



BSI Standards Publication

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

National foreword

This British Standard is the UK implementation of EN 14500:2021. It supersedes BS EN 14500:2008, which is withdrawn.

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Méthodes d'essai et de calcul

Abschlüsse - Thermischer und visueller Komfort - Prüf-
und Berechnungsverfahren

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European foreword

This document (EN 14500:2021) 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of an identical text or by endorsement, at the latest by September 2021, and conflicting national standards shall be withdrawn at the latest by September 2021.

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

This document supersedes EN 14500:2008.

The main modifications of this project of revision are relating to:

- the improvement of the method for the determination of the optical properties with an integrating sphere. The major improvement concerns the consideration of samples with scattering properties (critical samples). This implied the definition of specific requirements relating to the geometry of the test equipment and a methodology to identify if a sample is critical or not;
- the addition of a new method for the determination of the optical properties from direct measurement (without integrating sphere);
- the addition of a method for the determination of the cut-off angle;
- the improvement of the method for the determination of the darkening performance of curtain materials and complete products, including a method to qualify both the test equipment and the observer.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

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

1 Scope

This document 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 14501:2021.

This document also specifies the method to determine the darkening performance of external blinds, internal blinds and shutters, as specified in EN 14501:2021.

This document applies to the whole range of shutters, awnings and blinds defined in EN 12216, described as solar protection devices in this document. 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 1 Informative Annex D presents an approach for the determination of characteristics in case of projectable products.

Retro-reflecting products are outside the scope of this document for reflectance measurements.

NOTE 2 Retro-reflecting products refer to products for which the reflected radiation comes back to the light source in the same direction.

Products using a significant amount of fluorescent are outside the scope of this document.

NOTE 3 “Significant amount” refers to materials which are designed to be fluorescent or retroreflective and marketed as such. It does not refer to trace amounts of materials exhibiting fluorescence, e.g. for colour or identification purposes. Small amounts of materials such as titanium dioxide, which are not primarily included to achieve fluorescence, can be present.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 12216, *Shutters, external blinds, internal blinds — Terminology, glossary and definitions*

EN 14501:2021, *Blinds and shutters — Thermal and visual comfort — Performance characteristics and classification*

EN ISO 52022-1, *Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing (ISO 52022-1)*

EN ISO 52022-3:2017, *Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing (ISO 52022-3:2017)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12216, EN 14501:2021 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

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;
- 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;
- 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

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

3.3.1

angle of incidence

θ

angle between the normal to the plane of the solar protection device and the direction of the incident radiation

Note 1 to entry: See Figure 1.

3.3.2

altitude angle

α_s

projection of the angle of incidence on the vertical plane which contains the direction of the incident radiation

Note 1 to entry: See Figure 1.

3.3.3

azimuth angle

γ

projection of the angle of incidence on a plane which is normal to the plane of the solar protection device

Note 1 to entry: The intersection of this projection plane and the plane of the solar protection device is horizontal.

Note 2 to entry: See Figure 1.

