

LSSA PROJECT

USER HANDBOOK FOR BLOCK II SILICON SOLAR CELL MODULES

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**Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California**

CONTENTS

I.	INTRODUCTION -----	1-1
II.	MODULE DESCRIPTION -----	2-1
APPENDIX		
A.	QUALIFICATION TEST PROGRAM -----	A-1

Figure(s)

1-1.	Example of Subarray Assembled from Block II Modules -----	1-2
2-1.	Sensor Technology Module: Photographic Views -----	2-3
2-2.	Sensor Technology Module: Drawing -----	2-4
2-3.	I-V Curves for Sensor Technology Module -----	2-5
2-4.	Solarex Module: Photographic Views -----	2-6
2-5.	Solarex Module: Drawing -----	2-7
2-6.	I-V Curves for Solarex Module -----	2-8
2-7.	Solar Power Module: Photographic Views -----	2-9
2-8.	Solar Power Module: Drawing -----	2-10
2-9.	I-V Curves for Solar Power Module -----	2-11
2-10.	Spectrolab Module: Photographic Views -----	2-12
2-11.	Spectrolab Module: Drawing -----	2-13
2-12.	I-V Curves for Spectrolab Module -----	2-14
A-1.	Qualification Test Sequence -----	A-3
A-2.	Humidity Cycle -----	A-4

Table(s)

2-1.	Module Characteristics -----	2-2
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SECTION I

INTRODUCTION

The program of the Low-Cost Silicon Solar Array (LSSA) Project includes a series of competitive procurements of production quantities of solar cell modules. The objectives of this procurement effort are to stimulate reduction in manufacturing cost and to provide modules for test of solar cell arrays in practical applications.

The first in this series of procurements, designated Block I, included the purchase from five contractors of a quantity of modules having a total nominal power output of about 58 kilowatts. These modules were procured to the contractor's specifications as a means of ascertaining the state-of-the-art of terrestrial solar cell modules and of providing modules for early test and applications programs.

Block II, the second in the series of procurements, involved purchase of 123 kilowatts of total power capacity from four contractors. Block II introduced a degree of standardization by defining the module design specifications and by providing for a design qualification test program.

Figure 1-1 illustrates an example of a subarray assembled from Block II modules, shown mounted on a handling dolly.

The purpose of this User Handbook is to supply engineering data necessary for planning or investigating application programs utilizing the Block II modules. Anyone requiring additional technical information should direct his request to Mr. Larry N. Dumas, LSSA Project Operations Manager, at the Jet Propulsion Laboratory.

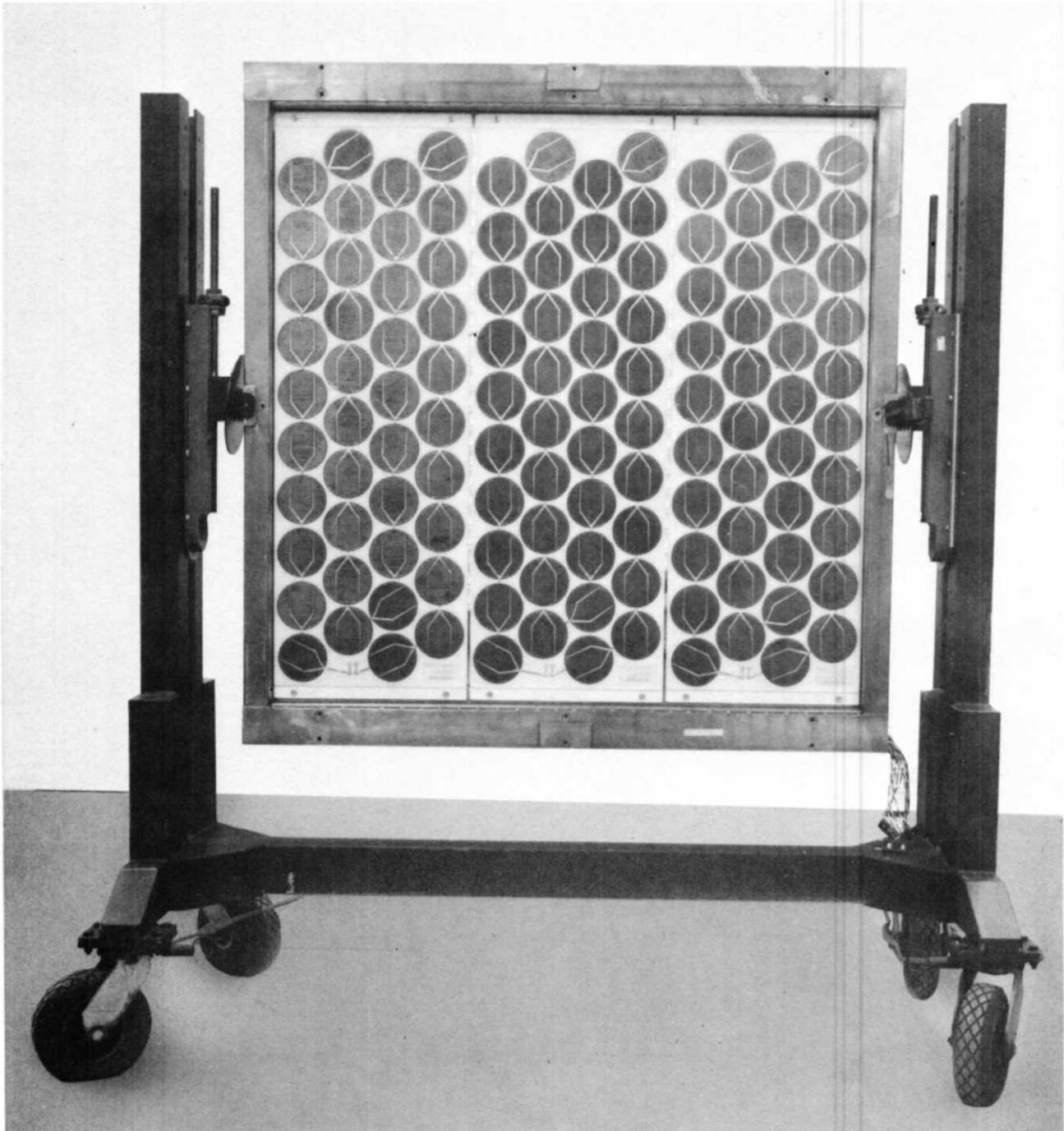


Figure 1-1. Example of Subarray Assembled From Block II Modules

SECTION II

MODULE DESCRIPTION

The Block II contractors were required to comply with a common set of requirements delineated in JPL Specification 5-342-1, Revision B, dated December 20, 1976, entitled Silicon Solar Cell Module Performance, Environmental Test and Inspection Requirements. The principal requirements in this specification are:

- (1) The configuration must permit assembly of modules into a four-foot-square subarray which produces not less than 60 watts at 15.8 volts output, when operated at a cell temperature of 60°C and exposed to insolation through an optical air mass of AM1 at a module irradiance of 100 mW/cm².
- (2) Breakdown voltage from terminals to ground must exceed 1500 Vdc.
- (3) Insulation resistance from terminals to ground, when measured at 1000 Vdc, must not be less than 100 megohms.
- (4) The modules must withstand the following test environment:
 - (a) 50 thermal cycles between -40°C and +90°C.
 - (b) 5 cycles of 95% relative humidity between 23°C and 41°C.
 - (c) 100 cycles of simulated wind loading between +50 lb/ft² and -50 lb/ft².

As the specification permits some options in configuration and in materials, the resulting modules supplied by the four contractors differ in several respects. The complete descriptions of the four types of modules are given in Table 2-1, Module Characteristics.

Samples of each type of module were subjected to a Qualification Test Program (see Appendix) to prove compliance with the requirements. In addition, all deliverable modules were subjected to an acceptance test, consisting of measurement of electrical performance and testing of insulation resistance and breakdown voltage.

