DOE/JPL 955402-82/2
9950-682

FINAL REPORT

DESIGN, FABRICATION AND TESTING

OF

BLOCK IV DESIGN SOLAR CELL MODULES

PART II: RESIDENTIAL MODULE

APRIL 1982

(NASA-CR-169158) DESIGN, FABRICATION AND TEST OF BLOCK 4 DESIGN SOLAR CELL MODULES. PART 2: RESIDENTIAL MODULE Final Report (ARCO Solar, Inc., Chatsworth, Calif.) 36 p HC A03/MF A01 CSCL 10A G3/44

N82-26795

Unclas 28145

ARCO SOLAR, INC.

CHATSWORTH, CALIFORNIA 91311

PREPARED UNDER CONTRACT NO. 955402

FOR

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA 91103

FINAL REPORT

DESIGN, FABRICATION AND TEST

OF

BLOCK IV DESIGN SOLAR CELL MODULES

PART II: RESIDENTIAL MODULE

APRIL 1982

WRITTEN BY

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ARCO SOLAR, INC.

CHATSWORTH, CALIFORNIA 91311

PREPARED UNDER CONTRACT NO. 955403

FOR

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA 91103

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.

ARCO Solar, Inc. believes there are no Subject Inventions made under this contract.

ABSTRACT

This final design report concludes work performed on the design, fabrication and test of the Block IV Residential Load Module by ARCO Solar, Inc. This report outlines design changes from the proposed module design through three iterations to the discontinuance of testing agreed upon by both JPL and ARCO Solar, Inc.

TABLE OF CONTENTS

INTRODUCTION

Part II of this report contains the program plan, design data and engineering and manufacturing documentation produced during the development and testing of a Residential Load module by ARCO Solar, Inc. The module described in this report includes two major innovations developed by ARCO for use on the John Long Home Project and proposed for use in the Block IV Residential Program. These are the use of ethylene/vinyl acetate (EVA) encapsulant and a Tedlar® film plastic front cover in a batten and seam roofing design. The design responds to requirements outlined by the Jet Propulsion Laboratory Document No. 5101-83, "Block IV Solar Cell Module Design and Test Specifications for Residential Applications," November 1, 1978.

PROGRAM OUTLINE

The program followed by ARCO Solar, Inc. during the design and fabrication of the Residential Module deviated from that proposed as we gained experience with the new plastic front, steel substrate module design. The major steps in the program included the following tasks:

1. Module design, including layouts, details and assembly drawings.
2. Design reviews with JPL to approve the Engineering, Manufacturing and Quality Control Documents.
3. Submittal of seven modules for qualification testing.
4. Submittal of the Final Design Report.

DESCRIPTION OF DESIGN

The concept for the 'S, Inc. Residential Module Design was based on a low-cost, batten and seam approach. This design was aimed at providing a module for use on rooftops of homes, apartment complexes and business offices. By eliminating the costly and heavy glass front typifying most photovoltaic module designs, the steel substrate could be a larger, 2-x4-foot size, well suited for the roofing installation business as it allows for the seams to be on 2 foot centers. Several iterations in the design occurred as we gained knowledge through the fabrication of modules for the John Long Project and the building of test samples for submittal to JPL.

Features common to all of the design iterations include the solar cell and circuitry design. Cells are 4.05 inches in diameter, single crystal grown by Czochralski technique. The ingots are sliced into wafers, texture etched and diffused for a shallow junction. Discrete pad ohmic contacts are printed using a thick film paste of silver on the front and a combination of silver and aluminum on the back surface. This printing technique is amenable to high volume and is presently used in our manufacturing plant.

Contact to the cell comes from the soldering of coated copper buss ribbon across the faces of the cell. Dual redundant ribbons on both front and back, soldered in many places, reduce the risk of power loss due to cell breakage. The contacts made to the discrete ohmic pads also allow for strain relief during thermal excursions.

The circuitry of three parallel strings allows for more fault protection than a single string module, and reducing the number of cells in series to 20 reduces the amount of hot spot heating possible. The provision of a bypass diode external to the circuit also reduces the hot spot problem.

Other features common to all iterations include the use of a plastic coated steel substrate with thin plastic film cover. This allows for lighter weight and less cost per area compared to glass front designs. Ethylene/vinyl acetate (EVA) pottant was used on all iterations for its superior hot spot endurance and lower moisture permeability.

Dual redundant terminations are a common feature in all of the rooftop designs as it provides for easy interconnection of modules under the battens. Grounding of modules also takes place here with the use of sheet metal screws through tabs on the substrate pan. Overlapping of modules combined with batten-covered edges gives water-repellant electrical connections and high packing density on the roof.

As outlined in the original proposal, the first design iteration included a Korad® acrylic film-coated steel substrate, EVA encapsulant and clear Korad® film cover. This design was used on the John Long Project and included a bent copper clip termination. Buss bars protruded from the laminate and bent over the flanges of the module pan. The clips were forced over these buss bars to make contact.

Several problems were encountered with this design, the major being electrical isolation of conductive components. The Korad® coating on the substrate pan was easily scratched, providing a shorting path to ground. Dielectric standoff was adequate as long as no scratches occurred. The spring clip and buss bar folded around the pan also posed an electrical standoff problem. Nomex® dielectric paper and polyester tape used in the terminal area provided the necessary isolation here. A secondary problem with this design was the moisture pick-up by the Korad® film. Evidence of this problem was seen during internal ARCO Solar qualification testing.

Because of the problems associated with Korad®, a new film was used in the second design. The second design incorporated Tedlar®-coated steel substrate pans and a clear film of 0.002-inch-thick Tedlar® as a cover sheet. Terminations included dual positive and negative pigtails. The substrate pan was used as a strain relief in this design. The diode was also changed to accept a higher current level. Seven modules of this version were submitted to JPL for testing. Internal qualification testing at AS, Inc. during the time of submittal showed some problems with this design also. The 2-mil Tedlar® cover film shrank excessively at high temperatures causing the film to peel away from the edges and resulting in delamination. The modules were recalled from JPL for a new submittal.

The third version of the design substituted 4-mil Tedlar® as a cover film to help the shrinkage problem. Seven new modules were submitted for test. Nine modules of this design were also submitted to AS, Inc. internal testing. After exposure to the Block IV specified thermal cycling, delamination occurred in the terminal area on these nine. This is consistent with the findings of JPL testing. The delamination was caused by stressing of the Tedlar® when terminations were prepared and the Tedlar® appeared to pull back a certain amount then stop. The delamination did not appear to progress further with more exposure. The failure of these modules to meet the visual criteria outlined in the Block IV specification prohibited continuing of tests. An agreement by ARCO Solar, Inc. and JPL was reached to end the program.

DESIGN DATA

The key elements of the final design described above are outlined in Table 1. The cells, circuit and module are included.

The power output of the module at 28°C and 1000 W/m^2 is a nominal 62 watts. A typical I-V curve is shown in Figure 1 at these conditions.

