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INTERIM SOLAR CELL TESTING PROCEDURES FOR TERRESTRIAL APPLICATIONS

JULY 1975

PREFACE

A Terrestrial Photovoltaic Workshop under the joint sponsorship of ERDA and NASA was held at the NASA Lewis Research Center in March 1975. Nearly 100 people attended from all segments of the solar cell community. The workshop was divided into three separate sessions:

(1) Solar Intensity and Spectrum Conditions for Terrestrial Photovoltaics

(2) Terrestrial Sunlight Simulation

(3) Methodology for Measurements and Calibration of Solar Cells

A broad spectrum of short papers was presented; then the attendees addressed key questions in the workshop sessions. The separate sessions were held concurrently.

This report presents an interim draft of procedures for testing solar cells for terrestrial applications that resulted from the workshop sessions. A final version of the test procedures manual is planned for the summer of 1976.

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INTERIM SOLAR CELL TESTING PROCEDURES FOR TERRESTRIAL APPLICATIONS*

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With many organizations and individuals either manufacturing or doing research on solar cells for terrestrial applications, there is a need for a set of standard test procedures. These procedures would afford a common basis for comparing solar cells and also provide data for the design of large arrays. This document is an interim draft of such a set of test procedures arising from an ERDA/NASA Workshop on Terrestrial Photovoltaic Measurements held March 19-21, 1975. A final draft is expected by summer 1976. This version included procedures for cell testing both outdoors in natural sunlight and indoors in simulated sunlight, a description of the necessary apparatus and equipment, the calibration and use of standard solar cells, and a proposed air-mass-two (AM2) solar spectrum.

1.0 DEFINITIONS AND STANDARD TEST CONDITIONS

The following terms are used throughout the procedures:

(1) Standard solar cell - a cell made from the same material as the test cell and used to set simulator irradiance levels (The standard cell is provided by the central testing laboratory or is directly traceable to it.

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*Also available as NASA TM X-71771, 1975.

It is calibrated in units of short-circuit current output per unit of radiant energy input (mW/cm^2).)

(2) Standard test conditions (STC) - cell temperature, $28^\circ \pm 2^\circ$ C; irradiance indoors set at 100 mW/cm^2 with standard cell

(3) Short-circuit current (I_{sc}) - the current (measured at STC) through a precision load resistor such that the voltage across the load resistor is less than 20 mV

(4) Open-circuit voltage (V_{oc}) - the voltage (measured at STC) across the unloaded (open) cell measured with a voltmeter with an internal resistance of at least 10 kΩ/V

(5) Test cell area - the entire front surface area of the cell, including grids and contacts

(6) Fill factor (FF) - the ratio of the maximum power output of the cell to the product of open-circuit voltage and short-circuit current:

$$FF = \frac{\text{Maximum power}}{V_{oc} I_{sc}}$$

(7) Cell efficiency - the ratio of the maximum power output of the cell to the product of cell area and incident irradiance:

$$\text{Eff } (\%) = \left(\frac{\text{Maximum power}}{\text{Area} \times \text{Irradiance}} \right) \times 100$$

As an aid in understanding the test procedures in this document, figure 1 shows a block diagram of the different types of test methods. The details of these test methods are presented in subsequent sections of this document.

2.0 NATURAL SUNLIGHT TESTING PROCEDURES

There are two basic testing methods for outdoor calibration of photovoltaic cells or arrays of cells. One method uses a suitable photovoltaic standard cell, and the other employs a pyranometer or pyrheliometer as reference. The former is called the standard solar cell method; and the latter, the pyranometer method. Methods other than these are not considered acceptable at this time.

2.1 Basic Reference Standards

Standard solar cell method. - The reference standard to be employed for determining intensity in this method is a calibrated photovoltaic cell obtained from the recognized calibration facility (NASA Lewis Research Center) or traceable to that facility. The reference cell must be supplied with a certificate of calibration indicating sensitivity. The calibration conditions for this cell are described in section 4.1. The reference cell must be made from the same type of material and have essentially the same spectral response characteristic as the cells or array of cells being tested.