3.3.4

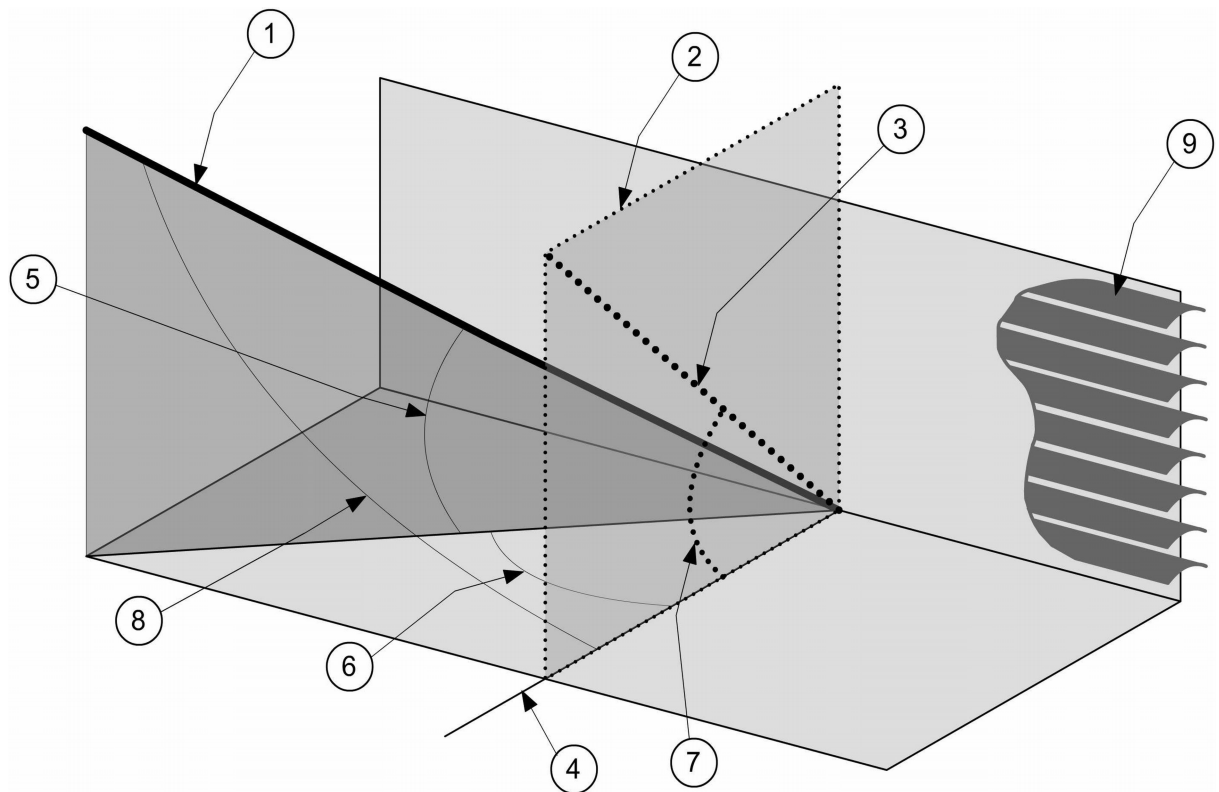
profile angle

α_p

projection of the altitude angle on a vertical plane which is perpendicular to the façade under consideration

Note 1 to entry: The profile angle is given by the following formula: $\text{tg } \alpha_p = \text{tg } \alpha_s / \cos \gamma$

Note 2 to entry: See Figure 1.

**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 α_s (angle in the vertical plane)
- 6 azimuth angle γ (angle in the horizontal plane)
- 7 profile angle α_p
- 8 angle of incidence θ
- 9 solar protection device

Figure 1 — Angle definitions**3.3.5****directional cut-off angle χ_{dir}**

minimum angle of incidence, within a given plane normal to the solar protection device, at which the direct-direct transmittance $\tau_{\text{dir-dir}}$ is below a defined level

3.3.6**cut-off angle χ**

maximum directional cut-off angle χ_{dir} , taking into account any plane normal to the solar protection device

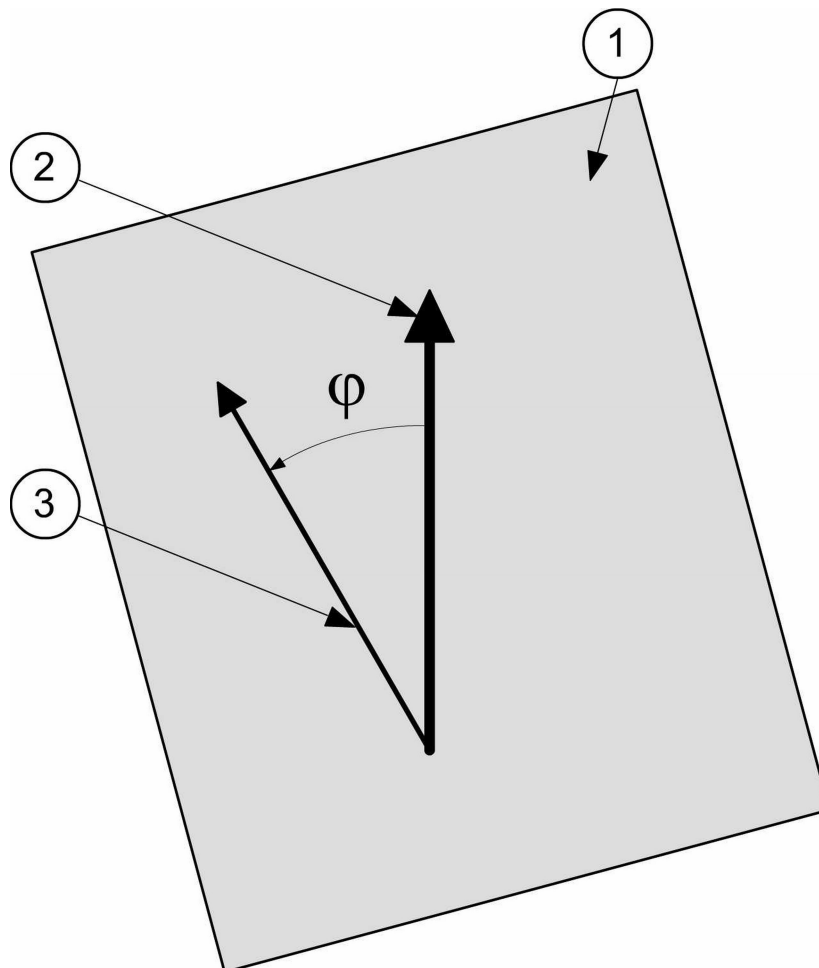
Note 1 to entry: The maximum directional cut-off angle is described as “first angle” in EN 14501:2021.

