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TRIANNUAL REPORT

on the

DESIGN, ANALYSIS AND TEST VERIFICATION OF ADVANCED ENCAPSULATION SYSTEMS

For Period Ending

31 July 1982

Contract 955567

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November 1982

The JPL Flat-Plate Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.

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Section 1.0

SUMMARY

Work has begun on the construction of the qualification modules. A study of the index of refraction sensitivity has been completed.

Section 2.0

INTRODUCTION

The objective of this program is to develop analytical methodology for advanced encapsulation designs. From these methods design sensitivities will be established for the development of photovoltaic module criteria and the definition of needed research tasks.

The program consists of four phases. In Phase I, analytical models were developed to perform optical, thermal, electrical and structural analyses on candidate encapsulation systems. From these analyses several candidate systems were selected for qualification testing during Phase II. Additionally, during Phase II, test specimens of various types will be constructed and tested to determine the validity of the analysis methodology developed in Phase I.

During Phase III the following items will be covered:

1. Correction of identified deficiencies and/or discrepancies between analytical models developed during Phase I and relevant test data obtained during Phase II of the above contract.

2. Improvement and extension of prediction capability of present analytical models.

3. Generation of encapsulation engineering generalities, principles, and design aids for photovoltaic module designers.

From these items the sensitivity of module performance to various material properties will be determined. This study will enable

the intelligent direction of research into assessment of module life potential by analyzing those materials and their properties which through aging would most influence module performance.

In Phase IV a finalized optimum design based on knowledge gained in Phases I, II and III will be developed and delivered to JPL.

Section 3.0

TECHNICAL DISCUSSION

3.1 QUALIFICATION MODULE CONSTRUCTION

The two-component metering and mixing machine was received from Development Associates. Several 2' x 4' modules were made using scrap cell strings. Bubbles were minimized in the pottant by eliminating a Craneglas spacer layer between the Acrylar front cover and the cells.

The optimum technique is a one-step casting. The substrate is covered by the Craneglas sheet followed by the cell string. Mixed polyurethane is then pumped onto the layup. The cells are pressed lightly to remove trapped air. The Acrylar top cover which has been primed with Development Associates Z-2881 primer is rolled onto a 4" diameter tube with the primed side out. The top cover is then carefully rolled out onto the urethane covered layup making sure air bubbles are not trapped.

This procedure eliminated most of the bubbles. Some small bubbles were still trapped in inter-cell areas. Several small ribbed wood substrates were constructed using nominal 1" x 2" select pine ribs. The actual dimensions were 1-1/2" x 3/4". These ribs were glued to 1/8" tempered Duron using the following epoxy composition:

80 parts	EPI-REZ 510
64 parts	EPI-CURE 855
2 parts	CAB-O-SIL

EPI-REZ and EPI-CURE are Celanese products. CAB-O-SIL is a fumed silica manufactured by Cabot Corporation. This system is a polyamid cured epoxy with a modulus of ∿ 150 ksi. The CAB-O-SIL makes the mixture thixotropic before curing. The ribs were secured with screws on 2' centers during curing.

A 4' x 4' substrate was prepared using 5 parallel ribs on 8" centers. These ribs are stiffer than those modeled in the Phase 1 report. This compromise was made to reduce cost and facilitate the construction of the qualification modules.

Several white urethane conformal coatings based on Development Associates' Z-2891 system have been tried for coating the front surface of wood under the cells. This system did not leave a smooth uniform white surface. A sprayed alkyd or acrylic paint will be used instead. Attempts to put a single sheet of type 10CP3110 Scotch Par on the back of the 4' x 4' ribbed substrate were largely unsuccessful. Using 6" wide strips proved successful. Type 4910 (3M) contact adhesive was used. JPL has recommended a 2 mil Scotch Par film be used instead of the 1 mil film now used.

3.2 INDEX OF REFRACTION STUDY

3.2.1 Introduction

Earlier work, summarized in the Phase 1 Report, considered a wide range of encapsulation designs, materials and cells. A thermal-optical computer program incorporating the optical relations as a subroutine was used. The materials considered were commercially available and had indices of refraction of 1.4 to 1.5 for both cover and pottant. Energy absorbed and temperature dependence of cell conversion efficiency were considered explicitly.

Tables have been generated for the following configurations of single-crystal silicon cells:

(a) Plain silicon

(b) Texturized, non-AR coated silicon

(c) Plain, AR-coated silicon with coating indices of refraction = 2.0, 2.2, 2.4, 2.6, 2.8, and 3.0.

