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FINAL REPORT

DESIGN, FABRICATION, TEST, QUALIFICATION AND PRICE ANALYSIS OF "THIRD GENERATION" DESIGN SOLAR CELL MODULES

PART 1: INTERMEDIATE LOAD MODULE

Technical Report 81-7
September 1981

(NASA-CR-169085) DESIGN, FABRICATION, TEST, QUALIFICATION AND PRICE ANALYSIS OF THIRD GENERATION DESIGN SOLAR CELL MODULES. PART 1: INTERMEDIATE LOAD MODULE Final Report (ARCO Solar, Inc., Chatsworth, Calif.) 29 p G3/44

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ARCO Solar, Inc.
Chatsworth, California 91311

Prepared Under Contract No. 955402

for

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91103

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PART 1: INTERMEDIATE LOAD MODULE

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Approved by

W. R. Bottenberg
Director of Development

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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, under NASA Contract.

ABSTRACT

This final design report presents an updated program plan for the design, fabrication, test and qualification of the "third generation" design intermediate load solar cell module. This updated program plan and narrative reflects the design and development work done and progress made in establishing a viable design for these modules. Design alterations from the preproduction plan are discussed based on experience gained during the preproduction phase of the program.

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1.0 Introduction

Part I of this report contains the updated program plan and narrative, engineering and manufacturing documentation, and an update documentation of design alterations made during the preproduction phase of the contract. This part of the contract covers the development of a design of an intermediate load center type module which is qualified under the specification, "BLOCK IV Solar Cell Module Design and Test Specification for Intermediate Load Center Applications," dated November 1, 1978.[1]

Part II of this report, to be issued later, covers the same material mentioned above for the Residential Module.

[1] DOE/JPL Document Number DOE/JPL-1012-78/10

2.0 Updated Program Plan and Narrative

The original program plan proposed on July 18, 1979 including task description and schedule is given in Appendix I. The preliminary design review of August 14, 1979 and the second review of September 3, 1980 have covered the design details and rationale for the preproduction intermediate load module design. In this section an updated program plan is presented which reviews the task descriptions, discusses deviations from the plan, and discusses progress and achievements in the program. This plan will focus primarily on the program after September 3, 1980.

2.1 Task Descriptions - Intermediate Load Module

2.1.1 Module Design [2.4.1][1]

The final design for the solar cells and module substantially met the objectives set out in the proposal. The key elements of the design in this proposal are shown in Table 2.1 by category.

In an interim design review on 9/3/80 the design package which supported the preproduction design outlined in Table 2.2 was considered and mutually agreed to by AS, Inc. and JPL. The delay in carrying out the original program was caused by the introduction of design improvements by AS, Inc. over the proposed design. These improvements are outlined in Tables 2.2 and 2.3.

This preproduction design achieved the basic design goals set out in the BLOCK IV specification. Several modifications were made during the preproduction phase, which will be discussed in Section 3. These changes have assured the integrity of the design and allowed it to meet the requirements of the qualification part of the program.

Table 2.5 contains data which compares proposed and nominal as-built performance of the modules.

Improvements in the design over previous generations of designs (represented for instance by the BLOCK III type module ASI 16-1200) include:

1. Larger cells, 102.8 mm vs. 76.2 mm. These larger cells reduce the cost of manufacture by making more efficient use of crystal growers and requiring fewer parts to handle per watt.

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[1]Figures in brackets refer to paragraph numbers in the proposal statement of work.

TABLE 2.1

Key Elements of Intermediate Load Module Design As Proposed

CELLS

- 100 mm Czochralski single-crystal silicon wafers, 9 mils thick
- P+ back surface field
- Texture etched surface
- Discrete pad ohmic contacts, two sets
- Thick-film printed silver collection grid and contacts
- Shallow diffusion

CIRCUIT

- Redundant busbar interconnects
- Discrete pad contact system for stress relief
- 35 cells connected in one series string, protected by external diodes

MODULE

- 0.3 m x 1.2 m nominal size
- Water-white tempered-glass superstrate
- PVB encapsulant
- 4 mil Tedlar (TM DuPont) back face sheet
- Extruded aluminum frame with rivet fasteners
- Hot melt butyl edge sealant
- Two sets of terminals enclosed in PVC molded junction box

TABLE 2.2

Key Elements of Intermediate Load Module Design
Preproduction Design (9/3/80)

CELLS

- 102.8 mm Czochralski single crystal silicon wafers, 12 mils thick
- Texture etched surface
- Discrete pad ohmic contacts, two sets
- Thick film printed silver front collection grid and contacts
- Thick film printed aluminum back collector
- Shallow diffusion

CIRCUIT

- Redundant busbar interconnects
- Discrete pad ohmic contact system for stress relief
- 35 cells connected in one series string, protected by external diode

MODULE

- 1' x 4' nominal size
- Water white tempered glass superstrate
- PVB encapsulant
- Metal foil laminate back face sheet (Tedlar/Steel/Tedlar)
- Extruded aluminum frame with rivet fasteners
- Hot melt butyl edge sealant
- Two sets of terminals enclosed in ABS molded junction box

TABLE 2.3

Design Deviations - Proposal vs. Preproduction Design (9/80)