Table 2-1. Module Characteristics

AR

IDENTIFYING	MANUFACTURER	SENSOR TECHNOLOGY	SOLAREX	SOLAR POWER	SPECTROLAB
	MFR'S PART NO.	20-10-1462-J	A-0221-D	E-10008-C	022962-G
PHYSICAL	PHOTOGRAPHIC VIEWS	Figure 2-1	Figure 2-4	Figure 2-7	Figure 2-10
	OVERALL DIMENSIONS (inches)		A = 524.90"	A = 203.80"	
	LENGTH	22.9	22.9	46.0	46.0
	WIDTH	11.4	22.9	15.3	15.3
	HEIGHT	1.8	1.8	1.9	1.4
	WEIGHT (lbs)	3.3	9.0	16.7	13.5
	NO. OF MODULES PER 4 FOOT SQUARE	8	4	3	3
	SUBARRAY PLANARITY ROGMT. (in/ft)	0.25	0.25	0.25	0.25
	MODULE DRAWING	Figure 2-2	Figure 2-5	Figure 2-8	Figure 2-11
	ELECTRICAL CONNECTIONS	Figure 2-2	Figure 2-5	Figure 2-8	Figure 2-11
	MATERIALS	Figure 2-2	Figure 2-5	Figure 2-8	Figure 2-11
	NO. OF CELLS	44	42	40	120
	CELL DIAMETER (inches)	2.2	3	4	2
CELL CONFIGURATION	N-P	N-P	P-N	N-P	
ELECTRICAL	QUALIFICATION PERFORMANCE ^①				
	VOLTAGE, RATED (Volts)	16.5	15.8	15.8	15.8
	CURRENT (Amps.)	0.576	1.18	1.81	1.62
	POWER, RATED (Watts)	9.5	18.6	28.6	25.6
	SOC PERFORMANCE (SAMPLE) ^②				
	POWER, MAXIMUM (Watts)	10.4	18.7	31.3	28.5
	VOLTAGE AT MAX. POWER (Volts)	18.7	16.3	16.6	17.3
	CURRENT AT MAX. POWER (Amps)	0.56	1.15	1.89	1.65
	VOLTAGE, OPEN CIRCUIT (Volts)	23.4	22.4	22.0	21.9
	CURRENT, SHORT CIRCUIT (Amps)	0.59	1.44	1.98	1.88
	FILL FACTOR	0.75	0.58	0.72	0.69
	EFFICIENCY, MODULE (%)	6.3	5.5	6.9	6.3
	EFFICIENCY, ENCAPSULATED CELL (%)	9.6	9.8	9.7	11.7
	TEMPERATURE CHARACTERISTICS (I-V Curves)	Figure 2-3	Figure 2-6	Figure 2-9	Figure 2-12
CIRCUIT CONFIGURATION	Series	Series	Series	Series - Parallel	
INSULATION RESISTANCE, MIN. (Meg Ω)	100	100	100	100	
BREAKDOWN VOLTAGE, MIN. (Vdc)	1500	1500	1500	1500	
THERMAL	NOMINAL OPERATING CELL TEMPERATURE (°C) ^③	42.9	47.1	46.0	41.1
ENVIRONMENTAL	TEMPERATURE RANGE (°C) ^④	-40 to +90	-40 to +90	-40 to +90	-40 to +90
	HUMIDITY, MAXIMUM RELATIVE ^④ (%)	95	95	95	95
	WIND LOAD, MAXIMUM ^④ (lb/ft ²)	±50	±50	±50	±50
LIFE	SERVICE LIFE DESIGN GOAL (Yrs)	10	10	10	10

NOTES

- ① Each module was required to produce not less than 86% of rated power when loaded to provide rated voltage under the following conditions:
 A. Module irradiated with 100 mW/cm² insolation at air mass one (AM1).
 B. Cell temperature equal to 60°C. See Appendix (Qualification Test Program) for details of electrical performance test.

- ② Standard Operating Conditions (SOC) are:
 A. Module irradiated with 100 mW/cm² insolation at air mass one (AM1).
 B. Cell temperature equal to NOCT. (See Note (3)).

The data presented here for each module design shows the characteristics obtained by measurement and extrapolation of the performance of one sample module of that design. I-V curves for the sample modules are given in Figures 2-3, 2-6, 2-9, and 2-12.

- ③ Nominal Operating Cell Temperature (NOCT) is defined as follows:

$$NOCT = 20^{\circ}C + T_R$$

where T_R is the cell temperature rise under the following conditions:

- Ambient temperature = 20°C
- Average wind velocity = 1 m/s ± 0.75 m/s
- Wind gusts = <4 m/s
- Insolation = 80 mW/cm²

- ④ The data given are the test limits, not measured limits. For details see Appendix (Qualification Test Program).