(d) Texturized, AR-coated silicon with coating indices of refraction = 2.0, 2.2, 2.4, 2.6, 2.8, and 3.0.

Fourteen tables were generated: one each for items (a) and (b) above and six each for items (c) and (d) above. AR coating thickness is set to yield a minimum reflectivity at 0.6 micron. Pottant and cover indices were varied from 1.0 to 2.0.

3.2.2 Discussion

3.3.2.1 Physical Description

In the present work power output is calculated for a single cell as in Phase I report. The cells are single-crystal and 10.2 cm square with a .13 cm intercell space.

3.2.2.2 Environment

The cell is subjected to AM1.5 sunlight with a tilt of 37°. The wind speed, module front and back side radiative properties, encapsulant material and thickness are such that a cell temperature of approximately 50° is achieved.

3.3.2.3 Analysis

For normal incidence Fresnel's equation can be expressed as

$$\rho = \left(\frac{N_1 - N_2}{N_1 + N_2}\right)^2$$

This relationship is used to calculate reflectance at the interface between media 1 and 2. In the earlier work the reflectance at the cover-air interface was measured while internal reflections were calculated using the above expression. Reflections at texturized and AR-coated cell surfaces are treated as described in Phase I Report.

In the present work the absorption in the cover and pottant layers is taken as zero. The temperature-related cell conversion efficiency was calculated based on the cell temperature of 50°C noted previously.

3.2.3 Results

Two sets of fourteen tables each were generated to complete the optical tasks of Phase IIIA. The results were generated using input data as specified in the Phase I Report. The first set of direct comparison with certain entries in Table 6-3 of Phase I Report. The second set of tables, Tables 9-16, present the module conversion efficiency and have a direct correspondence with the entries in Tables 1-8. The module conversion efficiency is calculated by dividing the power output by the product of incident flux and cell area. The table headings are self explanatory and only certain results will be discussed in detail.

TABLE 1. MODULE POWER OUTPUT (WATTS) AT AM1.5
PLAIN SILICON

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.17	1.16	1.15	1.14	1.12	1.10	1.08	1.06	1.04	1.02	1.00
1.1	1.23	1.23	1.22	1.21	1.19	1.17	1.15	1.13	1.11	1.09	1.07
1.2	1.28	1.28	1.28	1.27	1.26	1.24	1.22	1.20	1.17	1.15	1.13
1.3	1.32	1.33	1.33	1.32	1.31	1.29	1.27	1.25	1.23	1.21	1.18
1.4	1.36	1.37	1.37	1.37	1.36	1.34	1.32	1.30	1.28	1.26	1.23
1.5	1.38	1.40	1.41	1.40	1.40	1.38	1.37	1.35	1.32	1.30	1.28
1.6	1.40	1.42	1.43	1.43	1.43	1.42	1.40	1.38	1.36	1.34	1.32
1.7	1.42	1.44	1.45	1.46	1.46	1.45	1.43	1.42	1.40	1.37	1.35
1.8	1.42	1.45	1.47	1.48	1.48	1.47	1.46	1.44	1.42	1.40	1.38
1.9	1.43	1.46	1.48	1.49	1.49	1.49	1.48	1.46	1.45	1.43	1.41
2.0	1.43	1.46	1.49	1.50	1.51	1.50	1.49	1.48	1.47	1.45	1.43

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TABLE 2. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED CELL

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.48	1.47	1.46	1.43	1.41	1.38	1.35	1.32	1.28	1.25	1.22
1.1	1.51	1.51	1.50	1.48	1.46	1.43	1.40	1.37	1.34	1.31	1.27
1.2	1.53	1.54	1.53	1.52	1.50	1.47	1.45	1.42	1.39	1.35	1.32
1.3	1.55	1.56	1.56	1.55	1.53	1.51	1.48	1.45	1.42	1.39	1.36
1.4	1.55	1.57	1.57	1.56	1.55	1.53	1.51	1.48	1.45	1.42	1.39
1.5	1.55	1.57	1.58	1.57	1.56	1.55	1.53	1.50	1.47	1.45	1.42
1.6	1.54	1.56	1.58	1.58	1.57	1.56	1.54	1.52	1.49	1.46	1.44
1.7	1.53	1.55	1.57	1.58	1.57	1.56	1.55	1.53	1.50	1.48	1.45
1.8	1.51	1.54	1.56	1.57	1.57	1.56	1.55	1.53	1.51	1.49	1.46
1.9	1.49	1.53	1.55	1.56	1.57	1.56	1.55	1.53	1.51	1.49	1.47
2.0	1.47	1.51	1.54	1.55	1.56	1.55	1.55	1.53	1.52	1.50	1.47