CELLS	PROPOSED	PREPRODUCTION DESIGN
- Back Surface Field	P+	P+
- Diameter	100 mm one flat	102.8 mm 2 flats
MODULE		
- Size	0.300 x 1.2 mm	0.304 x 1.22 m (1 x 4 ft)
- Back Face Sheet	Tedlar	Tedlar/Steel/Tedlar
- J-Box	Square, PVC Plastic, Metal Screw	Round, ABS Plastic, Screw Lock With O-Ring

TABLE 2.4

Design Changes - Preproduction Design vs. Final Design

	PREPRODUCTION DESIGN (9/80)	FINAL (AS-BUILT)
MODULE		
- Grounding	No Positive Ground	Back Face Sheet Tabs Grounded to Frame
- Edge Sealant	Butyl Hot Melt	VAMAC (TM DuPont)
- Framing	Expanding Rivets	Counter Sunk Sheet Metal Screws
- Cell Shading	None Permitted	Up to Peripheral Grid Line

TABLE 2.5

Specification
ARCO Solar Module Model ASI-16-2300-20

	PROPOSAL	FINAL DESIGN (NOMINAL)
Open Circuit Voltage, Volts DC	21	20.8
Short Circuit Current*, Amps	2.5	2.5
Current at Maximum Power*, Amps	2.3	2.3
Voltage at Maximum Power*, Volts DC	16.1	16.1
Maximum Power*, Watts	37	37
Cell Diameter, mm	100	102.8
Number of Cells	35	35
Cell Efficiency*, %	14.0	12.5
Fill Factor	0.72	0.72
Area Coverage, %	74.0	76.0
Length, M (In)	1.20 (47.24)	1.22 (47.95)
Width, M (In)	0.300 (11.8)	0.304 (11.97)
Thickness, M (In)	0.04 (1.5)	0.04 (1.5)
Frame	Aluminum Extrusion or Glass Fiber Reinforced Polyester Pultrusions	Aluminum Extrusion

*Standard Conditions at 1000 W/M^2, 28^{o}C.

2. Discrete pad ohmic contacts. Old designs use two points of contact at the cell edge. When the cells crack the module fails due to open circuit condition. Placing a solder coated copper buss bar across the surface and contacting at many points makes failure due to cell breakage very unlikely. The discrete pad ohmic contact also provides for stress relief in the interconnect ribbon.

3. Thick film screen printed contacts. This contact system is amenable to high volume production using known technologies and available equipment, thus reducing cost compared to other contact systems. Replacing the silver back collector with aluminum substantially reduces the cost to manufacture cells.

4. Redundant busbar interconnects. Substantially reduces the risk of module failure due to cell breakage.

5. 35 cell module. By choosing the diameter of the cells and the module size carefully, very efficient packing can be obtained for a module using round cells. For intermediate load applications this increase of area efficiency is very important for minimizing system cost. In this module a very respectable 77.0% area coverage is achieved. Since this coverage is made by high efficiency single crystal cells, high module efficiencies result.

6. Water-white tempered glass superstrate. This superstrate provides part of the structural integrity of the module as well as excellent protection from hail damage.

7. Metal foil laminate back face sheet. As discussed in the proposal, AS, Inc. feels that the provision for a hermetically sealed encapsulant package is very important. The Tedlar (TM DuPont)/steel/Tedlar laminate on the back and glass on the front provides an excellent barrier to the transmission of oxygen and water vapor into the encapsulation system. This substantially increases the potential life of the package and interconnect system.

8. Extruded aluminum frame. This provides, along with the glass superstrate, a very rigid module which can take external shock well and can be walked on.

9. Hot melt edge sealant. This sealant protects the edges of the laminate structure and is readily applied in manufacture.

2.1.2 Inspection System Plan [2.4.2]

As part of the September 3, 1980 design review the Inspection System Plan was updated and rewritten to conform with the new design features and the basis of new manufacturing procedures required to implement the design. This plan was accepted by JPL on schedule, and was successfully used to monitor the preproduction phase of the modules.

2.1.3 Preliminary Design Review [2.4.3]

In order to consolidate design changes proposed by AS, Inc. over the proposed design, a second preliminary design review was held on September 3, 1980. Based on this PDR a list of action items was agreed upon and carried out by AS, Inc. A TDM covering these changes and authorizing preproduction was issued by JPL on October 1, 1980 and accepted by AS, Inc. on October 6, 1980.

2.1.4 Preproduction Fabrication, Inspection and Test

2.1.4.1 Fabrication [2.4.4.1]

As will be discussed in Section 3, three separate changes in the module design were made during the course of the preproduction phase of the program as a result of problems found during the testing part of the task. Two of the problems: Floating metal back plane and rivet loosening occurred during the first build of modules in October 1980. The second problem was butyl edge sealant flow during thermal cycle testing, in the November - December 1980 build. The detection of the butyl flow problem did not occur until March of 1981. As a result a third build of modules for the qualification test phase was made in March of 1981. AS, Inc. wished to present a set of modules which would fully qualify in the testing phase and as a result committed to several builds to reach this goal. The set of modules presented in March of 1981 represent the final design type of module which passed the qualification tests, as is discussed in Section 2.1.4.3 of this report.

2.1.4.2 Inspection/Delivery [2.4.4.2]

During the preproduction phase of this program the inspection plan performed according to requirement. Two thirds of the produced modules were sent to JPL for qualification testing.

2.1.4.3 Qualification Test [2.4.4.3]

One third of the produced modules in the March 1981 run were returned and tested by our quality assurance according to Section III Paragraph B of 5101-16A (November 1, 1978).