Pyranometer method. - The reference standard to be employed for determining intensity in this method is a pyranometer which has a traceable annual calibration to a recognized standard instrument. A pyranometer is a solar radiometer with hemispherical (180° field of view (FOV)) response and is used for the measurement of global radiation. The pyranometer must be either (1) a temperature-compensated unit which has less than ±1 percent deviation in sensitivity over the range -20° C to $+40^{\circ}$ C or (2) a unit which incorporates a temperature sensor and has a sensitivity-temperature correction supplied with its calibration. The pyranometer must be used with the receiver horizontal.

If desired, a normal-incidence pyrheliometer (NIP) can be substituted for the pyranometer provided the cell being tested has the same field of view as the NIP. The NIP used must meet the same calibration and temperature compensation requirements as the pyranometer.

2.2 Test Equipment

Standard solar cell method. - The following test equipment is used in the standard method:

(1) Standard cell: The natural sunlight intensity is determined by using the standard cell described in sections 2.1 and 4.1.

(2) Standard cell readout: The output of the standard solar cell is measured with equipment which meets the requirements described in section 4.3.

(3) Temperature monitoring and control: Monitoring and control of standard cell temperature must be in accordance with the specifications given in section 4.3. The temperature of all cells or arrays being tested must be measured to the same accuracy. For large arrays, temperatures should be monitored at a number of locations, with not less than one sensor per 4 square feet of surface area.

(4) Alinement and holding equipment: The surfaces of the standard cell and the cell or array being tested must be maintained perpendicular to the direct solar beam. Suitable manually operated or automatic tracking must be used to maintain this alinement during the entire testing time. A suitable alinement device is required to assure that the alinement is maintained.

(5) Test cell fixture: The solar cell to be tested is mounted on a test fixture which meets the requirements set forth in section 4.3. If an array of cells is being tested, array mounting and temperature control are at the option of the investigator. However, the actual temperature of the array must be reported, and four wire measurement techniques shall be employed insofar as possible.

(6) Test cell performance measurement equipment: The performance of the test cell is measured by using equipment which meets the requirements set forth in section 4.3.

Pyranometer method. - The following equipment is used in the pyranometer method:

(1) Pyranometer: The natural sunlight intensity is determined by using a pyranometer or pyrheliometer which meets the requirements described in section 2.1.

(2) Pyranometer readout: The milliwatt output of the pyranometer or pyrheliometer is measured by using a potentiometer or a device with sufficiently high input impedance (>1 MΩ) to have neglibible loading effect on the pyranometer. The voltage should be measured to $\pm 1/2$ percent. The readout device must be calibrated by using a voltage reference capable of 1/2 percent

accuracy in the output range of the pyranometer (~ 1 to 20 mV depending on type).

(3) Temperature monitoring and control: If a pyranometer or pyrheliometer is employed which is not temperature compensated, its temperature must be monitored to $\pm 0.5^{\circ}$ C and corrections applied to the sensitivity accordingly.

(4) Alinement and holding equipment: The pyranometer must be leveled in accordance with the instructions supplied with the device. The cell or array to be tested is mounted coplanar with the pyranometer receiver and leveled such that it is horizontal. If a pyrheliometer is used, it must be alined and maintained perpendicular to the sun.

(5) Test cell fixture: The test cell fixture is described in sections 2.2 and 3.3.

(6) Test cell performance measurement equipment: The test cell performance measurement equipment must meet the requirements set forth in section 4.3.

2.3 Test Procedures

Standard solar cell method. - The cell or array being tested is to be mounted such that the active receiver surface is essentially perpendicular to the direct solar beam. The standard photovoltaic cell is mounted coplanar with the test cell(s). All cells being tested are also coplanar.

Under the constraints of configuration and the use of a matching solar cell, the location is not extremely critical. The entire array must be irradiated fully by the direct solar beam. The surrounding area must be free of any highly reflective surfaces which would be capable of significantly increasing the solar and celestial radiation onto the cell or array. For work at low solar elevations (high zenith angles) the foreground should be dark, for example, dark earth or blacktop. Highly reflective materials, even such natural materials as bright sand, must not be on the surface in the foreground.