TABLE 3A, MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING, N=2.0

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.65	1.64	1.62	1.59	1.56	1.53	1.49	1.45	1.41	1.37	1.33
1.1	1.66	1.66	1.65	1.62	1.60	1.56	1.53	1.49	1.45	1.42	1.38
1.2	1.66	1.66	1.66	1.64	1.62	1.59	1.56	1.52	1.48	1.45	1.41
1.3	1.64	1.66	1.66	1.64	1.63	1.60	1.57	1.54	1.51	1.47	1.44
1.4	1.62	1.64	1.65	1.64	1.62	1.60	1.58	1.55	1.52	1.48	1.45
1.5	1.60	1.62	1.63	1.63	1.61	1.60	1.57	1.55	1.52	1.49	1.46
1.6	1.57	1.59	1.61	1.61	1.60	1.59	1.57	1.54	1.52	1.49	1.46
1.7	1.53	1.56	1.58	1.58	1.58	1.57	1.55	1.53	1.51	1.48	1.46
1.8	1.50	1.53	1.55	1.56	1.56	1.55	1.54	1.52	1.50	1.48	1.45
1.9	1.46	1.50	1.52	1.53	1.53	1.53	1.52	1.50	1.48	1.46	1.44
2.0	1.43	1.46	1.49	1.50	1.51	1.50	1.49	1.48	1.47	1.45	1.43

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TABLE 3B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING,N=2.0

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.65	1.64	1.63	1.60	1.57	1.53	1.49	1.45	1.41	1.37	1.34
1.1	1.65	1.65	1.64	1.62	1.59	1.56	1.52	1.48	1.45	1.41	1.37
1.2	1.64	1.65	1.64	1.63	1.60	1.57	1.54	1.51	1.47	1.44	1.40
1.3	1.63	1.64	1.64	1.63	1.61	1.59	1.56	1.53	1.49	1.46	1.42
1.4	1.61	1.63	1.63	1.63	1.61	1.59	1.57	1.54	1.51	1.47	1.44
1.5	1.59	1.61	1.62	1.62	1.61	1.59	1.57	1.54	1.52	1.49	1.45
1.6	1.57	1.60	1.61	1.61	1.60	1.59	1.57	1.55	1.52	1.49	1.46
1.7	1.55	1.58	1.59	1.60	1.60	1.59	1.57	1.55	1.52	1.50	1.47
1.8	1.52	1.56	1.58	1.59	1.59	1.58	1.56	1.55	1.52	1.50	1.47
1.9	1.50	1.54	1.56	1.57	1.57	1.57	1.56	1.54	1.52	1.50	1.47
2.0	1.47	1.51	1.54	1.55	1.56	1.55	1.55	1.53	1.52	1.50	1.47

TABLE 44. MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING, N=2.2

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.63	1.62	1.60	1.57	1.54	1.51	1.47	1.43	1.39	1.36	1.32
1.1	1.65	1.65	1.64	1.62	1.59	1.56	1.52	1.48	1.45	1.41	1.37
1.2	1.66	1.67	1.66	1.64	1.62	1.59	1.56	1.52	1.49	1.45	1.41
1.3	1.66	1.67	1.67	1.66	1.64	1.61	1.58	1.55	1.52	1.48	1.44
1.4	1.65	1.66	1.67	1.66	1.65	1.62	1.60	1.57	1.54	1.50	1.47
1.5	1.63	1.65	1.66	1.66	1.65	1.63	1.60	1.58	1.55	1.52	1.48
1.6	1.60	1.63	1.65	1.65	1.64	1.62	1.60	1.58	1.55	1.52	1.49
1.7	1.58	1.61	1.63	1.63	1.63	1.62	1.60	1.58	1.55	1.53	1.50
1.8	1.55	1.58	1.60	1.61	1.61	1.60	1.59	1.57	1.55	1.52	1.50
1.9	1.51	1.55	1.58	1.59	1.59	1.58	1.57	1.56	1.54	1.51	1.49
2.0	1.48	1.52	1.55	1.56	1.57	1.57	1.56	1.54	1.53	1.50	1.48

