples of calculation

D.4.1 General

For the following example, a detailed building model has been used to compute the shaded part of a glazing for various exposures, for the summer months (June, July, August), in order to obtain the unshaded part (x) needed to apply the formulas given in the present section.

Cases considered:

— Window dimensions: 1,40 m x 1,45 m

— Solar protection device dimensions: 1,40 x 1,45 m

— Solar protection device angle: 90°, 45° and 30°

Reduction factor of direct radiation

D.4.2 Mean values of x for summer

Table D.3 – Mean x value – Solar protection device at 90°

Orientation	Mean x value	Time (local solar time)
South	0,31	8 h to 16 h
East or west	0,42	5 h to 11 h, 13 h to 19 h
North	0,85	5 h to 7 h, 17 h to 19 h

Table D.4 – Mean x value – Solar protection device at 45°

Orientation	Mean x value	Time (local solar time)
South	0,22	8 h to 16 h
East or west	0,13	5 h to 11h, 13 h to 19 h
North	0,69	5 h to 7 h, 17 h to 19 h

Table D.5 – Mean x value – Solar protection device at 30°

Orientation	Mean x value	Time (local solar time)
South	0,18	8 h to 16 h
East or west	0,10	5 h to 11 h, 13 h to 19 h
North	0,58	5 h to 7 h, 17 h to 19 h

D.4.3 Calculations

Case 1: Fabric with holes (mainly direct transmission)

With τ_e = 0,10

Note: $F_{dir} = x + (1-x).\tau_e$

$F_{glo} = 0,85 \times F_{dir} + 0,15 \times F_{dif}$ (assumption from EN 13363-2)

Table D.6- – Mean F-value - β = 90°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,38	1	0,47
East or west	0,48	1	0,56
North	0,87	1	0,89

Table D.7 – Mean F-value - β = 45°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,30	0,5	0,33
East or west	0,21	0,5	0,26
North	0,72	0,5	0,69

Table D.8 – Mean F-value - β = 30°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,25	0,3	0,26
East or west	0,19	0,3	0,21
North	0,62	0,3	0,57

Consider a glazing type C (according to EN 14501) with g = 0,59, the following values of g_{tot} are obtained:

Table D.9 – Value of g_{tot} - β = 90°

Orientation	gtot
South	0,28
East or west	0,33
North	0,53

Table D.10 – Value of g_{tot} - β = 45°

Orientation	g_{tot}
South	0,19
East or west	0,15
North	0,41

Table D.11 – Value of g_{tot} - β = 30°

Orientation	g_{tot}
South	0,15
East or west	0,12
North	0,34

If we consider 3 solar protection devices parallel to the glazing, with τ_e = 0,10 and

ρe = 0,10 (black) ρe = 0,40 (grey) ρe = 0,70 (white)

The values of g_{tot} calculated with EN 13363-1 for these glazing and solar protection devices are:

Table D.12 – Value of g_{tot} - β = 0°

ρ_e	g_{tot}
0,10	0,11
0,40	0,09
0,70	0,07

In the case of the marquisolette, with 2/3 parallel and 1/3 projected at 45°, the normal procedure should be:

- Calculate 2/3 of height as parallel, like in table D.12 above, according to the colour,
- Calculate 1/3 as oblique, like in table D.10, according to orientation,
- Sum up the two components.

So the projecting solar protection devices can be reasonably compared to the parallel solar protection device.

Case 2: Fabric with mainly diffuse transmission

With τ_e = 0,10

Note: $F_{dir} = x + (1-x).C_{ard}.\tau_e$

$F_{glo} = 0{,}85 \times F_{dir} + 0{,}15 \times F_{dif}$ (assumption from EN 13363-2)

Table D.13 – Mean F-value - β = 90°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,33	1	0,43
East or west	0,44	1	0,52
North	0,85	1	0,87

Table D.14 – Mean F-value - β = 45°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,27	0,5	0,30
East or west	0,19	0,5	0,24
North	0,71	0,5	0,68

Table D.15 – Mean F-value - β = 30°

Orientation	F_{dir}	F_{dif}	F_{glo}
South	0,23	0,3	0,24
East or west	0,16	0,3	0,18
North	0,61	0,3	0,56

This case induces a slight reduction in the F value, due to scattering of diffused radiation in a larger solid angle, but without changing the respective positioning of the solar protection device types.

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