In Table 2.6 a summary of the results is shown for the tested modules. These modules have met the requirements for this part of the test program for qualification.

2.1.5 Sample Cells [2.4.8]

Thirty-six 2 x 2 cm solar cells with spectral characteristics typical of the cells to be used in fabricating the modules were supplied to JPL on schedule.

2.1.6 Documentation [2.4.9]

2.1.6.1 Program Plan (SC-1)

An updated program plan was presented after the September 1980 design review. This plan was not met on time due to design changes incorporated in the module as a result of problems found during the preproduction phase. All other requirements have been met.

2.1.6.2 Technical Progress Reports (SE-1)

The requirement for these reports was waived in March 1980.

2.1.6.3 Design Review Data (DR-1)

This data has been prepared and sent to JPL.

2.1.6.4 Engineering and Manufacturing Data (CM-1)

This data has been prepared and sent to JPL.

2.1.6.5 Inspection Plan (QA-1)

This plan has been prepared and submitted for approval to JPL. The TDM of October 1, 1980 approved this plan.

2.1.6.6 Price Estimate (MG-1)

Formats A and B have been prepared and SAMICS/SAMIS programs have been run based upon these inputs. Figures 2.1 - 2.5 show the results obtained in this analysis.

2.1.6.7 Delivery Date (QA-3)

The delivery data package for the modules has been prepared and submitted to JPL as required.

TABLE 2.6

Test Result Summary

Final Design Modules*

	SERIAL NUMBER	TEST VOLTAGE, VOLTS PRE	POST	I (TEST), AMPS PRE	POST	POWER, WATTS PRE	POST	GROUND, PRE	POST	ISOLATION, A PRE	POST	ENVIRONMENT, P/F POST
1	143316	17.32	17.23	2.04	2.02	35.26	34.80	0	1	5	10	PASS
2	143320	17.32	17.23	2.03	2.01	35.21	34.63	0	1	4	7	PASS
3	143322	17.32	17.23	2.05	1.94	35.71	33.43	0	0	4	10	PASS
4	143323	17.32	17.23	1.98	1.96	34.24	33.77	0	0	4	6	PASS
5	143324	17.32	17.23	1.95	1.92	33.69	38	0	1	4	6	PASS
6	143328	17.32	17.23	1.95	1.94	33.82	33.43	0	0	5	8	PASS
7	143331	17.32	17.23	1.97	1.94	34.07	33.43	0	0	4	13	PASS
8	143334	17.32	17.23	1.95	1.92	33.72	33.08	0	0	5	7	PASS
9	143337	17.32	17.23	1.99	1.96	34.43	33.77	0	0	4	6	PASS

*Features Include:
1. Grounded Steel Foil
2. VAMAC Edge Sealant

PROCESS	PRODUCT	VALUE ADDED					PERCENT
PACKG	PAKMOD	226.059	$/CARTON	=	1.7126	$/PEAK-WATT	2.40
FINTEST	MODTEST	243.705	$/MODULE	=	7.3850	$/PEAK-WATT	10.36
CLEANMOD	CLNMOD	10.701	$/MODULE	=	.3243	$/PEAK-WATT	.45
FRAME	FRAMMOD	14.624	$/MODULE	=	.4431	$/PEAK-WATT	.62
HIPOT	HIPOTTEST	4.904	$/MODULE	=	.1486	$/PEAK-WATT	.21
TERMSOD	SODTRLUG	30.558	$/MODULE	=	.9260	$/PEAK-WATT	1.30
EDGTRM	TRMLAM	3.992	$/MODULE	=	.1210	$/PEAK-WATT	.17
POSLAMCT	POSLMCKT	12.370	$/MODULE	=	.3749	$/PEAK-WATT	.53
LAMMOD	LAMCKT	452.728	$/MODULE	=	13.7190	$/PEAK-WATT	19.24
ASLMMOD	ASMMOD	393.302	$/MODULE	=	11.9182	$/PEAK-WATT	16.71
PRLAMCT	PRELMCKT	12.370	$/MODULE	=	.3749	$/PEAK-WATT	.53
TASOD	SODMODCK	31.367	$/MODULE	=	.9505	$/PEAK-WATT	1.33
TACKTSUB	CKTSUBTA	42.192	$/SUBCKT	=	1.2785	$/PEAK-WATT	1.79
CELSTSOD	SCIS	217.862	$/CELLCK	=	6.6019	$/PEAK-WATT	9.26
SPSP	SODPACELL	18.959	$/CELL	=	20.0202	$/PEAK-WATT	28.07
GLSWASH	CLGLASS	68.580	$/GLAS	=	2.0782	$/PEAK-WATT	2.91
AFIXBTYL	DSPBUTYL	98.567	$/MODULE	=	2.9869	$/PEAK-WATT	4.19
TOTAL VALUE ADDED:		9412.980	$/CARTON	=	71.3104	$/PEAK-WATT	