3.3.7

rotation angle ϕ

within the plane of the sample, angle of rotation of the sample from the reference arrow defined conventionally by the supplier of the sample

Note 1 to entry: See Figure 2 and 7.4.2.



Key

- 1 test sample
- 2 reference arrow
- 3 upright position of the sample at the test equipment

Figure 2 — Rotation angle

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 D₆₅ 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 (see Figure 3):

- « dir » for directional (parallel beam radiation with arbitrary direction θ);
- « n » for normal (parallel beam radiation with normal incidence $\theta = 0^\circ$ or near normal in case of reflected radiation $\theta \leq 8^\circ$);
- « dif » for diffuse (radiation evenly distributed from all incident directions θ).

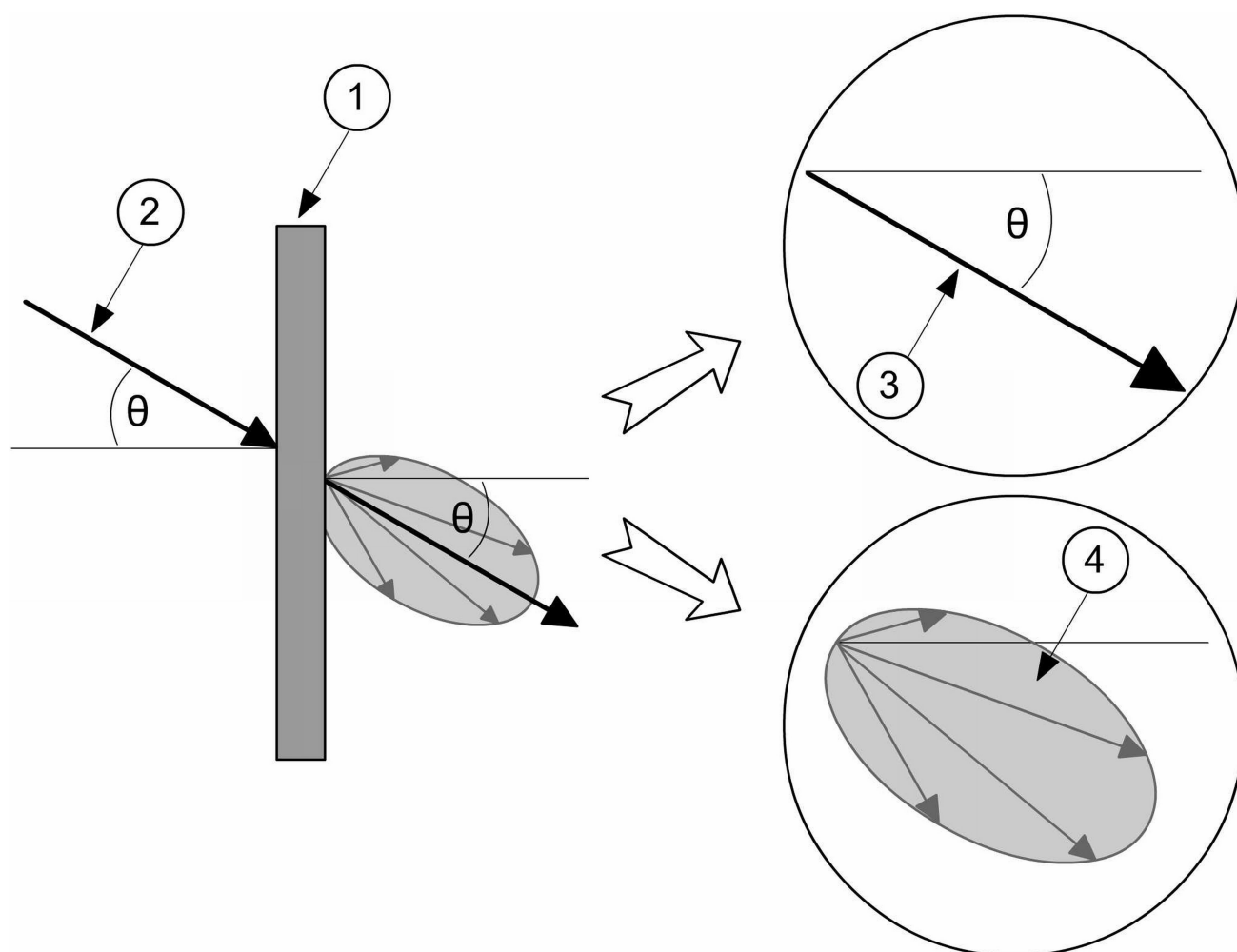
The following subscripts are used to indicate the geometry of the transmitted or reflected radiation:

- « dir » for directional (radiation reflected or transmitted in the specular or regular direction respectively);
- « n » for normal (radiation transmitted in the normal direction or near normal in case of reflected radiation $\theta \leq 8^\circ$);
- « h » for hemispherical (radiation collected in the half space behind the sample plane);
- « dif » for diffuse (radiation collected in all outgoing directions except the direct).

Complementary a particular subscript is used to distinguish values for the two different sides:

- « ' » for properties of the reverse side of the main labelled side.

NOTE For example, when ρ relates to one side of a sample, ρ' relates to the reverse side.



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 3 — Direct and diffuse components of transmitted radiation

4.4 Optical factors

The optical factors are designated as follows:

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

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

5.1 General

The test methods described in this document 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. When combined to a glazing, the properties of the whole product, which consists of one or more elements, shall be then calculated according to EN ISO 52022-1 or EN ISO 52022-3.

A whole product may also be tested. However, except when it is specified (e.g. for the darkening performances in Clause 9), methods described in this standard are not intended to be used directly on complete products.

Spectral properties shall be displayed with at least 3 digits (e.g. 0,123 or 12,3 %) and integrated properties shall be displayed with 2 digits (e.g. 0,12 or 12 %). Conventional rounding rules shall be applied.

NOTE 1 ISO 19467 provides a method to determine the solar factor of complete products (windows and doors with or without sola shading).

NOTE 2 This document characterizes the product performance through the properties of the curtain (centre of product values). However, peripheral gaps and/or holes and the installation conditions can have an effect on the performance under real conditions.

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 3 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 by considering the weighted mean of areas covered and not covered by the solar protection device.

5.2 Venetian blinds and louvres

The solar and light characteristics of venetian blinds and louvres shall be calculated using the properties of individual slats.

The slats characteristics shall be measured according to Clause 6 or Clause 7. The characteristics of a complete venetian blind or a louvre combined to a glazing shall be calculated according to EN ISO 52022-3:2017, Annex D.

Additional information given in Annex F should be considered.

NOTE 1 If products cannot be appropriately characterized using EN ISO 52022-3 (for example mirror finished and/or special shaped slats), a more detailed calculation method (e.g. raytracing) can be necessary.

NOTE 2 CEN ISO/TR 52022-2:2017, Annex G presents a more detailed calculation method for the calculation of solar and light characteristics of complete venetian blinds combined with a glazing. This method is based on EN ISO 52022-3:2017, Annex D but considers a direct transmission of the incident radiation through the venetian blind.

5.3 Roller blinds

The solar and light characteristics of roller blinds shall be calculated using the properties of the fabric.

The fabric characteristics shall be measured according to Clause 6 or Clause 7. It is assumed that the properties of the complete product are the same as those of the curtain material.

The characteristics of a complete roller blind combined to a glazing shall be calculated according to either EN ISO 52022-1 or EN ISO 52022-3.

Darkening performance shall be determined either on the curtain material or on a complete product, as specified in Clause 9.

5.4 Pleated blinds

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

5.5 Projecting awnings

Fabric properties of projecting awnings may be determined according to Clause 6 or Clause 7.

5.6 Shutters

The solar and light characteristics of shutters shall be calculated using the properties of the curtain material (e.g. laths).

The curtain material characteristics shall be measured according to Clause 6 or Clause 7. It is assumed that the properties of the complete product are the same as those of the curtain material.

The characteristics of a complete shutter combined to a glazing shall be calculated according to either EN ISO 52022-1 or EN ISO 52022-3.

Darkening performance shall be determined either on the curtain material or on a complete product, as specified in Clause 9.

Additional information given in Annex G should be considered.

6 Determination of transmittance and reflectance with an integrating sphere

6.1 Measurement principles

6.1.1 Spectral and integral methods

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

Spectral method

The relevant spectral characteristic (e.g. the normal-hemispherical spectral transmittance $\tau_{n-h}(\lambda)$) 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 spectrometer as detector. When a spectral characteristic of a sample is known, the corresponding integral characteristic can be calculated according to 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 $\tau_{e,n-h}$), 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 $\tau_{v,n-h}$), the sensitivity of the detector shall correspond to the photopic spectral sensitivity of the human eye $V(\lambda)$ and the spectral power distribution $SD65(\lambda)$ 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 $S(\lambda)$ that corresponds with the standard solar spectrum and to use a detector with a spectral sensitivity $w(\lambda)$, so that $S(\lambda)w(\lambda) = SD65(\lambda)V(\lambda)$.