Direct roof mounting of this module results in a high Nominal Operating Cell Temperature of 65°C (at 20°C ambient, 1000 W/m^2, 1 m/s wind). The module derating coefficients are 3.66 mA/°C/module and 49 mV/°C/module. Data at 28°C, 1000 W/m^2 and at NOCT, 1000 W/m^2 are given in Table II for both cell and module. The respective efficiencies are also included.

ENGINEERING AND MANUFACTURING DOCUMENTATION

Layouts, details and assembly drawings done for the Residential Block IV Module Design are attached as an appendix. The module drawings include the latest revision only. These drawings detail the module submitted for final testing.

TABLE I

KEY ELEMENTS OF RESIDENTIAL MODULE DESIGN

CELLS

- 4.05 inch (103 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

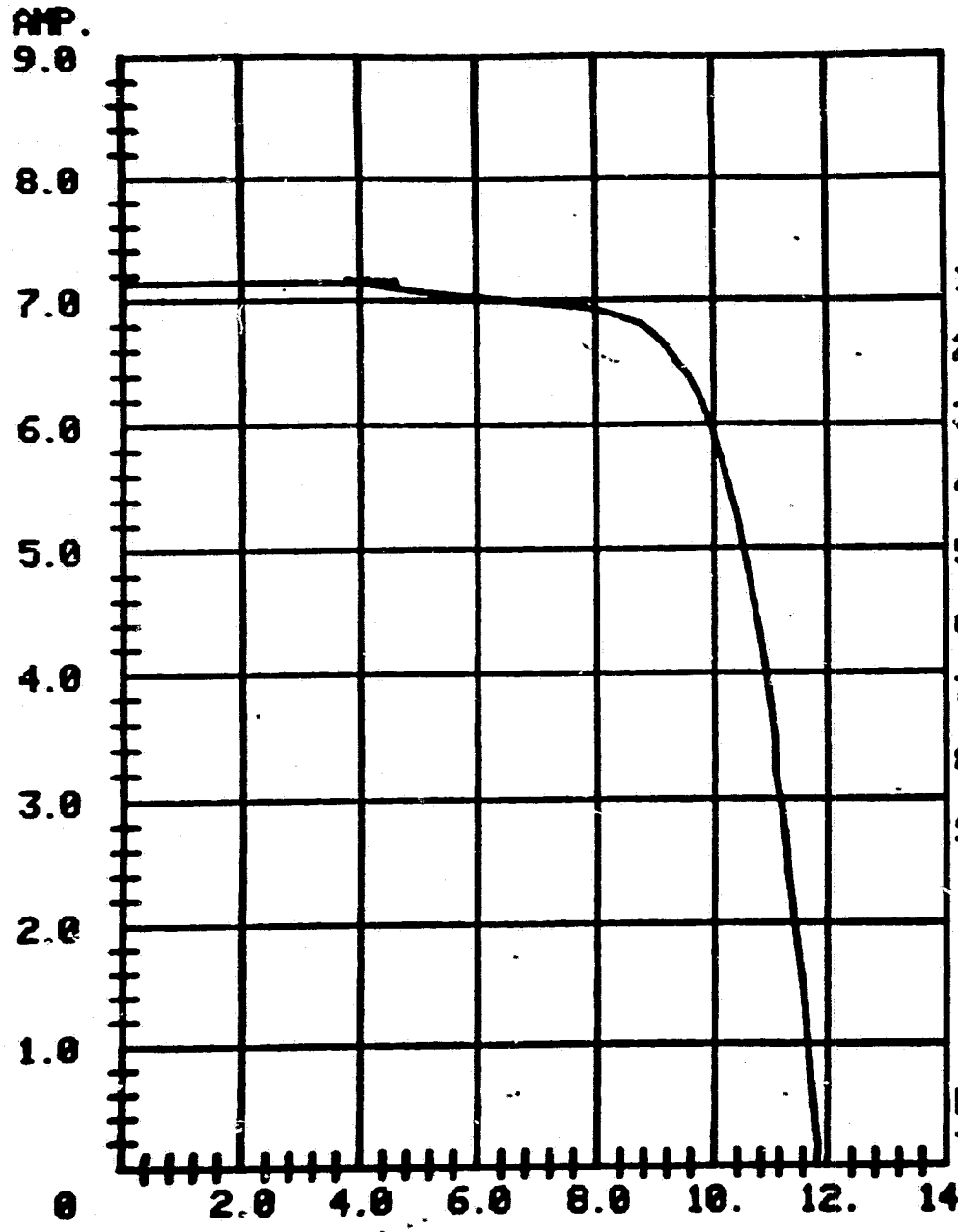
CIRCUIT

- Redundant buss bar interconnects
- Discrete pad ohmic contact system for stress relief
- 60 cells connected in three series strings of 20 each protected by external diode

MODULE

- 2-x4-foot nominal size
- Tedlar® coated steel substrate
- Clear Tedlar® cover film
- Two sets of pigtails, one each on either side of module

FIGURE 1



ARCO SOLAR

MODEL #
SERIAL # 53
DATE

1 CELL AREA (SQ MM)
8129
2 # OF CELLS IN PARALLEL
3
3 # OF CELLS IN SERIES
20
4 AMBIENT TEMP (DEG C)
21
5 STANDARD TEMP (DEG C)
28
6 I TEMP COR(UA/SQ CM/DEG C)
7
7 V TEMP COR(UV/DEG C/CELL)
-2439
8 AM1 CAL CURRENT (0.1'S MA)
512
9 TEST VOLTAGE (0.01'S V)
920
10 MIN I(TEST) (0.01'S A)
10

