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Glass in building – Determination of the emissivity

National foreword

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Verre dans la construction - Détermination de l'émissivité

Glas im Bauwesen - Bestimmung des Emissionsgrades

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European foreword

This document (EN 12898:2019) has been prepared by Technical Committee CEN/TC 129 “Glass in building”, the secretariat of which is held by NBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2019, and conflicting national standards shall be withdrawn at the latest by September 2019.

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 12898:2001.

The main changes compared to the previous edition are the following:

— introduction of a method to determine the emissivity using Fourier Transform Infrared (FTIR) spectrophotometers where the spectral range is limited;

— provision of a new method for the calculation of corrected emissivity; and

— clarification of rounding rules for normal emissivity.

In this version, the procedures covering transmittance and diffuse reflectance measurements and calculation of total normal transmittance have been moved to an informative annex (Annex C).

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This document specifies a procedure for determining the emissivity at room temperature of the surfaces of glass and coated glass.

The emissivity is necessary for taking into account heat transfer by radiation from surfaces at the standard temperature of 283 K in the determination of the U value and of the total solar transmittance of glazing according to [1] to [4].

The procedure, being based on spectrophotometric regular reflectance measurements at near normal incidence on materials that are non-transparent in the infrared region, is not applicable to glazing components with at least one of the following characteristics:

a) with rough or structured surfaces where the incident radiation is diffusely reflected;

b) with curved surfaces where the incident radiation is regularly reflected at angles unsuitable to reach the detector while using regular reflectance accessories;

c) infrared transparent.

However, it can be applied with caution to any glazing component provided its surfaces are flat and non-diffusing (see 3.1.6) and it is non-transparent in the infrared region (see 3.1.7).

Although transmittance measurements are included in this document, they are only necessary to check if the sample is non-transparent in the infrared region in the context of this document (see 3.1.7). If the sample is transparent in the infrared region, this document is not applicable.

The previous version of this document was based on the use of reflectance measurements using double beam dispersive infrared spectrophotometers capable of measuring over almost the entire spectral range of a black body at the standard reference temperature and determining the emissivity by the 30 ordinate method [6]. This version takes account of Fourier Transform Infrared (FTIR) spectrophotometers where the spectral range is limited. It describes a method whereby spectrophotometers can be used to determine emissivity if they are able to measure up to the 24th ordinate point and if they satisfy a noise criterion for this spectral range. It allows the inclusion of data from the 25th ordinate point up to the 30th ordinate point. A new informative annex (Annex D) describing the principles of absolute reflection accessories has been added to this version. These accessories are intended to be used by qualified personnel.

As FTIR spectrophotometers are single beam instruments as opposed to dispersive spectrophotometers which are double beam instruments (and thus able to correct for instrument drift), a procedure was developed by the European funded project, THERMES, to correct for drift. This procedure is described in [10] and [16]. Other categories of ordinate errors using FTIR spectrophotometers are discussed in [14].

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.iso.org/obp

3.1.1
infrared
5 µm to 50 µm spectral range

3.1.2
emissivity
ratio of the energy emitted by a given surface at a given temperature to that of a perfect emitter (black body with normal and corrected emissivity = 1,0) at the same temperature

Note 1 to entry: Two different definitions of emissivity should theoretically be used to describe radiation exchange between:

a) glass surfaces facing each other in multiple glazing (effective emissivity);

b) a glass surface facing a room (hemispherical emissivity).

However, in practice numerical differences were found to be negligibly small (see [5]). Thus, corrected emissivity is used to describe both types of heat exchange with a close approximation.

3.1.3
specular reflectance
regular reflectance
reflectance according to the laws of geometrical optics, without the diffuse component

Note 1 to entry: The measurement arrangement should be such that the instrument beam reaches the detector after being specularly reflected on the surface of the sample (reference mirror) at an angle of incidence ≤ 10°.

3.1.4
diffuse reflectance
reflectance not containing any regular component, due to rough surfaces and/or transparent materials containing inhomogeneous particles

3.1.5
total reflectance
sum of regular and diffuse reflectance

3.1.6
non-diffusing glazing component
glazing component with a diffuse reflectance ≤ 0,05, measured at the near infrared wavelength of 2 µm (see Annex C)

Note 1 to entry: The purpose of this measurement is to ensure that the sample is non-diffusing in the measurement range. Most integrating spheres sold with visible/near infrared spectrophotometers have a port designed to measure diffuse reflectance. Diffuse reflectance measurements in the infrared range are difficult to perform.