Accuracy

A broad-band light-source/detector system shall be considered to be sufficiently accurate, when the solar or light characteristics for a solar control glazing with a selectivity of $\tau_v / \tau_e > 1,5$ and the results of a clear glass sample do not differ more than 4 % relatively from the results determined with a calibrated spectrometer with a relative accuracy of 2 % or better.

6.1.2 Absolute and relative measurements (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 measurement is termed absolute.

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

NOTE 1 Absolute measurements for reflectance determination 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:

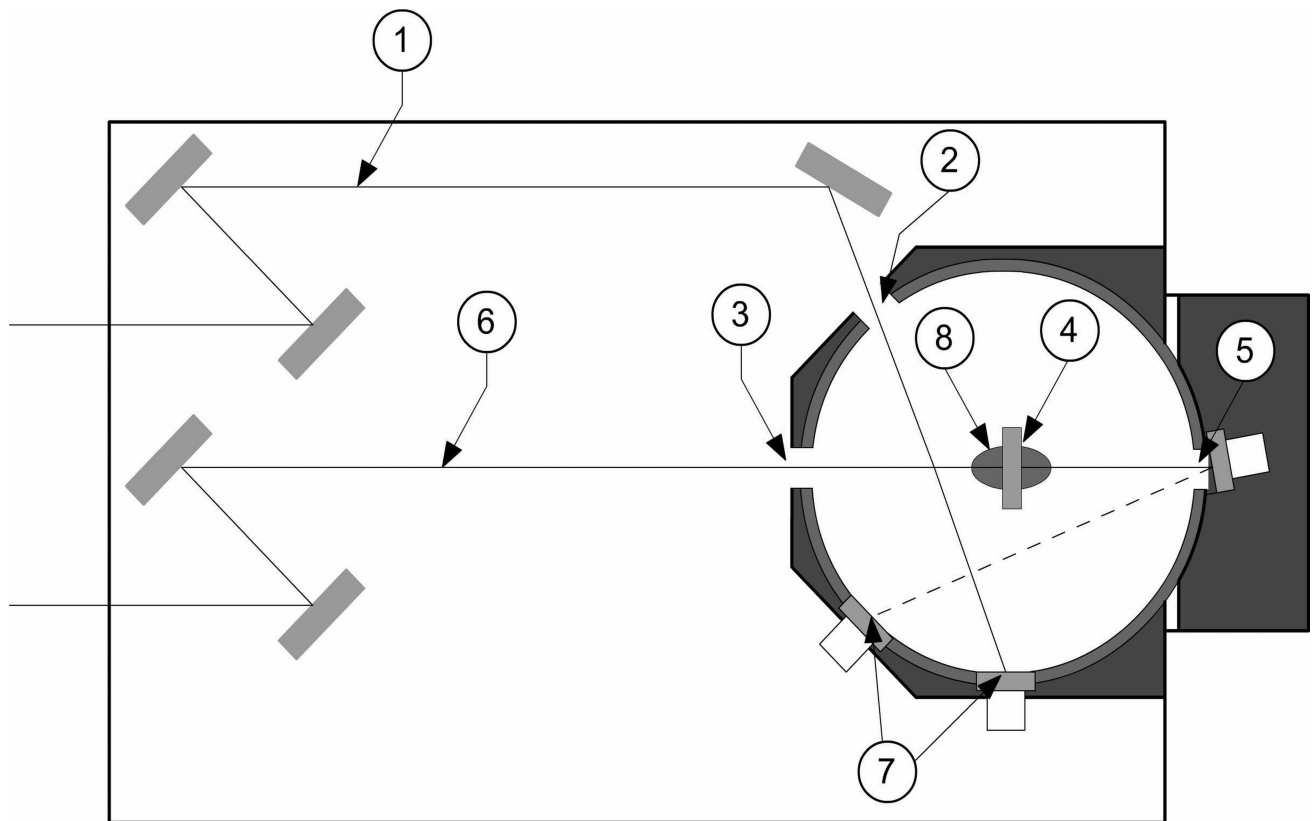
- equipment for irradiation (see 6.2.2);
- equipment for detection (see 6.2.3);
- reference samples (see 6.3).

6.2.2 Equipment for irradiation

6.2.2.1 Single or double-beam instrument

Two types of instruments are possible:

- a single beam recording instrument uses only one light beam;
- 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.



