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PERFORMANCE TEST PROCEDURE FOR SOLAR CELLS AND CALIBRATION PROCEDURE FOR SOLAR CELL STANDARDS FOR SPACE VEHICLE SERVICE

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PERFORMANCE TEST PROCEDURE FOR SOLAR CELLS AND CALIBRATION PROCEDURE FOR SOLAR CELL STANDARDS FOR SPACE VEHICLE SERVICE

(From Standards Proposal No. 997, formulated under the cognizance of JEDEC Committee JS-4 on Photosensitive Semiconductor Devices. This Standard Supersedes JEDEC Publication No. 58)

PERFORMANCE TEST PROCEDURE FOR SOLAR CELLS FOR SPACE VEHICLE SERVICE

I. PURPOSE

To test and classify the output of solar cells for space vehicle service in accordance with the requirements of EIA Format JS4-RDF4. (See Appendix)

II. PREPARATION FOR TEST

A. Spectral Response

The mean spectral response and the range of spectral response variation of the population to be tested should be known in order to decide on the applicable test method.

III. TEST PARAMETERS

A. *Temperature on the active area of the solar cell during the test shall be 28° ± 2°C, unless specified* differently.

B. When short circuit current is measured the terminal voltage shall not exceed 100 mV.

C. Irradiance is to be adjusted to that magnitude necessary to generate output characteristics in the solar cells under test comparable to those obtained in normal near earth space sunlight as determined by application of standard cells (See Calibration Procedure for Solar Cell Standards).

If a light source with non-adjustable irradiance (like sunlight as received on the earth's surface) is used, the short circuit current $I_{(SC)T}$ (expol) under near earth space conditions of the cell under test will be obtained by extrapolation from the measured short circuit currents $I_{(SC)St}$ (meas) and $I_{(SC)T}$ (meas) of the standard cell and the cell under test, respectively, by application of the equation:

$$I_{(SC)T}\ (\text{expol}) = \frac{I_{(SC)St}\ (\text{cal})}{I_{(SC)St}\ (\text{meas})} \cdot I_{(SC)T}\ (\text{meas});$$

where $I_{(SC)St}$ (cal) is the calibration value of the standard cell.

Other output data of the cells under test can be obtained, if the I-V characteristics of the cells are measured in addition to the short circuit currents and are extrapolated to correspond to the extrapolated short circuit current values.

The irradiance of the light source shall be recalibrated by use of standard cells sufficiently frequently so as to assure accuracy of irradiance within specified limits throughout the tests. This calibration frequency may be as high as immediately preceding and following a measurement on a solar cell under test–e.g. if natural sunlight without stable atmospheric conditions is used–or as low as every few hours if a very constant artificial light source is used.

IV. METHODS FOR PERFORMANCE TESTING OF SOLAR CELLS

Two basic approaches are possible:

A. Use of a light source of any spectral distribution if the solar cells to be tested are effectively identical.

B. Application of a known light source either:

   1. consisting of natural sunlight at an altitude sufficient to make it effectively identical to actual space sunlight, or

   2. simulating space sunlight with a defined spectral distribution and intensity.

APPROACH A.

1. GENERAL

The spectral variations of normal production solar cells are generally too large for consideration of these cells as "effectively identical" solar cells, for which no regard to the spectral distribution of the light source would have to be given. However, these spectral response variations are usually small enough and sufficiently controlled, so that a stable artificial light source can be found with a spectral distribution similar enough to that of space sunlight as to maintain the errors due to spectral response variations within acceptable limits. If this condition is fulfilled, a single standard cell with a spectral response near the mean of those from the production cells is sufficient to calibrate the irradiance of the test light source. It should be noted that use of a group of 3 standard cells with differing spectral responses according to approach B.2 provides a better calibration method.

2. TEST CONDITIONS

In this approach, solar cells of sufficiently small variations in spectral response are tested and calibrated using a light source having a broad spectral distribution within the major part of the solar cell spectral response, (such as Air Mass Zero sunlight or light from a tungsten filament bulb at 2854° Kelvin color temperature) and satisfying the following conditions a through g, and using auxiliary systems satisfying the conditions h through j:

a. The incident radiation shall be collimated within 6 degrees, and be normal to the receiving plane of the cell, unless it is shown that the angle of incidence dependence of the parameters of the cells under test is sufficiently uniform and similar enough to that of the standard cell as not to cause significant errors.

b. Irradiance shall not deviate more than ± 1%/cm from the mean irradiance in any direction over an area having 1.4 times the lateral dimensions of the active area of the largest cell in the test. Irradiance uniformity shall be measured by means of the short circuit current of a special solar cell having an active area with lateral dimensions not exceeding 20% of those of the active area of the smallest cell included in the test run.

c. Irradiance shall not fluctuate or vary more than ± 0.5% during the time between successive calibrations of the irradiance.

d. Irradiance shall be adjusted so that the calibration value of the standard cell is reproduced within ± 0.75%, as determined by the readout system used for the cells to be tested.

e. If simultaneous measurements are to be performed, the above listed conditions shall be met at the locations of all cells to be measured simultaneously, and further, the irradiances at all these locations shall be within ± 0.5% of the mean value.

f. Spectral distribution within the active area of the cells to be tested shall be sufficiently uniform as not to introduce significant errors.

g. The spectral distribution of the light source shall be sufficiently constant in time as not to cause significant errors in the cells with different spectral responses within the population.

h. A fixture shall be provided, which allows reproducible positioning of the cells to be tested. The various cells in the test run, including the standard cell, shall be centered with respect to their active area in the area of uniform irradiance.

i. Provision for temperature control shall be made, preferably by forced circulation through the cell test fixture of a liquid from a thermostatically controlled reservoir. The cell test fixture shall be designed to provide good heat flow from the cell to the cooling medium.

j. The precision of the readout system shall be ± 0.5%.