The standard cell and the cell (or array) to be tested are alined perpendicular to the sun. The current-voltage (I-V) characteristic of the cell (or array) being tested is recorded at the same time as the output of the standard cell. The solar intensity as measured by the output of the standard cell must remain constant within 0.5 percent during measurement and should be at least 60 mW/cm^2.

Pyranometer method. - The solar cell or array to be tested is mounted with its receiving surface horizontal and coplanar with the pyranometer receiver. The measurement must be performed at solar elevation angles greater than 45^o (zenith angles $<45^o$). The most desirable location is one with an unobstructed horizon in all directions. There must be no shading of the direct solar beam hitting either the pyranometer or the cells being tested. If an unobstructed horizon is impractical, measurements shall not be made while there are any large reflections which preferentially strike either the pyranometer or the cells of the array. At no time is the upward-looking hemisphere to be blocked to more than 10 percent of the total solid angle.

The I-V characteristic of the cell or array being tested is recorded at the same time as the output of the pyranometer. The solar intensity as measured by the pyranometer must remain constant within 0.5 percent during measurement.

If a pyrheliometer is substituted for a pyranometer, the solar cell to be tested is mounted in a collimating tube with the same FOV as the pyrheliometer. The parallel-mounted instruments must be alined and maintained perpendicular to the sun. The I-V characteristic of the test cell is recorded at the same time as the output of the pyrheliometer. The solar intensity as measured by the pyrheliometer must remain constant within 0.5 percent during measurement.

3.0 INDOOR TESTING PROCEDURES

Artificial light sources of various types and different calibration procedures have been used in the past to measure solar cell output, with considerable discrepancy in results. The solar cell test procedure described here for use with an artificial light source will provide reliable measurements which can be reproduced in various laboratories throughout the world. In order to get accurate measurements, a great deal of concern must be placed on the stability and spectrum of the light source and the method of setting the intensity of the light with a standard solar cell.

3.1 Basic Reference Standards

The light source intensity is to be set by using a calibrated standard solar cell such as that described in section 4.1. The light source to be used with this test procedure is a filtered xenon arc lamp which simulates a solar spectrum, as described in section 4.2.

3.2 Test Equipment

The following test equipment is used in the indoor testing procedure:

(1) Standard solar cell: The light intensity is adjusted by using a standard cell which meets the specification described in section 4.1.

(2) Light source: The light source is a filtered xenon arc lamp which meets the specification described in section 4.2.

(3) Standard solar cell readout: The output of the standard solar cell is measured by using equipment which meets the requirement described in section 4.3.

(4) Temperature monitoring and control: The temperatures of the test cell and the standard cell are monitored and controlled as described in section 4.3. The test cell temperature must be maintained at $28^{\circ} \pm 2^{\circ}$ C.

(5) Test cell fixture: The solar cell to be tested is mounted on a fixture which meets the requirements set forth in section 4.3. This test cell fixture may also be interchangeable with the standard cell.

(6) Test cell measurement equipment: The performance of the test cell is measured by using equipment which meets the requirements set forth in section 4.3.

3.3 Test Procedure

The test procedure is as follows: Turn on and stabilize the light source. Adjust the light source intensity to 100 mW/cm^2 as determined by measuring the short-circuit current of a calibrated standard solar cell held at a temperature of $28^o \pm 2^o$ C. Replace the standard cell with a test fixture that is temperature controlled. Set cell temperature to $28^o \pm 2^o$ C by using a dummy solar cell with a thermocouple attached to the top of the cell. Place the cell to be measured in the test fixture and measure output with four terminal contacts and appropriate electronic readout equipment.

4.0 SUPPLEMENTAL TEST PROCEDURES

4.1 Calibration of Standard Cells

In order to make accurate performance measurements on solar cells under a variety of light sources, it is necessary that calibrated standard solar cells be available to set or measure intensity. This section describes the interim procedure to be used for calibration of these solar cell standards under natural sunlight.