3.1.7
glazing component non-transparent in the infrared region
glazing component with a total normal transmittance ≤ 0,05 at 283 K, measured spectrophotometrically

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

ε	total corrected emissivity at 283 K
ε_n	total normal emissivity at 283 K
E	reading of the spectrophotometer with the sample placed on the sample support of the reflectance accessory
E_0	the instrument reading without placing anything on the sample support
E_{st}	the instrument reading with the reference mirror replacing the sample
R_n	total normal reflectance at 283 K
R_n (λ_i)	spectral normal reflectance at wavelength λ_i
$R_{n,st}$	spectral normal reflectance of the reference mirror
T_n (λ_i)	spectral normal transmittance at wavelength λ_i
T_n	total normal transmittance at 283 K
N	number of measurement points to determine total normal reflectance

4 Brief outline of the procedure to determine corrected emissivity

The procedure for determining the corrected emissivity of coated glass surfaces includes the following steps:

a) the spectral regular reflectance of a glazing component non-transparent in the infrared region at near normal incidence, R_n (λ_i), shall be determined with an infrared spectrophotometer in the range (5 to 50) µm (see Clause 5);

b) total normal reflectance at 283 K, R_n, shall be calculated using the integration procedure specified in 5.4 from the corresponding spectral reflectance values measured according to step a);

c) total normal emissivity, ε_n, shall be calculated from the total normal reflectance as specified in Clause 6;

d) the corresponding corrected emissivity, ε, shall be determined from the normal emissivity in accordance with Formula (6).

NOTE 1 The corrected emissivity, calculated from the normal emissivity with the help of a multiplicative correction factor, takes into account the effect of the angular distribution of emissivity in the heat transfer calculations of glazing according to [1] to [4].

NOTE 2 Both the normal and the corrected emissivity are total emissivities at 283 K, i.e. they are integrated over the relevant spectral range using as a weighting function Planck's radiation function for a black body at 283 K (see [6]).

For uncoated soda lime silicate glass surfaces or for soda lime silicate glass surfaces with coatings which have no effects on the emissivity, the normal emissivity to be used in the calculations specified in [1] to [4] shall be 0,89 (see [7]). For all other glazing materials or components it shall be measured.

NOTE 3 With reasonable confidence ε_n = 0,89 can be used for uncoated borosilicate glass, glass ceramics, alkaline earth silicate glass and alumino silicate glass (see [7]).

NOTE 4 For temperatures included in the range 253 K to 313 K emissivity is not strongly dependent on the temperature (see [7] and [8]).

5 Spectral normal reflectance measurements and calculations

5.1 Sample preparation

Samples shall be of a size suitable for being inserted into the sample compartment or placed on the reflectance accessory. In doing so, care shall be taken to ensure that the portion of the coated surface probed by the instrument beam is free of damage or any surface contamination. The procedures recommended by the producer for storing the samples and cleaning their surfaces shall be followed.

The sample shall be supported in a suitable way to ensure that the measuring spot during transmittance and reflectance measurements falls on a flat part.

5.2 Spectral normal reflectance measurements

5.2.1 General

The spectral regular reflectance curve of the sample at near normal incidence between 5 µm and 50 µm shall be determined with an infrared spectrophotometer equipped with a specular reflectance accessory at near normal incidence.

5.2.2 Test apparatus

The following equipment shall be used for the measurements:

— a spectrophotometer covering the spectral range 5 µm to 50 µm. Alternatively, a spectrophotometer that covers the spectral range from 5 µm to a wavelength less than 50 µm can be used as long as it is capable of measuring up to the 24th point (23,3 µm) and satisfying the noise criterion (see 5.4.3) for all points up to the 24th point inclusive;

— a reference mirror (free of surface scratches and contamination, see [6], [8] and [9]) whose spectral regular reflectance at near normal incidence Rn,st (λ) shall be traceable to a standard material from a metrological laboratory [15];

— a specular reflectance accessory consisting of a suitable array of mirrors and a sample support. When the accessory is placed in the sample compartment of the spectrophotometer and the sample (or reference mirror) placed on the sample support, the instrument beam reaches the detector after being specularly reflected on the surface of the sample (reference mirror) at an angle of incidence ≤ 10°.