I(TEST) = 6645000 UA
ISC = 7138000 UA
VOC = 11834000 UV

ENTER COMMAND LETTER
->

TABLE II

CELL/MODULE CHARACTERISTICS

RESIDENTIAL BLOCK IV DESIGN

AM 1.5 1000 W/m^2

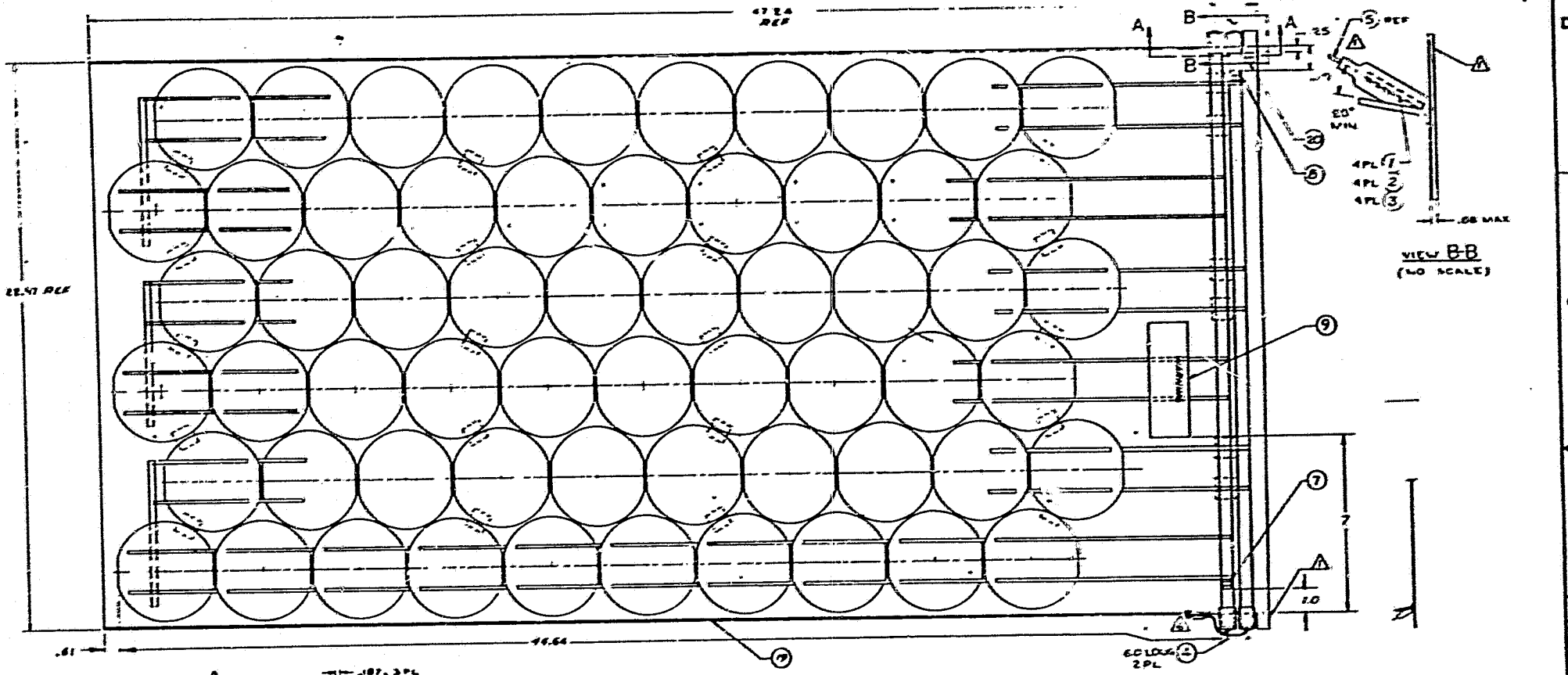
	CELL		MODULE	
	28°C	65°C	28°C	65°C
V_{oc}, Volts	0.595	0.505	11.9	10.1
I_{sc}, Amps	2.30	2.32	7.04	7.10
V_L, Volts	0.480	0.390	9.60	7.80
I_L, Amps	2.15	2.17	6.58	6.64
P_L, Watts	1.03	0.85	63.2	51.8
η_{aa}*	12.6%	10.4%	13.0%	10.6%
η_{mod}*			9.8%	8.0%

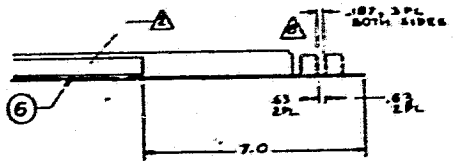
Cell area: 81.3 cm^2 Module area: 6437.0 cm^2

Three parallel strings of 20 cells each

*η_{aa} = efficiency based on cell area η_{mod} = efficiency based on module area

APPENDIX





VIEW A-A

ITEM	QTY	PART NO	DESCRIPTION
10	1	011788	LABEL - GROUND
9	1	012490	LAMINATION ASSY
8	2	701458-00	ALPHA SLEEVE TUBE 3/16 Ø
7	6	701459-00	WIRE, 16 AWG, WHITE, TEFN
6	2	700420-03	NUT, HEX 4-40
5	1	701440-01	WASHER, LOCK #8
4	2	701331-01	WASHER, FLAT
3	1	701442-01	SCREW, 8-32 x 3/8 PHD
2	1	701222-02	TERMINAL BLOCK
1	1	700312-02	INSULATOR, END
	1	700669-10	BYPASS DIODE ASSY, ECG
	1	012494-02	LABEL WARNING

ITEM	QTY	PART NO	DESCRIPTION
20	1	011654-02	POLARITY LABEL, POS
19	1	011654-01	POLARITY LABEL, NEG
18	1	011676-00	LABEL, IDENTIFICATION
17	2	700723-00	WIRE, #10 AWG, THHN
16	2	700722-00	WIRE, BLACK #10 AWG, THHN
15	4	700920-01	ALPHA SLEEVE TUBE 1/4 Ø
14	3	700911-02	ALPHA SHRINK TUBE 1/8 Ø
13	AS REQ'D	700116-00	EPOXY

ARCO Solar, Inc.