Test equipment. - The following test equipment is needed in the calibration of standard solar cells:

(1) Cell holder: The cell to be calibrated is mounted in a hermetically sealed container. The holder must be capable of being cooled and a thermocouple or thermistor provided for temperature monitoring. Four output terminals (voltage + and -; current + and -) shall be provided.

(2) Intensity monitor: Sunlight intensity is measured by using a normal-incidence pyrheliometer (NIP). The standard cell being tested must have the same field of view as the NIP (5^o 42' full angle). The sun must be tracked within $\pm 2^o$ during testing.

(3) Test cell measurement equipment: The readout equipment specifications are given in section 4.3.

Calibration procedure. - Calibration of solar cells is performed in natural sunlight under the following conditions:

(1) Intensity: The sunlight intensity must be between 80 and

100 mW/cm^2 at the time of the test.

(2) Intensity stability: The atmospheric conditions must be sufficantly stable so that the variation in cell current is less than ± 0.5 percent during any 30-second measurement period.

(3) Clouds and haze: The sky must be clear and blue with no observable cloud formations within a 15° half-angle cone surrounding the sun.

(4) Turbidity: The atmospheric turbidity during measurement as determined from measurements at 380 and 500 nm must be less than 0.2. As an alternate, the ratio of uncollimated to collimated short-circuit current (using the NIP collimation angle) must be less than 1.2.

(5) Air mass: The optical air mass between the test cell and the sun must be between 1 and 2.5.

Cell temperature must be maintained at $28^{\circ} \pm 2^{\circ}$ C during testing. Adequate measurement of cell spectral response is necessary to characterize cell type insofar as possible. The average of at least three short-circuit current measurements (voltage output across the precision resistor) on at least two different days is used as the calibration value. Calibration values are reported as mA/mW/cm^2. This calibration must be performed with a 0.1 percent precision resistor at a voltage less than 20 mV across the cell.

4.2 Light Source for Solar Cell Testing

The required source for the sunlight simulator is a short-arc xenon lamp modified by optics and filters to meet the requirements listed here. Commercially available air-mass-zero (AM0) sunlight simulators, with short-arc xenon lamps, are generally completely acceptable. The main reason for the choice of xenon lamps is the broadband spectral output.

The sunlight simulator should have the following characteristics:

(1) Total irradiance: The simulator must be capable of at least 100 mW/cm^2 as measured with a standard solar cell of the same type as cells to be tested.

(2) Nonuniformity of total irradiance: Nonuniformity of total irradiance is defined (in percent) as

$$\left(\frac{\text{Maximum irradiance - Minimum irradiance}}{2 \times \text{Average irradiance}}\right) \times 100$$

where the maximum and minimum irradiances are in the plane of the test cell or array. The area of the detector must be less than one-quarter of the test cell area. Nonuniformity of total irradiance should be less than 5 percent.

(3) Temporal stability of irradiance: The temporal stability is defined in a similar manner to the nonuniformity of total irradiance. It must be within 2 percent over the period of time required to make cell measurements as determined by a solar cell detector.

(4) Solar beam subtense angle: The angle subtended by the apparent source of the simulator on a point on the test cell must be less than 30°.

(5) Spectral distribution of irradiance: The spectral distribution of irradiance shall be the spectrum of a short-arc xenon lamp, with near infrared (IR) line filtering. Table I shows the percentage of total irradiance in various wavelength intervals for a typical xenon AM0 simulator and the proposed air-mass-2 (AM2) Thekaekara spectrum.

4.3 Common Test Equipment

Most of the solar cell tests described previously require essentially identical equipment. The details and specifications of this equipment are listed here.

Standard solar cell readout. - A digital voltmeter, potentiometric recorder, or other suitable measuring instrument capable of measuring with an error less than ±1 percent over the range 0 to 100 mV is used to measure standard cell output. If preamplifiers are used in order to match an automatic data system level, the system must meet the less than ±1 percent error requirement as demonstrated by impressing known voltages across an input impedance equal to that of the standard cell device.

