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ABSTRACT

This report covers the period from 12 December 1977 to 30 October 1978 and is the third major report for JPL under the program "Conceptual Approach Study - 200 W/Kg Solar Array". The first major written report (No. 77SD4207, dated 31 August 1977) described the design tradeoffs that led to a conceptual design of a planar solar array with a specific power of 200 W/Kg. The second report (No. 77SD4243, dated 31 August 1977) described the conceptual design of a concentrator-array that met the requirements of an ion drive propulsion system for the Halley Comet Rendezvous Mission Study. This report documents those activities that were directed by JPL to support the earlier conceptual design work with proof of concept models on the one hand, and laboratory test and evaluation of alternate designs and materials that hold promise for further mass economies, on the other.

In support of this advanced solar blanket technology the following work has been accomplished:

1. Preparation of an 80-cell solar module for a 1000 cycle thermal test to be conducted at NASA Marshall Space Flight Center.
2. Fabrication of a 660-cell solar panel and performance evaluation of this article after a "0" g flight test.
3. Design improvement of the cell interconnect for further mass reduction.
4. Completion of UV exposure and thermal cycle tests for a variety of cell cover material and adhesives.
5. Preparation of a quantity of representative solar array test specimens for space flight on NASA's Long Duration Exposure Facility (LDEF).

Section 1.0, Introduction

The work in this phase of the program for an ultra-lightweight solar array was orientated to the development and proof testing of advanced technology used in solar blanket fabrication. Of the five principal elements of construction in a solar blanket, i.e., solar cells, cell covers and adhesives, cell interconnects, flexible substrate and power buses, this program concentrated on improvements that could be affected with cell covers and cell interconnects. Proof testing consisted of ultraviolet exposure and thermal cycling. Test articles were fabricated for laboratory testing and space flight on NASA's Long Duration Exposure Facility.

Section 2.0, Blanket Technology Development

Section 2.1, 80 Cell Module for Thermal Vacuum Testing

The first article to be tested under this phase of work was an 80-cell module that had been manufactured in Phase II of this program, see Figure 2-1. This module had already been flexed mechanically by repeated wrapping and unwrapping (15 cycles) onto a 25 cm diameter drum under a tensional stress of 29 N/m. The module was constructed of 50 micron thick Solarex cells, interconnected by silver-plated invar interconnects 50 micron thick. Weld bonding was used exclusively. The welded matrix of 20 series x4 parallel connected cells was bonded to 25 micron thick Kapton-H substrate with a 12-15 micron bond line of RTV-655. The entire assembly was overcoated with a 50 micron thick cover of RTV-655.

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Figure 2-1
80-Cell Modules in Flexure Test

The testing at GE in this phase of work emphasized thermal stressing of the module. The thermal conditions for a low earth orbit were simulated in a vacuum belljar, using thermal heaters to achieve the 60°C upper limit and LN₂ to reach the -110°C lower temperature of a temperature cycle that spanned 20 minutes. The module was suspended in the vertical plane with a weight on the lower edge of 4.45N, simulating the tension of a deployed array, see Figures 2-2 and 2-3. A rough vacuum of 25 micron was maintained throughout the test.

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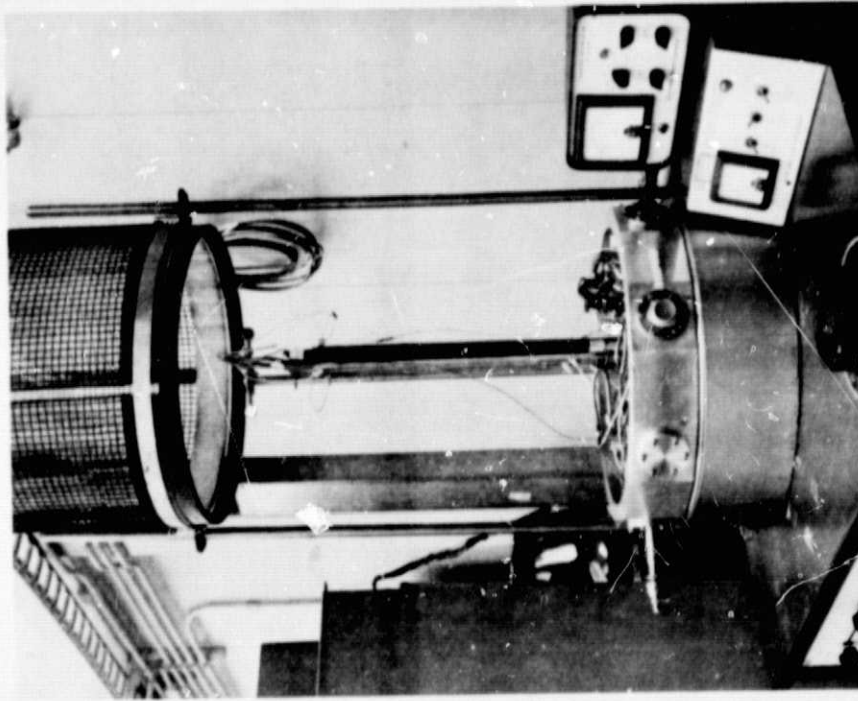