ASI-15-2200

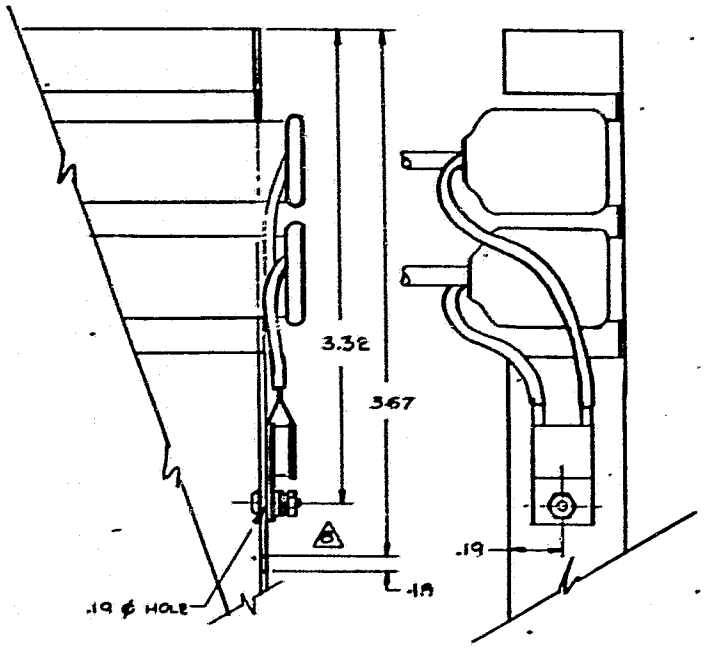
RESIDENTIAL MODULE ASSY

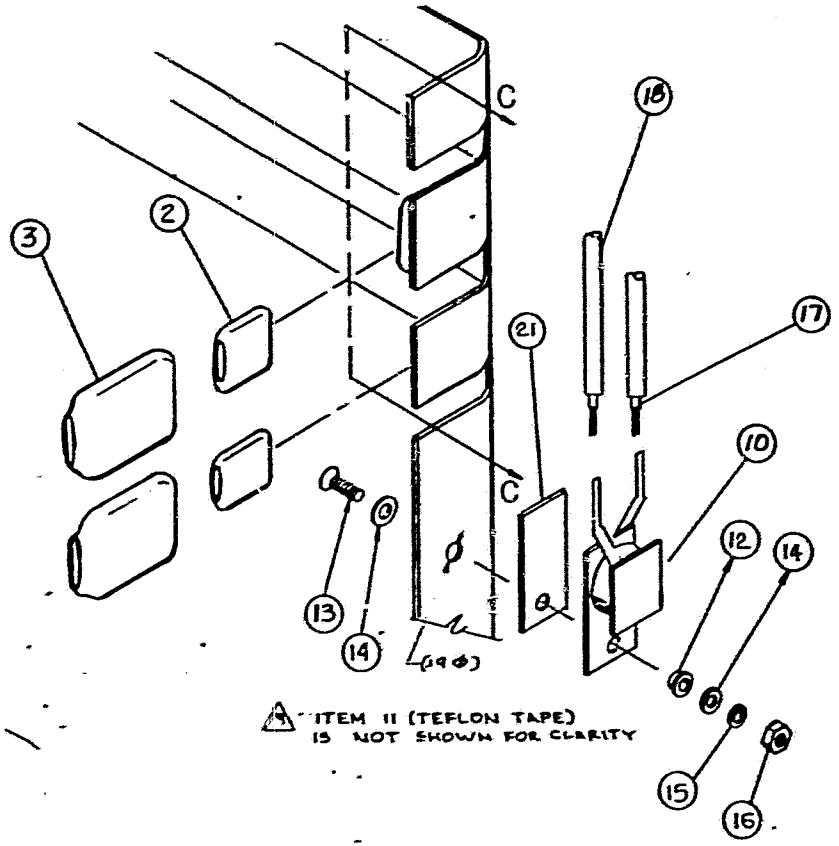
D | 001 | 012431 | F

1. WRAP TEFLON TAPE (ITEM 11) AROUND DIODE ASSY
2. CUT PER MFG SPEC NO 81-039.
3. ILLUMINATED ACTIVE SURFACE AREA 903.4 IN²
4. SEE SHEET 2 FOR DIODE INST DETAILS
5. ECO LOC MAY SYSTEM VOLTAGE
6. TEST PER 81-015
7. 600 VOC MINOT REQUIREMENT
8. LABEL TO BE MARKED WITH MODEL NO, SERIAL NO, PLANT ID, MAX SYSTEM VOLTAGE, DATE OF MFG
9. FOAM AFTER LAMINATION

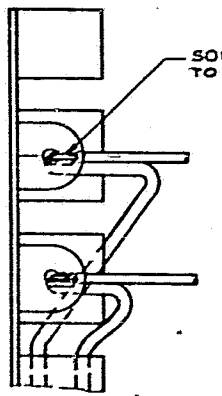
UNLESS OTHERWISE SPECIFIED

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		SEE SHEET 1		





ITEM 11 (TEFLON TAPE) IS NOT SHOWN FOR CLARITY



VIEW C-C

(ITEMS 2 & 3 ARE NOT SHOWN)

ORIGINAL PAGE IS OF POOR QUALITY

QTY PLOD	FSCM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE
FRACTIONS DECIMALS ANGLES
1/X X ±
XX ±
XXX ±
X XX°

BREAK ALL SHARP EDGES
C.10 E.30
REMOVE ALL BURRS
DIMENSIONS PER USAS Y 14.5

FINISH

CONTRACT NO.

APPROVALS	DATE
DRAFTSMAN MKK	1/26/81
CHECKER	
DESIGNER	
ENGINEER	
APPROVED	

ARCO Solar, Inc.