TABLE 4B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING, N=2.2

POTTANT INDEX OF REFRACTION N	COVER INDEX OF REFRACTION-N 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.65	1.64	1.62	1.60	1.56	1.53	1.49	1.45	1.41	1.37	1.33
1.1	1.65	1.65	1.64	1.62	1.59	1.56	1.52	1.48	1.45	1.41	1.37
1.2	1.64	1.65	1.64	1.63	1.60	1.57	1.54	1.51	1.47	1.44	1.40
1.3	1.63	1.64	1.64	1.63	1.61	1.59	1.56	1.53	1.49	1.46	1.42
1.4	1.61	1.63	1.64	1.63	1.61	1.59	1.57	1.54	1.51	1.48	1.44
1.5	1.59	1.62	1.63	1.62	1.61	1.59	1.57	1.55	1.52	1.49	1.46
1.6	1.57	1.60	1.61	1.61	1.61	1.59	1.57	1.55	1.52	1.50	1.47
1.7	1.55	1.58	1.60	1.60	1.60	1.59	1.57	1.55	1.53	1.50	1.47
1.8	1.53	1.56	1.58	1.59	1.59	1.58	1.57	1.55	1.53	1.50	1.48
1.9	1.50	1.54	1.56	1.58	1.58	1.57	1.56	1.55	1.53	1.50	1.48
2.0	1.48	1.52	1.55	1.56	1.57	1.56	1.55	1.54	1.52	1.50	1.48

TABLE 5A. MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING, N=2.4

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.59	1.58	1.56	1.54	1.51	1.47	1.44	1.40	1.36	1.33	1.29
1.1	1.62	1.62	1.61	1.59	1.56	1.53	1.50	1.46	1.42	1.39	1.35
1.2	1.64	1.65	1.64	1.62	1.60	1.57	1.54	1.51	1.47	1.43	1.40
1.3	1.65	1.66	1.66	1.65	1.63	1.60	1.57	1.54	1.51	1.47	1.44
1.4	1.64	1.66	1.67	1.66	1.64	1.62	1.60	1.57	1.53	1.50	1.47
1.5	1.63	1.66	1.67	1.66	1.65	1.63	1.61	1.58	1.55	1.52	1.49
1.6	1.62	1.65	1.66	1.66	1.65	1.64	1.62	1.59	1.57	1.54	1.50
1.7	1.60	1.63	1.65	1.65	1.65	1.64	1.62	1.60	1.57	1.54	1.51
1.8	1.57	1.61	1.63	1.64	1.64	1.63	1.61	1.60	1.57	1.55	1.52
1.9	1.55	1.58	1.61	1.62	1.62	1.62	1.61	1.59	1.57	1.55	1.52
2.0	1.52	1.56	1.59	1.60	1.61	1.60	1.59	1.58	1.56	1.54	1.52

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TABLE 5B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING, N=2.4

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.64	1.64	1.62	1.59	1.56	1.52	1.49	1.45	1.41	1.37	1.33
1.1	1.65	1.65	1.63	1.61	1.58	1.55	1.52	1.48	1.44	1.41	1.37
1.2	1.64	1.65	1.64	1.62	1.60	1.57	1.54	1.51	1.47	1.44	1.40
1.3	1.63	1.64	1.64	1.63	1.61	1.59	1.56	1.53	1.49	1.46	1.42
1.4	1.61	1.63	1.64	1.63	1.61	1.59	1.57	1.54	1.51	1.48	1.44
1.5	1.60	1.62	1.63	1.62	1.61	1.60	1.57	1.55	1.52	1.49	1.46
1.6	1.57	1.60	1.61	1.62	1.61	1.59	1.57	1.55	1.52	1.50	1.47
1.7	1.55	1.58	1.60	1.61	1.60	1.59	1.57	1.55	1.53	1.50	1.47
1.8	1.53	1.56	1.58	1.59	1.59	1.58	1.57	1.55	1.53	1.51	1.48
1.9	1.51	1.54	1.57	1.58	1.58	1.58	1.56	1.55	1.53	1.51	1.48
2.0	1.48	1.52	1.55	1.56	1.57	1.57	1.56	1.54	1.53	1.51	1.48