As an alternative, Annex D provides a method for determining absolute reflectance by comparing the energy of the beam reflected from the sample to that of the incident beam. However, these accessories can be difficult to align and should be used with caution.

5.2.3 Measurement

The spectral regular reflectance curve of the sample at near normal incidence shall be determined with the relative method. The following measurements are required to determine the spectral normal reflectance of the sample R_n (λ_i) at each wavelength λ_i reported in Table A.1 of Annex A:

— E the instrument reading with the sample placed on the sample support of the reflectance accessory;

— E_{st} the instrument reading with the standard reference mirror replacing the sample;

— E_0 the instrument reading without placing anything on the sample support.

These wavelengths are selected at the centre of equal energy wavelength intervals of Planck's radiation function at 283° K [6].

Measurements shall be taken at each wavelength λ_i reported in Table A.1 over the wavelength range for which the spectrophotometer is capable.

At each wavelength λ_i the sample normal reflectance R_n (λ_i) shall be calculated as follows:

$$R_n(\lambda_i) = \frac{E(\lambda_i) - E_0(\lambda_i)}{E_{st}(\lambda_i) - E_0(\lambda_i)} \cdot R_{n,st}(\lambda_i) \qquad (1)$$

with $R_{n,st}$ (λ_i) = spectral normal reflectance of the reference mirror at the wavelength λ_i.

5.2.4 Accuracy

The accuracy is estimated to be of the order of ± 0,01, expressed as absolute uncertainty of regular reflectance (see [6]).

NOTE In Annex B, information on procedures to improve the measurement accuracy is given.

5.3 Interpolation

If the spectra are measured at fixed wavelength or wavenumber intervals, then the reflectance and, if necessary, transmittance values corresponding to the wavelength intervals detailed in Table A.1 shall be linearly interpolated from the neighbouring wavelength points of the spectrum.

5.4 Determination of normal reflectance

5.4.1 General

The spectrophotometer shall be capable of measuring normal reflectance up to the 24th point (i.e. 23,3 µm) as detailed in Table A.1 and in accordance to the noise criterion described in 5.4.3. Thus, a minimum of the first 24 points shall be used in Formula 2. In addition, points 25 through 30 can be included, provided that they satisfy the noise criterion in a consecutive order. For example, if the 27th point satisfies the noise criterion, it should only be used in the calculations if both the 25th and 26th points also satisfy the noise criterion.

NOTE 24 is considered to be the minimum number of points needed to capture an acceptable amount of the black body curve while acknowledging the current measurement capability (see [17]).

5.4.2 Calculation method

The total normal reflectance value, R_n, at a temperature of 283 K shall be determined from the spectral reflectance curve by taking the mathematical average of the first 24 or more measured points at the ordinate wavelengths in Table A.1 and calculated as follows:

$$R_n = \frac{1}{N}\sum_{i=1}^{i=N} R_n\left(\lambda_i\right) \quad (2)$$

where

R_n = the total normal reflectance value of the N measured points;

$R_n (\lambda_i)$ = the normal reflectance at wavelength λ_i, i corresponding to the ith point;

N = the number of measurement points described above.

5.4.3 Noise criterion

The following procedure shall be followed to determine the points considered usable for calculating the average value of reflectance in accordance with 5.4.2.

This procedure should be followed every six months to evaluate the performance of the spectrophotometer.

A normal baseline measurement shall be performed with the standard reference mirror, as for routine measurements. Ten measurements shall be carried out over the maximum wavelength range of the spectrophotometer, without moving the sample. Corrections for reflectance (i.e. multiplying by the reflectance values of the standard reference mirror) may or may not be used for this procedure. In the case that corrections are not applied, the values determined should be equal or close to 1,0.

For each wavelength, the difference between the maximum and minimum values shall be determined. The differences shall be tabulated for all 30 points, or up to the last measured point of the spectrophotometer, in accordance with Formula (3).

$$\Delta R_i = R_{i\,\max} - R_{i\,\min} \quad (3)$$

where

ΔR_i = the reflectance difference for the point;

$R_{i\,\max}$ = the maximum value of the 10 measured values at the ith point;

$R_{i\,\min}$ = the minimum value of the 10 measured values at the ith point.