Temperature monitoring and control. - Each standard cell holder is fitted with a suitable thermocouple or thermistor, which is used to set temperature at standard conditions. With this sensor the measuring equipment must be capable of 1° C accuracy. Standard cell temperature is to be main-

CORRECTION

THE UNITS ON P. 11 FOR H_2O AND O_3 SHOULD BE CM.

THE IRRADIANCE VALUES IN TABLE II ARE IN $W/cm^2 \cdot \mu m$.

CHANGE THE SECOND SENTENCE IN 5.0 TO "TABLE II LISTS THE AM2 IRRADIANCE VALUES, IN COLUMN 2, IN $W/cm^2 \cdot \mu m$ FOR CORRESPONDING WAVELENGTHS, AND IN COLUMN 3, IN NUMBER OF PHOTONS/$cm^2 \cdot sec$ FOR WAVELENGTH INTERVALS BETWEEN THE CORRESPONDING WAVELENGTH AND THE ONE ABOVE IT".

THE INTEGRATED AREA UNDER THE AM2 SPECTRAL IRRADIANCE CURVE IS 0.0749 W/cm^2 OR 74.9 mW/cm^2.

tained at $28^{o} \pm 2^{o}$ C.

Test fixture. - The solar cell to be tested is mounted on a test fixture which has the following features: vacuum holddown design, temperature-controlled block, and four terminal contacts (current + and -; voltage + and -).

Test cell measurement equipment. - Equipment must be capable of measuring the voltage and current of the solar cell over the range between open-circuit voltage and short-circuit current with an error less than 0.5 percent. Short-circuit current must be measured at a voltage less than 20 mV. Open-circuit voltage is measured with a meter with an internal resistance of at least 10 kΩ/V. Instruments such as digital voltmeters and X-Y plotters shall be calibrated at least daily.

5.0 AIR-MASS-TWO SPECTRAL DATA

For purposes of theoretical calculations, a proposed interim air-mass-two spectral distribution is provided. Table II lists the AM2 irradiance values in $mW/cm^2/\mu m$ for corresponding wavelengths and in number of $photons/sec/cm^2$ for wavelength intervals. The source of the data is Dr. M. Thekaekara of NASA Goddard Space Flight Center. Parameters used in converting the Thekaekara AM0 data to AM2 include

Precipitable water, mm	2.000
Ozone, mm	0.340
Aerosol scattering parameters:	
Alpha	1.300
Beta	0.040

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TABLE I. - PERCENTAGE OF TOTAL