TABLE 6A. MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING, N=2.6

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.53	1.53	1.51	1.49	1.46	1.43	1.39	1.36	1.33	1.29	1.26
1.1	1.58	1.58	1.56	1.54	1.52	1.49	1.46	1.42	1.39	1.35	1.32
1.2	1.60	1.61	1.60	1.59	1.57	1.54	1.51	1.48	1.44	1.41	1.37
1.3	1.62	1.63	1.63	1.62	1.60	1.58	1.55	1.52	1.48	1.45	1.42
1.4	1.63	1.64	1.65	1.64	1.63	1.60	1.58	1.55	1.52	1.49	1.45
1.5	1.62	1.65	1.65	1.65	1.64	1.62	1.60	1.57	1.54	1.51	1.48
1.6	1.61	1.64	1.65	1.66	1.65	1.63	1.61	1.59	1.56	1.53	1.50
1.7	1.60	1.63	1.65	1.65	1.65	1.64	1.62	1.60	1.57	1.55	1.52
1.8	1.58	1.62	1.64	1.65	1.65	1.64	1.62	1.60	1.58	1.55	1.53
1.9	1.56	1.60	1.62	1.63	1.64	1.63	1.62	1.60	1.58	1.56	1.53
2.0	1.53	1.58	1.60	1.62	1.63	1.62	1.61	1.60	1.58	1.56	1.53

TABLE 6B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING,N=2.6

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.63	1.63	1.61	1.58	1.55	1.52	1.48	1.44	1.40	1.36	1.32
1.1	1.64	1.64	1.63	1.61	1.58	1.55	1.51	1.48	1.44	1.40	1.36
1.2	1.64	1.64	1.64	1.62	1.60	1.57	1.54	1.50	1.47	1.43	1.40
1.3	1.63	1.64	1.64	1.63	1.61	1.58	1.55	1.52	1.49	1.46	1.42
1.4	1.61	1.63	1.63	1.63	1.61	1.59	1.57	1.54	1.51	1.47	1.44
1.5	1.59	1.62	1.63	1.62	1.61	1.59	1.57	1.55	1.52	1.49	1.46
1.6	1.57	1.60	1.61	1.62	1.61	1.59	1.57	1.55	1.52	1.50	1.47
1.7	1.55	1.58	1.60	1.61	1.60	1.59	1.57	1.55	1.53	1.50	1.47
1.8	1.53	1.56	1.58	1.59	1.59	1.58	1.57	1.55	1.53	1.51	1.48
1.9	1.51	1.54	1.57	1.58	1.58	1.58	1.56	1.55	1.53	1.51	1.48
2.0	1.48	1.52	1.55	1.56	1.57	1.57	1.56	1.54	1.53	1.51	1.48

TABLE 7A, MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING, N=2.8

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.47	1.47	1.45	1.43	1.40	1.37	1.34	1.31	1.28	1.25	1.22
1.1	1.52	1.52	1.51	1.49	1.47	1.44	1.41	1.38	1.35	1.31	1.28
1.2	1.56	1.56	1.56	1.54	1.52	1.50	1.47	1.44	1.40	1.37	1.34
1.3	1.58	1.59	1.59	1.58	1.56	1.54	1.51	1.48	1.45	1.42	1.39
1.4	1.59	1.61	1.61	1.61	1.59	1.57	1.55	1.52	1.49	1.46	1.43
1.5	1.60	1.62	1.63	1.63	1.61	1.60	1.57	1.55	1.52	1.49	1.46
1.6	1.59	1.62	1.63	1.64	1.63	1.61	1.59	1.57	1.54	1.51	1.48
1.7	1.59	1.62	1.63	1.64	1.64	1.62	1.61	1.59	1.56	1.53	1.50
1.8	1.57	1.61	1.63	1.64	1.64	1.63	1.61	1.60	1.57	1.55	1.52
1.9	1.56	1.59	1.62	1.63	1.63	1.63	1.62	1.60	1.58	1.56	1.53
2.0	1.54	1.58	1.61	1.62	1.63	1.62	1.62	1.60	1.58	1.56	1.54