(1980 DOLLARS)
10 kW/YEAR

Figure 2.1. SAMICS/SAMIS Cost Estimate for Intermediate Load Module

PROCESS	PRODUCT	VALUE ADDED					PERCENT
PACKG	PAKMOD	20.094	$/CARTON	=	.1522	$/PEAK-WATT	1.16
FINTEST	MODTEST	19.490	$/MODULE	=	.5906	$/PEAK-WATT	4.52
CLEANMOD	CLNMOD	5.266	$/MODULE	=	.1596	$/PEAK-WATT	1.22
FRAME	FRAMMOD	2.201	$/MODULE	=	.0667	$/PEAK-WATT	.51
HIPOT	HIPOTTEST	.772	$/MODULE	=	.0234	$/PEAK-WATT	.18
TERMSOD	SODTRLUG	3.447	$/MODULE	=	.1044	$/PEAK-WATT	.80
EDGTRM	TRMLAM	1.098	$/MODULE	=	.0333	$/PEAK-WATT	.25
POSLAMCT	POSLMCKT	1.258	$/MODULE	=	.0381	$/PEAK-WATT	.29
LAMMOD	LAMCKT	38.920	$/MODULE	=	1.1794	$/PEAK-WATT	9.02
ASLMMOD	ASMMOD	47.853	$/MODULE	=	1.4501	$/PEAK-WATT	11.09
PRLAMCT	PRELMCKT	1.258	$/MODULE	=	.0381	$/PEAK-WATT	.29
TASOD	SODMODCK	2.727	$/MODULE	=	.0826	$/PEAK-WATT	.63
TACKTSUB	CKTSUBTA	3.745	$/SUBCKT	=	.1135	$/PEAK-WATT	.87
CELSTSOD	SCIS	37.068	$/CELLCK	=	1.1233	$/PEAK-WATT	8.59
SPSP	SODPACELL	6.961	$/CELL	=	7.3504	$/PEAK-WATT	56.23
GLSWASH	CLGLASS	8.215	$/GLAS	=	.2489	$/PEAK-WATT	1.90
AFIXBTYL	DSPBUTYL	10.658	$/MODULE	=	.3230	$/PEAK-WATT	2.47
TOTAL VALUE ADDED:		1725.501	$/CARTON	=	13.0720	$/PEAK-WATT	

(1980 DOLLARS)
100 kW/YEAR

Figure 2.2. SAMICS/SAMIS Cost Estimate for Intermediate Load Module

PROCESS	PRODUCT	VALUE ADDED					PERCENT
PACKG	PAKMOD	3,589	$/CARTON	=	,0272	$/PEAK-WATT	,37
FINTEST	MODTEST	1,975	$/MODULE	=	,0598	$/PEAK-WATT	,82
CLEANMOD	CLNMOD	4,099	$/MODULE	=	,1242	$/PEAK-WATT	1,71
FRAME	FRAMMOD	1,055	$/MODULE	=	,0320	$/PEAK-WATT	,44
HIPOT	HIPOTTEST	,403	$/MODULE	=	,0122	$/PEAK-WATT	,17
TERMSOD	SODTRLUG	1,155	$/MODULE	=	,0350	$/PEAK-WATT	,48
EDGTRM	TRMLAM	,740	$/MODULE	=	,0224	$/PEAK-WATT	,31
POSLAMCT	POSLMCKT	,345	$/MODULE	=	,0105	$/PEAK-WATT	,14
LAMMOD	LAMCKT	6,107	$/MODULE	=	,1851	$/PEAK-WATT	2,55
ASLMMOD	ASMMOD	18,031	$/MODULE	=	,5464	$/PEAK-WATT	7,53
PRLAMCT	PRELMCKT	,345	$/MODULE	=	,0105	$/PEAK-WATT	,14
TASOD	SODMODCK	,452	$/MODULE	=	,0137	$/PEAK-WATT	,19
TACKTSUB	CKTSUBTA	,677	$/SUBCKT	=	,0205	$/PEAK-WATT	,28
CELSTSOD	SCIS	19,564	$/CELLCK	=	,5929	$/PEAK-WATT	8,17
SPSP	SODPACELL	5,089	$/CELL	=	5,3734	$/PEAK-WATT	74,04
GLSWASH	CLGLASS	3,037	$/GLAS	=	,0920	$/PEAK-WATT	1,27
AFIXBTYL	DSPBUTYL	3,306	$/MODULE	=	,1002	$/PEAK-WATT	1,38
TOTAL VALUE ADDED:		957,948	$/CARTON	=	7,2572	$/PEAK-WATT	

(1980 DOLLARS)
1 MW/YEAR

Figure 2.3. SAMICS/SAMIS Cost Estimate for Intermediate Load Module

PROCESS	PRODUCT	VALUE ADDED					PERCENT
PACKG	PAKMOD	2,735	$/CARTON	=	,0207	$/PEAK-WATT	,30
FINTEST	MODTEST	1,166	$/MODULE	=	,0353	$/PEAK-WATT	,51
CLEANMOD	CLNMOD	4,048	$/MODULE	=	,1227	$/PEAK-WATT	1,78
FRAME	FRAMMOD	,996	$/MODULE	=	,0302	$/PEAK-WATT	,44
HIPOT	HIPOTTEST	,355	$/MODULE	=	,0108	$/PEAK-WATT	,16
TERMSOD	SODTRLUG	1,041	$/MODULE	=	,0315	$/PEAK-WATT	,46
EDGTRM	TRMLAM	,719	$/MODULE	=	,0218	$/PEAK-WATT	,32
POSLAMCT	POSLMCKT	,299	$/MODULE	=	,0091	$/PEAK-WATT	,13
LAMMOD	LAMCKT	6,599	$/MODULE	=	,2000	$/PEAK-WATT	2,90
ASLMMOD	ASMMOD	16,534	$/MODULE	=	,5010	$/PEAK-WATT	7,26
PRLAMCT	PRELMCKT	,299	$/MODULE	=	,0091	$/PEAK-WATT	,13
TASOD	SODMODCK	,346	$/MODULE	=	,0105	$/PEAK-WATT	,15
TACKTSUB	CKTSUBTA	,532	$/SUBCKT	=	,0161	$/PEAK-WATT	,23
CELSTSOD	SCIS	18,472	$/CELLCK	=	,5598	$/PEAK-WATT	8,12
SPSP	SODPACELL	4,966	$/CELL	=	5,1464	$/PEAK-WATT	74,62
GLSWASH	CLGLASS	2,764	$/GLAS	=	,0837	$/PEAK-WATT	1,21
AFIXBTYL	DSPBUTYL	2,941	$/MODULE	=	,0891	$/PEAK-WATT	1,29
TOTAL VALUE ADDED:		910,419	$/CARTON	=	6,8971	$/PEAK-WATT	