Key

- 1 reference beam ϕ_r
- 2 port N°2
- 3 port N°3
- 4 support N°4
- 5 port N°5
- 6 sample beam ϕ_s
- 7 reference port
- 8 detector (e.g. at the highest or the lowest point of the sphere)

Figure 4 — Schematic representation of a double beam spectrometer with an integrating sphere

6.2.2.2 Geometric conditions

The equipment for irradiation shall fulfil the following geometric requirements:

- the minimum beam cross-section at the sample port (Port N°3), ab_3 , shall fulfil one of the following requirement:
 - rectangular: $6 \text{ mm} \cdot 10 \text{ mm}$ ($ab_3 = wb_3 \cdot hb_3$);
 - circular: 9 mm diameter ($ab_3 = \pi \cdot db_3^2 / 4$);
- the beam cross-section at the sample port (Port N°3), ab_3 , shall be a minimum of 60 mm^2 . Additionally the perimeter of the beam-cross section, $perib_3$, shall not exceed the following specific ratio of the beam surface: $perib_3 < 0,55 \cdot ab_3$.

The actual beam shall at least cover one of the minimum cross-sections defined above;

- the irradiance shall be nearly homogeneous on the relevant area;
- the required minimum area between the aperture area (a_3) and the cross-sectional beam area (ab_3) and of Port N°3 in Figure 4 and Figure 5 shall ensure that there are no lateral losses;
- the area between the beam cross-section ab_3 and the area a_3 of Port N°3 in Figure 4 and Figure 5 shall be at least 50 mm^2 ($a_3 - ab_3 \geq 50 \text{ mm}^2$);

NOTE 1 This limit is not specified as a dimensionless quantity relative to a sphere parameter, because here the sample thickness is relevant as a scaling factor with reference to lateral shift.

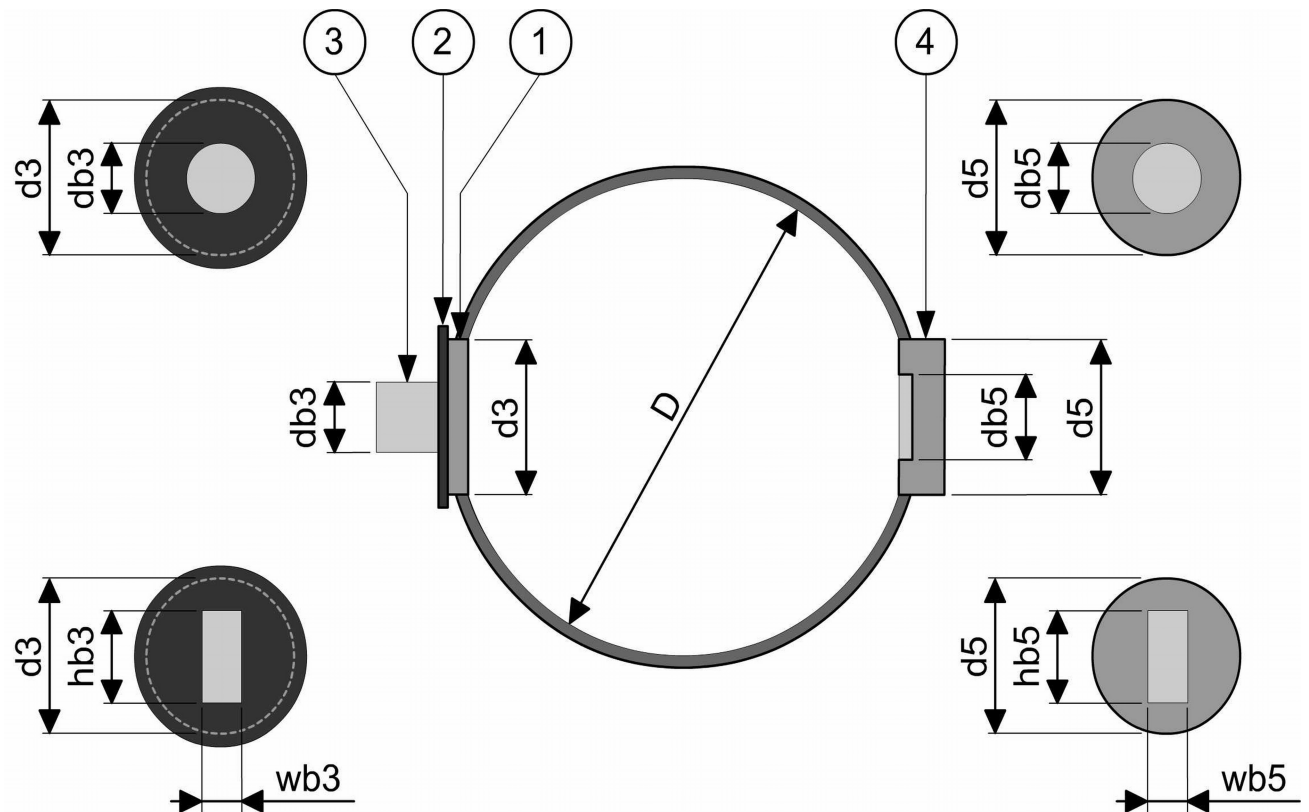
NOTE 2 If a sample is optically “thick” or thicker than 1 mm, special care should be taken for the measurement in order to ensure there are no lateral losses. Specific requirements for thick translucent samples are given in 6.4.4.