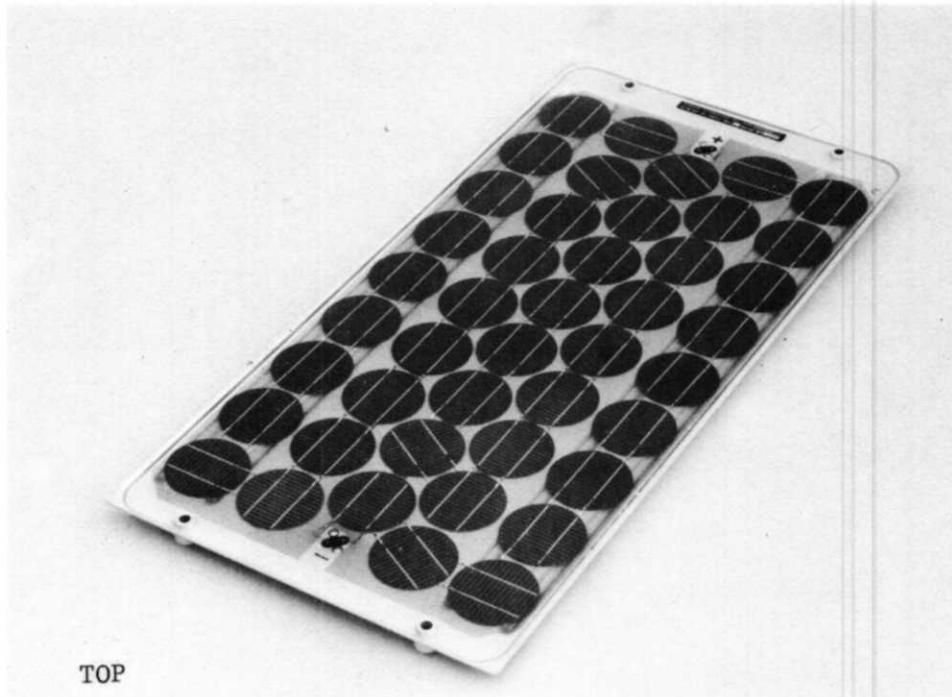


Figure 2-1. Sensor Technology Module: Photographic Views

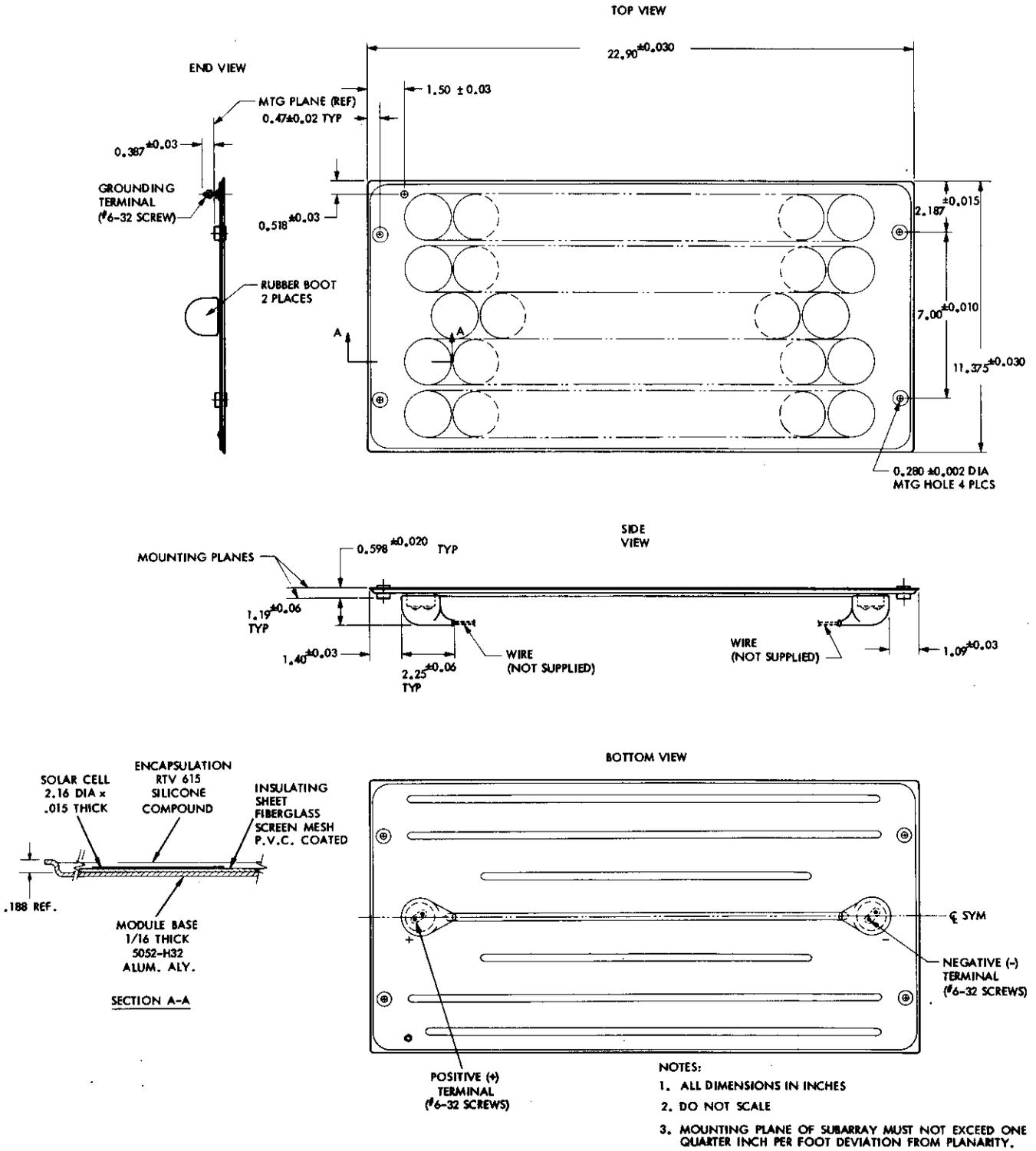


Figure 2-2. Sensor Technology Module: Drawing

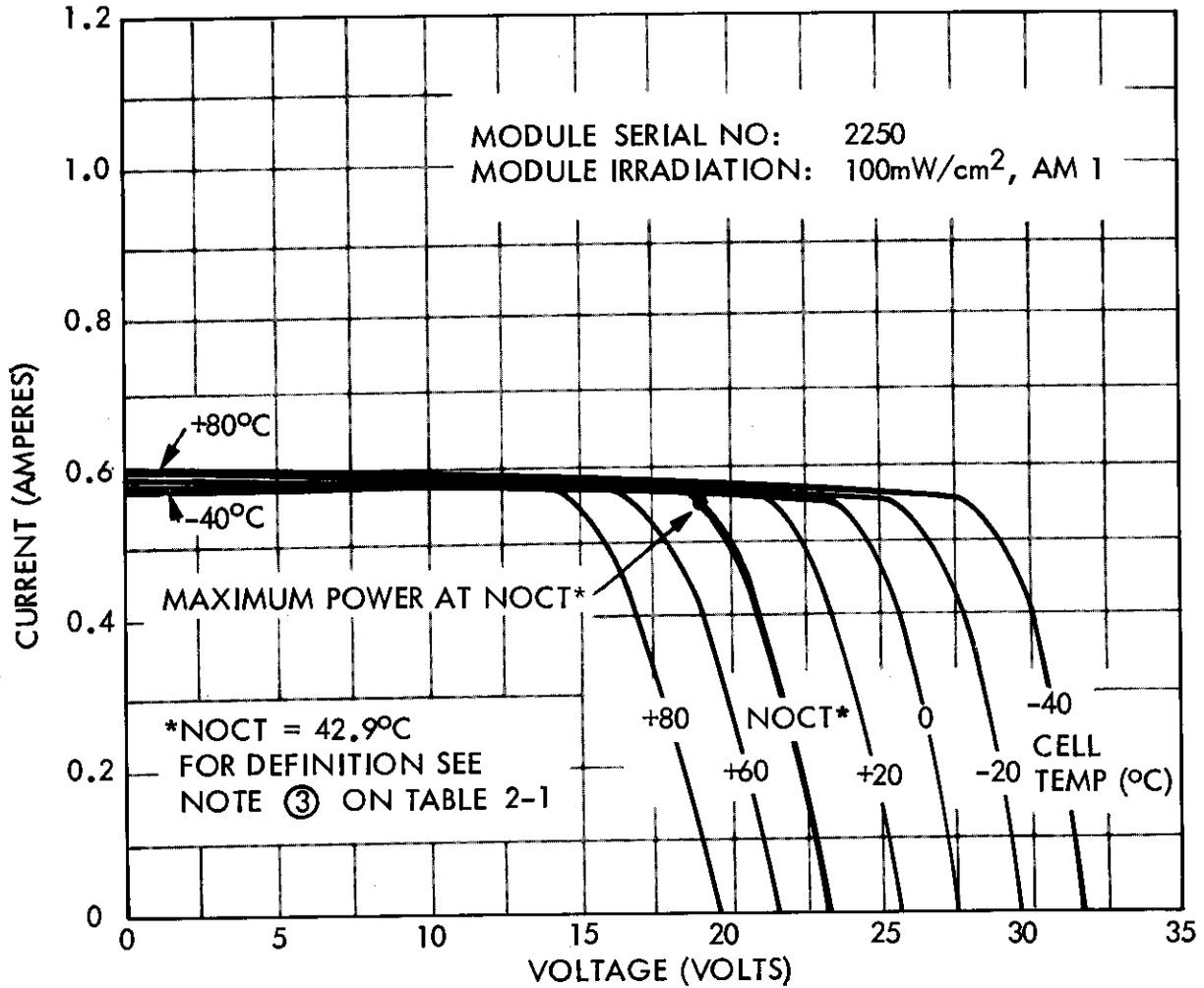


Figure 2-3. I-V Curves for Sensor Technology Module

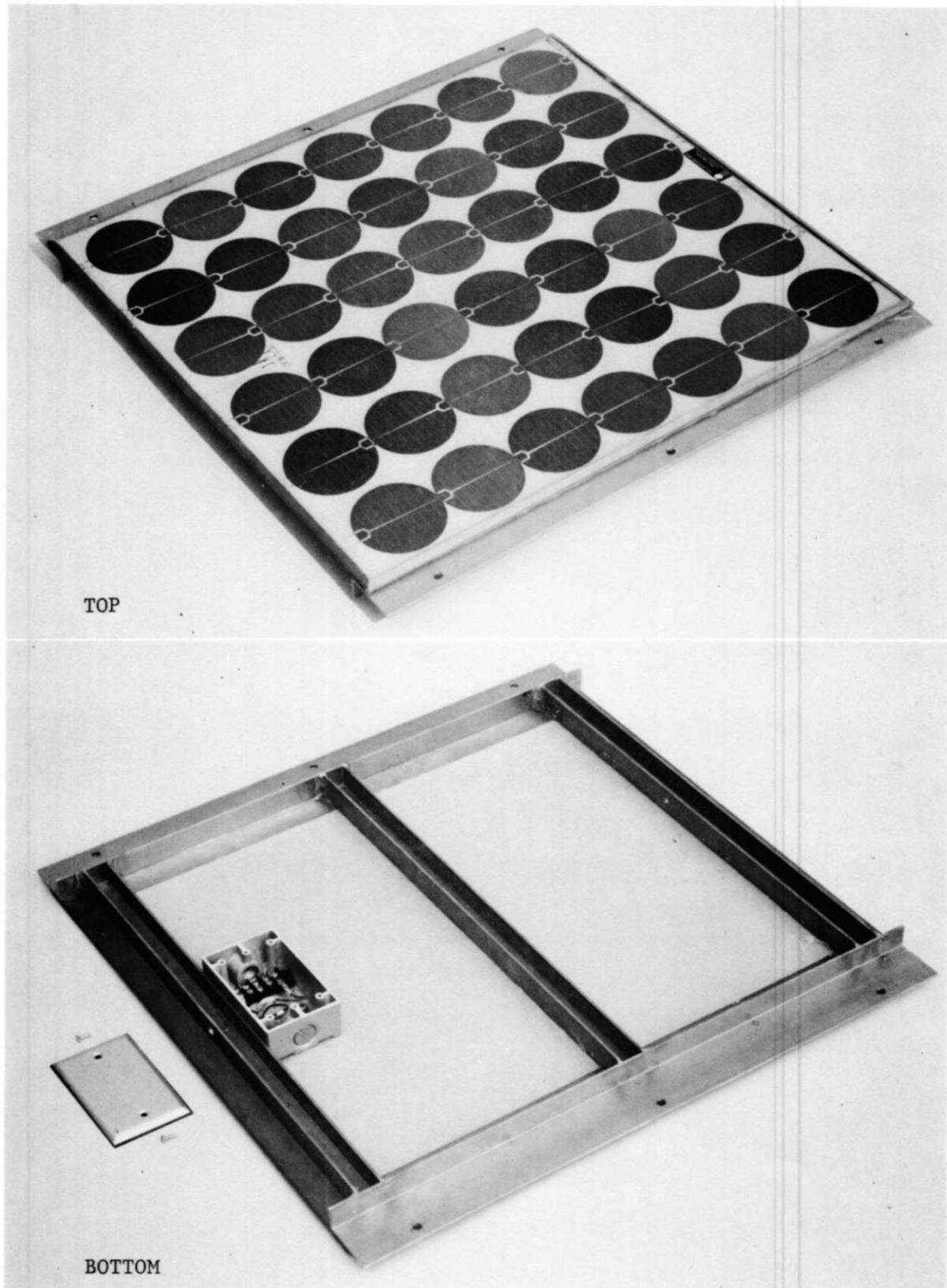
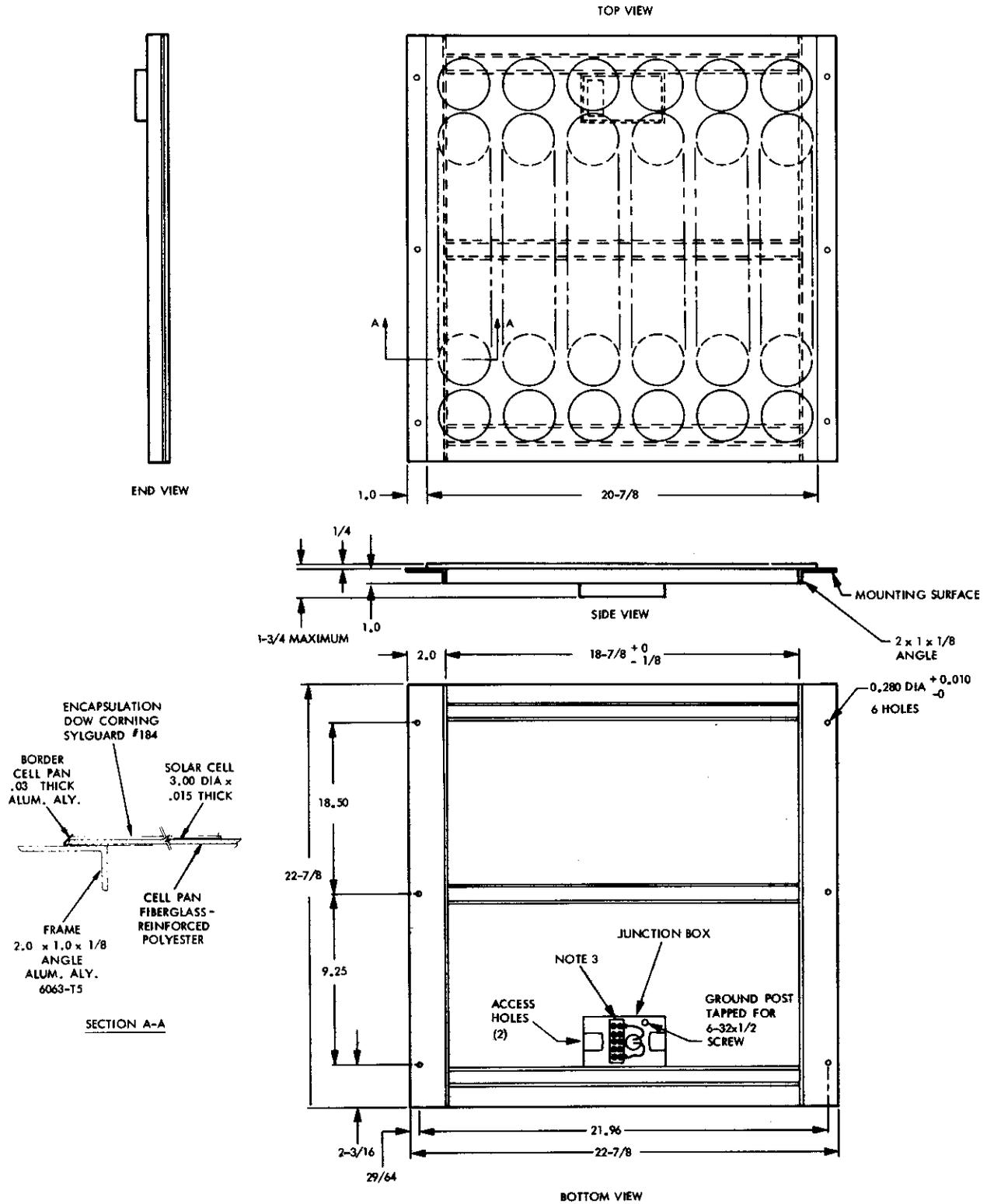


Figure 2-4. Solarex Module: Photographic Views



- NOTES:**
1. ALL DIMENSIONS IN INCHES
 2. UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:
FRACTIONS: $\pm 1/32$, DECIMALS: $+0.020$
 3. 5 TERMINAL, CLOSED BACK, TERMINAL BLOCK-670, SCREW SIZE-5-40x1/4, WILL ACCOMODATE SOLDER LUGS FOR #22 TO #16 AWG WIRE
 4. DO NOT SCALE
 5. MOUNTING PLANE OF SUBARRAY MUST NOT EXCEED ONE QUARTER INCH PER FOOT DEVIATION FROM PLANARITY.