(1980 DOLLARS)
2 MW/YEAR

Figure 2.4. SAMICS/SAMIS Cost Estimate for Intermediate Load Module

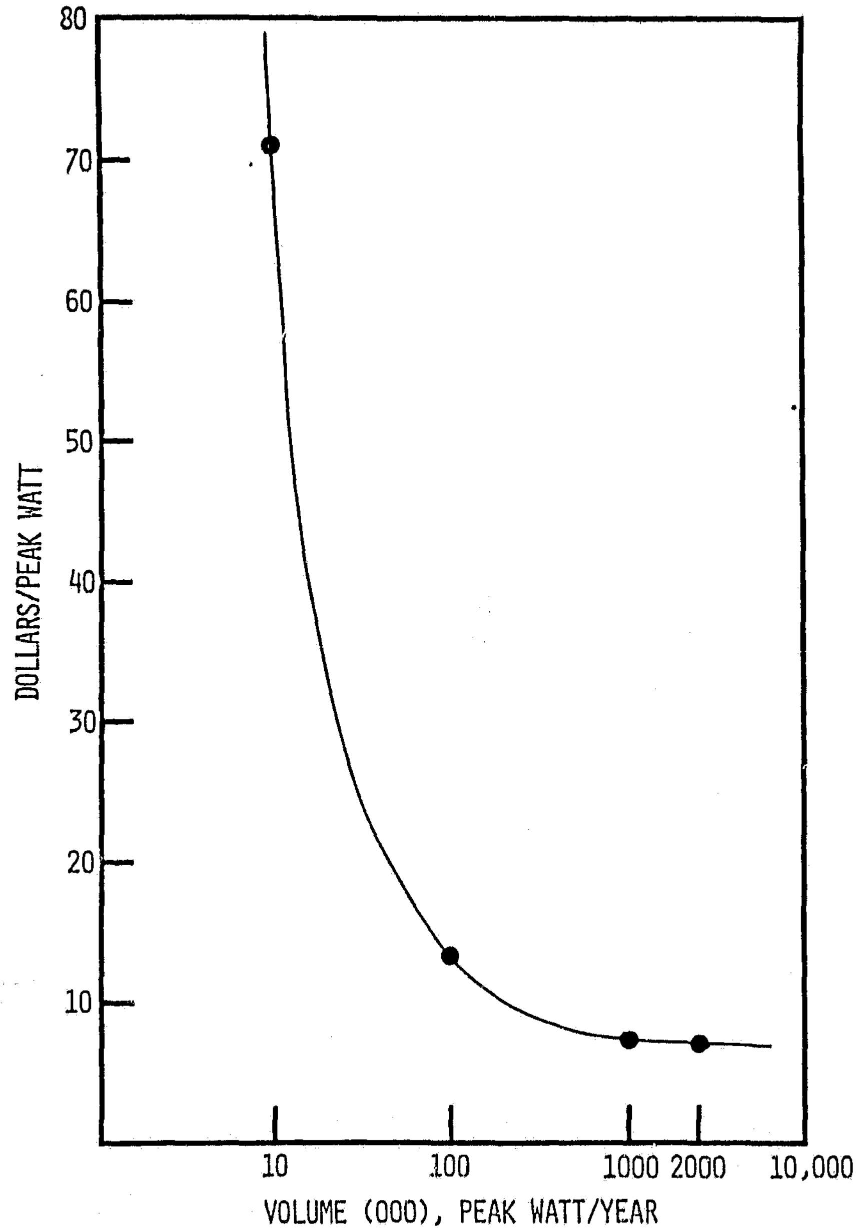


Figure 2.5. SAMICS/SAMIS Estimate for Cost/Peak Watt for Factory Volume

3.0 Discussion of Design Alterations During Preproduction Phase

This section describes those design alterations which were required to make a module which qualifies under the test specification. These design alterations were made to the preproduction approved design of September 3, 1980 and are all incorporated in the attached data package. Table 3.1 shows the design elements in the final design.

3.1 Problems With Expanding Rivet Fasteners

Expanding rivet fasteners were originally proposed to connect the frame extrusion together. During thermal cycling of the fabricated modules it was found that the rivets loosened and backed out, causing the frames to be loose. A change was made to countersink the aluminum end pieces to accept a sheet metal screw. Countersinking was required to provide a flush surface to meet the length size requirement. The sheet metal screw also provided a positive permanent contact of the foil tab to the frame. This requirement arose as a result of the problem found in the next section.

