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Edition 1.0 2017-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Method for measuring photovoltaic (PV) glass –
Part 1: Measurement of total haze and spectral distribution of haze

Méthode de mesure du verre photovoltaïque (PV) –
Partie 1: Mesurage de la brume totale et de la répartition spectrale de la brume

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METHOD FOR MEASURING PHOTOVOLTAIC (PV) GLASS –

Part 1: Measurement of total haze and spectral distribution of haze

FOREWORD

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International Standard IEC 62805-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this standard is based on the following documents:

FDIS	Report on voting
82/1297/FDIS	82/1321/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62805, published under the general title *Method for measuring photovoltaic (PV) glass*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This document differentiates from the other standards related to haze measurement as follows:

- the scope of this document is restricted to total haze and spectral distribution of haze measurement for PV glass,
- the wavelength range of measurement is different from the visible wavelength range of the other haze test method. In this standard, the wavelength range is typically from 280 nm to 1 250 nm which is related to the spectral response of common solar cells,
- the spectral haze at each wavelength λ is specified in this standard, while the haze integrated over the visible wavelength range 380 nm to 830 nm is always obtained in the other haze test standards.

This part of IEC 62805 establishes IEC requirements for measuring haze and for calculating the total haze of the glass used in photovoltaic modules, especially for the transparent conductive oxide coated (TCO) glass used as substrates for thin-film solar cells.

Thin-film photovoltaic (PV) technology has experienced rapid growth and achieved significant technological advances in recent years due to its advantage over other technologies, including low consumption of raw materials, better performance under high temperatures, reduced sensitivity to overheating, and easier building integration. For the different kinds of thin-film technology used today, such as amorphous silicon (a-Si), amorphous silicon/microcrystalline silicon (a-Si/μ-Si) tandem, cadmium telluride (CdTe), and perovskite thin-film solar cells, TCO glass is used as the substrate. For silicon-based thin-film solar cells, textured TCO substrates are used to introduce surface texture and light scattering within the solar cell structures in order to enhance the light absorption. Such TCO glass with specific surface morphology and light scattering level can enhance the light absorption in specific wavelength ranges. Therefore, the haze values including total haze and spectral distribution of haze are important properties of TCO glass and thus to the solar cell efficiency.

At present, there are no published international standard for measuring the spectral distribution of haze. The haze detection method found in other active international standards only characterizes the visible range of light-scattering ability of transparent material, which is not adequate for measuring the haze of PV glass. In this standard, the wavelength range, equipment requirement and calculation method have been adjusted based on the characteristics of PV glass.

The aim of this standard is:

- to provide specific test methods for measuring haze for PV glass, especially for TCO glass;
- to develop the measurement procedure for spectral distribution of haze in the solar response wavelength range, typically from 280 nm to 1 250 nm;
- to provide the calculation method for total haze in the solar response wavelength range, typically from 280 nm to 1 250 nm.

METHOD FOR MEASURING PHOTOVOLTAIC (PV) GLASS –

Part 1: Measurement of total haze and spectral distribution of haze

1 Scope

This part of IEC 62805 specifies a method for measurement and calculation of the total haze and the spectral distribution of haze of glass used in photovoltaic (PV) modules.

This document is applicable to glass used in PV modules, including transparent conductive oxide coated (TCO) glass and other kinds of glass used in PV modules.

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.

IEC 60904-3:2016, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 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 http://www.iso.org/obp

3.1
PV glass
glass used in PV modules, including cover or front glass, back glass and substrate glass

3.2
transparent conductive oxide coated (TCO) glass
flat glass coated with a transparent conductive oxide film that is used as a conductive layer

Note 1 to entry: This note applies to the French language only.

3.3
total haze
ratio of the scattered photon flux to the total photon flux transmitted through the PV glass in the wavelength range 280 nm to 1 250 nm, when the direction of the scattered light deviates more than 2,5° from the direction of the incident beam

Note 1 to entry: In this document, the wavelength range of 280 nm to 1250 nm is chosen as the representative response spectrum of the common solar cells. If the PV glass is used in a PV module in which the response spectrum of the solar cell is beyond the range 280 nm to 1250 nm, a different wavelength range can be used for the measurement.