Figure 2-5. Solarex Module: Drawing

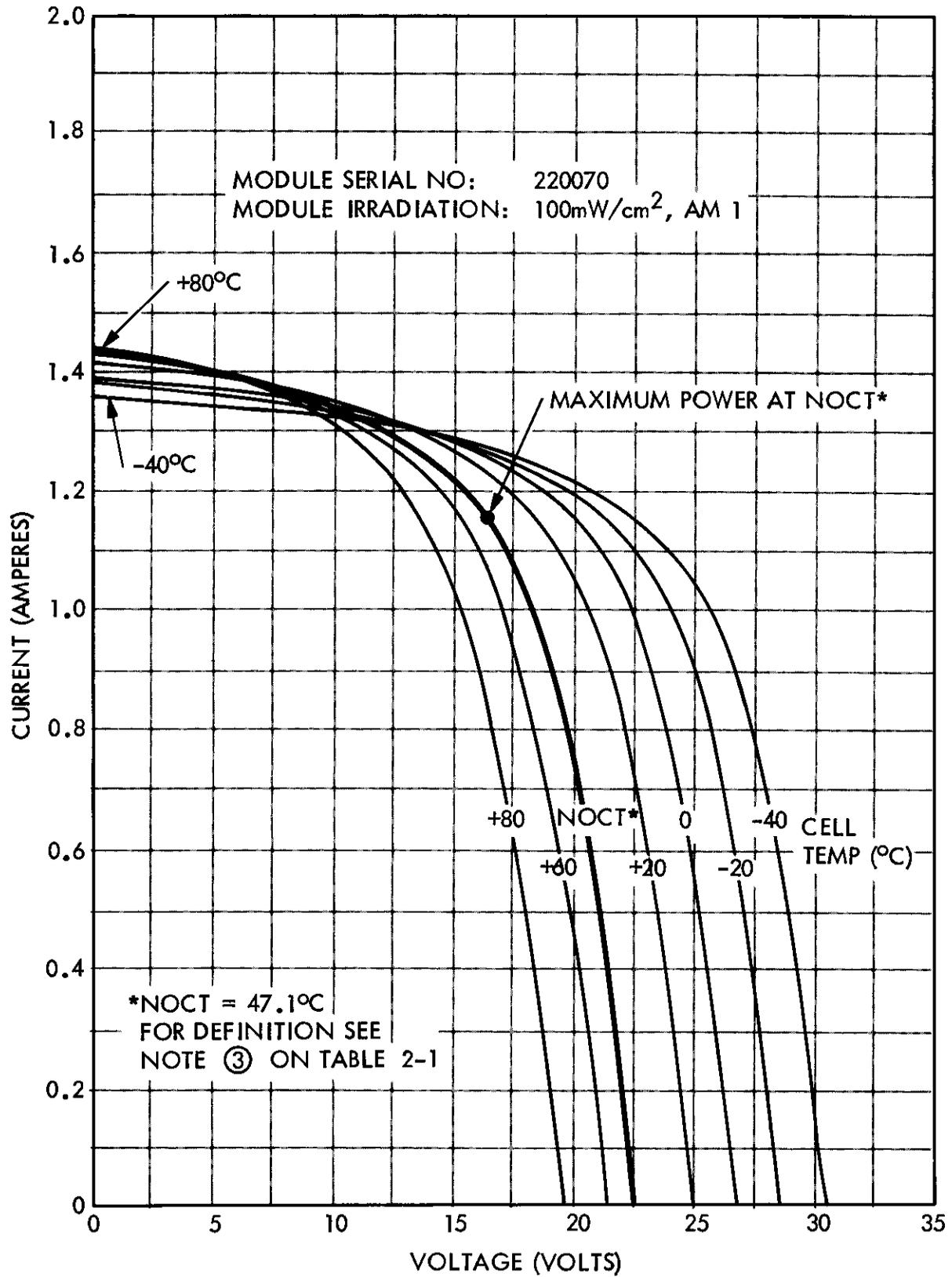


Figure 2-6. I-V Curves for Solarex Module

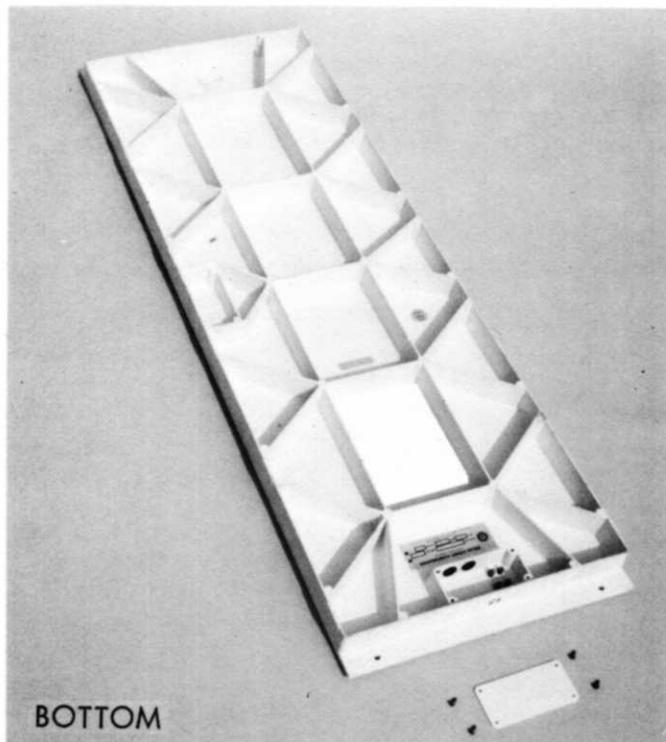
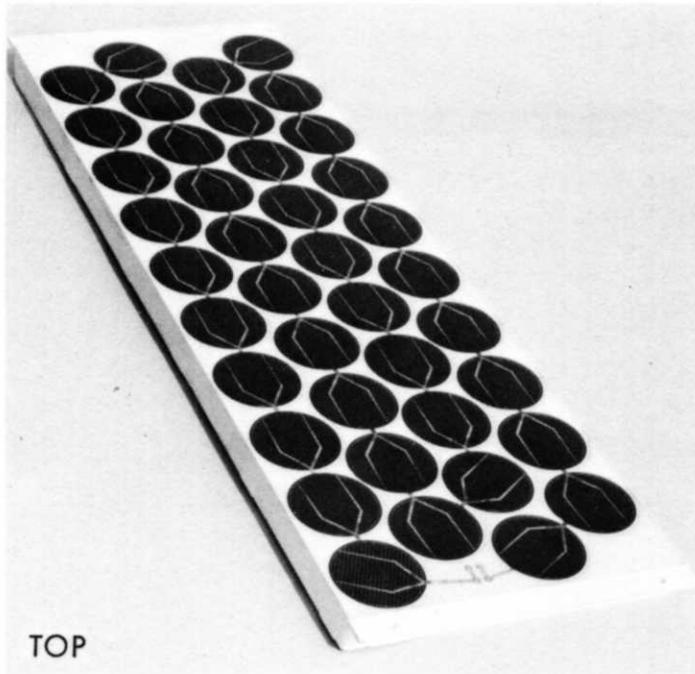