Figure 2-3
Vacuum Belljar
Test Station

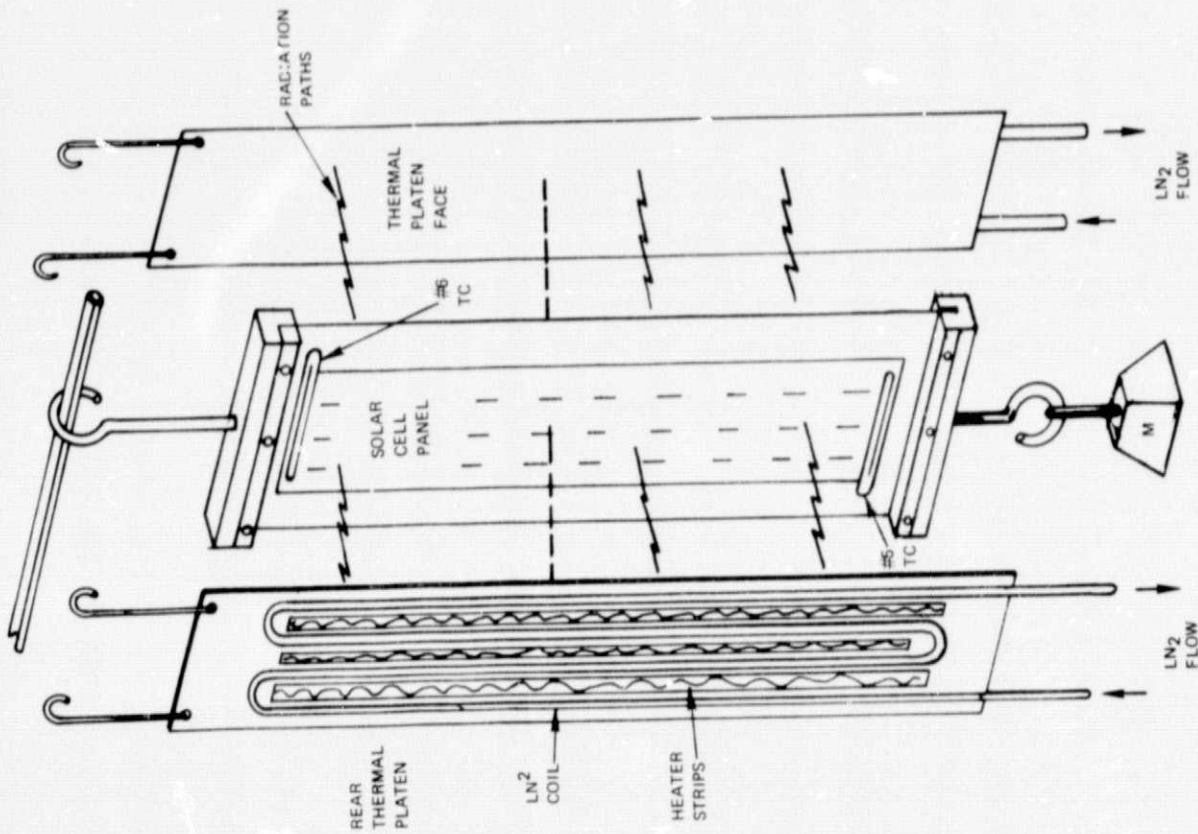


Figure 2-2
Thermal Vacuum Test Setup
Exploded View

The module was exposed to fifty complete cycles from -110°C to 60°C with approximately 1 minute soak at each end. The electrical characteristics Figure 2-4A & B were recorded before and after testing, using the Spectrolab large area pulsed solar simulator (LAPSS). The maximum power measured 4.66 watts after the test as compared to 4.68 watts before the test. The difference of 0.02 watts is well within the error band of repeatability for this measurement. A visual inspection revealed no cracked cells or opened interconnects.

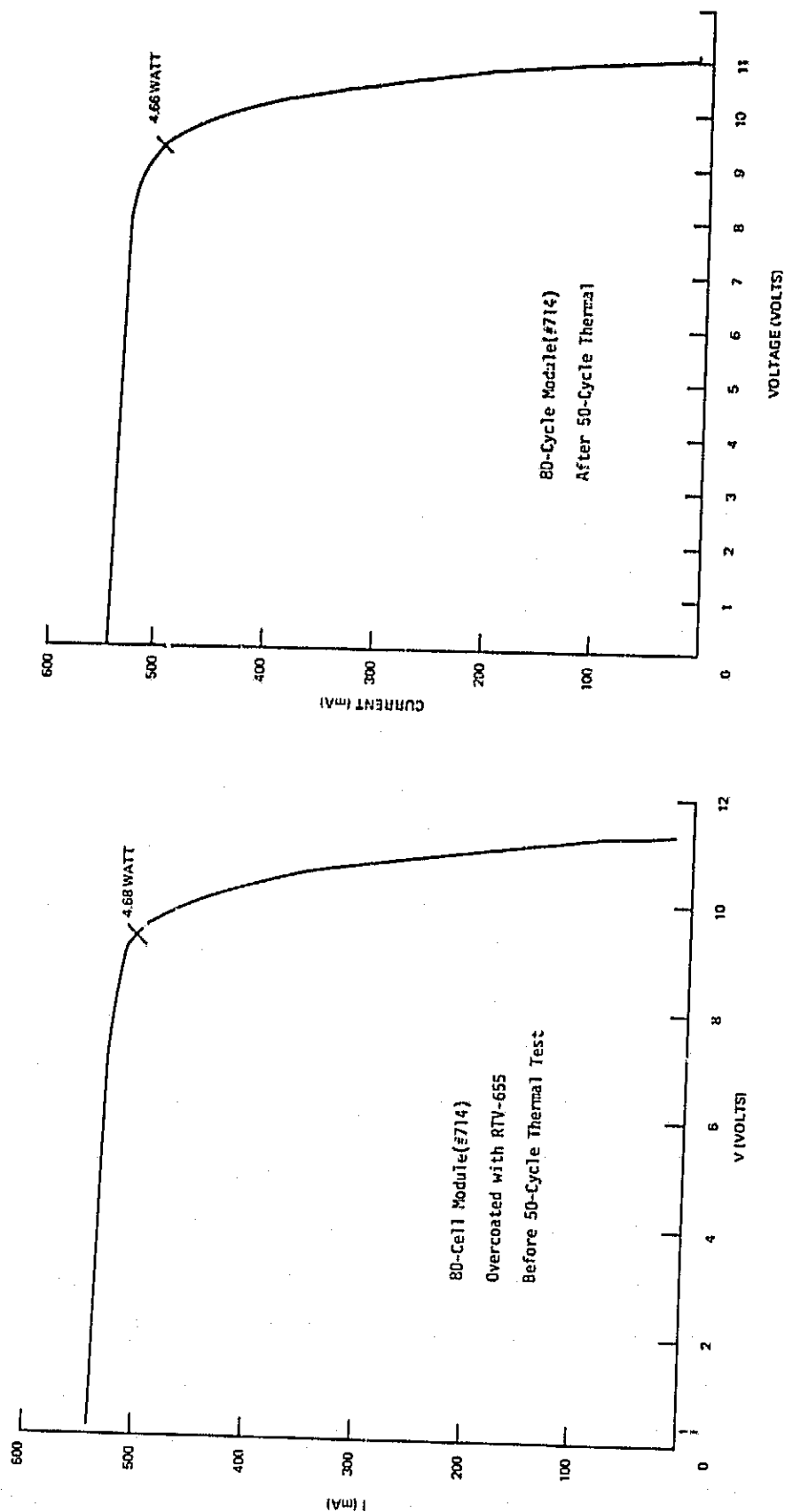


Figure 2-4A & B
I-V Curves Before and After Thermal Cycling

Section 2.2 660-Cell Solar Panel for KC-135 Flight Test

The second test article to be fabricated and tested was a 660-cell solar panel see Figure 2-5. The overall width and the placement of the indicated fold line were specified by the Solar Electric Propulsion (SEP) flight test array configuration fabricated by the Lockheed Missile & Space Company. The solar panel consisted of four electrically independent modules, known as Sections, see Figure 1-6. Sections A1 and A2, later designated as Module #419 and Module #563 respectively, consisted of 220 (55s x 4p) $2 \times 2 \text{ cm}^2$ solar cells manufactured by Solarex. Sections B1 and B2, designated as Module #150 and Module #79, consisted of 110 (55x x 2p) $2 \times 4 \text{ cm}^2$ cells made by Optical Coating Laboratory Inc.

All the cells were welded to Ag-plated interconnects and the welded assembly cement bonded to 1 mil Kapton -H. The entire assembly was then covered with a 2-3 mil coating of RTV-655.