All points up to and including the 24th point shall satisfy the relationship (4).

$$\Delta R_i \le 0{,}02 \quad (4)$$

If this condition is not satisfied then the spectrophotometer shall be deemed incapable of performing the measurement. If this condition is satisfied then, from the 25th point, all points shall be evaluated in ascending order according to (4). Only those points satisfying this condition shall be used in determining the average. Any point not satisfying this requirement, and all those above it, shall be excluded from the calculation. All calculations shall be performed without rounding.

6 Calculation of total normal emissivity and corrected emissivity

6.1 Total normal emissivity

Total normal emissivity ε_n at 283 K is determined in accordance with Formula (5).

$$\varepsilon_n = 1 - R_n \qquad (5)$$

In all cases, intermediate rounding shall not be undertaken. In the case of multiple measurements (i.e. more than one measurement on the same sample), the mathematical averaging of the normal emissivity shall be performed before rounding.

NOTE The uncertainty resulting when the measurement range of the spectrometer does not cover the 30 selected wavelengths reported in Table A.1 is discussed in [6].

6.2 Corrected emissivity

For soda lime silicate glass and coated soda lime silicate glass the corrected emissivity, ε, shall be determined from the normal emissivity in accordance with Formula (6).

$$\varepsilon = 1{,}188\ 7\ \varepsilon_n - 0{,}496\ 7\ \varepsilon_n{}^2 + 0{,}245\ 2\ \varepsilon_n{}^3 \qquad (6)$$

For surfaces other than coated soda lime silicate glass, uncoated soda lime silicate glass, borosilicate glass and glass ceramics Formula (6) may be applied with caution, considering that it is not supported by experimental evidence comparable to that obtained for glass (see [5], [7], [8], [11], [12] and [13]).

NOTE Although the constants used in Formula (6) are given to four decimal places, this does not imply the same level of accuracy for the value of emissivity.

7 Test report

The test report shall state the following as a minimum:

— sample size (mm);

— material(s) of glazing component;

— thickness of glazing component (mm);

— type of coating (if any, if known) on the surface being measured;

— storage, handling and cleaning conditions;

— manufacturer and model code of the spectrophotometer;

— type of spectrophotometer (single or double beam or FTIR; spectral range; specify if automatic, if interfaced to a computer; if purged with gas);

— operating conditions during the scan;

— manufacturer and model of the reflectance accessory and angle of incidence;

— type of reference mirror and source of calibration;

— total normal emissivity.

The value of N shall be stated in the report.

The value of the measured normal reflectance at each selected ordinate shall not be reported unless specifically requested by the manufacturer or test sponsor. In this case, the values shall be reported to at least four significant figures.

The corrected emissivity shall not be reported.

The total normal emissivity given in the test report shall be truncated at three decimal places and then rounded to two decimal places (see examples). This rounded value shall be used to determine the corrected emissivity. For the determination of the U value in accordance with EN 673 [2], the total corrected emissivity shall not be rounded.

Examples of normal emissivity truncated at three decimal places and then rounded to two decimal places are given in Table 1.

Table 1 — Examples of rounding rules for normal emissivity

Step	Example 1	Example 2	Example 3
Normal emissivity (as measured)	0,044 1	0,044 9	0,045 0
Truncated at three decimal places	0,044	0,044	0,045
Rounded to two decimal places	0,04	0,04	0,05
Normal emissivity for determination of corrected emissivity	0,04	0,04	0,05

Annex A
(normative)

Table for determining total normal reflectance

Table A.1 — 30 selected wavelengths (λ_i) for determining total normal reflectance, R_n, at 283 K

Ordinal number i	**Wavelength(λ_i)** µm	**Ordinal number** i	**Wavelength (λ_i)** µm
1	5,5	16	14,8
2	6,7	17	15,6
3	7,4	18	16,3
4	8,1	19	17,2
5	8,6	20	18,1
6	9,2	21	19,2
7	9,7	22	20,3
8	10,2	23	21,7
9	10,7	24	23,3
10	11,3	25	25,2
11	11,8	26	27,7
12	12,4	27	30,9
13	12,9	28	35,7
14	13,5	29	43,9
15	14,2	30	50,0[a]

[a] 50 µm has been chosen because this wavelength is the limit of most commercially available spectrophotometers. This approximation has a negligible effect on the accuracy of the calculation.