TABLE 7B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING,N=2.8

POTTANT INDEX OF REFRACTION N	COVER INDEX OF REFRACTION-N 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.62	1.61	1.59	1.57	1.54	1.50	1.46	1.43	1.39	1.35	1.31
1.1	1.63	1.63	1.62	1.60	1.57	1.54	1.50	1.47	1.43	1.39	1.36
1.2	1.63	1.64	1.63	1.61	1.59	1.56	1.53	1.50	1.46	1.43	1.39
1.3	1.62	1.63	1.63	1.62	1.60	1.58	1.55	1.52	1.49	1.45	1.42
1.4	1.61	1.63	1.63	1.62	1.61	1.59	1.56	1.53	1.50	1.47	1.44
1.5	1.59	1.61	1.62	1.62	1.61	1.59	1.57	1.54	1.52	1.49	1.45
1.6	1.57	1.60	1.61	1.61	1.61	1.59	1.57	1.55	1.52	1.50	1.47
1.7	1.55	1.58	1.60	1.60	1.60	1.59	1.57	1.55	1.53	1.50	1.47
1.8	1.53	1.56	1.58	1.59	1.59	1.58	1.57	1.55	1.53	1.51	1.48
1.9	1.51	1.54	1.57	1.58	1.58	1.58	1.56	1.55	1.53	1.51	1.48
2.0	1.48	1.52	1.55	1.56	1.57	1.57	1.56	1.54	1.53	1.51	1.48

TABLE 8A. MODULE POWER OUTPUT (WATTS) AT AM1.5
AR COATING,N=3.0

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.41	1.40	1.39	1.37	1.34	1.32	1.29	1.26	1.23	1.20	1.17
1.1	1.46	1.46	1.45	1.43	1.41	1.39	1.36	1.33	1.30	1.27	1.24
1.2	1.50	1.51	1.50	1.49	1.47	1.44	1.42	1.39	1.36	1.33	1.30
1.3	1.53	1.54	1.54	1.53	1.51	1.49	1.47	1.44	1.41	1.38	1.35
1.4	1.55	1.57	1.57	1.56	1.55	1.53	1.51	1.48	1.45	1.42	1.39
1.5	1.56	1.58	1.59	1.59	1.58	1.56	1.54	1.51	1.49	1.46	1.43
1.6	1.56	1.59	1.60	1.60	1.60	1.58	1.56	1.54	1.52	1.49	1.46
1.7	1.56	1.59	1.61	1.61	1.61	1.60	1.58	1.56	1.54	1.51	1.48
1.8	1.55	1.59	1.61	1.62	1.62	1.61	1.59	1.58	1.55	1.53	1.50
1.9	1.54	1.58	1.60	1.62	1.62	1.61	1.60	1.59	1.56	1.54	1.52
2.0	1.53	1.57	1.60	1.61	1.62	1.61	1.60	1.59	1.57	1.55	1.53

TABLE 8B. MODULE POWER OUTPUT (WATTS) AT AM1.5
TEXTURIZED WITH AR COATING, N=3.0

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	1.60	1.59	1.57	1.55	1.52	1.48	1.45	1.41	1.37	1.34	1.30
1.1	1.61	1.61	1.60	1.58	1.55	1.52	1.49	1.45	1.42	1.38	1.35
1.2	1.62	1.62	1.62	1.60	1.58	1.55	1.52	1.49	1.45	1.42	1.38
1.3	1.61	1.63	1.62	1.61	1.59	1.57	1.54	1.51	1.48	1.45	1.41
1.4	1.60	1.62	1.62	1.62	1.60	1.58	1.56	1.53	1.50	1.47	1.43
1.5	1.59	1.61	1.62	1.62	1.61	1.59	1.57	1.54	1.51	1.48	1.45
1.6	1.57	1.60	1.61	1.61	1.60	1.59	1.57	1.55	1.52	1.49	1.46
1.7	1.55	1.58	1.60	1.60	1.60	1.59	1.57	1.55	1.53	1.50	1.47
1.8	1.53	1.56	1.58	1.59	1.59	1.58	1.57	1.55	1.53	1.50	1.48
1.9	1.51	1.54	1.57	1.58	1.58	1.58	1.56	1.55	1.53	1.51	1.48
2.0	1.48	1.52	1.55	1.56	1.57	1.57	1.56	1.54	1.53	1.51	1.48

TABLE 9. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
PLAIN SILICON
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08
1.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09
1.2	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09
1.3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10
1.4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10
1.5	0.11	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11
1.6	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
1.7	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
1.8	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
1.9	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
2.0	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

TABLE 10. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED CELL
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10
1.1	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
1.2	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11
1.3	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11
1.4	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.8	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 11A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=2.0
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.3	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.8	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.9	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
2.0	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