Figure 2-5
Inspection of 660-Cell Panel

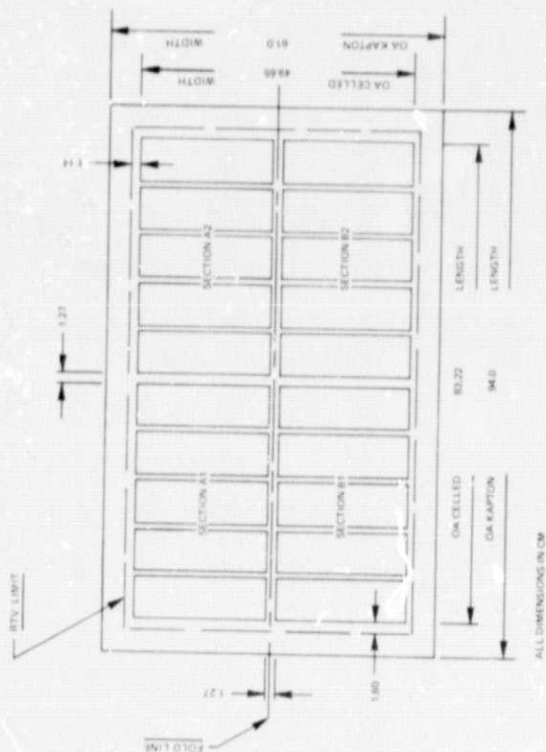


Figure 2-6
Layout of Flight Solar Panel

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All the cells in this panel are known as 2 mil cells. It may be noted, however, that the overall thickness of the Solarex cell is 3 mil, while the OCLI cell is only 2 mil thick. The OCLI cell top surface was texturized and AR coated, while the Solarex cell was essentially smooth with an AR coating as well. While over 1500 of the Solarex cells had been processed prior to this panel, this was the first opportunity to work with the OCLI cell. New fixtures had to be made for the welding process.

Each module section consisted of a single string of 55 cells in series. There, were 2 cells in parallel for the $2 \times 4 \text{ cm}^2$ cells and 4 in parallel in the case of the $2 \times 2 \text{ cm}^2$ cells. The electrical performance of these modules was recorded before and after the "0" g flight test, see Figure 1-7A, B, C, and D.

Representative I-V Curves, Before and After Flight Test

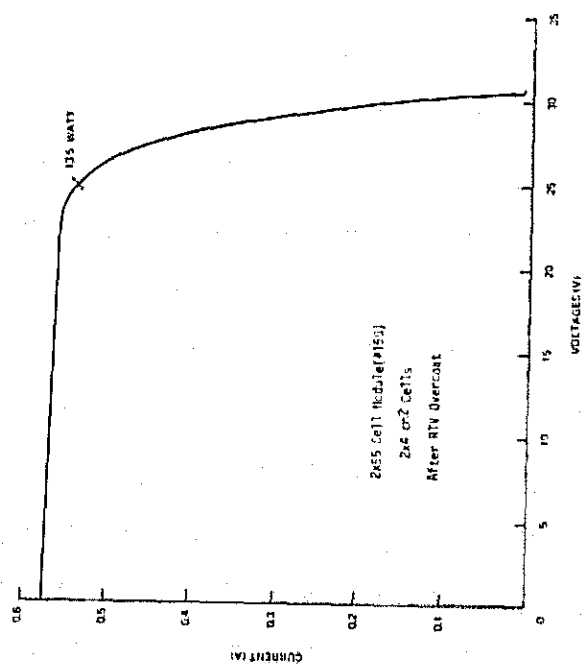
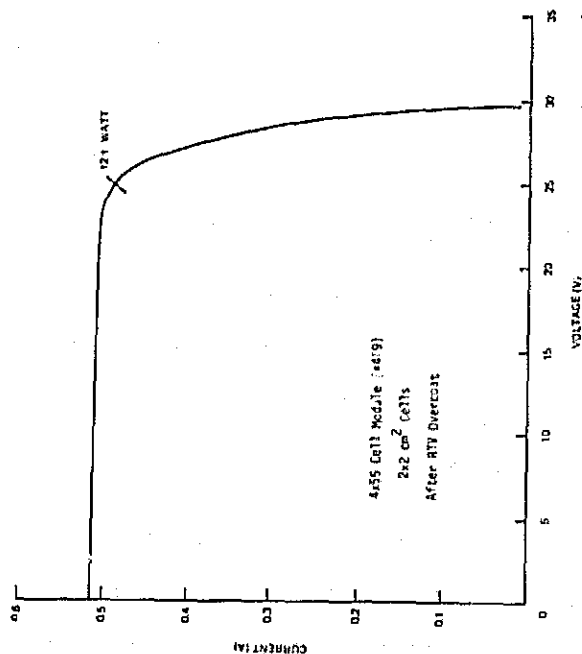


Figure 2-7C

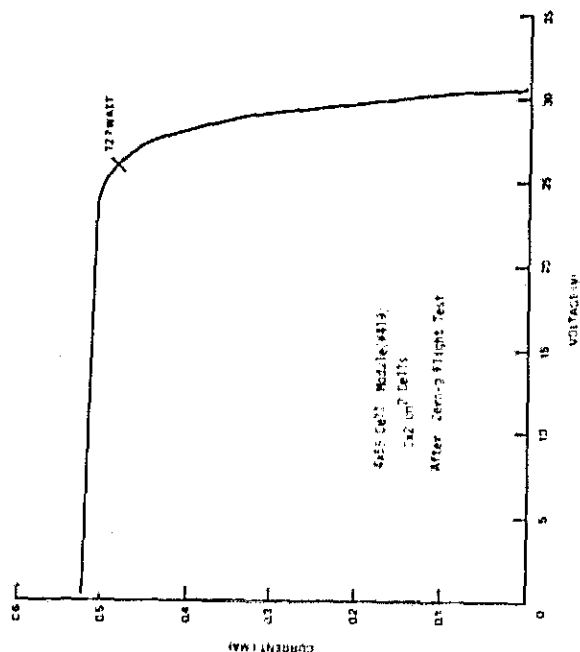


Figure 2-7B

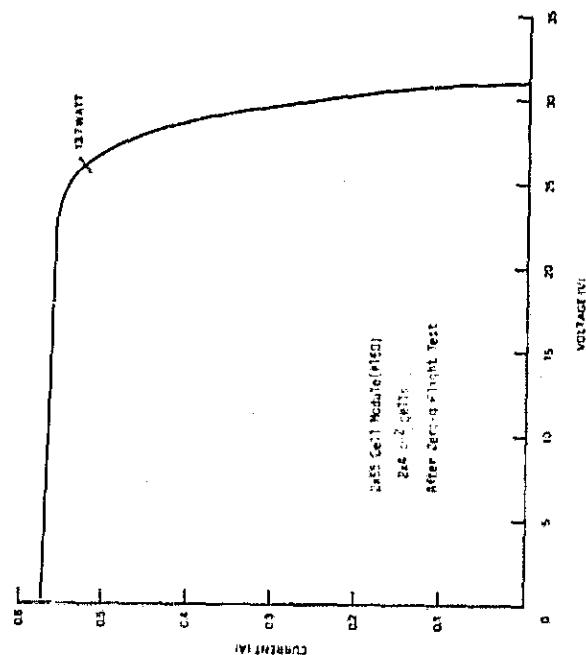


Figure 2-7D

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Section 2.3, Post Motem on KC135 Flight Test

The 660 cell panel was taped into a rectangular opening cut into a panel of Advanced SEP test configuration. The SEP configuration consisted of mass equivalent, simulated solar cells and an in-blanket, planar-through mirror system. The purpose of this test was to demonstrate the fold-out and fold-up capabilities of the flat-pack stowed Advanced SEP solar array in a "0" g environment. The array configuration, including the 660 cell panel, was deployed and retracted a total of 40 times.

When the solar panel left GE on 6 February 1978 there were no cracked $2 \times 2 \text{ cm}^2$ cells. On the other hand 9 of the $2 \times 4 \text{ cm}^2$ cells were cracked in Module #150 and 23 were cracked in Module #79. Upon return to GE in August it was observed that there were still no cracked $2 \times 2 \text{ cm}^2$ cells, whereas there were now 14 cracked cells in Module #150 and 28 cracked cells in Module #79.

