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Space systems — Single-junction solar cells — Measurement and calibration procedures

Systèmes spatiaux — Cellules solaires simple jonction — Méthodes de mesure et d'étalonnage

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Foreword

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ISO 15387 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This International Standard is consistent with the principles associated with photovoltaic solar cells established by IEC/TC 82, *Solar photovoltaic energy systems*. It provides specific requirements and procedures that apply to the use of solar photovoltaic cells in outer space. It introduces the principle of the air mass zero cell, which serves as a standard reference for primary calibration purposes. All further calibration is then compared to the results obtained with these cells.

The calibration procedures for primary solar cells are established, as well as the corresponding measuring methods for secondary cells. Calibration methods using extra-terrestrial and synthetic techniques are given. Comparative tests are in preparation.

Space systems — Single-junction solar cells — Measurement and calibration procedures

1 Scope

This International Standard specifies measurement and calibration procedures of single-junction space solar cells only. The main body of this international standard specifies the requirements for Air Mass Zero (AM0) standard calibration and the relative measurement procedures are provided as annexes.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60891, *Procedures for temperature and irradiance corrections to measured current-voltage (I-V) characteristics of crystalline silicon photovoltaic (PV) devices*

IEC 60904-1, *Measurement of photovoltaic current-voltage (I-V) characteristics*

IEC 60904-2, *Requirements for reference solar cells*

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

IEC 60904-7, *Computation of spectral mismatch error introduced in the testing of a photovoltaic (PV) device*

IEC 60904-8, *Guidance for the measurement of spectral response of a photovoltaic (PV) device*

IEC 60904-9, *Solar simulator performance requirements*

IEC 61798, *Linearity measurement methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
air mass (AM)
length of path through the earth's atmosphere traversed by the direct solar beam, expressed as a multiple of the path traversed to a point at sea level with the sun directly overhead

NOTE The value of air mass is 1 at sea level with a cloudless sky when the sun is directly overhead and the air pressure P = 1,013 × 10^5 Pa.

At any point on the earth surface, the value of the air mass is given by:

$$AM = (P/P_0) \times (1/\sin\theta)$$

where

P = local air pressure in pascals;

P_0 = 1,013 × 10^5, in pascals;

θ = solar elevation angle (degrees).

3.2
air mass zero
AM0
absence of atmospheric attenuation of the solar irradiance at one astronomical unit from the sun

3.3
AM0 standard solar cell
calibrated solar cell used to measure irradiance or to set simulator irradiance levels in terms of an air mass zero (AM0) reference solar spectral irradiance distribution

3.4
ambient temperature
T_{amb}
temperature of the air surrounding the solar cell as measured in a vented enclosure and shielded from solar, sky and ground radiation

3.5
angle of incidence
angle between the direct irradiant beam and the normal to the active surface

3.6
astronomical unit
AU
unit of length defined as the semi major axis of earth orbit

NOTE 1 AU = 149 597 890 km ± 500 km.

3.7
cell temperature
T_j
cell temperature as one of ambient air in absence of cell illumination or under short duration light pulse (flash)

NOTE T_j is not very different from the temperature of the cell exposed face.

3.8
current temperature coefficient
α
change of the short-circuit current of a solar cell as a function of the change of cell temperature

NOTE α is expressed in amperes per degree Celsius ($A \cdot °C^{-1}$).

3.9
conversion efficiency
ratio of “maximum electrical power output” to the product of generator area and incident irradiance measured under defined test conditions and expressed as a percentage

3.10
current-voltage characteristics
output current of a solar cell as a function of output voltage, at a particular temperature and irradiance

NOTE I = f(V).

3.11
fill factor
FF
ratio of maximum power to the product of open circuit voltage and short-circuit current

NOTE FF = $P_{max}/(V_{oc} \times I_{sc})$.

3.12
irradiance
radiant power incident upon unit area of surface

NOTE It is expressed in watts per square metre ($W \cdot m^{-2}$).

3.13
irradiation
integration of irradiance over a specified period of time

NOTE It is expressed in megajoules per square metre ($MJ \cdot m^{-2}$) per hour, day, week, month or year.

3.14
linearity
performance of a solar cell with respect to:

— the variation of the slope of short-circuit current to irradiance;

— the variation of the slope of open circuit voltage to the logarithm of irradiance;

— the variation of the slope of short-circuit current and open-circuit voltage to cell temperature; and

— the variation of relative spectral response at a specified voltage

3.15
load current
I_L
current supplied by the solar cell at a particular temperature and irradiance, into a load connected across its terminals

3.16
load voltage
V_L
voltage appearing across the terminals of a load connected to the terminals of the solar cell at a particular temperature and irradiance

3.17
load power
P_L
power supplied to a load connected to the terminals of the solar cell at a particular temperature and irradiance;

NOTE $P_L = V_L \times L_L$.