3.2 Problems With Floating Ground Back Plane Foil

In the initial design the laminated steel foil back face sheet was not grounded to the frame or any external ground. During the HiPot test arcing occurred above 500 volts from the foil to the frame due to capacitive coupling. This problem was solved by putting tabs on the back face sheet which fit between the end-cap and side rail during framing. The metal screws then pierced the tabs and connected foil, end-cap and frame. By direct grounding of the foil it was found that the leakage current was less than 10 μ amps at 3000 VDC, indicating that the circuit-to-foil link was good. This design successfully passed qualification testing.

3.3 Cosmetic Problem of Butyl Hot Melt Flow During Thermocycling

An edge sealant between the frame and laminate is required to protect the edge of the laminate from moisture and oxygen entry. The originally specified material was based on a butyl hot melt sealant which was easily handled in manufacturing. However, during thermal cycling it was found that the sealant flowed and was pooled by gravity to a slight extent on the bottom of the inside of the frame. This was not a failure of function per se but did represent a cosmetic change in the appearance of the module after testing. To cure this problem a change was made to a hot melt sealant based on VAMAC (TM DuPont). This sealant has similar properties to the butyl sealant but does not flow at high temperatures.

TABLE 3.1

Key Elements of Intermediate Load Module Design
Final Design (3/1/81)

CELLS

- 102.8 mm Czochralski single crystal silicon wafers, 12 mils thick
- Texture etched surface
- Discrete pad ohmic contacts, two sets
- Thick film printed solar front collection grid and contacts
- Thick film printed aluminum back collection
- Shallow diffusion

CIRCUIT

- Redundant busbar interconnects
- Discrete pad ohmic contact system for stress relief
- 35 cells connected in one series string, protected by external diodes

MODULE

- 1' x 4' nominal size
- Water white tempered glass superstrate
- PVB encapsulant
- Metal foil laminate back face sheet (Tedlar/Steel/Tedlar)
- Metal foil grounded to frame by tabs at back face sheet corners
- Extruded aluminum frame with counter sunk sheet metal screws
- Hot melt VAMAC (TM DuPont) edge sealant
- Two sets of terminals enclosed in ABS molded junction box

3.4 Problem With Cell Shading

Due to close spacing of cells and drift during lamination all modules produced have one or more cells slightly shaded by the frame. Based on agreement, shading of cells is now permitted to the outer peripheral grid line on the cells.

4.0 Engineering and Manufacturing Documentation

The complete, final sets of CM-1 data have been delivered and the interface control drawing, and module assembly drawings are included in Appendix I.

APPENDIX I

PROPOSED PROGRAM PLAN
BLOCK IV Intermediate Load Solar Cell Development, JPL No. 955402

Task Descriptions

Intermediate Load

1. Perform design of intermediate load solar cell module including details, layouts and assembly drawings. Incorporate innovations that lead to cost reductions and/or better performance.

2. Fabricate and assemble 29 solar cell modules according to the drawing requirements specified in Task 1.

3. Perform a detailed inspection of each module per the Detailed Inspection System Plan developed under Task 13e.

4. Perform qualification testing of 9 modules in accordance with JPL test document, Exhibit I-L.

5. Deliver 29 Intermediate Load Solar Cell modules to JPL.

Design Reviews

6. Prepare and present at JPL, a preliminary and a final design, production and inspection review for both the Intermediate Load and Residential Load modules.

2 cm x 2 cm Solar Cells

7. Fabricate (36) 2 cm x 2 cm solar cells for each module design. These cells shall have spectral characteristics typical of the cells to be used in both types of modules.

Documentation

8. a. Program Plan - Prepare a program plan that identifies milestones and tasks necessary to complete this program.

   b. Technical Progress - Prepare monthly reports that give the status of the program, citing progress and problems.

   c. Design Review Data - Prepare preliminary and final design review packages including the design, rationale, predicted performance, manufacturing data, inspection plan, etc.

d. Engineering and Manufacturing Data - Provide drawings, manufacturing flow charts, and interface control drawings.

e. Inspection System Plan - Prepare an inspection plan to describe the steps necessary to insure an acceptable module when fabricated.