The measured data, see Table 2-L on modules #419, #563 and #150 show essentially no change before and after flight. While the performance of Module #79 has been impaired by the presence of the 28 cracked cells, it is still a functioning unit. The successful deployment and retraction of this panel in this "0" g environment is rather noteworthy, since the flexible substrate solar array design was not designed for flat-pack stowage in mind. From the shock and mechanical stress point of view, this test was the roughest yet conducted.

Table 2-1
Electrical Performance-660 Cell Panel Before & After Flight Test

MODULE	Electrical Parameters				Observations
	I _{SC}	V _{OC}	P _{MP}		
419 (220-2x2 cm ² CELLS)	BEFORE	29.8	12.1		NO CRACKED CELLS
	AFTER	30.7	12.7		
563 (220-2x2 cm ² CELLS)	BEFORE	30.2	12.5		NO CRACKED CELLS
	AFTER	30.8	13.2		
150 (110-2x4 cm ² CELLS)	BEFORE	30.8	13.5		9 CRACKED CELLS
	AFTER	31.3	13.7		
79 (110-2x4 cm ² CELLS)	BEFORE	31.2	13.3		23 CRACKED CELLS
	AFTER	31.6	12.7		

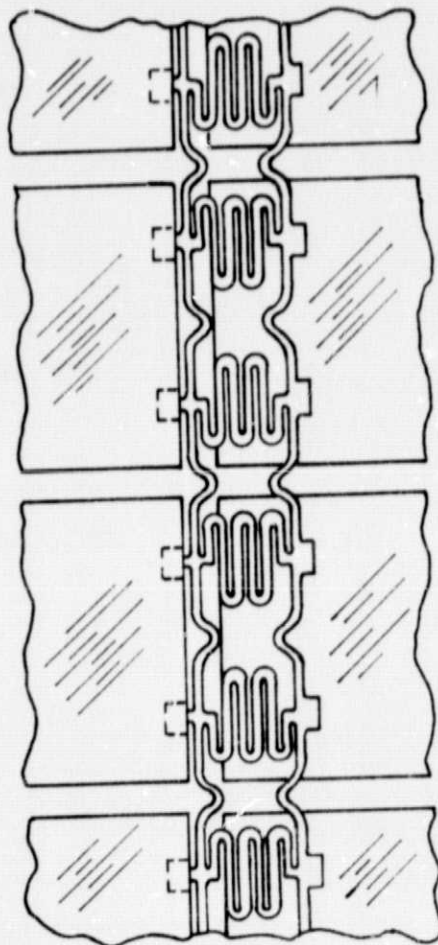
Section 2.4, Solar Cell Interconnect Improvement

The objective here was to reduce the mass of the cell interconnect while not adversely affecting the functional properties of the interconnect. The cell interconnect is used to bond together, both physically and electrically, small area solar cells into large area solar power arrays. Approximately $160,000 \text{ } 2 \times 2 \text{ cm}^2$, 12% efficient, solar cells are required to create a 10 KW solar power supply. Next to the cell itself, the cell interconnect is the next largest contributor to the weight of the solar array, see Table 2-2. While the primary function of the interconnect is to conduct electricity with a minimum I^2R loss (a 2% criterion was adopted), its physical properties must provide in-plane stiffness and yet allow for flexure because of thermally induced stress.

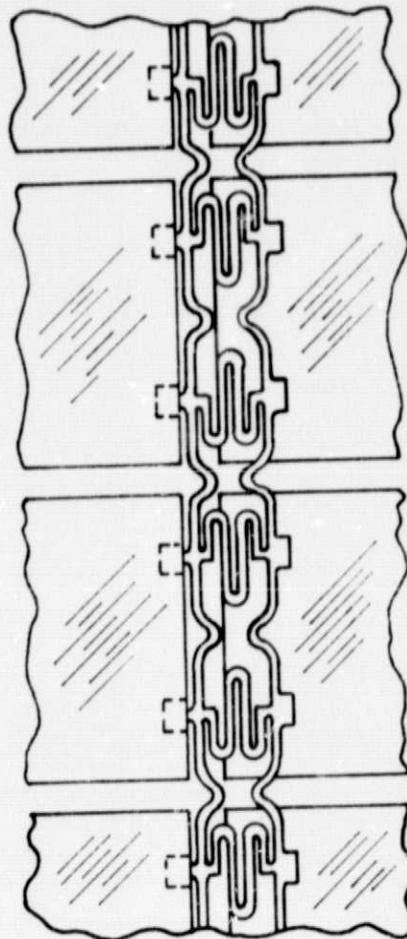
Table 2-2
Mass Breakdown-Flexible Substrate
Solar Array

Component	Mass
2 x 2 cm ² Solar Cells, 50 micron thick	78 mg/each
Baseline cell interconnect, 50 micron thick	31.3 mg/cell
Kapton-H Substrate, 25 micron thick	14.4 mg/cell
RTV-655 silicone, 65 micron total thickness	27.2 mg/cell
Total mass per cell	150.9 mg

The baseline interconnect at the beginning of this task was 25 micron thick Invar, plated on both sides with 12 micron of silver for conductivity and weldability reasons. A serpentine pattern, see Figure 2-7, had been adopted to provide for flexure in the series-connection direction. A 180 degree loop was configured into the design to provide for a limited amount of flexure in the parallel-connection direction. Since this design had performed satisfactory through all of the physical and thermal tests given it, there appeared to be little reason for a radical departure from this basic design. While some mass reduction could be affected by thinning the Invar, it appeared more progress could be made using the silver thickness and interconnect surface area as the principal variables.



a) OLD BASELINE INTERCONNECT, 2-1/2 CYCLE SERPENTINE



b) MODIFIED CELL INTERCONNECT, 1-1/2 CYCLE SERPENTINE

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Figure 2-8
The Serpentine Interconnect

The interconnect surface area was reduced by removing one cycle of the serpentine, while keeping the strand thickness (0.6 mm) the same. The length of the interconnect in the series direction was reduced accordingly from 9.6 mm to 7.5 mm. Both designs have a surface area that is 21% of the total included area.

An experiment was conducted, using the new design, whereby the silver thickness was varied and the total mass measured. These measured values were used to project estimates based on 25 micron thick Invar. The most attractive projection, see Column A in Table 2-3, assumed a total interconnect thickness of 38.1 microns which provided a silver thickness of 6.35 micron per side, or 1/2 that of the earlier baseline design.

Table 2-3
Interconnect Mass vs Thickness
1 1/2 Cycle Serpentine Design

Design Parameter	Unplotted Invar	Measured Values Silver-Plated Invar #3			Project Estimates Assuming 254 Micron Thick Invar		
		#1	#2	#3	A	B	C
Total Thickness (micron)	29.2	76.7	72.1	63.5	38.1	50.8	76.2
Total Mass (mg/cell)	10.2	36.2	34.4	27.8	15.9	22.6	36.7
Mass of Silver (mg/cell)	----	26.0	24.1	17.6	6.96	13.7	27.8
Silver Thickness (micron)	----	23.9	21.3	17.1	6.35	12.5	25.4

There were several concerns regarding this thickness of silver, i.e., weldability, bond strength and ohmic resistance. A second experiment showed that weldability and bond strength actually improved as the silver thickness was decreased, see Table 2-4. The low weld bond strength for the 76 micron interconnect may be explained by the fact that the weld power had to be increased by 60% to get a sound weld. This, it is felt, is deleterious to the weld bond strength. Out of 18 samples tested to destruction, 4 cells broke before the weld bond did. The silver pad on the cell pulled off in 12 cases and the weld bond parted in the remaining 2 samples. From this test, it would appear that the 8.9 micron silver (38 micron total thickness) results in best weld bond. The ohmic resistance of 45.5 milliohms per cell will result in a voltage drop of 8.0 mV, assuming a cell current at maximum power of approximately 175 mA (recently reported by Spectrolab). This value is less than 1.8% of the expected maximum power voltage of 450 mV.