IRRADIANCE IN VARIOUS

WAVELENGTH INTERVALS

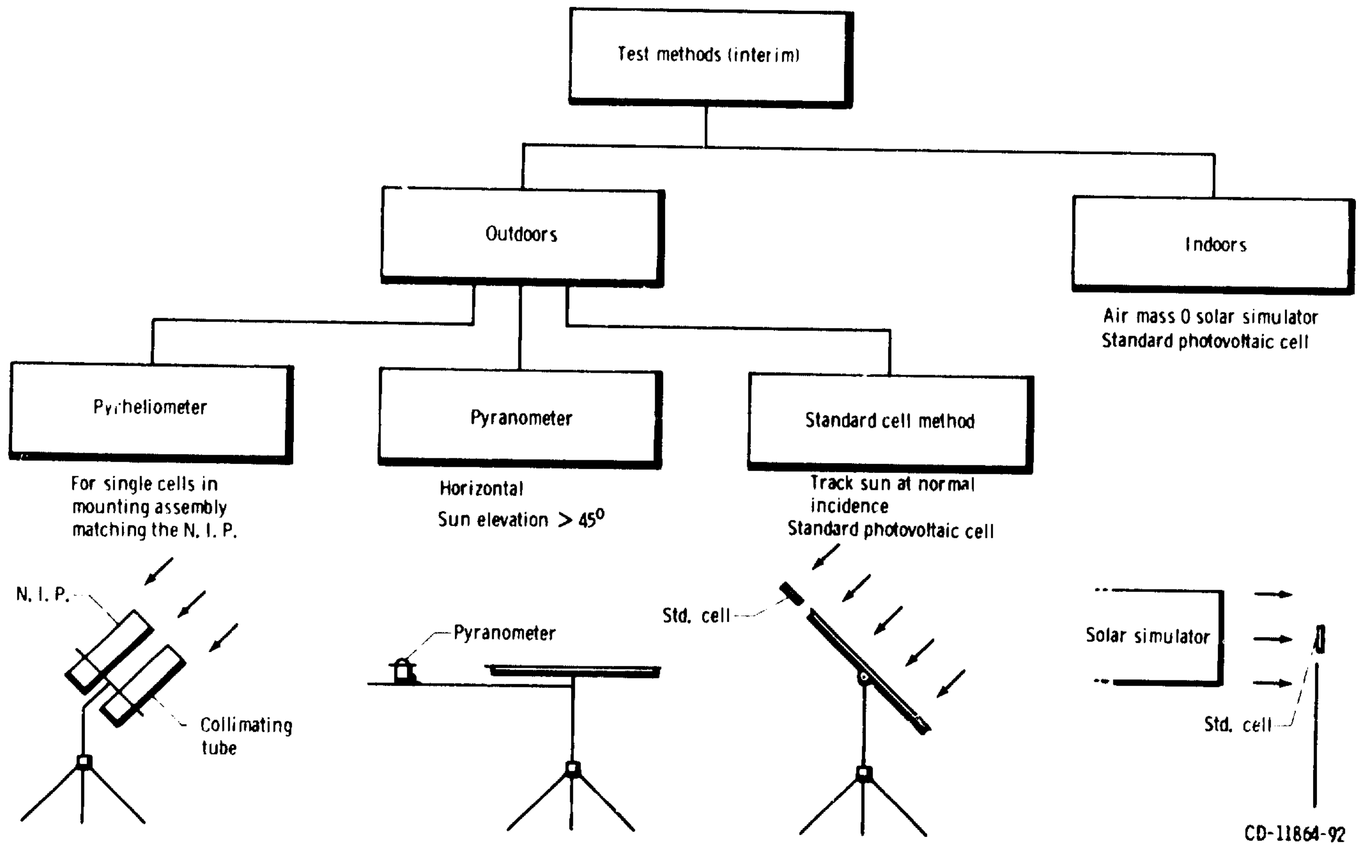
Wavelength interval, $\Delta\lambda$, μm	Xenon air-mass-zero simulator	Thekaekara air-mass-two spectrum
	Total irradiance, percent	
0.25 - 0.4	6.28	2.80
0.4 - 0.5	13.88	12.70
0.5 - 0.6	14.33	15.41
0.6 - 0.7	12.67	15.13
0.7 - 0.8	9.66	13.29
0.8 - 0.9	8.37	7.69
0.9 - 1.0	7.12	4.40
1.0 - 2.5	27.69	28.58
Total	100	100