Figure 2-7. Solar Power Module: Photographic Views

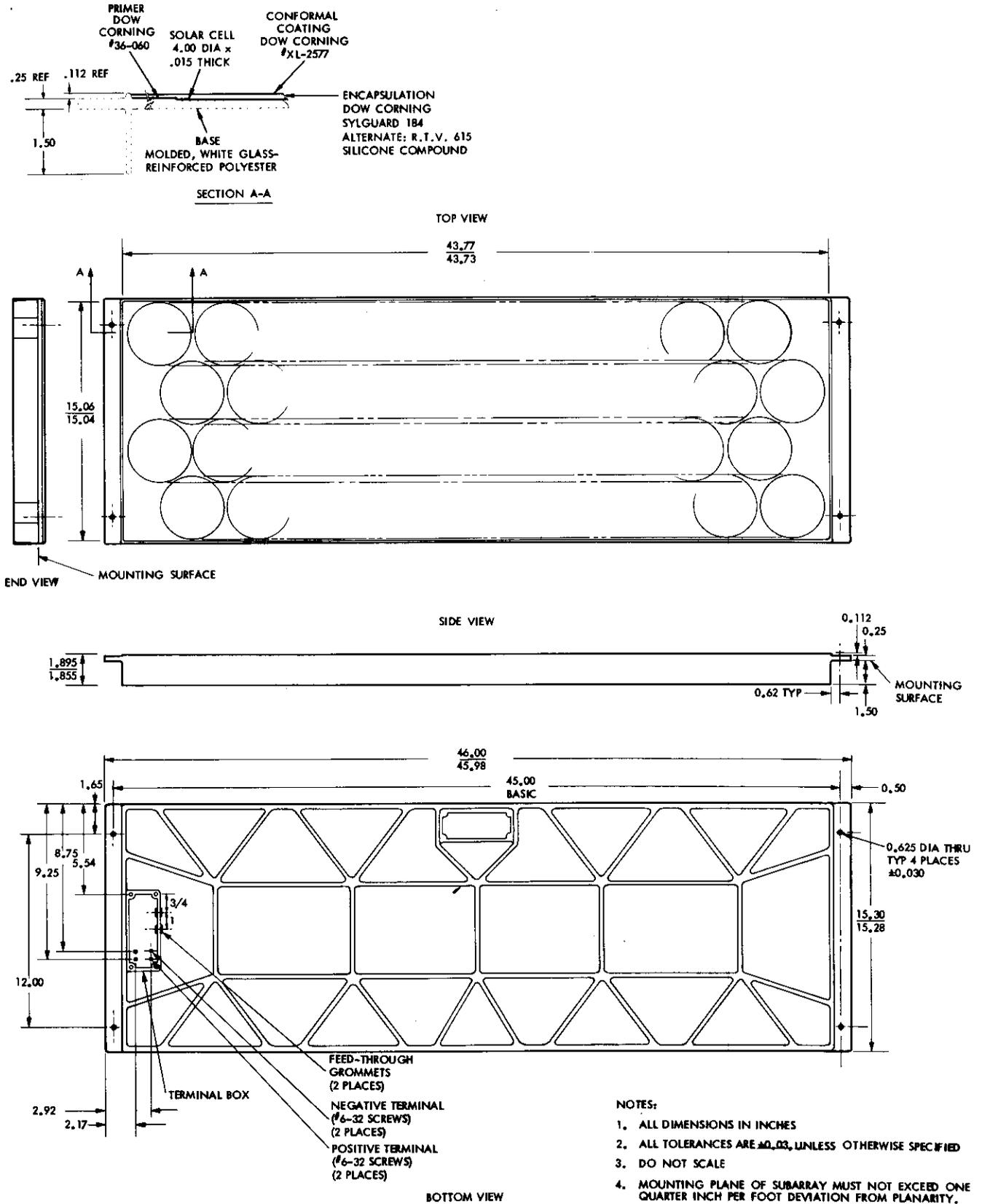


Figure 2-8. Solar Power Module: Drawing

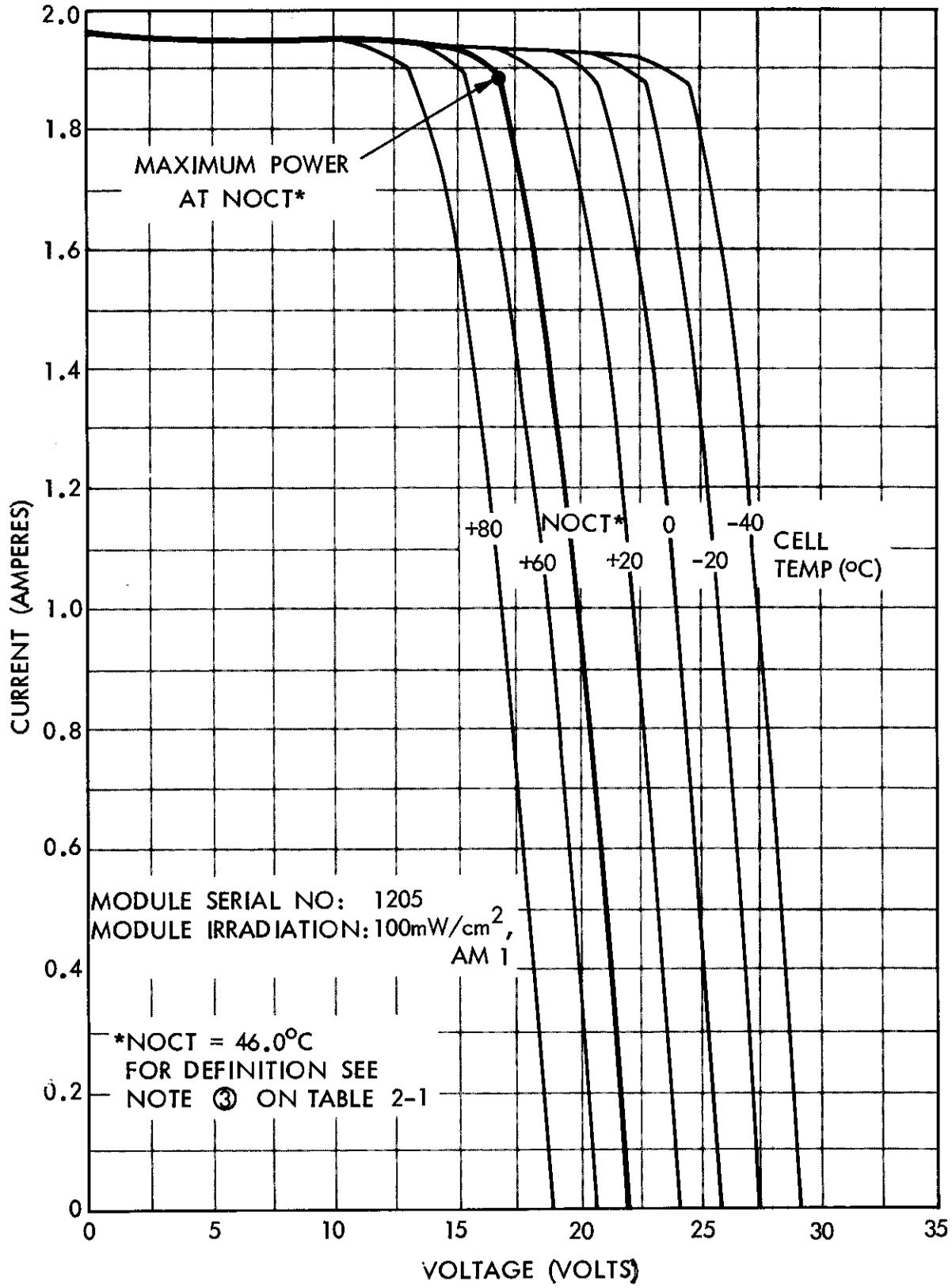


Figure 2-9. I-V Curves for Solar Power Module

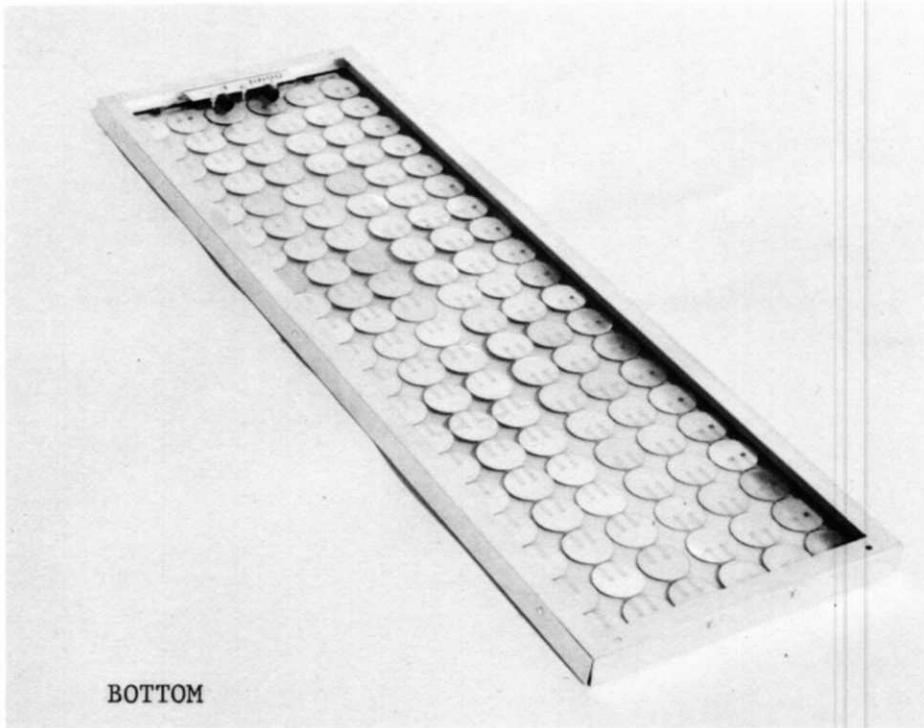
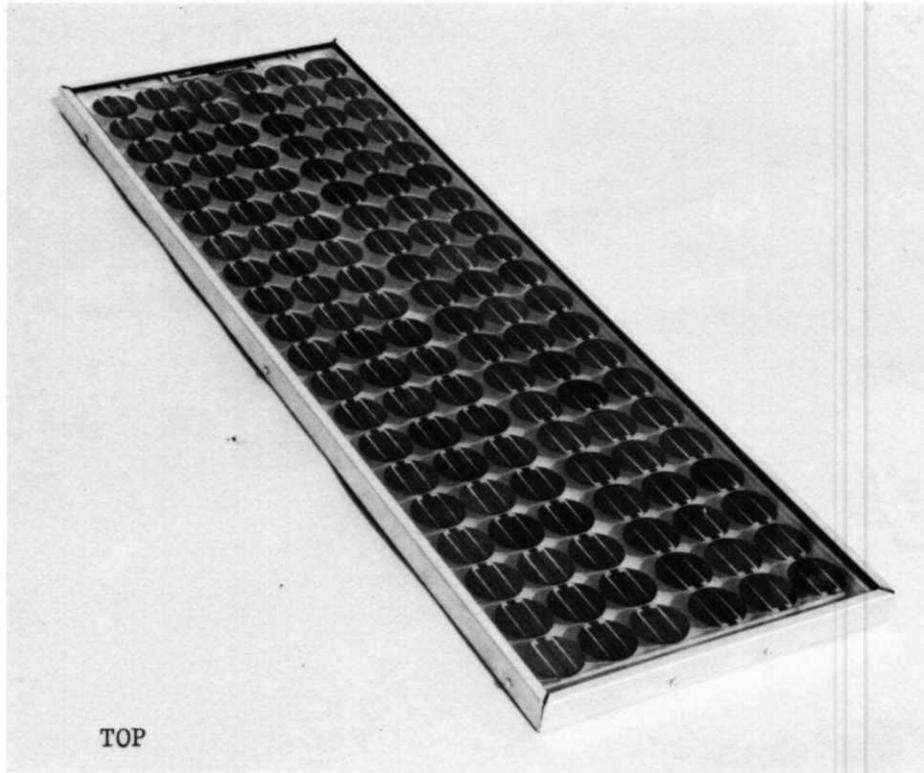
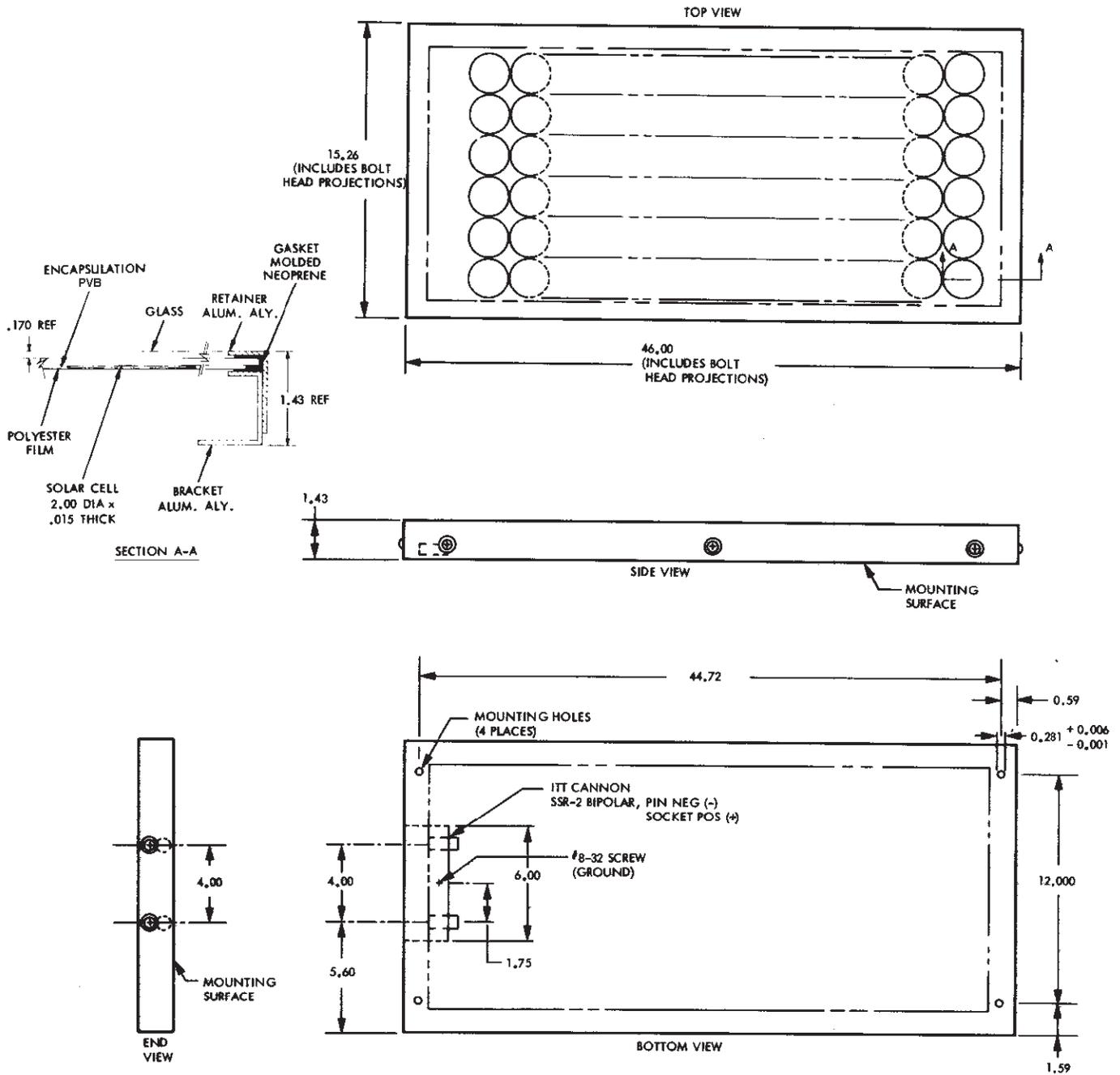