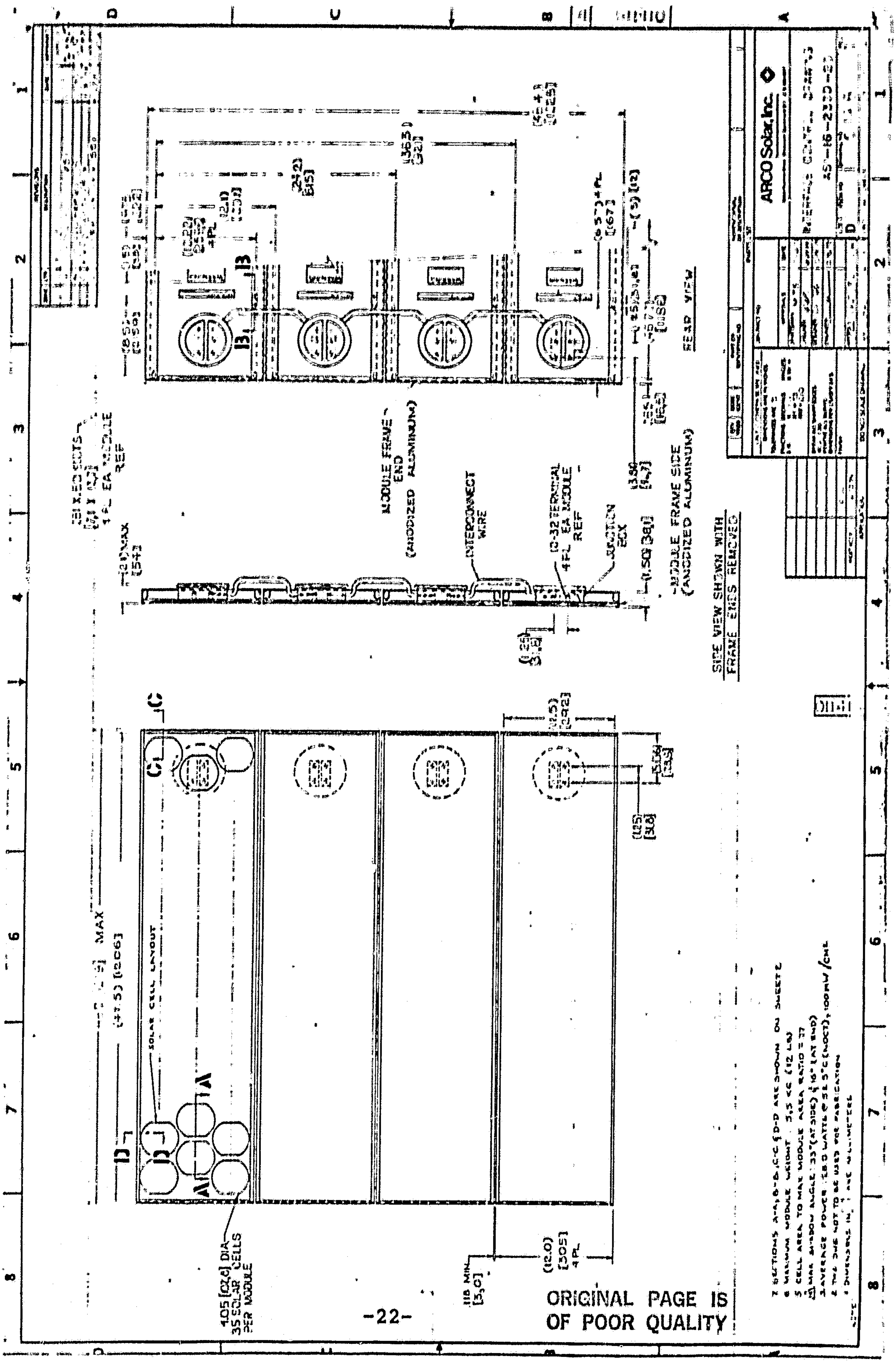
f. SAMICS/SAMIS Price Estimate - Prepare cost estimates for fabrication of both modules.

g. Delivery Data - Prepare data reports documenting performance characteristics of each module.

h. Final Design Report - Prepare a final report which updates the actual design and development Engineering and Manufacturing documentation.

APPENDIX II

Engineering and Manufacturing Documentation



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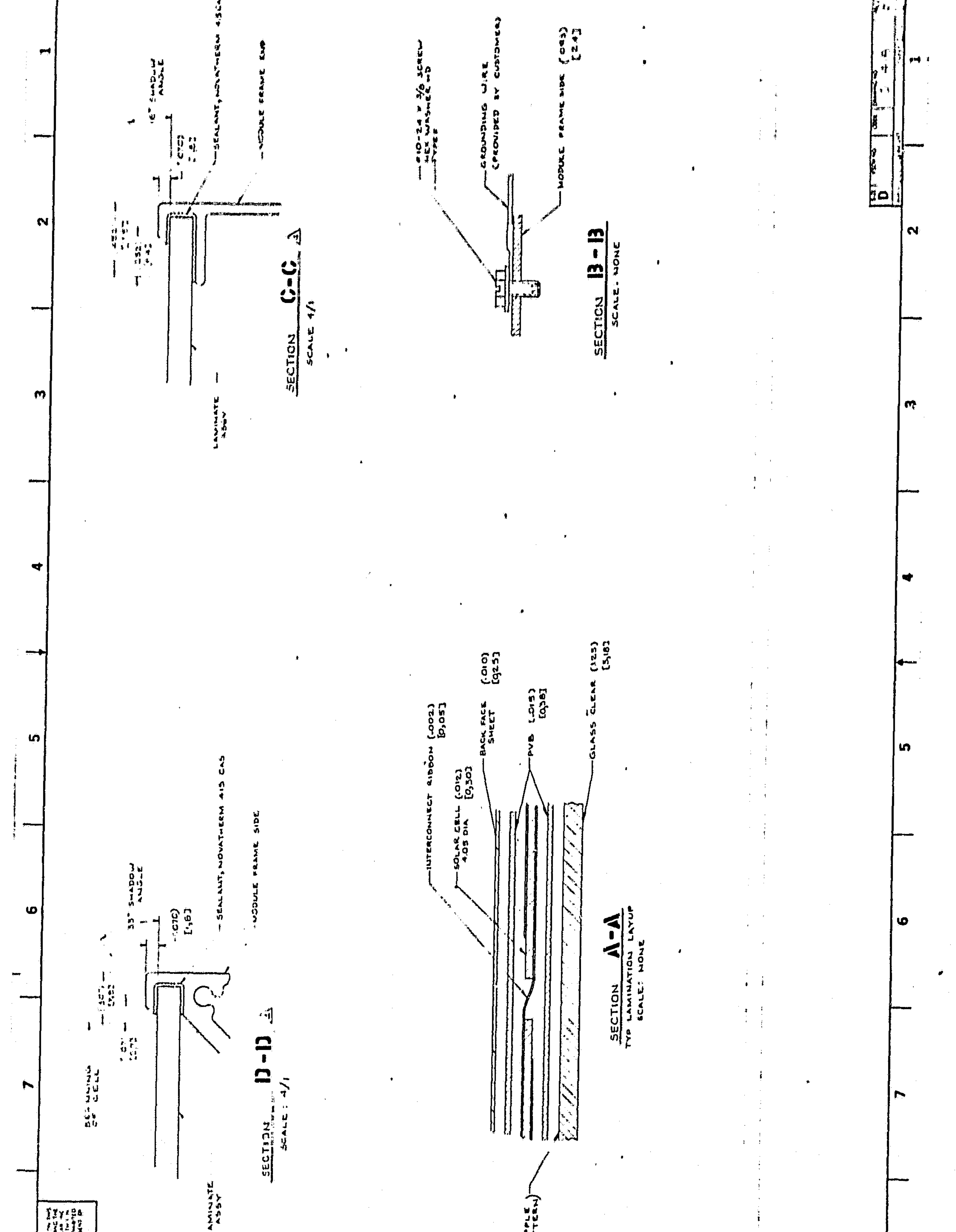