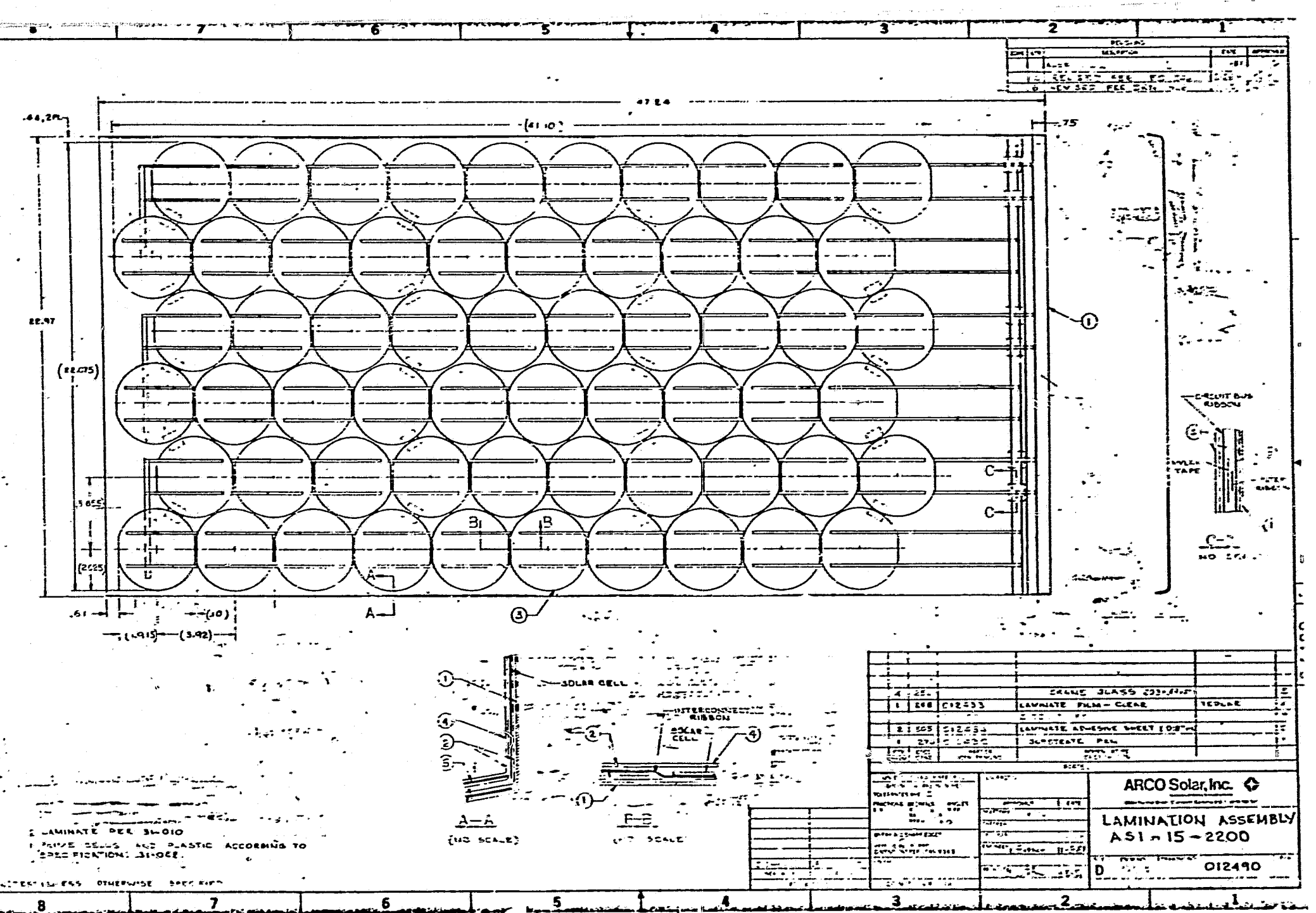
ASI 15-2200
RESIDENTIAL MODULE ASSEMBLY

SIZE	FSCM NO	DRAWING NO.	REV
C		012431	F

SCALE NONE/SHEET | WEIGHT | SHEET 2 OF 2

NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE DRAWING



ITEM	QTY	PART NO.	DESCRIPTION	MATERIAL
4	25		CRANE GLASS .03 THK	
3	1	012533	LAMINATE FILM — CLEAR	TEDLAR
2	1	012493	LAMINATE ADHESIVE SHEET .028 THK	
1	27	012520	SUBSTRATE PAN	

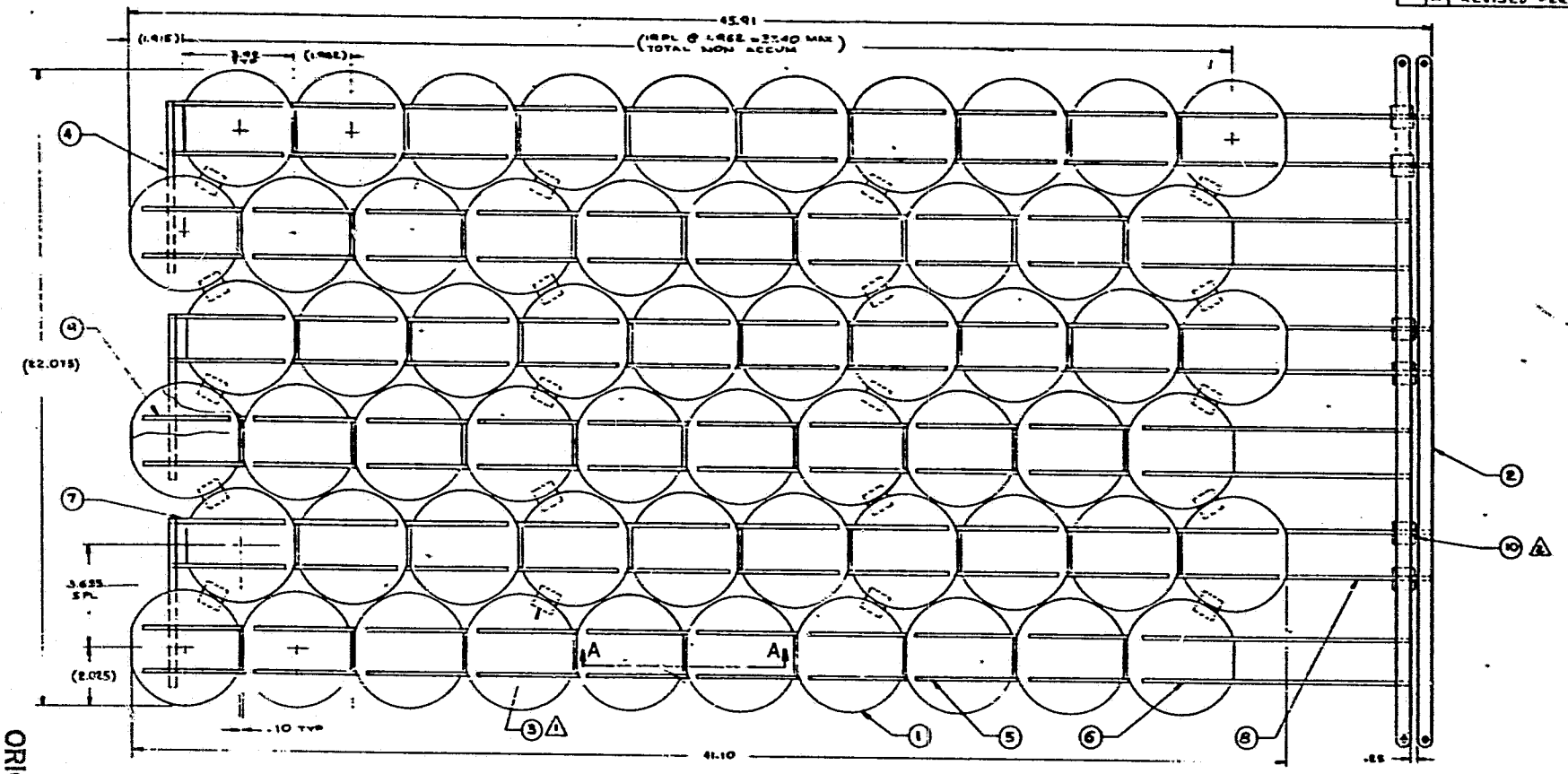
ARCO Solar, Inc.

LAMINATION ASSEMBLY
ASI n 15 — 2200

D 012490

2 LAMINATE PER 31-010

1 SOLAR CELLS AND PLASTIC ACCORDING TO SPECIFICATION: 31-0CE.



SECTION A-A
(NO SCALE)

	6	EES	701347-00	DOUBLE FACED MYLAR TAPE	1" x 1"	10
	6	256	700258-00	INTERCONNECT RIBBON, .10 x .002	3.85 LONG	9
	6	256	700258-00	INTERCONNECT RIBBON, .10 x .002	8.30 LONG	8
	6	256	700258-00	INTERCONNECT RIBBON, .10 x .002	3.75 LONG	7
	6	256	700258-00	INTERCONNECT RIBBON, .10 x .002	0.75 LONG	6
	108	256	700258-00	INTERCONNECT RIBBON, .10 x .002	7.25 LONG	5
	3	256	700259-01	CIRCUIT BUS RIBBON, .20 x .002	5.50 LONG	4
	50	285	700615-00	DOUBLE FACED MYLAR TAPE	.75" x .75"	3
	2	256	512489	CIRCUIT BUS RIBBON	-	2
	50	104	511866-2370-2	SOLAR CELL - 4.05 Ø	-	1
	QTY REQD	CODE SEES	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION		

PARTS LIST

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE
	-	RELEASED PER ECO 5E	7-22-81
	A	REVISED PER DRN 427	7-22-81

ARCO Solar, Inc.