Table 2-4
Weld Bond Strength and Ohmic Resistance
vs. Silver Thickness

Parameter	Unplated Invar	Silver-Plated Invar	
Total Thickness (micron)	29.2	38.1	50.8
Ultimate Tensile of Weld Bond (gram force)	---	390.0	336.0
Ohmic Resistance (10^{-3} ohm)	2900.0	45.5	18.9
			7.5
			217.0
			76.2

Since a voltage drop of 2% was the criterion adopted early in the program, it would appear that as little as 4.4 micron of silver on silver on both sides of 29.2 micron thick interconnect will meet both the voltage drop criterion and yield a weld bond strength which exceed the adhesion bond strength of the silver metallization on the cell itself. If this were implemented, an interconnect mass of 15 gram per cell is predicted for a mass reduction of 57% over the 2 1/2 cycle serpentine baseline interconnect.

One final evaluation was made on the new interconnect design. One-cell wide test configurations were made up consisting of 25 micron Kapton-H and the 1-1/2 cycle interconnect bonded to the Kapton with RTV-665 silicone. This construction is representative of that used in the sample production to this date. Nine samples of the 1 1/2 cycle interconnect and four samples of the old 2 1/2 cycle design were tested for deformation loads in tension. A maximum load of 622 gram was sustained by the 1 1/2 cycle design, while the 2 1/2 cycle design deformed at 522 gram.

From the data cited above, it may be concluded that the 1 1/2 cycle serpentine design, etched in 1.5 mil thick silver-plated Invar, produces a cell interconnect that meets or exceeds the performance of the old design and the performance criteria established for it, while at the same time reducing the mass significantly. It is recommended that this new interconnect design be adopted as the baseline design for future fabrication.

Photolithography, acid-etch techniques have been developed for fabrication of production quantities (see Figure 2-9).

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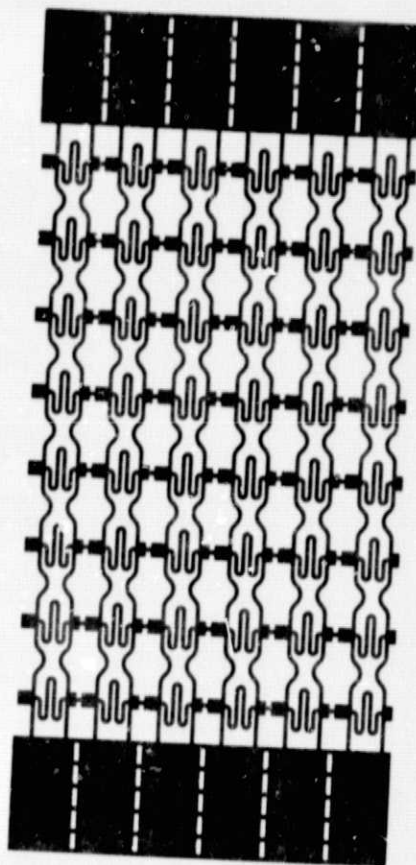


Figure 2-9
Etch Master for 1 1/2 Cycle Serpentine
Cell Interconnect

Section 2.5 Solar Cell Cover Development

The search for a superior cell covering material was a key part of this phase of work. The screening of candidate materials was accomplished by two principal laboratory tests, i.e., continuous exposure to 1 EUVS (one equivalent ultraviolet sun) in a vacuum environment for at least 500 hours at a temperature of 85°C, and thermal cycling from -23°C to 65°C also in a vacuum enclosure. The initial list of five candidate materials was expanded to a total of eleven covers and adhesives. The solar radiation facility is shown in Figure 2-10. The thermal cycle equipment was shown in Figure 2-3 above.