TABLE II. - PROPOSED AIR-MASS-TWO SPECTRAL DISTRIBUTION

Wave-length, μm	Irradiance, $mW/cm^2/\mu m$	Number of photons per sec per cm^2	Wave-length, μm	Irradiance, $mW/cm^2/\mu m$	Number of photons per sec per cm^2
0.290	0	---------	0.525	0.1156	1.508×10^{15}
.295	.0000	---------	.530	.1159	1.538×10^{15}
.300	.0000	---------	.535	.1153	1.551×10^{15}
.305	.0000	---------	.540	.1140	1.553×10^{15}
.310	.0001	---------	.545	.1130	1.551×10^{15}
.315	.0008	3.54×10^{12}	.550	.1120	1.552×10^{15}
.320	.0050	2.32×10^{13}	.555	.1122	1.561×10^{15}
.325	.0075	5.08×10^{13}	.560	.1111	1.568×10^{15}
.330	.0105	7.43×10^{13}	.565	.1124	1.584×10^{15}
.335	.0138	1.02×10^{14}	.570	.1134	1.614×10^{15}
.340	.0177	1.34×10^{14}	.575	.1144	1.643×10^{15}
.345	.0193	1.59×10^{14}	.580	.1147	1.667×10^{15}
.350	.0217	1.79×10^{14}	.585	.1150	1.685×10^{15}
.355	.0236	2.01×10^{14}	.590	.1148	1.701×10^{15}
.360	.0255	2.21×10^{14}	.595	.1141	1.709×10^{15}
.365	.0288	2.48×10^{14}	.600	.1135	1.713×10^{15}
.370	.0320	2.82×10^{14}	.605	.1134	1.723×10^{15}
.375	.0334	3.07×10^{14}	.610	.1137	1.738×10^{15}
.380	.0344	3.22×10^{14}	.620	.1137	3.582×10^{15}
.385	.0353	3.36×10^{14}	.630	.1137	3.582×10^{15}
.390	.0371	3.53×10^{14}	.640	.1141	3.65×10^{15}
.395	.0421	3.92×10^{14}	.650	.1140	3.71×10^{15}
.400	.0530	4.76×10^{14}	.660	.1136	3.76×10^{15}
.405	.0630	5.38×10^{14}	.670	.1127	3.79×10^{15}
.410	.0693	6.79×10^{14}	.680	.1119	3.82×10^{15}
.415	.0725	7.37×10^{14}	.690	.1114	3.85×10^{15}
.420	.0737	7.66×10^{14}	.6983	.0887	3.91×10^{15}
.425	.0737	7.85×10^{14}	.700	.1102	5.95×10^{14}
.430	.0737	7.94×10^{14}	.710	.1089	3.89×10^{15}
.435	.0771	8.22×10^{14}	.720	.1071	3.89×10^{15}
.440	.0867	9.03×10^{14}	.7277	.0906	2.77×10^{15}
.445	.0949	1.01×10^{15}	.730	.1058	8.29×10^{14}
.450	.1022	1.11×10^{15}	.740	.1040	3.88×10^{15}
.455	.1066	1.19×10^{15}	750	.1026	3.88×10^{15}
.460	.1089	1.24×10^{15}	.7621	.0656	3.877×10^{15}
.465	.1097	1.27×10^{15}	.770	.0997	2.52×10^{15}
.470	.1107	1.298×10^{15}	.780	.0981	2.11×10^{15}
.475	.1131	1.33×10^{15}	.790	.0965	3.85×10^{15}
.480	.1167	1.38×10^{15}	.800	.0950	3.84×10^{15}
.485	.1130	1.39×10^{15}	.8059	.0812	2.10×10^{15}
.490	.1133	1.39×10^{15}	.825	.0906	6.74×10^{15}
.495	.1157	1.42×10^{15}	.830	.0895	1.88×10^{15}
.500	.1165	1.46×10^{15}	.835	.0889	1.87×10^{15}
.505	.1161	1.47×10^{15}	.8465	.0359	3.04×10^{15}
.510	.1147	1.475×10^{15}	.860	.0397	2.19×10^{15}
.515	.1127	1.468×10^{15}	.870	.0344	1.62×10^{15}
.520	.1136	1.476×10^{15}	.875	.0340	7.52×10^{14}

TABLE II. - CONCLUDED.