CIRCUIT ASSY

SIZE D | DRAWING NO 012556 | REV A

SHEET 1 OF 1

- SOLDER PER SPEC 81-201
- LOCATE ITEM 3 AS SHOWN

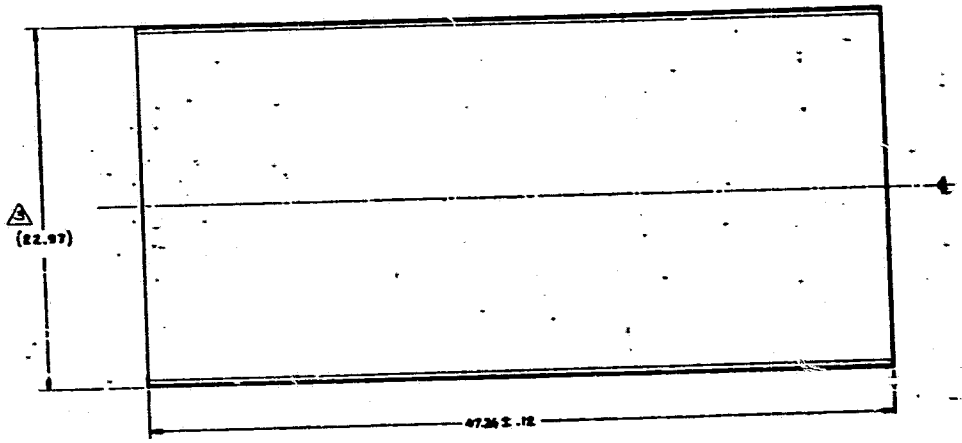
UNLESS OTHERWISE SPECIFIED

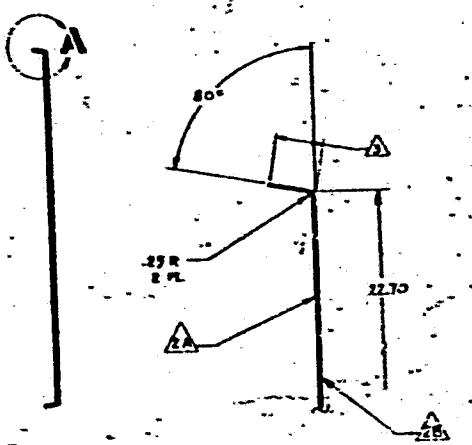
DO NOT SCALE DRAWING

APPLICATION

NEXT ASSY USED ON

REVISIONS			
PTR	LTR	DESCRIPTION	DATE
		LINE PER PROD PER EC 21	1-25-91
	A	REVISED PER EO 218	1-30-91





DETAIL A
SCALE : FULL

3 THE ACTUAL VALUE OF THE SIDE FLANGES TO BE DETERMINED BY THE WIDTH OF THE RAW STOCK (24.00 ±.06) AND THE PAN HELD TO 22.70 ±.03 - BOTH FLANGES TO BE EQUAL WITHIN ±.05.

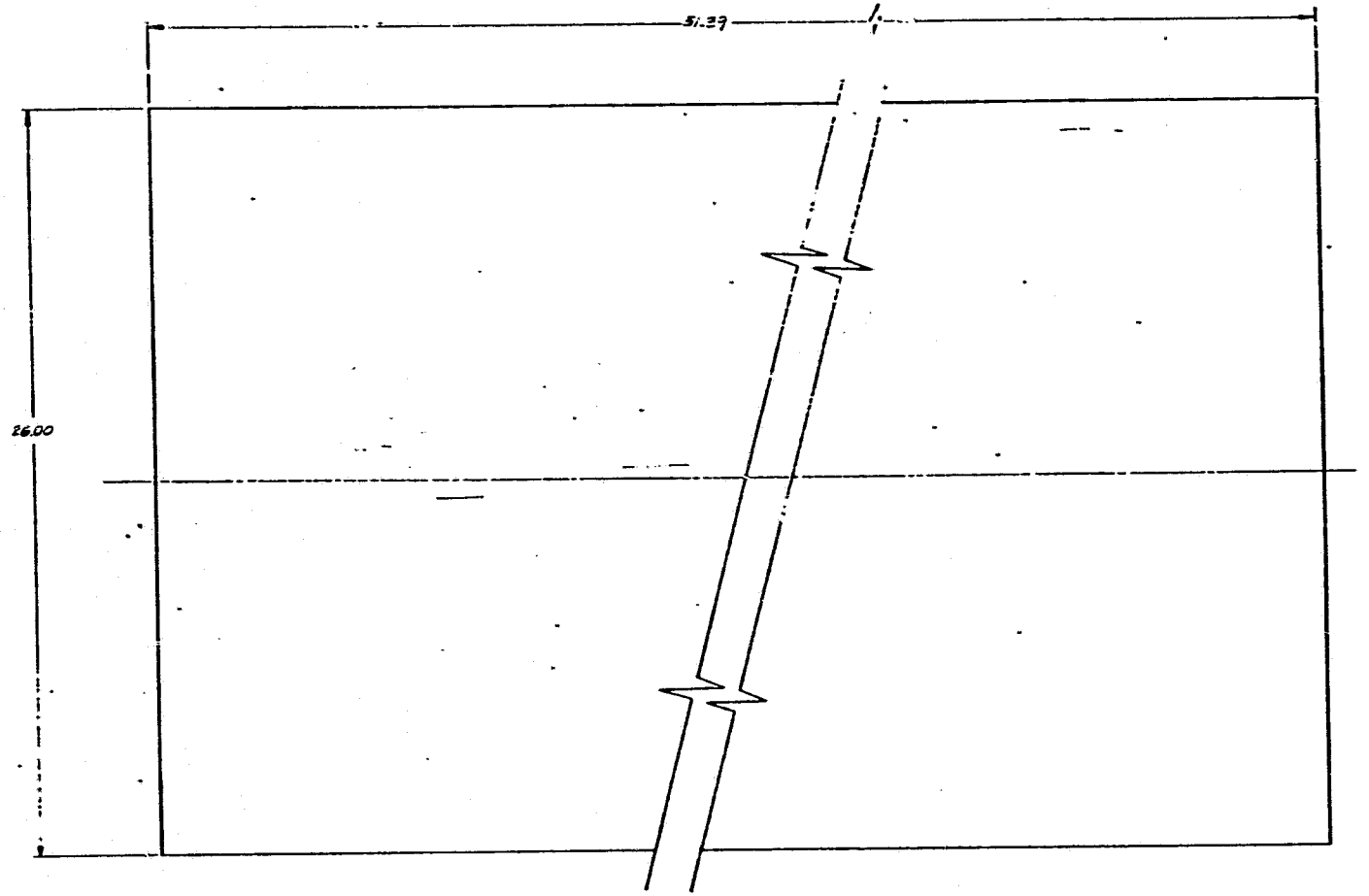
4 FINISH: A. BOND INSIDE OF PAN WITH .0015 THICK TEDLAR P/N E477C1249-00 FILM, COLOR CHARCOAL NO.15080 DCC
B. BACK SIDE TO HAVE A CLEAR EPOXY WASH .0004 THK. MAX.