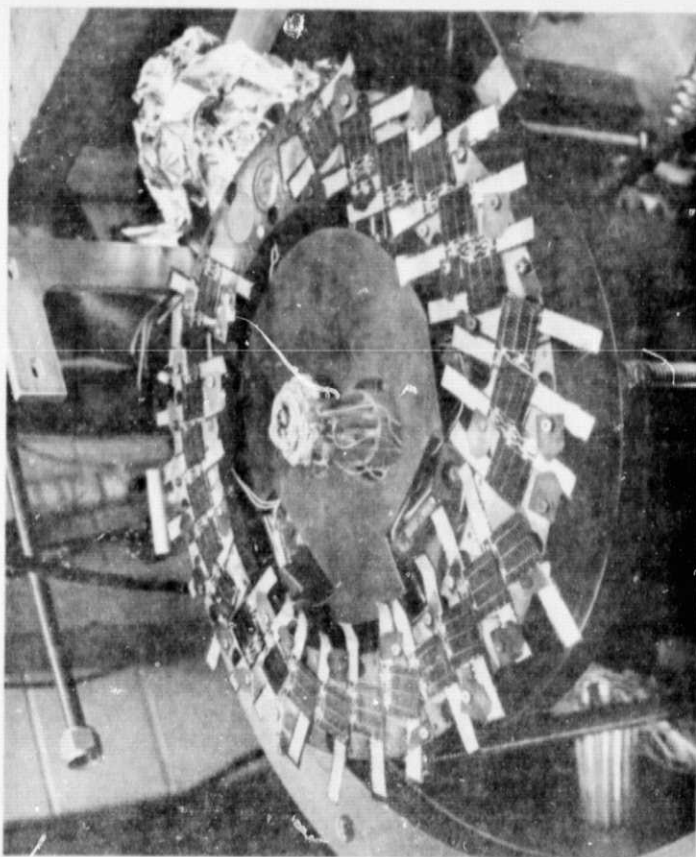


Figure 2-10
UV Exposure Facility with Test Specimens

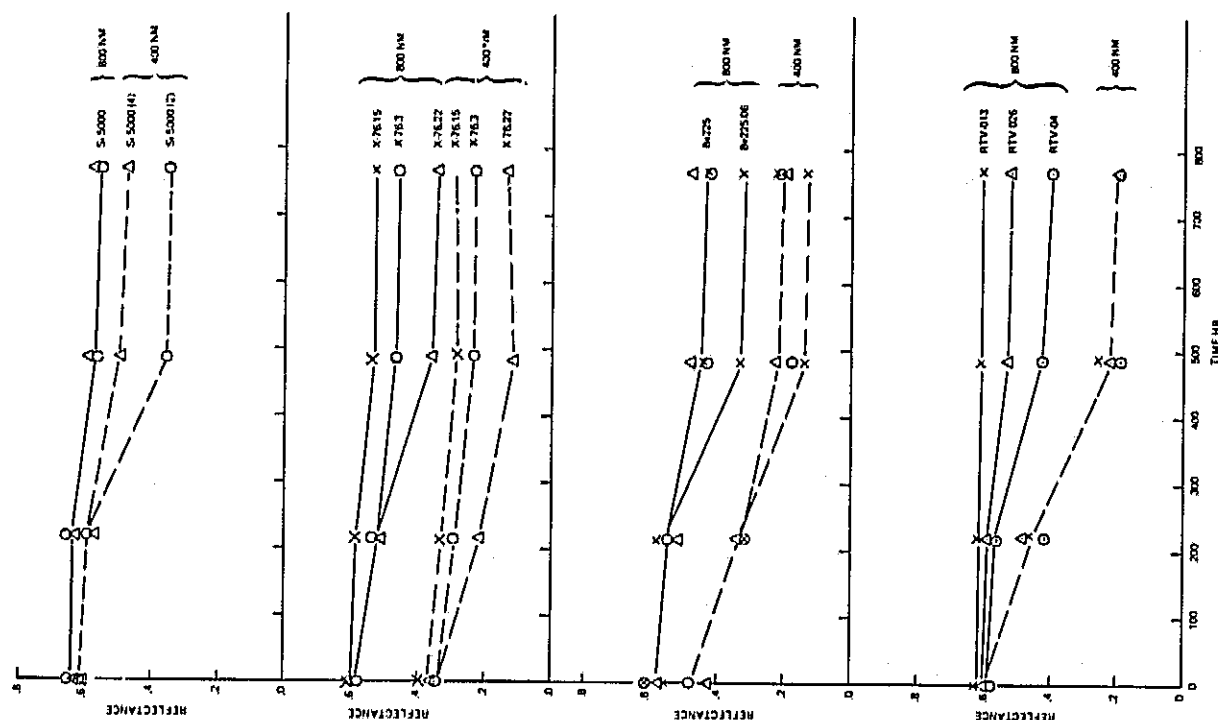
The materials selected for test were chosen on the basis of prior experience as optically transparent thin films, manufacturer's supportive data or the preliminary screening accomplished during earlier phases of this program. The success with the RTV class of silicones and the known radiation resistance and excellent physical properties of the polyimides over a wide range of temperatures led to the selection of these two material groups as principal source of candidate materials. The original list of five materials was expanded when the opportunity to place an experiment on LDEF (Long Duration Exposure Facility) presented itself, see Table 2-5.

Table 2-5 Cell Cover Materials (Expanded List)

Material	Classification	Primary Use
* RTV 655	RTV Silicone	Cell Cover/Adhesive
DC93500	RTV Silicone	Cell Cover/Adhesive
* Silicon 5000	Hard Coat Silicone	Cell Cover
Silicone 908 M ₂	Hard Coat Silicone	Cell Cover
R-43117	Silicone Conformal Coating	Cell Cover/Adhesive
* BE-225	Polyimide-Silicone Copolymer	Cell Cover/Adhesive
* BE-120/120A	Polyimide-Silicone Copolymer	Cell Cover/Adhesive
* X-76	Polyimide	Cell Cover
K-14	Acrylic Emulsion	Cell Cover/Adhesive
N-580	Acrylic Emulsion	Cell Cover/Adhesive
R-658	Acrylic Emulsion	Cell Cover/Adhesive
FEP Teflon	Fluorocarbon	Cell Cover
Ceria Glass	Inorganic	Cell Cover

Note: Only the * items were on the original list.

Two UV tests were conducted during this period. In the first test four materials, Silicone 5000, X-76, BE 225 and RTV electrons-655, were exposed to 1EUVS and 15 keV at a dose level of $3.8 (10)^{10}$ electrons/cm²-sec for 766 hours while the specimen temperature was maintained at 125°C. The coatings were applied directly to aluminum substrates as per Space Division Materials and Processing Lab procedure. The optical transmittance was determined by spectral reflectance measurement using an in-situ integrating sphere. The reflectance data from this test is shown in Figure 2-11. Since transmission is zero, the complement of this data is absorbance.



Optical Reflectance vs Sun Hours Exposure

Figure 2-11

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When the specimens were removed from the vacuum enclosure at the end of the test, all were observed to be heavily darkened by the combined UV, electron and temperature stress. Subsequent analysis and discussion with material specialists resulted in the following conclusions. Since the aluminum substrate has an average reflectance in the visible and near UV of approximately 88%, the specimen coatings were actually exposed to 1440 hours of 1EUVS illuminance. Secondly, the high steady state temperature of 125°C is viewed to be more detrimental than the UV illuminance or the electron fluence of $(10)^{16}$ electrons/cm². Two general observations may be drawn from these plots. Almost all the degradation on these films occurs within 480 hours of exposure and the degradation at 400 nm is substantially worse than at 800 nm. The reflectance data from Figure 2-11 is shown in tabular form in Table 2-6. This measured reflectance is the sum of the vacuum-film interface and the film-aluminum interface. The reflectance at the aluminum interface is assumed to remain unchanged throughout the test.

Table 2-6
Total Reflectance vs Wavelength and Exposure Time

Material	305 nm			400 nm			800 nm		
	0 hrs	480 hrs	766 hrs	0 hrs	480 hrs	766hrs	0 hrs	480 hrs	766 hrs
Silicone 5000	0.58	0.34	0.33	0.61	0.36	0.36	0.65	0.56	0.55
(% Change from 0 hrs)	----	41	43	----	41	41	---	14	15
x-76	0.44	0.21	0.20	0.33	0.24	0.24	0.58	0.47	0.46
(% Change from 0 hrs)	----	52	54	----	27	27	----	19	21
BE-225	0.44	0.28	0.25	0.47	0.18	0.21	0.60	0.43	0.42
(% Change from 0 hrs)	----	36	43	----	62	55	----	28	30
RTV-655	0.56	0.24	0.23	0.62	0.19	0.20	0.59	0.43	0.40
(% Change from 0 hrs)	----	57	59	----	69	68	----	27	32

In view of the disappointing results of the above UV exposure test, a second UV exposure test was conducted specifically as a screening step for the cover materials and adhesives to be used on experiment for NASA's Long Duration Environmental Facility. This time the covers and adhesives were applied to the 50 micron cells themselves. The environmental temperature was held at 85°C during the test. The UV intensity and electron dosage remained at 1 EUV $\bar{s}$ and 3.8 (10¹⁰) kev electrons/cm² sec as before. Twenty-eight covered solar cells were irradiated for 500 hours continuously. The results of this test are shown in Figure 2-12 as a bar chart of change in short circuit current, both after covering and after exposure.

Examination of this data leads to the following conclusions:

1. Ceria glass provides an effective UV screen for nearly all of the cement bond materials. The acrylic K-14 comes in a poor 4th out of the five glass-covered specimens. The silicone DC-93500, on the other hand, is ranked No. 1, when covered by ceria glass.
2. Those specimens covered with 2 mil FEP Teflon cemented to the cells did not fare well at all, since the near-UV part of the electromagnetic spectrum is passed readily by this material and attack the adhesive. Again K-14 comes out in the bottom rank of these specimens. The DC-93500 silicone suffers the minimum degradation of this group.
3. In the group of specimens that had neither glass or FEP Teflon covers; i.e., where the polymer coatings were cast in place, the soft silicone (DC-93500, RTV-655 and R-43117) performed better than the co-polymers (BE120, BE120A and BE225), the polyimide (X-76) or the hard coat silicones (Si5000 and 908M₂). This data would support the contention already established by other sources that the soft silicones and the R-658 acrylic are the most promising as unprotected cover materials.

