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TECHNICAL SPECIFICATION

colour inside

Primary optics for concentrator photovoltaic systems

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PRIMARY OPTICS FOR CONCENTRATOR PHOTOVOLTAIC SYSTEMS

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62989, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/1281/DTS	82/1376/RVDTS

Full information on the voting for the approval of this technical specification 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.

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

- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

PRIMARY OPTICS FOR CONCENTRATOR PHOTOVOLTAIC SYSTEMS

1 Scope

This document encompasses key characteristics of primary optical elements (lenses and mirrors) and lens or mirror parquets for concentrator photovoltaics including: optical performance, mechanical geometry, mechanical strength, materials, and surface morphology. The document identifies the essential characteristics, the corresponding quantities of interest, and provides a method for measurement of each quantity.

This document allows lens and mirror manufacturers, concentrator module manufacturers, test laboratories and other interested parties to define lens/mirror qualities and inspect lenses and mirrors. There are no pass/fail criteria associated with the document.

This document defines the test conditions rather than to specify the precise setup of a measurement apparatus. For example, this enables laboratories to acquire reliable and comparable measurement results irrespective of the existing large variety of experimental setups for focal spot characterization. High priority is given to comparable and reproducible measurements of the irradiance distribution in the focal plane and of the optical efficiency. This requires trade-offs that reduce the similarities to outdoor conditions. Furthermore, it is intended not to refer to properties of specific solar cells as this document is dedicated to concentrator optics.

The terms for lenses are applicable for mirrors, unless otherwise specified.

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 60050-845, *International Electrotechnical Vocabulary. Lighting*

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

IEC 62108:2007, *Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval*

IEC 62788-1-4, *Measurement procedures for materials used in photovoltaic modules – Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

ISO 489:1999, *Plastics – Determination of refractive index*

ISO 10110-1:2006, *Optics and photonics – Preparation of drawings for optical elements and systems – Part 1: General*

ISO 10110-7, *Optics and photonics – Preparation of drawings for optical elements and systems – Part 7: Surface imperfection tolerances*

ISO 10110-8:2010, *Optics and photonics – Preparation of drawings for optical elements and systems – Part 8: Surface texture; roughness and waviness*

ISO 10110-19:2015, *Optics and photonics – Preparation of drawings for optical elements and systems – Part 19: General description of surfaces and components*

ISO 10303-21, *Industrial automation systems and integration – Product data representation and exchange – Part 21: Implementation methods: Clear text encoding of the exchange structure*

ISO 11664-1 (CIE S 014-1/E:2006), *Colorimetry – Part 1: CIE standard colorimetric observers*

ISO 11664-2 (CIE S 014-2/E:2006), *Colorimetry – Part 2: CIE standard illuminants*

ISO 11664-4 (CIE S 014-4/E:2007), *Colorimetry – Part 4: CIE 1976 L*a*b* Colour space*

ISO 14782, *Plastics – Determination of haze for transparent materials*

3 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
entrance aperture
entrance aperture of the primary concentrator optics lies in a plane perpendicular to the direction of irradiation and is defined as the smallest plane area bound by a simple, usually convex, geometric shape that covers all optically concentrating parts of the concentrator

Note 1 to entry: An optically inactive part in the entrance aperture (e.g. draft facets of Fresnel lenses, secondary mirrors of Cassegrain optics, wires and solar cells in the entrance aperture, mounting structures, rounded aperture corners) may not be subtracted from the area of the entrance aperture if it is not part of an adjacent entrance aperture and is smaller than 10 % of the total entrance aperture.

3.2
target area
plane area of simple geometric shape (e.g. square, rectangle, circle) that is located in proximity of the focal spot of the primary concentrator optics

Note 1 to entry: The target area is centred on the barycentre (centre of mass) of the focal spot. The target area shall have a maximum radius at least 2 times the intercept radius.

Note 2 to entry: In a measurement setup, the target area may be part of a larger detector if it is ensured that the radiant flux impinging on the target area can be discriminated from the radiant flux impinging on the parts of the detector lying outside the target area.

3.3
intercept radius
radius of a circular area that results in 95 % of the radiant flux incident on the entire target area

Note 1 to entry: Intercept radius is expressed in millimetres.

3.4
optical efficiency
ratio of radiant flux (Watts) on the target area within the intercept radius to the radiant flux on the entrance aperture of the primary optics, expressed as percentage value

3.5
encircled energy
accumulated radiometric power in a circle on the target as a function of the radius of the target area

Note 1 to entry: Encircled energy in shown in the encircled energy graph. The graph identifies the accumulated power as a function of the radius of the target area. The intercept radius and the optical efficiency can directly be read from the graph. The value for the encircled energy required to calculate the optical efficiency is 95 % of the maximum (see Figure 1).