1 MATERIAL: ZINC GALVANIZED STEEL SHEET PER ASTM-A-446, GRADE A, G-90

UNLESS OTHERWISE SPECIFIED

PARTS LIST

ARCO Solar, Inc.



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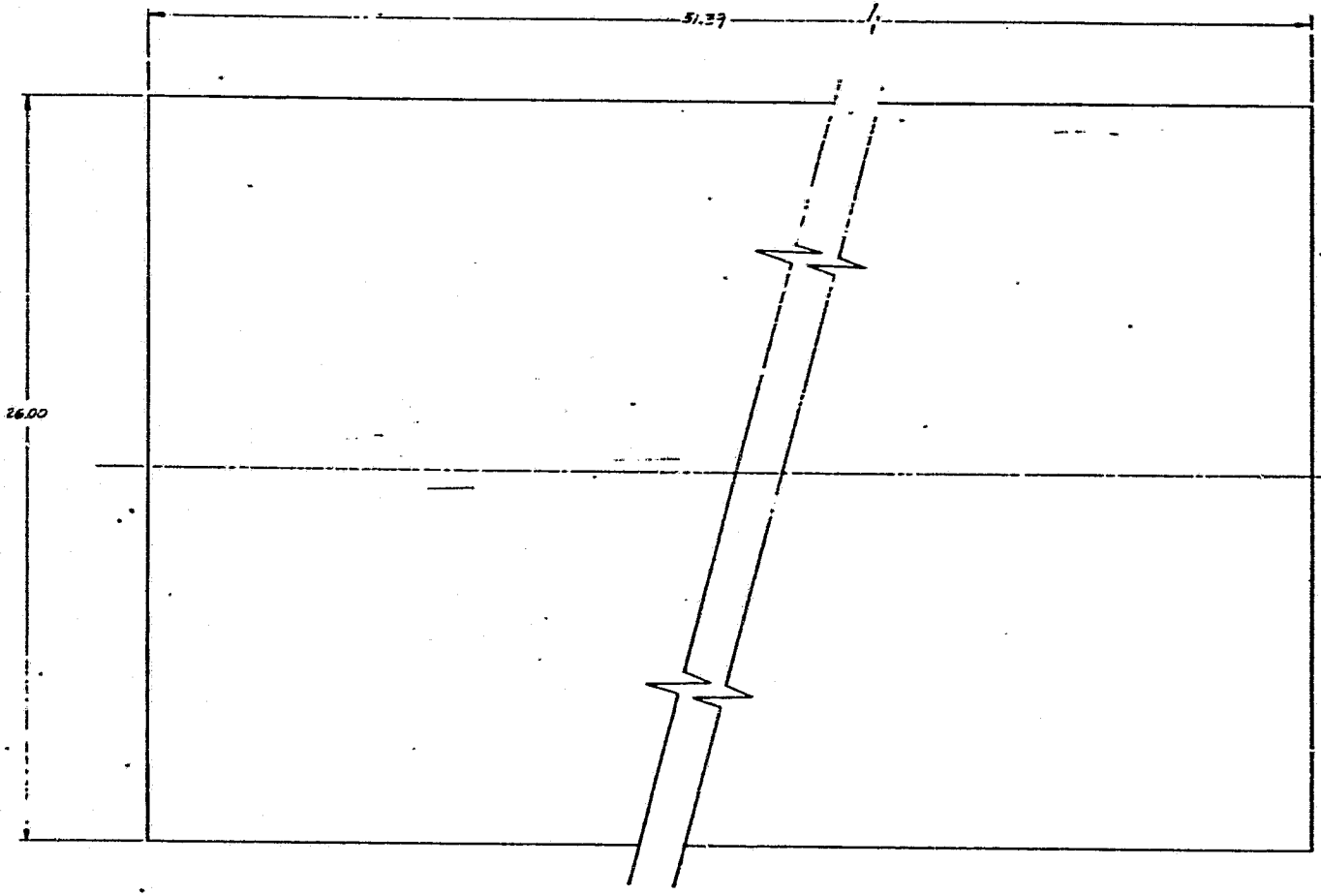
ARCO Solar, Inc.

TEDLAR LAMINATE FILM
RESIDENTIAL MODULE

D 244

C-12433

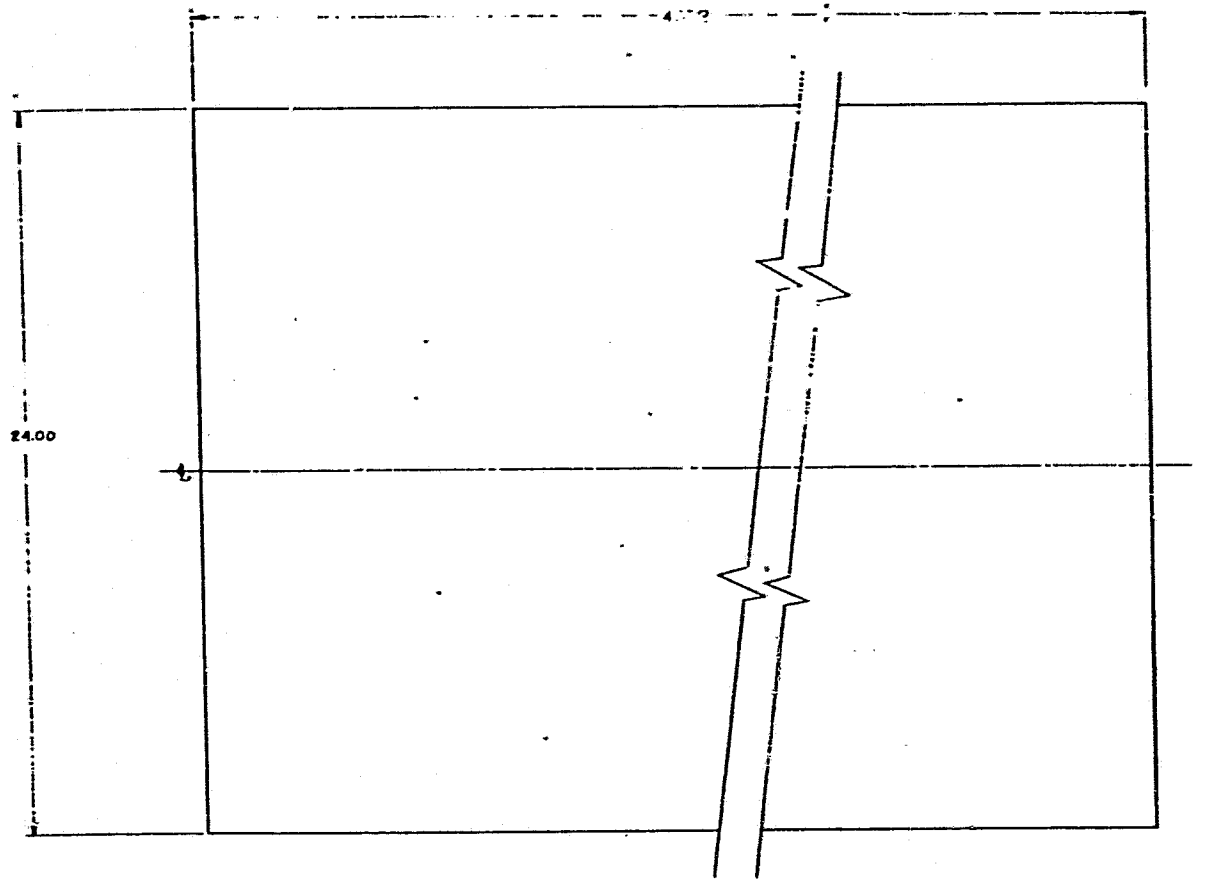


1. MATL: TEDLAR FILM CLEAR .004 THK
2. ALL DIMENSIONS SPECIFIED

ARCO Solar, Inc.