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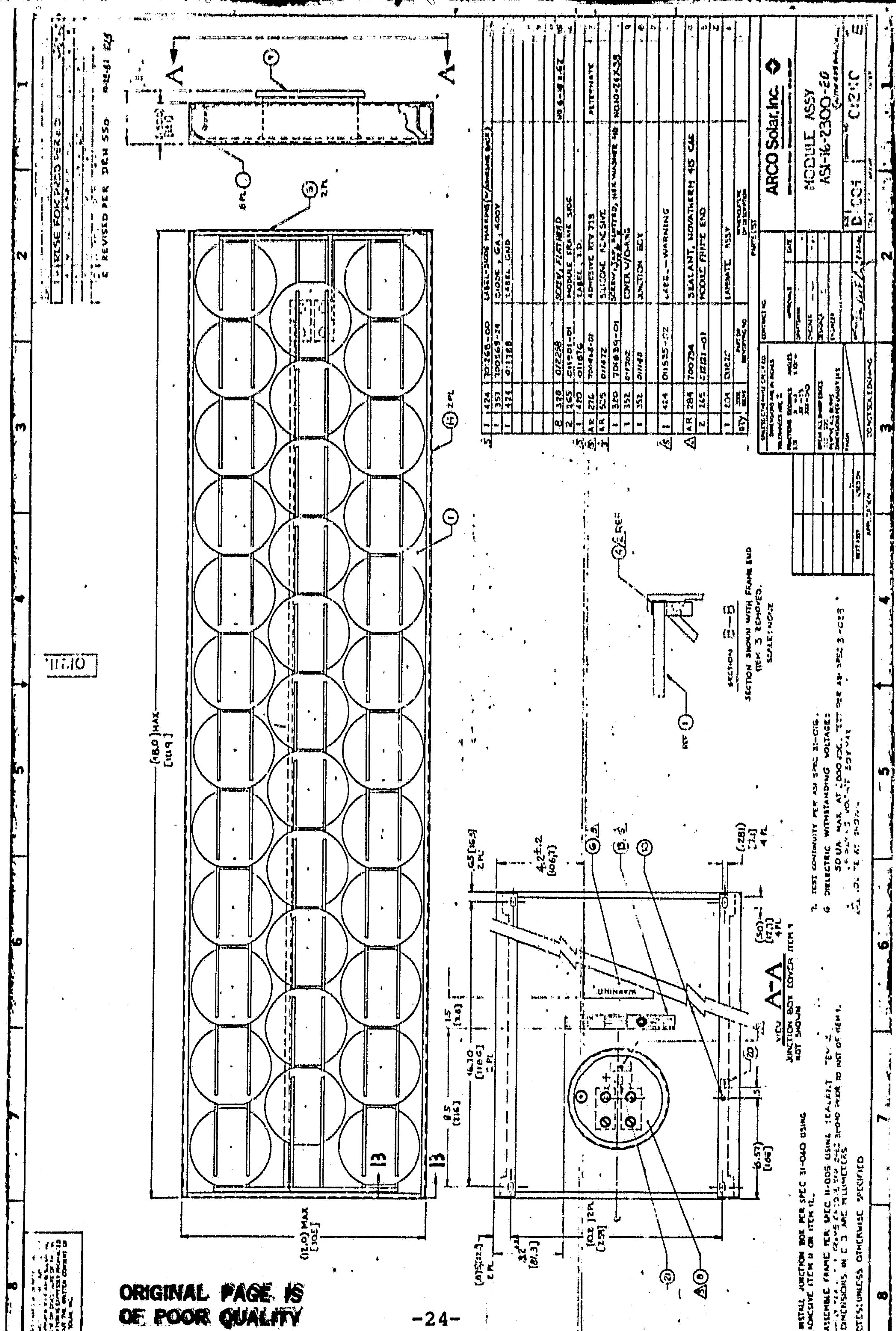

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