3.4
spectral distribution of haze
a plot or table of haze versus wavelength

Note 1 to entry: The haze of PV glass is measured at a specific set of wavelengths (λ), for this standard in the wavelength range 280 nm to 1 250 nm.

3.5
single beam spectrometer
type of spectrometer, where all the light coming from a radiation source passes through the sample under test so that to measure the intensity of the incident light the sample must be removed and all the light can be measured directly

3.6
double beam spectrometer
more advanced type of spectrometer, where the light source is split into two separate beams before it reaches the sample under test, so that one beam passes through the sample and the second one is used for reference

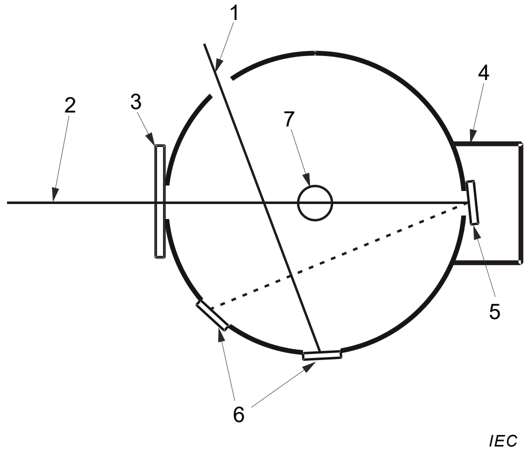
Note 1 to entry: This has the advantage that the reference reading and sample reading are take place at the same time.

4 Apparatus

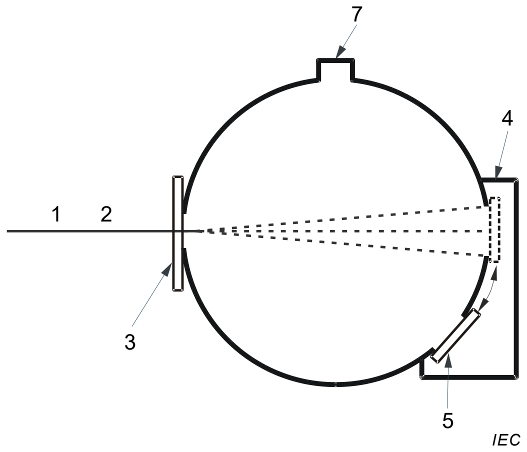
4.1 General

Both double-beam instruments and single-beam instruments may be used for the haze measurements. The apparatus shall consist of the following elements:

- a stabilized light source. The wavelength range of the light source shall include 280 nm to 1 250 nm. For the single-beam instrument, the voltage of the light source shall be stabilized within ±1 %;
- for the double-beam instrument, an optical system that forms two parallel beams of monochromatic radiation of the same wavelength λ and approximately equal radiant flux from the output of the monochromator;
- an integrating sphere fitted with ports and a photodetector. A diameter of the integrating sphere of not less than 150 mm is recommended. (If an integrating sphere with diameter less than 150 mm is used, the total area of the sphere ports shall not exceed 4 % of the internal surface area of the integrating sphere. 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 schematic arrangements of the double-beam integrating sphere and the single-beam integrating sphere used for measurement are shown in Figure 1a) and Figure 1b) respectively. The photodetector is mounted in the photodetector port in a manner that allows it to view with equal efficiency all parts of the sphere. Ingress of stray external light into the integrating sphere shall be prevented.



a) **Double beam**



b) **Single beam**

Key

1 reference beam
2 sample beam
3 sample
4 light trap
5 standard white plate
6 reference port
7 detector (at the bottom or on the top of the integrating sphere)

It is recommended that a standard calibrated with a double-beam instrument is used for a single-beam instrument to obtain the greatest accuracy in transmittance measurement.

NOTE 1 The standard white plate usually has the same reflectance property as the inner face of the integrating sphere.