- the beam cross-sectional area at Port N°5, ab_5 , in Figure 4 and Figure 5 shall be smaller than the area (a_5) of Port N°5 in Figure 4 and centred within it.

For measurement of samples less than 1 mm thick, a minimum “gap” between the edges of the beam cross-section and Port N°5 corresponding to $(a_5 - ab_5)/A > 0,001$ shall be ensured when no sample is mounted. The clearance between the edges of port N°5 and the beam cross section when there is no sample shall be at least $1/20$ of the radius of the port N°5;

NOTE 3 Special care should be taken for the measurement of sample of more than 1 mm thick.

- stray radiation outside the irradiated area of the sample shall be avoided;
- in the case of diffuse irradiation, an integrating sphere shall be used as a light source.



Key

- 1 port N°3
- 2 sample
- 3 incident beam
- 4 port N°5

Figure 5 — Definition of geometrical parameters for integrating spheres

Rectangular ports and beams are characterized by the height h and the width w . The beam cross-sectional areas ab_3 and ab_5 , the port areas a_3 and a_5 and the sphere area A are calculated directly from the linear dimensions. It is important to note that the beam cross sections at port N°3 and port N°5 are different in general due to non-parallel light beams.

6.2.2.3 Polarization

The characteristics of solar protection devices or materials for non-normal incidence depend on the state of polarization of the irradiating beam. Directional measurements can only be performed with unpolarised incident irradiation if no polarization arises from the source or the deflecting or focusing optics (if present) and if the detector is insensitive to polarization. Therefore, in general, for non-normal measurements, two separate measurements shall be made with the incident radiation fully linearly polarized 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 polarized even if the incident radiation is unpolarized.

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

NOTE 3 Mounting fabric samples with the yarn direction rotated 45° to the vertical will minimize possible polarization effects which can occur even for light at normal incidence due to polarization of the incident beam by the optical components of the measuring instrument, if the light path lies within a horizontal plane. This is a common configuration, e.g. in double-beam spectrometers.

6.2.3 Equipment for detection

6.2.3.1 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. One or several detectors are placed inside.

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 1 Integrating spheres are not suitable for measuring luminescent materials.

NOTE 2 The higher the reflectance of the sphere coating is, the higher is the sensitivity of the detection equipment.

NOTE 3 Common materials for sphere coatings are BaSO₄ and pressed and low-density sintered PTFE.

NOTE 4 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 6.2.3.2.

6.2.3.2 Requirements

The integrating sphere shall fulfil the following requirements:

- 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;
- the inner surface of the sphere shall have a normal-hemispherical solar reflectance > 0,92 for spectral measurement;
- in case of broad band measurements, non-selectivity is more important than a high reflectance. A coating with a normal-hemispherical reflectance > 0,80 with very good non-selectivity shall be used.

NOTE 1 The average reflectance of the inner surface can be verified by the following formula:

$$\Phi_r(\Phi_t) = E_{\text{ind}} \cdot A \cdot \frac{1 - \rho_k}{\rho_k} \quad (1)$$

where

$\Phi_r(\Phi_t)$ is the reflected (transmitted) flux;

E_{ind} is the indirect irradiance /illuminance on diffusing window in the front of the detector;

A is the area of the sphere surface;

ρ_k is the average reflectance of the whole surface of the sphere.

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:

$$K(\lambda)_{rel} = \frac{\rho_k(\lambda)(1 - \rho_{k,max})}{\rho_{k,max}(1 - \rho_k(\lambda))} \quad (2)$$

where

$\rho_k(\lambda)$ is the normal-hemispherical spectral reflectance of the sphere coating including ports.

$\rho_{k,max}$ is the maximum of $\rho_k(\lambda)$.