Annex B
(informative)

Procedures to improve the accuracy of spectral normal reflectance measurements

B.1 General

The method described in 5.2 is sensitive to misalignments. The influence of sample tilt errors can be minimized by averaging at least three measurements performed with re-positioned sample.

Specular reflectance measurements carried out with different spectrophotometers generally lead to different results owing to the different actual conditions of measurement vs. ideal conditions (angle of incidence, finite beam size and divergence, viewing angle of the detector, polarization, alignment of the mirrors of the reflectance accessory).

The accuracy of reflectance measurements is influenced by the quality of the instrument, reflectance accessory and reference mirror.

B.2 Spectrophotometer

Uncertainties arise from incorrect wavelength scale, detector nonlinearity and non-uniform response over the sensitive window; stray light; divergence of the incident beam (potentially causing vignetting of the reflected beam as its path increases, see [9]).

A range of measurement errors typical of Fourier Transform spectrophotometers is described in [14].

The wavelength scale can be checked with polystyrene films whose absorption peaks feature minima at known wavelengths.

The photometric accuracy can be checked with the help of rotating sectors which produce a known transmittance by intercepting a given percentage of the instrument beam or of samples with a known transmittance traceable to a reference material from a metrological laboratory or one accredited to ISO/IEC 17025 [18] for calibration (see [15]).

B.3 Reference mirror

The reference mirror should have a reflectance as close as possible to that of the sample, to limit errors due to nonlinearity of the detector (see [9]).

The accuracy of reflectance measurements improves if the reference mirror is carefully stored and handled (see [6], [8] and [9]).

Some laboratories use as a reference mirror an opaque first surface Al, Ag or Au mirror to which the spectral reflectance suggested by some literature source is attributed. In this case, discrepancies arise due to non-uniform production and storage conditions, non-uniform literature references, insufficient data for wavelengths > 30 µm. The experience of interlaboratory comparisons (see [6]) shows that the spread of results becomes worse when such domestically calibrated mirrors are used. For this reason a reference mirror traceable to a metrological laboratory or one accredited to ISO/IEC 17025 for calibration should be used.

B.4 Reflectance accessory

Care should be taken to ensure that the set of mirrors in the accessory is properly aligned, maximizing the detector reading.

Annex C
(informative)

Transmittance and diffuse reflectance measurements and calculation of total normal transmittance

C.1 Transmittance measurements

Glazing components including at least one glass plate are not infrared transparent and do not request transmittance measurement.

For glazing components not including glass or coated glass the spectral regular transmittance curve of the sample at normal incidence between 5 µm and 50 µm should be determined with an infrared spectrophotometer by placing it in the sample compartment perpendicularly to the beam. As for reflectance, if the spectrophotometer is not capable of measuring over the entire wavelength range, the procedure of 5.4 should be followed.

C.2 Calculation of total normal transmittance

Where applicable, total normal transmittance at a temperature of 283 K should be determined from the spectral transmittance curve by taking the mathematical average of spectral transmittance, T_n (λ), measured at N wavelengths (λ_i) given in Table A.1.

NOTE The purpose of this determination is to confirm that a given glazing component consisting of materials other than glass and coated glass is non-diffusing (see 3.6).

$$T_n = \frac{1}{N}\sum_{i=1}^{i=N} T_n\left(\lambda_i\right) \tag{C.1}$$

where $N \geq 24$, as described in 5.4.2.

C.3 Diffuse reflectance measurements

Diffuse reflectance at 2 µm for near normal incidence irradiation is determined as the difference between hemispherical reflectance and regular reflectance (see [9]).

Glazing components consisting of float glass, coated float glass and laminated float glass have a negligible diffuse reflectance and do not require diffuse reflectance measurements.