Wave-length, µm	Irradiance, $mW/cm^2/\mu m$	Number of photons per sec per cm^2	Wave-length, µm	Irradiance, $mW/cm^2/\mu m$	Number of photons per sec per cm^2
0.8875	0.0344	1.398×10^{15}	2.008	0.0059	2.36×10^{15}
.900	.0348	1.948×10^{15}	2.014	.0067	3.83×10^{14}
.9075	.0357	1.204×10^{15}	2.057	.0062	2.84×10^{15}
.915	.0365	1.243×10^{15}	2.124	.0060	4.31×10^{15}
.925	.0180	1.263×10^{15}	2.156	.0056	2.0×10^{15}
.930	.0131	3.63×10^{14}	2.201	.0064	2.96×10^{15}
.940	.0214	8.13×10^{14}	2.266	.0060	4.54×10^{15}
.950	.0199	9.84×10^{14}	2.320	.0055	3.59×10^{15}
.955	.0224	5.07×10^{14}	2.338	.0052	1.13×10^{15}
.965	.0250	1.147×10^{15}	2.356	.0049	1.07×10^{15}
.975	.0523	1.889×10^{15}	2.388	.0030	1.51×10^{15}
.985	.0487	2.49×10^{15}	2.415	.0026	9.15×10^{14}
1.018	.0580	8.89×10^{15}	2.453	.0023	1.14×10^{15}
1.082	.0464	1.77×10^{16}	2.494	.0014	9.46×10^{15}
1.094	.0434	2.95×10^{15}	2.537	.0002	4.56×10^{14}
1.098	.0465	9.93×10^{14}	2.900	.0001	7.46×10^{14}
1.101	.0491	7.95×10^{14}	2.941	.0003	1.21×10^{14}
1.128	.0078	4.31×10^{15}	2.954	.0003	5.79×10^{13}
1.131	.0093	1.46×10^{14}	2.973	.0005	1.135×10^{14}
1.137	.0085	3.05×10^{14}	3.005	.0005	2.41×10^{14}
1.144	.0129	4.305×10^{14}	3.045	.0002	2.13×10^{14}
1.147	.0114	2.10×10^{14}	3.056	.0002	3.38×10^{13}
1.178	.0343	4.15×10^{15}	3.097	.0001	9.53×10^{13}
1.189	.0356	2.29×10^{15}	3.132	.0004	1.37×10^{14}
1.193	.0415	9.256×10^{14}	3.156	.0017	3.99×10^{14}
1.222	.0361	6.85×10^{15}	3.204	.0001	6.92×10^{14}
1.236	.0369	3.16×10^{15}	3.214	.0002	2.43×10^{13}
1.264	.0305	5.94×10^{15}	3.245	.0002	1.009×10^{14}
1.276	.0328	2.43×10^{15}	3.260	0002	4.92×10^{13}
1.288	.0323	2.52×10^{15}	3.285	.0013	3.09×10^{14}
1.314	.0251	4.89×10^{15}	3.317	.0011	6.39×10^{14}
1.335	.0151	2.82×10^{15}	3.344	.0002	2.95×10^{14}
1.384	.0001	2.55×10^{15}	3.403	.0011	6.52×10^{14}
1.432	.0021	3.75×10^{14}	3.450	.0012	9.33×10^{14}
1.457	.0052	6.64×10^{14}	3.507	.0012	1.199×10^{15}
1.472	.0046	5.43×10^{14}	3.538	.0011	6.33×10^{14}
1.542	.0230	7.34×10^{15}	3.573	.0009	6.27×10^{14}
1.572	.0219	5.29×10^{15}	3.633	.0010	1.035×10^{15}
1.599	.0214	4.67×10^{15}	3.673	.0008	6.63×10^{14}
1.608	.0205	1.52×10^{15}	3.696	.0010	3.84×10^{14}
1.626	.0205	3.01×10^{15}	3.712	.0011	3.14×10^{14}
1.644	.0196	2.97×10^{15}	3.765	.0009	9.99×10^{14}
1.650	.0193	9.69×10^{14}	3.812	.0008	7.62×10^{14}
1.676	.0169	3.94×10^{15}	3.888	.0007	1.11×10^{15}
1.732	.0150	7.67×10^{15}	3.923	.0007	4.82×10^{14}
1.782	.0121	5.99×10^{15}	3.948	.0007	3.47×10^{14}
1.862	.0001	4.48×10^{15}	4.045	0	---------
1.955	.0030	1.37×10^{16}			



Test methods (interim)
Outdoors
Indoors
Air mass 0 solar simulator
Standard photovoltaic cell
Pyrheliometer
For single cells in
mounting assembly
matching the N. I. P.
Pyranometer
Horizontal
Sun elevation > 45°
Standard cell method
Track sun at normal
incidence
Standard photovoltaic cell
N. I. P.
Collimating
tube
Pyranometer
Std. cell
Solar simulator
Std. cell
CD-11864-92

Figure 1.