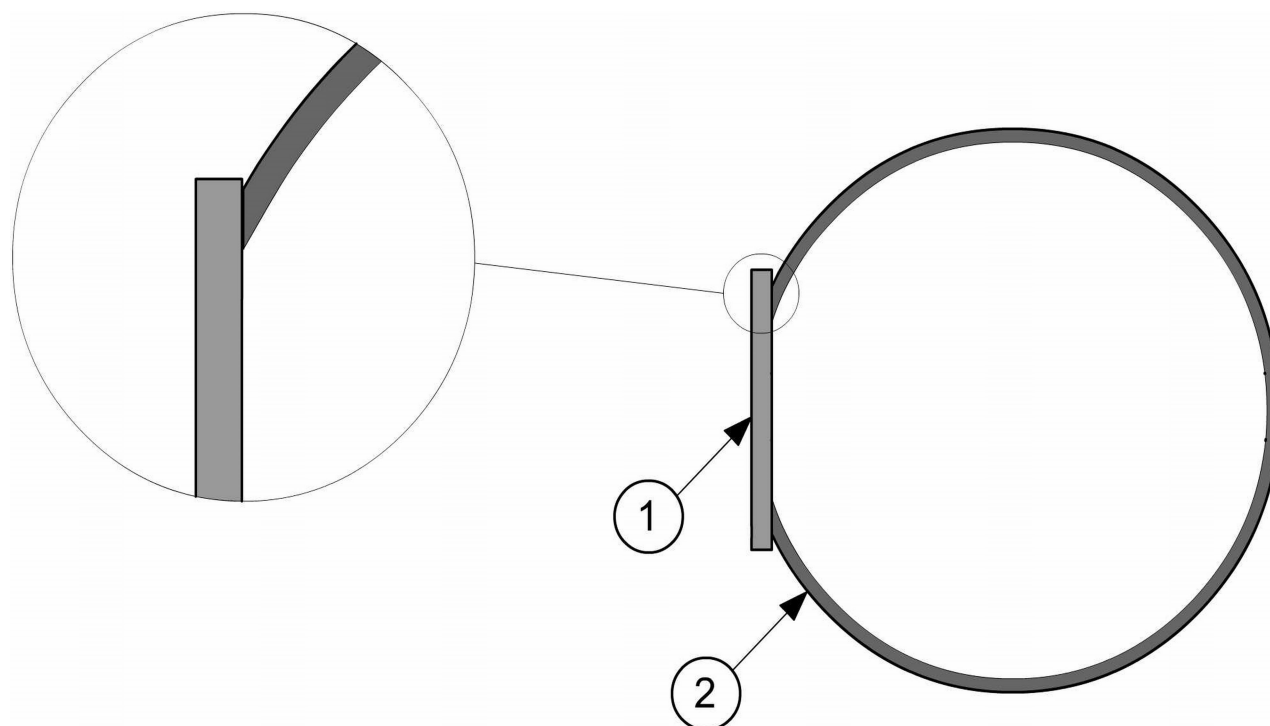
NOTE 2 Sphere paints are available commercially for which the relative factor $K(\lambda)_{rel}$ is listed as a function of wavelength.

NOTE 3 Ideally, the internal surface will be isotropic diffuse reflecting.

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.

— 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 or the port sides shall be chamfered, 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

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 minimized.

With reference to Figure 4 and Figure 5, the allowable ranges of port N°3 and port N°5 are defined as areas a_3 and a_5 relative to the interior sphere area A . The area A refers to the inner surface area of an “ideal” sphere without taking deviations such as ports into account and is calculated from the internal diameter D as $A = \pi D^2$.

Definitions based on diameters should be avoided since they are not defined for rectangular cross sections.

- The allowable ratio a_5/A for the area a_5 of Port N°5 in Figure 4 and Figure 5 to the inner surface A of the sphere wall shall fulfill the following condition:

$$0,003\ 5 \leq a_5/A \leq 0,007$$

- The area of the sample port shall not exceed $1/144$ of the internal surface area of the sphere;

Large differences in reflectance between sphere wall and the plug closing port 5 shall be avoided.

Detectors shall either be:

- radiometers/photometers which are sensitive to radiation/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.

NOTE 4 An absolute calibration of detectors is possible but not necessary.

For all types of detectors care shall be taken about sufficient linearity and low temperature dependence.

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 solar reflectance $> 0,92$ for spectral method).

NOTE 5 Errors can be caused by detectors with a sensitivity that depends on the position of the beam on the photosensitive area.

For the test equipment for the method A (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 minimize 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 6.2.3. It is recommended to put the observed area as close as possible to the sample port in order to minimize the necessary size of the baffle for the observed area.

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

For the test equipment for the method C, the detector can be at the highest or the lowest point of the sphere. The line of sight of the detector shall be baffled against the reference beam and the sample beam.

6.3 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 solar 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 solar 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 solar 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.