Annex D
(informative)

Determination of absolute reflectance by comparing the energy of the beam reflected from the sample to that of the incident beam

D.1 General

The determination of emissivity for glass in building involves the measurement of reflectance from 5 µm to 50 µm according to this Standard. In the past, many laboratories have used relative reflectance accessories with reference materials. However, the availability of reference materials has all but ceased and those available are extremely expensive. This Annex describes two types of absolute reflectance accessories (VW and IW) that may be adapted for these types of instruments.

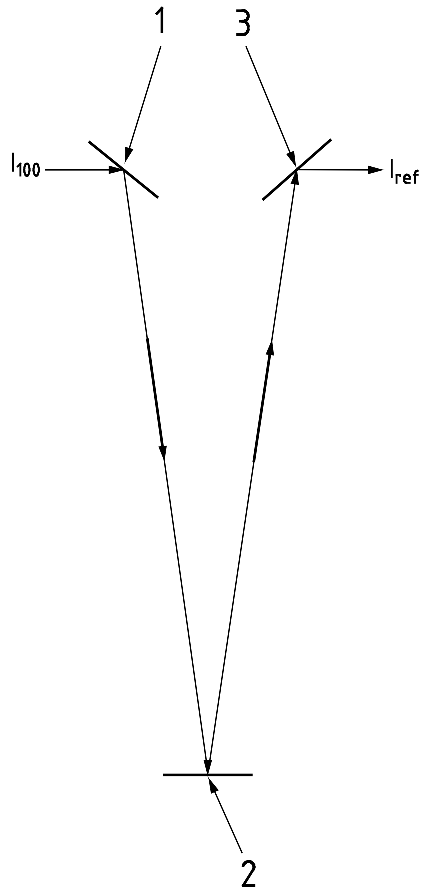
VW accessories have been used by metrological laboratories for calibrating standards for some time. They are particularly suitable for measuring high reflectance standards as they measure the reflectance squared, thus improving the uncertainty by a factor of about two. When appropriate precautions are followed, up to 0,2 % uncertainty may be achieved. However, to achieve such an uncertainty, the measurements are extremely time consuming and expensive. As alignment is critical for these instruments they have generally not been used by laboratories other than metrological ones. IV accessories are also capable of making absolute reflectance measurements and have appeared in some commercial accessories.

The ability to fabricate precise optical instrumentation has greatly improved over the last couple of decades. In the future, these accessories may become available with increased ease of usage. However, at present, they are still difficult to maintain the required alignment and, as such, should be considered for measurement only by experienced operators.

NOTE More detailed information about the accessories described in this annex can be found in Bruker Absolute Reflection Unit A519 Operating Instructions (BRUKER OPTIK GmbH, Rudolf-Plank-Str. 27, 76275 Ettlingen, www.brukeroptics.com).

D.2 VW absolute reflectance accessory (also known as a “Strong-type” accessory)

The two configurations of this type of accessory are indicated in Figures D.1 and D.2.



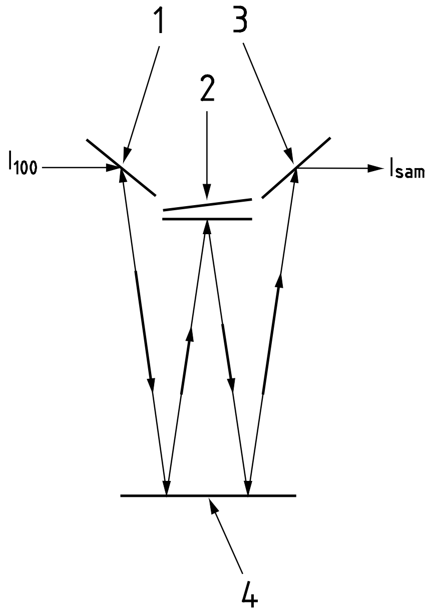
Key

1 mirror 1

2 mirror 2

3 mirror 3

Figure D.1 — V configuration



Key

1 mirror 1

2 mirror 2

3 mirror 3

4 sample

Figure D.2 — W configuration

$$I_{ref} = I_{100} x\ R_{Mirror1} x\ R_{Mirror2} x\ R_{Mirror3} \quad (D.1)$$

$$I_{sam} = I_{100} x\ R_{Mirror1} x\ R_{sample} x\ R_{Mirror2} x\ R_{sample} x\ R_{Mirror3} \quad (D.2)$$