TABLE 11B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=2.0
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 12A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=2.2
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.3	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12
1.4	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12
1.5	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12
1.6	0.13	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
1.9	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 12B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=2.2
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 13A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=2.4
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11
1.1	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.2	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12
1.5	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12
1.6	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12
1.7	0.13	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13
1.8	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
1.9	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
2.0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

TABLE 13B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=2.4
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 14A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=2.6
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10
1.1	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11
1.2	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11
1.3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.5	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12
1.6	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12
1.7	0.13	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13
1.8	0.13	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13
1.9	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
2.0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

TABLE 14B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=2.6
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.1	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.2	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 15A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=2.8
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10
1.1	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
1.2	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11
1.3	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11
1.4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12
1.7	0.13	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12
1.8	0.13	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
1.9	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.13
2.0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

TABLE 15B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=2.8
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11
1.1	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11
1.2	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.3	0.13	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

TABLE 16A. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
AR COATING, N=3.0
ELECTRICAL POWER OUT/INCIDENT POWER

COVER
INDEX OF REFRACTION-N

POTTANT INDEX OF REFRACTION N	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10
1.1	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10
1.2	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
1.3	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11
1.4	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12
1.9	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
2.0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

TABLE 16B. MODULE POWER CONVERSION EFFICIENCY AT AM1.5
TEXTURIZED WITH AR COATING, N=3.0
ELECTRICAL POWER OUT/INCIDENT POWER

POTTANT INDEX OF REFRACTION N	COVER INDEX OF REFRACTION-N 1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
1.0	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11
1.1	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11
1.2	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
1.3	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1.4	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12
1.5	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.6	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.7	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.8	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
1.9	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12
2.0	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12

Tables 1-8 present electrical power output for AM1.5 with the integrated incident energy flux taken as .114 watts/cm^2 (see footnote page 82, Phase I Report). In the Phase I Report the cover index of refraction was about 1.5-1.6 with a pottant index of 1.4. Entering Table 1 at these indices yields a power output of 1.34 watts. This compares favorably with the output, 1.32 watts, of the superstrate design of Table 6-3, Phase I Report, (second entry from top). Similarly entering Table 2 at these indices results in a power output of 1.52 watts. Again, this compares favorably with the output, 1.47 watts, of the texturized superstrate design of Table 6-3 (ninth entry from top). The last comparisons can be made between data taken from Tables 4A and 4B and entries seventeen and eighteen of Table 6-3. These are 1.61 watts versus 1.57 watts for the superstrate design and 1.58 watts versus 1.52 watts for the texturized AR coated cell--both with an AR coating index of 2.2. The values calculated in the present study are all somewhat higher than the values previously calculated due to a slightly greater amount of energy transmitted to the cell surface in the absence of absorption by the pottant and front cover.

Several conclusions can be drawn from observation of the data in Tables 1-8. These are:

- The maximum power output occurs for an AR-coated cell with an index of refraction of 1.3-1.4 and 1.1-1.2 for the pottant and cover layers respectively.

- Compared to a bare cell surface, texturized cell surfaces result in greater power output.

- The results with texturized cells should be viewed with caution as a simplistic model was used.

These conclusions are in agreement with conclusions established in the earlier report.

The upper left hand entry in all tables corresponds to the unencapsulated cell case since both cover and pottant indices equal 1. The following points are highlighted since they aid in further discussion of Phase IIIA tabulated results:

- Mismatch of indices of adjacent layers results in higher reflectance.
- Higher reflectance at any interface reduces the energy available for conversion to electrical output.
- Air index is 1; silicon cell index is 3.73.
- Neglecting absorption in the cover and pottant layers increases the energy available for conversion to electrical output.

Starting with the upper left hand entry of the tables and increasing the cover index with the pottant index held constant, the cover and pottant reflectance increases with a reduction in the power output. In a somewhat similar fashion, the power output drops when holding the pottant index at a constant value greater than 1. However, in this case the reflectance at the pottant-cover interface decreases initially reaching a minimum as the cover and pottant indices approach one another. As a result the maximum power output shifts towards the diagonal elements of the table.

Section 4.0

CONCLUSIONS AND RECOMMENDATIONS

There are no conclusions and recommendations for this period.

Section 5.0

PLANNED ACTIVITIES

During the next period construction of the qualification modules will continue. Phase III work will begin.