3.18
maximum power
P_{max}
power at the point on the current-voltage characteristics where the product of current and voltage is a maximum at a particular temperature and irradiance

NOTE $P_{max} = V_{max} \times I_{max}$

3.19
maximum power voltage
V_{Pmax}
voltage corresponding to maximum power at a particular temperature and irradiance

3.20
maximum power current
I_{Pmax}
current corresponding to maximum power at a particular temperature and irradiance

3.21
module
assembly of interconnected solar cells

3.22
open circuit voltage
V_{oc}
voltage across a solar cell with no load at a particular temperature and irradiance

3.23
ozone content
volume of ozone at standard temperature and pressure in a vertical column of the atmosphere

NOTE Ozone content is measured with a Dobson spectrophotometer.

3.24
pyranometer
radiometer normally used to measure global sunlight irradiance on a horizontal plane

NOTE A pyranometer can also be used at an angle to measure the total sunlight irradiance on an inclined plane, which in this case includes an element caused by radiation reflected from the foreground.

3.25
pyrheliometer
radiometer, complete with a collimator, used to measure direct sunlight irradiance

NOTE This instrument is sometimes called normal incidence pyrheliometer, or NIP.

3.26
rated current
assigned value of current of a solar cell at the rated voltage under specified operating conditions

3.27
rated power
assigned value of power output of a solar cell at rated voltage under specified operating conditions

3.28
rated voltage
assigned value of voltage under specified operating conditions

3.29
relative spectral response
$S(\lambda)_{rel}$
spectral response normalized to unity at wavelength of maximum response

NOTE $S(\lambda)_{rel} = S(\lambda)/S(\lambda)_{max}$

3.30
short circuit current
I_{SC}
output current of a solar cell in the short-circuit condition at a particular temperature and irradiance

3.31
solar cell
basic photovoltaic device that generates electricity when exposed to sunlight

3.32
solar constant
rate of total solar energy at all wavelengths incident on a unit area exposed normally to rays of the sun at one astronomical unit in AM0 conditions

NOTE The average of values is 1 367 $W \cdot m^{-2} \pm 7\ W \cdot m^{-2}$.

3.33
solar elevation angle
θ
angle between the direct solar beam and the horizontal plane

NOTE This angle is measured in radians.

3.34
spectral irradiance
E_λ
irradiance per unit bandwidth at a particular wavelength

NOTE The units are expressed as $W \cdot m^{-2} \cdot m^{-6}$.

3.35
spectral photon irradiance
$E_{p\lambda}$
photon flux density at a particular wavelength

NOTE $E_{p\lambda} = 5{,}035 \times 10^{14}\ \lambda \cdot E_\lambda$, where λ is expressed in micrometers.

3.36
spectral irradiance distribution
spectral irradiance plotted as a function of wavelength

NOTE The units are expressed as $W \cdot m^{-2} \cdot m^{-6}$.

3.37
spectral response
$S(\lambda)$
short-circuit current density generated by unit irradiance at a particular wavelength as a function of wavelength

NOTE The units is $A \cdot W^{-1}$.

3.38
standard test conditions
STC
at cell temperature of 25 °C ± 1 °C and at one solar constant AM0 irradiance of 1 367 $W \cdot m^{-2}$ as measured with an AM0 standard solar cell using the AM0 reference extraterrestrial solar spectral irradiance

NOTE Cell temperature of 28 °C only applies to 8.4.1.

3.39
voltage temperature coefficient
β
change of the open circuit voltage of a solar cell as a function of the change of cell temperature

NOTE β is expressed in volts per degree Celsius ($V \cdot °C^{-1}$).

4 Symbols and abbreviated terms

AM	air mass
AM0	air mass zero
AU	astronomical unit
α	coefficient of current temperature
β	coefficient of voltage temperature
CAST	China Academy of Space Technology
CNES	French National Space Research Center
ESA	European Space Agency
E_λ	spectral irradiance
$E_{p\lambda}$	photonic spectral irradiance
FF	fill factor
GMT	Greenwich mean time
GPS	global positioning system
I_L	load current
I_{Pmax}	maximum power current
I_{sc}	short circuit current
INTA-Spasolab	Instituto Nacional de Técnica Aerospacial - Spasolab
I-V	current-voltage
JPL	Jet Propulsion Laboratory
NASA-GRC	National Aeronautics and Space Administration – Glenn Research Center
NASDA	National Space Development Agency of Japan
NIP	normal incidence pyrheliometer
NSBF	National Scientific Balloon Facility in Palestine, Texas
P_L	load power
P_{max}	maximum power
PTB	Physikalisch-Technische Bundesanstalt
PV	photovoltaic
RTD	platinum resistance thermometers
$S(\lambda)$	spectral response
$S(\lambda)_{rel}$	relative spectral response
STC	standard test conditions
T_{amb}	ambiant temperature
T_j	cell temperature

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