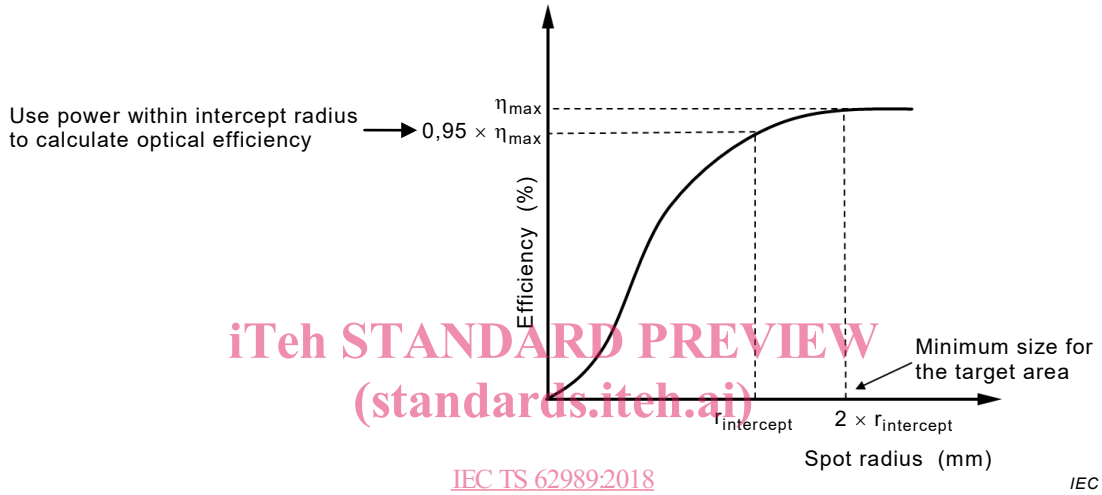

Figure 1 – Example of efficiency versus spot size – Encircled energy level of 95 %

3.6
parquet efficiency
arithmetic mean of the optical efficiencies of all optics in the parquet, all measured at the same entrance aperture to target area distance

3.7
geometric concentration
ratio of the circle defined by the intercept radius to the size of the entrance aperture (dimensionless)

3.8
local concentration
ratio of the irradiance (watts per square metre) at a point on the target area to the average irradiance of the entrance aperture (dimensionless)

3.9
focal distance
distance between the entrance aperture (most exterior surface of the primary optics) and target area that minimizes the intercept radius

3.10
solar-weighted transmittance of photon irradiance
proportion of the solar spectral photon irradiance optically transmitted (or reflected) through the specimen, throughout the range of the terrestrial solar spectrum (280 nm to 2 500 nm)

Note 1 to entry: Additional analysis, including representative solar weighted transmittance which may not include wavelengths as low as 280 nm or as great as 2 500 nm may also be reported.

3.11
UV cut-off wavelength
λ_{cUV}
wavelength of light below which the sample is considered optically absorbing and above which the material is considered transmitting (or reflecting)

Note 1 to entry: In this procedure, the absolute transmittance of 10 % (corresponding to the optical absorbance of 1) is considered as the threshold of the UV cut-off wavelength.

3.12
yellowness index
YI
calculated value identifying the yellowness of the test specimen perceived by a human observer, as defined in ISO 17223

4 Primary optics for concentrator photovoltaic systems

All primary optics datasheets complying with this document shall provide, as part of their product marking and documentation, the information specified below. See later clauses of this document for further explanation of individual specifications. In addition to the information indicated by the examples, it is required to include a technical drawing of the primary optics and the indicated graphs. Some of the specifications are optional; however, if a manufacturer of primary optics chooses to include optional information, it should be reported and measured using the definitions provided in this document (see Tables 1 to 6).

Table 1 – Characteristics: product identification

Clause	Characteristics	Parameter
4	Product identification	
4	Manufacturer	
4	Model number	
4	Type of primary optics	

Table 2 – Characteristics: optics

Clause	Characteristics	Symbol and unit of measure
5	**OPTICS**	
5.1	**Source definitions**	
Table 7	Angular size (termed collimation half-angle of source)	θ, deg
5.1	Source spectrum	–, W/(m^{2}nm)
5.2	**Optical material properties**	
5.2.1	Spectral transmittance of lens material, calculation of yellowness index, calculation of UV-cutoff wavelength	$\alpha,\tau(\lambda, T,h,$ incidence angle) , UV-cut-off, 1-nm increment (as ISO)
5.2.2	Spectral hemispherical reflectance of mirrors	$\rho(\lambda)$
5.2.3	Dispersion	V_D
5.2.4	Refractive index	$n(\lambda,T,h)$, –
5.3	**Focusing characteristics (see Table 7 for description of Methods A-C)**	
5.3	Focal length	$F(T_{nom})$, df/dT
5.3	Lens/mirror efficiency	η, %
5.3	Parquet efficiency	η, %
5.3	Focal spot size and uniformity	95 % in intercept radius
5.3	Deformation caused by differential thermal expansion; irradiance distribution	-, (T), I(λ,T,h), shape, materials, bonding technique; measured as efficiency $\Delta\eta$/K
	Optional Compliance to other standards and specifications, including design qualification and type approval CPV module (IEC 62108)	
	Optional Coatings: mechanical and functional properties	
	Optional Soiling	

Table 3 – Characteristics: mechanics

Clause	Characteristics	Parameter
6	Mechanics	
6.1	Minimum radius	
6.2	Surface hardness (static)	
6.3	Impact resistance (dynamic)	-, f(T)
Optional	Recommendations for transport/shipping, storage, installation, operations, maintenance/cleaning, polishing, recycling/disposal	

Table 4 – Characteristics: materials

Clause	Characteristics	Parameter
7	Materials	
7	Type and manufacturing process	
7	Material type	
7	Manufacturing process	
7	Chemistry	
7	Mass, grain size	mol
7	Chemical composition	
7	Permeability	
7	Absorptivity	%
7	Thermal expansion	10^{-6} m/(m K)
7	Moisture expansion	10^{-6} m/(m %)
7	Durability	
7	UV-absorbants (optional)	
7	Yellowness index	CIE
7	Accelerators	
7	Non-voluntary compliance RoHS, WEEE, OH&S, among others	