APPROACH B.

1. USE OF HIGH ALTITUDE SUNLIGHT

Testing of solar cells may be performed in sunlight through high altitude flights (airplane, balloon, space vehicle, etc.) with recovery provision for the cells, or even on suitable earth-surface locations. Caution has to be used to assure that the test altitude is sufficient so that residual atmosphere above the test position does not have a differential effect on the various cells in the test run, including the standard cell. In general the altitude chosen will have to be higher, the larger the difference in spectral response of the cells is. This approach is generally practical only for small quantities of cells, such as sample groups from larger populations.

The test conditions listed in Sections IV.A.2.b, c, and e through j are to be applied here. To insure irradiance and spectral uniformity over the test area, collimation of the light falling onto the cells in high altitude tests may not be desirable. Reflection of light from test personnel and nearby structures, including portions of equipment and its supports, of airplane or balloon, etc., onto the cells under test or the standard cell is to be prevented.

2. USE OF SUNLIGHT SIMULATORS

Testing of solar cells is preferably performed in simulated sunlight.

The simulator shall be adjusted or checked for compliance with the spectral distribution of sunlight within acceptable tolerances by means of a set of calibrated standard cells of differing spectral responses.

If the solar cells to be tested have a limited variation in their spectral responses, as will be the case with solar cells of the same type originating from well controlled production runs, it will be sufficient to use three standard cells of different spectral response for adjustment or checkout of the solar simulator. One of the standard cells shall have a spectral response nearly identical to the mean spectral response of the population to be tested. The other two standard cells shall have spectral responses outside of the extreme deviations from the mean spectral response.

If solar cells with larger variations in spectral response are to be tested as will, for instance, occur in radiation damage studies or with solar cells of differing materials or designs, then five standard cells of differing spectral responses shall be used for the adjustment or checkout of the solar simulator. In this case, one of the standard cells shall cover at least the whole range of wavelengths encompassed by the various spectral responses to be tested. Two of the standard cells shall have spectral responses of such shape as to permit check-out of the simulator with emphasis on the two extremes of the wavelength band involved. The two remaining standard cells shall be intermediate in spectral response.

In all cases shall the simulator be adjusted so that all standard cells reproduce their calibration values under the simulator to be checked out within 3%. After this is accomplished, the simulator is suitable for testing of solar cells with spectral responses falling within the range of the standard cells used for the calibration.

The conditions listed in IV.A.2. a through j have to be met. The standard cell covering the whole range of wavelengths, shall be used to satisfy condition IV.A.2.d.

CALIBRATION PROCEDURE FOR SOLAR CELL STANDARDS FOR SPACE VEHICLE SERVICE

I. PURPOSE OF STANDARD CELLS

To provide known and stable means for the calibration of light sources used for the evaluation of the performance of solar cells for space vehicle service. (Referring to EIA Format JS4-RDF4 and the Performance Test Procedure for Solar Cells for Space Vehicle Service.)

II. DEFINITION

A. Primary standards are to provide a stable reference for comparison purposes.

B. Lower generation standards are to be traceable to the primary standards.

III. PREPARATION OF STANDARD CELLS

Standard cells shall meet the following conditions:

A. IV-Characteristics

The output current of a solar cell, when illuminated with one sun-equivalent of radiation, shall not vary by more than 1/4 percent in the range of output voltage from zero to 100 mV.

B. Spectral Response

Solar cells used as standards shall have accurately known spectral response characteristics. These shall represent the spectral response under normal operating conditions, including irradiance for those cases where spectral response is dependent on this quantity.

C. Packaging

1. Solar cell standards shall be durably encapsulated and preferably hermetically sealed to prevent the changing of cell characteristics. Light shall enter the package through a window of polished

optical material having uniform transmission within ± 3% in a wavelength range covering at least the response range of the standard cell.

2. The cells shall be soldered to a heat sink of material with compatible thermal expansion coefficient, which forms part of a standard cell package satisfying outline drawing Fig. 1. The standard cell temperature shall be controllable by circulation of a fluid through the package. A thermocouple mounted to the solar cell is desirable.

3. The package shall have permanently attached a four-conductor cable with a four-terminal microphone connector, Amphenol type 91-858 or equivalent, for quick-connection to the read-out equipment. Pin connections to be as follows: 1 and 4 positive, 2 and 3 negative.

4. Before ultimate closure, the package shall be flushed several times with dry inert gas and finally be evacuated to at least 10^{-2} mm of mercury or filled with a chemically inactive, dry gas.

D. **Identification and Accompanying Data**

Each standard solar cell shall be identified in the following manner and accompanied by the following information:

1. Identification

A number, and preferably the manufacturer's name stamped or engraved on the package.

2. Accompanying Data

a. Cell description information (i.e., N/P, P/N, Silicon, GaAs, irradiated, etc.) and generation of the standard.

b. Short circuit current calibration value in 3 significant figures and a reference IV-curve, both with date measured, cell temperature, and calibration method used.

c. If extrapolation according to paragraph IV.B has been used in the calibration of the lower generation standard, all four values of short circuit current entering into the equation of the referenced paragraph shall be listed.

d. The spectral response curve, including measurement method, cell temperature, and date of measurement.

e. Temperature gauge type and calibration data or, if temperature gauge not used, specify circulating fluid type and temperature and flow rate corresponding to cell temperature stated in b. above.

f. Any other applicable data of measurements or calculations pertaining to the standard.