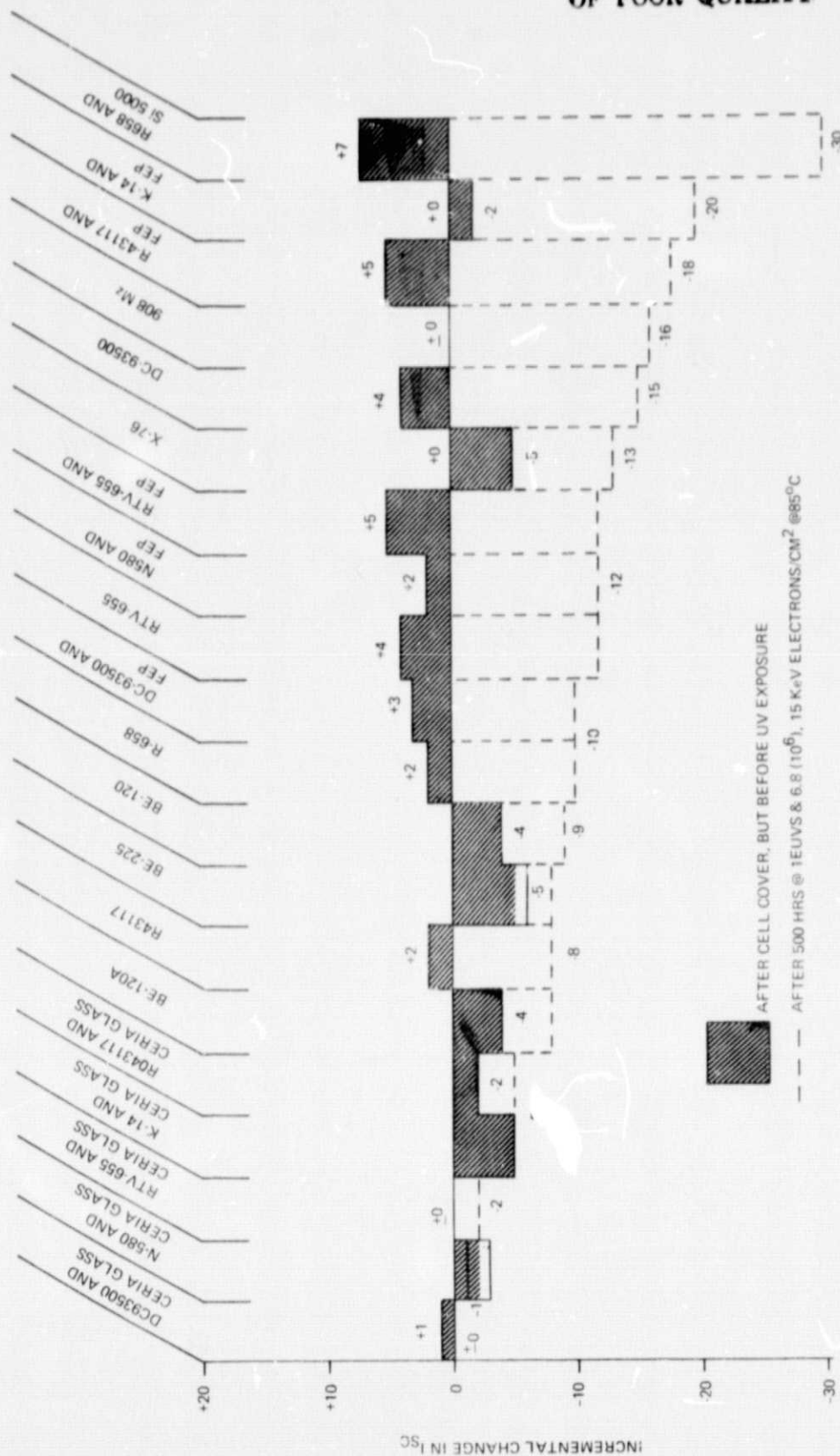


Figure 2-12
Changes in Short-Circuit Current After UV Exposure

In an attempt to get a better understanding of what was behind the darkening of the cast silicone films as compared to the same materials covered with ceria glass, optical transmittance spectra of these materials was taken using a Cary 14 spectrophotometer. Both vacuum processing and ambient processing procedures were used. No difference in optical properties could be detected as a consequence of vacuum processing, however. The reduced data from those spectra is shown in Table 2-7. The ceria doped glass with its anti-reflection, UV blocking filter is an effective shield for the ultraviolet. This is why minimal degradation in short circuit current is observed when this cover is used. Both FEP Teflon and the di-methyl silicones are to be preferred over the methyl-phenyl type of silicone because of the shorter UV cutoff with the latter material. The ideal cell cover would have zero absorptance down into the UV past the effective absorption edge of the silicon solar cell. In lieu of that, the next best situation is to block the UV so that it cannot attack the cover material.

Table 2-7
Optical Transmittance of Selected Cell Covers

Material	Thickness (Micron)	Transmittance @ 500 nm	Wavelength (nm)		Comments
			$\tau = 0.5$	$\tau = 0$	
PPE Ceria Glass	109	0.96	350	342	Effective UV Block Filter
FEP-Teflon Type A	51	0.97	200	195	Good UV Transmittance
FEP-Teflon Type C	51	0.93	208	195	Good UV Transmittance
RTV-655	100	0.93	274	272	Methyl-Phenyl Type
RTV-567	343	0.78	281	278	Methyl-Phenyl Type
RTV-615	152	0.94	216	208	Di-methyl Type
RTV-670	76	0.95	216	207	Di-methyl Type

Section 2.6

Two Experiments for LDEF Flight

Two experiments were fabricated for space flight aboard NASA's Long Duration Exposure Facility (LDEF), see Table 2-8. One experiment is called the Passive Tray, as there is no electrical connection to the on-board data system. The second experiment is known as the Active Tray, since each test specimen is wired into the data system for periodic monitoring and recording of the electrical output during space flight.

Passive Tray

Table 2-8
Two Experiments for LDEF

- 30 individual 50 micron thick, $2 \times 2 \text{ cm}^2$ solar cells with weld bonded, silver-plated interconnects.
- Cells are cement bonded to 25 micron thick Kapton-H with same adhesive as that used over the face of the cell.
- Kapton-H bonded to 1.6 mm thick aluminum, $23.6 \text{ cm} \times 41.4 \text{ cm}$ in area.
- Cell cover materials - see Table 2-9.

Active Tray

- 5 test specimens:
 - One 9-cell ($3\text{s} \times 3\text{p}$) module of 50 micron, $2 \times 2 \text{ cm}^2$ cells
 - Three single cell specimen of 50 micron, $2 \times 2 \text{ cm}^2$ cells
 - One single cell specimen using a 50 micron, $2 \times 4 \text{ cm}^2$ cell
- Cells bonded to Kapton-H as above.
- Kapton-H bonded to individual thick aluminum mounting blocks.
- Cell interconnect terminated in 1 ohm resistors
- Cell cover materials - see Table 2-10.