Figure 2-10. Spectrolab Module: Photographic Views



- NOTES:
1. ALL DIMENSIONS IN INCHES
 2. ALL TOLERANCES ARE ± 0.03 , UNLESS OTHERWISE SPECIFIED
 3. DO NOT SCALE
 4. MOUNTING PLANE OF SUBARRAY MUST NOT EXCEED ONE QUARTER INCH PER FOOT DEVIATION FROM PLANARITY.

Figure 2-11. Spectrolab Module: Drawing

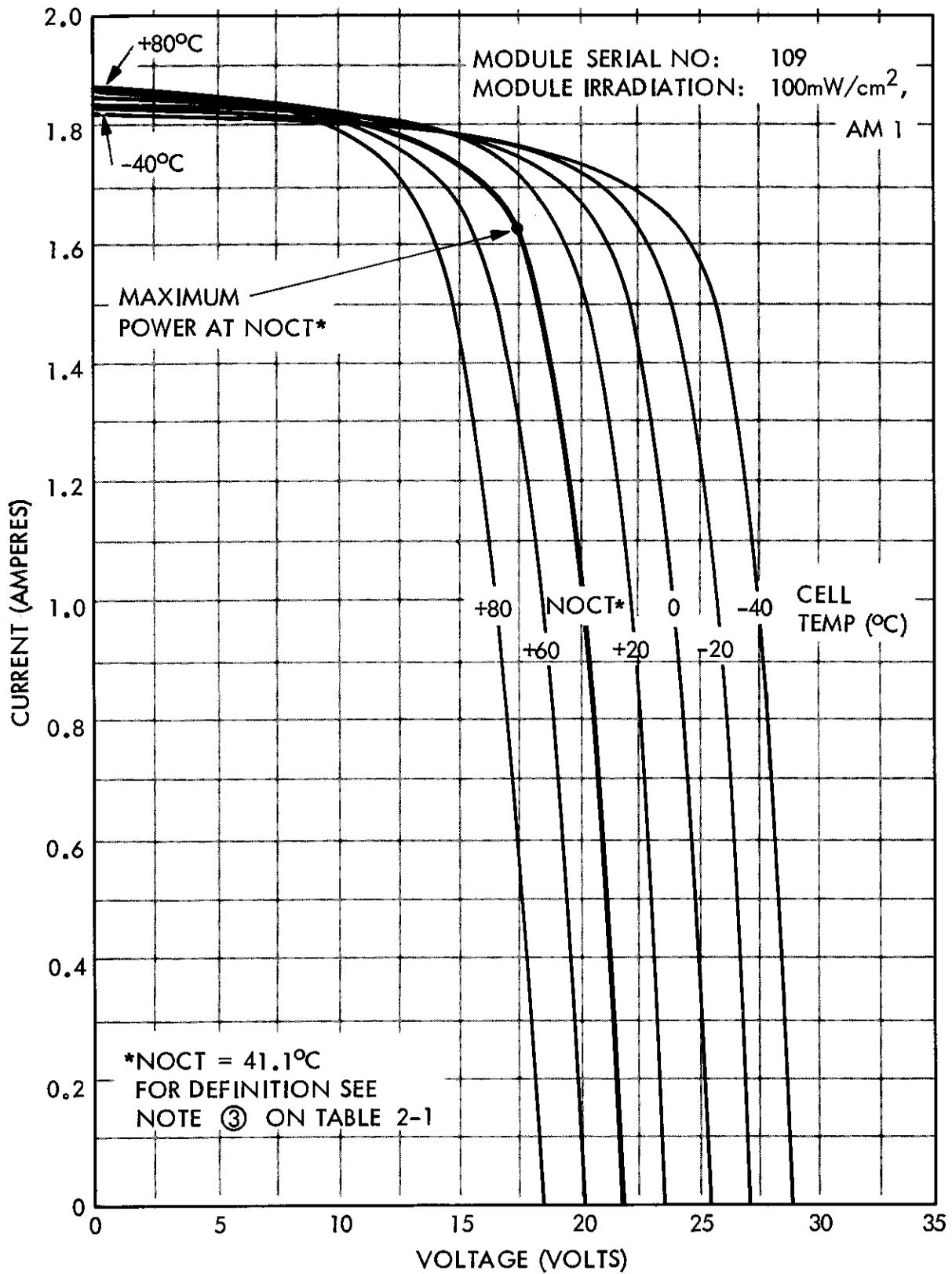


Figure 2-12. I-V Curves for Spectrolab Module

APPENDIX

QUALIFICATION TEST PROGRAM

During initial production of each Block II module design, a sample lot was subjected to a qualification test program to establish electrical characteristics and to prove compliance with required ranges of environmental exposure. The integrity of this design qualification is verified throughout subsequent production by applying essentially the same tests to periodically selected samples.

The block diagram in Figure A-1 shows the qualification test sequence with the names of individual tests given in the blocks, which are alphabetically coded. Note that some tests occur more than once in the sequence. The description of each test is as follows:

A. Visual Inspection

This consists of detailed visual examination of the module for mechanical degradation of a degree judged to threaten continued successful performance of the module. Such degradation may appear as breaks, cracks, delamination, spalling, etc.

B. Electrical Performance

The purpose of this test is to obtain current-voltage (I-V) characteristic curves, first to establish a performance baseline, and subsequently to examine for performance degradation. Furthermore, the test verifies that the module design produces the required power output, i.e., not less than 86% of the rated power, where the latter is the expected power output when the module is loaded to produce rated voltage under the following conditions:

- (1) Module irradiated with 100 mW/cm^2 simulated insolation at air mass one (AM1).
- (2) Cell temperature stabilized at 60°C by control of ambient air temperature.