$$R_{sample} = \sqrt{\frac{I_{sam}}{I_{ref}}} \quad (D.3)$$

where

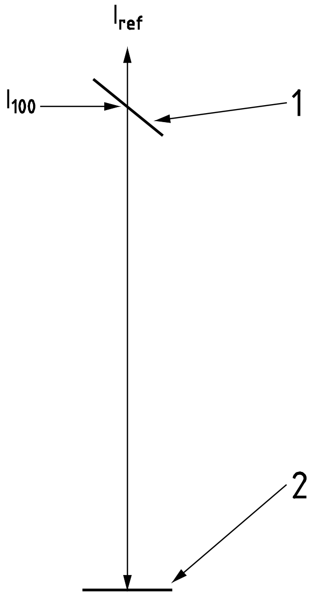
I_{100}, I_{ref} and I_{sam}	are the incident beam intensity, the measured intensity for the V configuration and the measured intensity for the W configuration respectively;
$R_{Mirror1}$, $R_{Mirror2}$, $R_{Mirror3}$ and R_{sample}	are the reflectance values of the respective components.

Formula D.1 describes the resulting intensity in the V configuration as a function of the incident intensity and the reflectance values of the mirror component. Similarly, Formula D.2 describes the resulting intensity in the W configuration as a function of the incident intensity and the reflectance values of the mirror components and the reflectance value of the sample. In this case mirror 2 has been rotated about the centre of the sample. We can note that the total beam path length is equivalent for the two different configurations. Dividing Formula D.2 by Formula D.1 and taking the square root of the result leads to Formula D.3 which shows that the reflectance of the sample can be determined by these two measurements.

Provided the samples are completely opaque in the IR spectral region such as coated glass, using two equivalent mirrors for mirror 2 in the two configurations may be considered. While introducing another source of uncertainty based on the reflectance difference between the two mirrors, this would allow the mirrors to be permanently mounted, thus probably reducing the uncertainty due to alignment when moving mirror 2 for the two configurations.

D.3 IV absolute reflection accessories

The two configuration of the IV accessory are indicated in Figures D.3 and D.4.

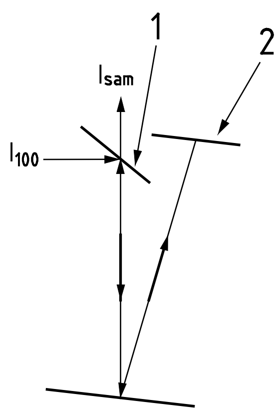


Key

1 beamsplitter

2 mirror 1

Figure D.3 — I configuration



Key

1 beamsplitter

2 mirror 1

Figure D.4 — V configuration

$$I_{ref} = I_{100} x\ R_{Beamsplitter} x\ R_{Mirror1} x\ T_{Beamsplitter} \quad \text{(D.4)}$$

$$I_{sam} = I_{100} x\ R_{Beamsplitter} x\ R_{sample} x\ R_{Mirror1} x\ R_{sample} x\ T_{Beamsplitter} \quad \text{(D.5)}$$

$$Rsample = \sqrt{\frac{Isam}{Iref}} \quad \text{(D.6)}$$

where

I_{100}, I_{ref} and I_{sam}	are the incident beam intensity, the measured intensity for the I configuration and the measured intensity for the V configuration respectively;
R_{Mirror1}, R_{sample} and $R_{\mathrm{Beamsplitter}}$	are the reflectance values of the respective components and $T_{\mathrm{Beamsplitter}}$ is the transmittance of the beam splitter.

Formula D.4 describes the resulting intensity in the I configuration as a function of the incident intensity and the reflectance and transmittance values of the mirror and beam splitter components. Similarly, Formula D.5 describes the resulting intensity in the V configuration as a function of the incident intensity and the reflectance and transmission values of the mirror and beam splitter components and the reflectance value of the sample. In this case, mirror 1 has been rotated about the centre of the sample. Note that the total beam path length is equivalent for the two different configurations. Dividing Formula D.5 by Formula D.4 and taking the square root of the result leads to Formula D.6 which shows that the reflectance of the sample can be determined by these two measurements.

D.4 Uncertainty

A measurement uncertainty analysis should be undertaken to verify that the measurement uncertainty is at least as good as the measurement uncertainty of relative accessories commonly used today.

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