LDEF Experiments

The purpose of these two experiments, see Figures 2-13 and 14, is to expose a variety of cell cover materials and adhesives to vacuum ultraviolet illumination and high energy particles found in a low earth orbit. The schedules of cover materials and adhesives for these two experiments are given in Tables 2-9 and 2-10. The sources for these materials are as follows:

RTV Silicones and silicone 5000

GE Co., Waterford, NY 12188

DC-93500 and R-4-3117

Dow Corning, Midland, MI 48640

908M₂ Glass Resin

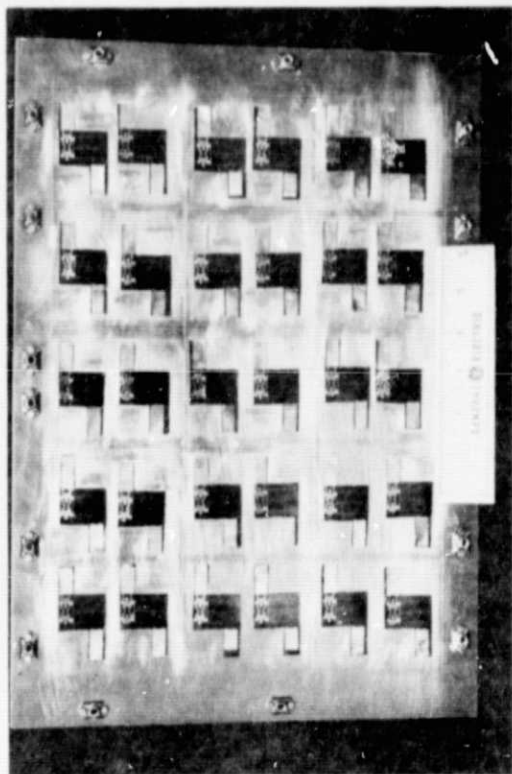
Owens-Illinois, Toledo, OH 43666

BE225HUP & BE-120

Bergston and Associates, Summit, NY 07901

X-76

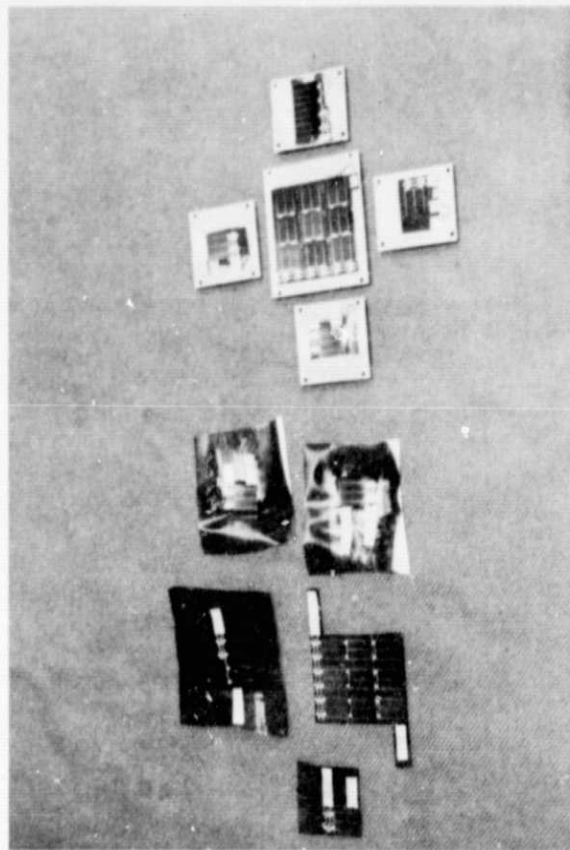
GE Co., Schenectady, NY 12301



LDEF Passive Tray

Figure 2-13

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LDEF Active Tray

Figure 2-14

Passive Experiment

The 30 cells in the Passive Tray were paired off into 15 specimens with a variety of cell covers or encapsulants overcoating these cells. The schedule of these materials, shown in Table 2-9, reflects the experience gained in the laboratory. The K-14 and N-580 acrylics have been dropped, as an example, based on adverse test results and difficulties in processing thin films from these emulsions. All of the materials were processed under laboratory conditions using the manufacture's instructions for each material. The electrical properties (I-V curve) for each cell was recorded after weld bonding and after overcoating.

Table 2-9
Schedule of Materials for the LDEF Passive Tray

Specimen	Adhesive/Encapsulant		Adhesive/Encapsulant Thickness(micron)		Cover Material (where appropriate)	
	Cell A	Cell B	Cell A	Cell B	Cell A	Cell B
1	RTV-655	RTV-615	25-30	50-75	NA	NA
2	X-76	X-76	25-50	50-75	NA	NA
3	RTV-655	RTV-615	12	12	100 Micron	100 Micron
4	RTV-655	RTV-615	12	12	Ceria glass	Ceria glass
5	5000 Silicone	5000 Silicone	12	12	50 Micron	50 Micron
6	908M ₂ Silicone	908 M ₂ Silicone	12	12	FEP Teflon	FEP Teflon
7	DC-93500	DC-93500	25-50	50-75	NA	NA
8	DC-93550	R-43117	12	12	NA	NA
9	DC-93500	DC-93550	12	12	100 Micron	50 micron
10	BE-225	BE-225	25-50	50-75	Ceria glass	FEP Teflon
11	R-43117	R-43117	25-50	50-75	50 Micron	50 Micron
12	R-43117	R-43117	12	12	FEP Teflon	FEP Teflon
13	RTV-619	RTV-619	12	12	NA	NA
14	RTV-615	RTV=615	12	12	50 Micron	50 Micron
15	RTV-619	RTV629	12	12	FEP Teflon	FEP Teflon
					100 Micron	100 Micron
					Ceria glass	Ceria glass

Active Experiment

The test specimens for the active tray were processed in a manner similar to that noted above for the passive tray, except that the aluminum substrates upon which the cells specimens were bonded was much thicker. Each specimen was electrically terminated at binding posts and shunted by a 1 ohm resistor. The I-V curve was taken for each test specimen after welding and after overcoating. The schedule of cell covers and adhesives vs well as the recorded electrical properties is given in

Table 2-10.

Table 2-10
Specimens for LDEF Active Tray

Specimen	Description	Cell Cover/Adhesive	P (mW)	I _{SC} (mA)	V _{OC} (mV)
D1	9 cells (3s x 3p) 2x2 cm ² each	50 Micron RTV-655	525	407	1670,
B60	One 2x2 cm ² cell	25-50 Micron BE-120	52.6	126	534
B-13	One 2x2 cm ² cell	25-50 Micron R-43117	53.4	140	515
B-12	One 2x2 cm ² cell	100 Micron Ceria Glass bonded with DC-93500	49.3	128	501
B-61	One 2x4 cm ² cell	50 Micron FEP Teflon bonded with DC-93500	110	284	522

3.0 Conclusions and Recommendations

The mechanical soundness of the ultra-lightweight, flexible substrate solar array incorporating the new 50 micron thick silicon solar cell has been reinforced by the work accomplished in this phase of the program. Every thermal stress-cycle test was passed with no difficulty. The zero-g deployment and retraction tests showed that the solar blanket could take extreme shock with minimal degradation. The specific power at the module level was increased from 300 W/Kg reached in 1977 to approximately 370 W/Kg using the 1 1/2 cycle cell interconnect developed this year and the improved Solarex cell made available this year.

The salient weak point in the present design is the cell cover material. Prior to this year's work, RTV-655 was the baseline cover material. The ease with which this silicone may be processed over large areas, its beginning-of-life optical clarity, its favorable index of refraction (n_{SC} increases after it is applied) and its excellent low temperature properties are all desirable. This year's UV tests were disappointing. Subsequent analysis of the data shows that RTV-615, or any other di-methyl group silicone, will have better resistance to darkening by UV absorption. Further work is needed to find a better cell cover with the same desirable features of a cast-in-place covering.