Figure 1 – Schematic of the integrating sphere

Figure 1 and the text describe the configuration with the wavelength determining element (e.g. a monochromator) in front of the integrating sphere and a non-selective detector at the output of the integrating sphere. In practice, configurations using white light at the input of the integrating sphere and a wavelength selecting element with detector at the output of the integrating sphere may be used as well. The procedures described in this standard apply to both configurations.

4.2 Performance of test instrument

The wavelength range of the instrument shall include 280 nm to 1 250 nm.

The spectral bandwidth shall be adjusted to less than the required measuring wavelength interval.

The wavelength accuracy of the instrument shall be within ±0,5 nm from 280 nm to 900 nm, and ±1 nm from 900 nm to 1 250 nm.

In the wavelength range of 280 nm to 1 250 nm, the accuracy of transmittance measurement shall be within ±0,3 %, and the repeatability of transmittance measurement shall be within ±0,1 %.

Geometric condition for illumination and detection: The angle between normal of the sample and optical axis of the illuminating beam for the measurement should be ≤ 10°. The angle that any ray of the illuminating beam may make with the beam axis should be ≤ 3°.

NOTE The accuracy only refers to the instrument itself, and it does not include the uncertainty of the standard white reference plate used.

5 Test specimens

Test specimens shall meet the following requirements:

– Specimens shall be cut from the PV glass sample.
– Specimens shall be free of dust, grease or other contamination.
– Specimens shall be "wall mounted" against the sphere port rather than being center mounted or mounted at a distance from the sphere.
– Specimens shall be large enough to completely cover the entrance port of the integrating sphere.
– Three separate specimens shall be taken from each sample representing different areas of the PV glass.

NOTE While it is possible to cut tempered PV glass, it is very difficult and requires specialized equipment. Therefore, the test specimen is cut from non-tempered PV glass samples.

6 Conditioning

The test shall be done in an environment maintained at (23 ± 2) °C and (40 ± 15) % relative humidity.

The test specimen shall be maintained in the same environment for not less than 4 h prior to measurement unless otherwise agreed between customer or supplier.

7 Procedure

7.1 General

The wavelength range of the measurement shall be at least over the range from 280 nm to 1 250 nm with preferred wavelength intervals of 1 nm, but a coarser interval up to 5 nm is allowed if the resultant haze versus wavelength curve is smooth over the range of interest.

Adequate time shall be allowed for the lamp of instrument to reach equilibration (typical 15 min to 30 min of warm-up time).

The scanning wavelength range from 280 nm to 1 250 nm shall be set up first for the instrument before any measurements are performed.

7.2 Measurements of spectral distribution of haze

A spectrophotometer with the integrating sphere as shown in Figure 1 shall be used.

Make the four readings of spectral values of $\tau_1(\lambda)$, $\tau_2(\lambda)$, $\tau_3(\lambda)$ and $\tau_4(\lambda)$ respectively according to the procedure in Table 1. Figure 2 shows the positions of the specimen, the light trap and the standard white plate in a double-beam instrument for measurement of each of the spectral values. The positions of the specimen, the light trap and the standard white plate for single-beam instrument are the same as that in double-beam instrument except for the structural difference of these two kinds of spheres. The specimen shall be mounted against the transmittance port of the integrating sphere. The outside (air) facing surface of PV glass shall face the incident beam during the course of the measurement. For TCO glass sample, the uncoated side shall face the incident beam. In the case of float glass, the tin rich side shall face the incident beam.

Table 1 – Reading procedure

Spectral values	Specimen in position	Light trap in position	Standard white plate in position	Measured value	Figures referenced
$\tau_1(\lambda)$	no	yes	yes	Incident flux of light	Figure 2a)
$\tau_2(\lambda)$	yes	yes	yes	Total flux of light transmitted by specimen	Figure 2b)
$\tau_3(\lambda)$	no	yes	no	Scattered flux of light by apparatus	Figure 2c)
$\tau_4(\lambda)$	yes	yes	no	Scattered flux of light by apparatus and specimen	Figure 2d)

The light trap shall be in its position during the measurement of $\tau_1(\lambda)$ and $\tau_2(\lambda)$ to avoid measurement errors caused by the ingress of external light into the sphere.