When the test is performed to examine for performance degradation the purpose is to verify that the stresses of the qualification tests do not cause more than 5% degradation in power output, measured under the above conditions.

Typically, the electrical performance test is run at a cell temperature other than 60°C , a common value being 28°C . In such case, the point on the I-V curve which is comparable to the rated voltage point on the 60°C I-V curve will have previously been determined by a combined experimental and analytical procedure involving calculation and application of temperature coefficients for current and voltage.

C. Insulation Resistance

This test verifies that the insulation resistance between the (shorted-together) output terminals of the module and module ground is not less than 100 megohms, measured with 1000 volts applied, of either polarity. The test is applicable only to module designs which include a ground terminal.

D. Dielectric Breakdown

This test verifies that the insulation between the (shorted-together) output terminals of the module and module ground will not suffer dielectric breakdown when subjected to 1500 volts DC. The voltage is applied over a 45 second period in uniformly spaced 500 volt steps, and held at the 1500 volt level for one minute. The test is applicable only to module designs which include a ground terminal.

E. Thermal Cycling

This test requires that the module be subjected to 50 cycles of cell temperature variation between -40°C and $+90^{\circ}\text{C}$. The variation is approximately linear, at a rate not exceeding 100°C per hour, with a six hour period per cycle.

F. Humidity Cycling

This test requires that the module be subjected to the humidity regime depicted in Figure A-2. The subsequent electrical performance test must follow within one hour of removal of the module from the humidity chamber.

G. Mechanical Load Cycling

This test verifies, by simulation, that wind which produces mechanical loading of 50 pounds per square foot will not result in mechanical or electrical degradation. The test is performed by applying 100 cycles of mechanical load, normal to the module surface, ranging between +50 and -50 pounds per square foot.

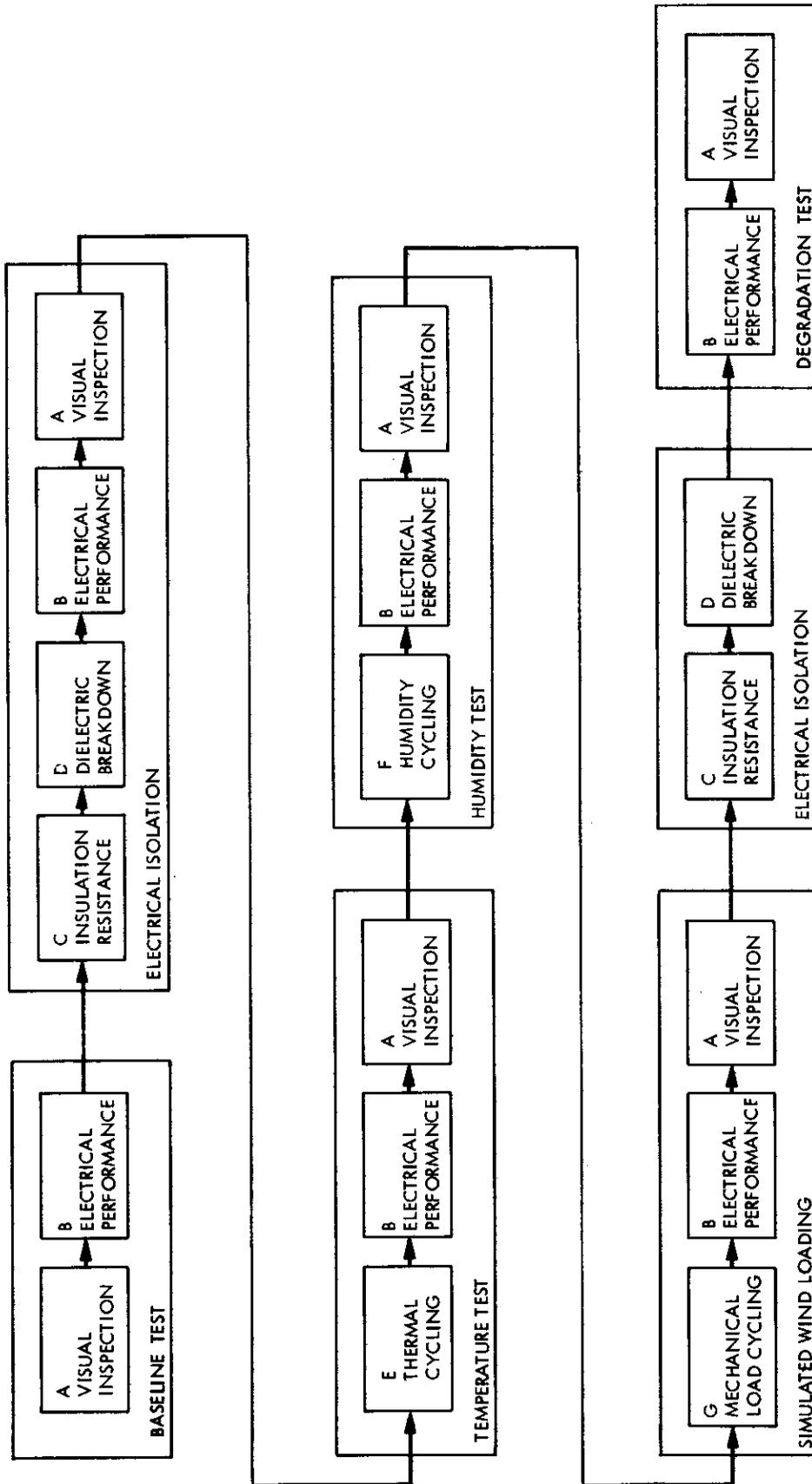


Figure A-1. Qualification Test Sequence

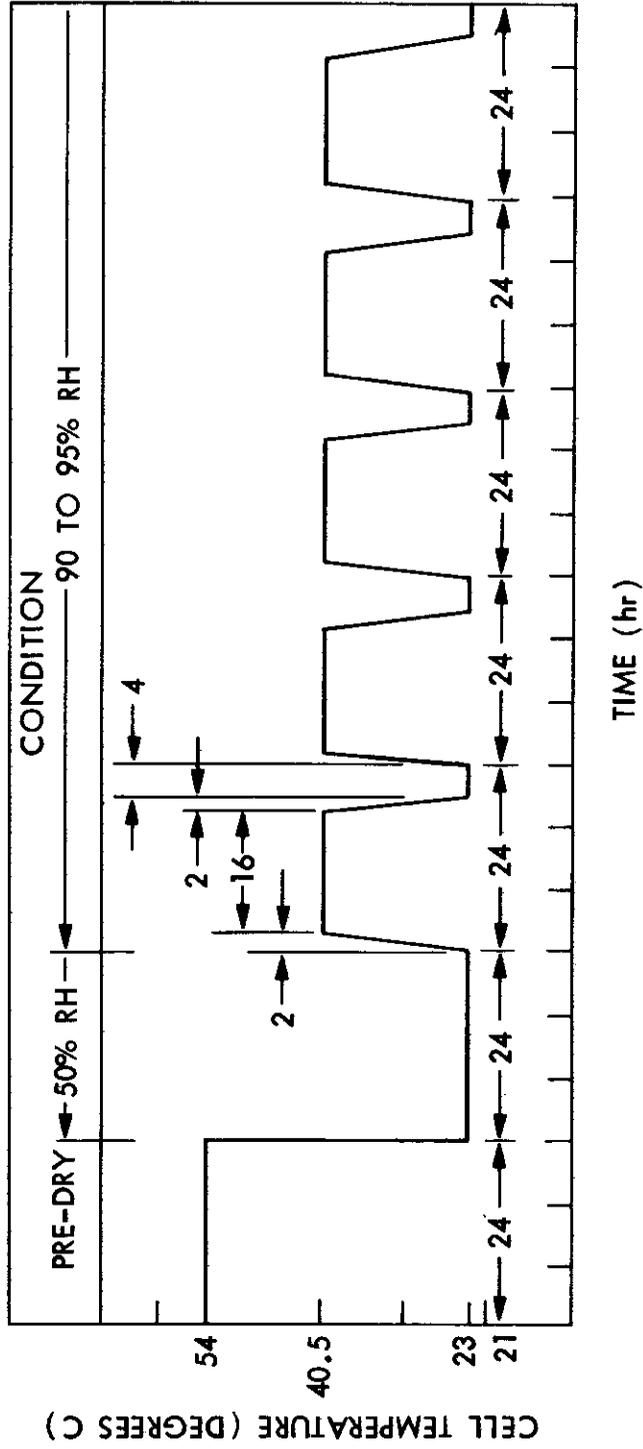


Figure A-2. Humidity Cycle