TEDLAR LAMINATE FILM
RESIDENTIAL MODULE

D 244



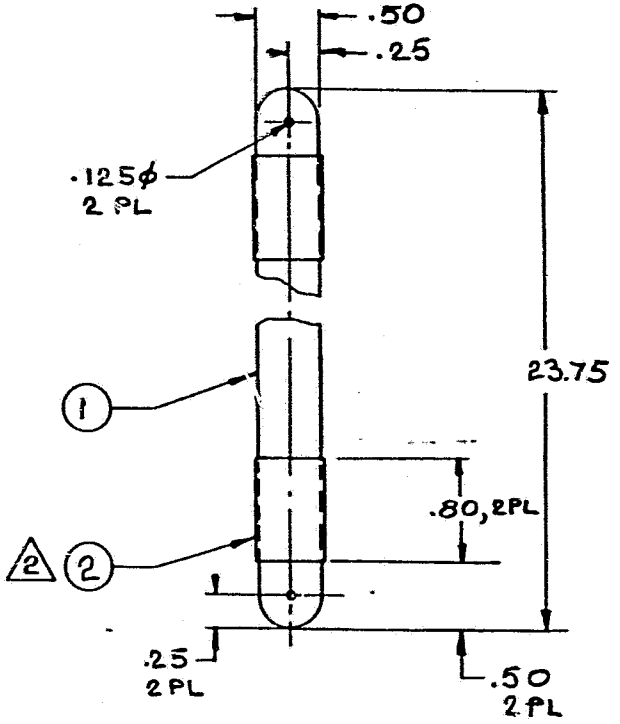
3 ARCO SOLAR PROPRIETARY COMPOUND
2 SOURCE: DU PONT CO
POLYMER PRODUCTS DEPT
WILMINGTON, DE
1 MATL: ETHYLENE VINYL ACETATE BASE RESIN 1.015 THICK
NOTES: UNLESS OTHERWISE SPECIFIED

ARCO Solar, Inc.

EVA ENCAPSULANT SHEET
RESIDENTIAL MODULE

D C12454

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	–	RELEASED PER ECO 213	1-30-81	
	A	REVISED PER ECO 246	2-26-81	
	B	REVISED PER DRN 417	7-14-81	



ITEM	QTY REQD	CODE	PART NO	DESCRIPTION	MATERIAL
1	1	256	700818-00	RIBBON	COPPER, .010 THK
2	2			ADHESIVE COATED TEDLAR	(3.0 x 1.0)

PARTS LIST

NOTES:
2. APPLY CLEAR TEDLAR (ITEM 2) WITH ADHESIVE SIDE TOWARD BUS RIBBON AS SHOWN
1. COPPER RIBBON WITH SOLDER FINISH PER SPEC 20-001

NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE –
FRACTIONS DECIMALS ANGLES
X = .03
BREAK ALL SHARP EDGES
REMOVE ALL BURRS
DIMENSIONS PER USAS Y 14.5
FINISH
DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS	DATE
DRAFTSMAN M TS	1-24-81
CHECKER	
DESIGNER	
ENGINEER T. Gilbert	7/27/81
APPROVED	

ARCO Solar, Inc.
Subsidiary of Atlantic Richfield Company
20554 Plummer Street Chatsworth California 91311 (213) 998-0667

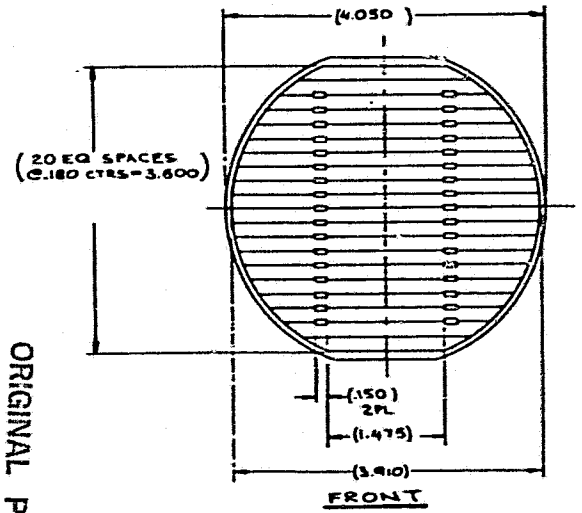
CIRCUIT BUS RIBBON

SIZE	FSCM NO.	DRAWING NO.	REV
B		012489	B

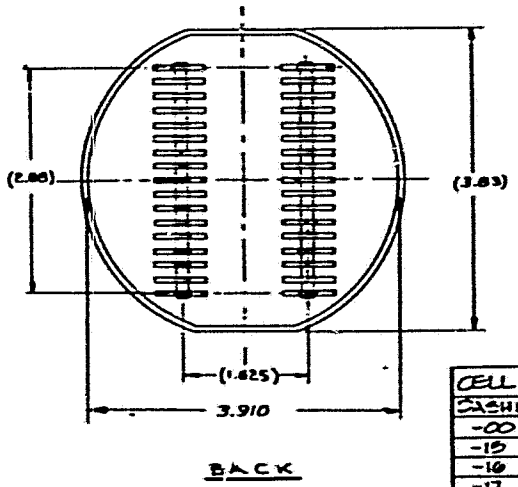
SCALE 1/1 WEIGHT SHEET 1 OF 1

011886

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	–	[illegible] PER ECO #29	7-6-80	
	A	REVISED PER DCN 239	2-20-81	
	B	REVISED PER DRN 425	7-13-81	



FRONT



BACK

CELL OUTPUT @ AM1 @ 25°C	
DASH NO	OUTPUT (AMPS)
-00	NO TEST
-15	1.599 AND LOWER
-16	1.600 TO 1.699
-17	1.700 TO 1.799
-18	1.800 TO 1.899
-19	1.900 TO 1.949
-20	2.000 TO 2.099
-21	2.100 TO 2.199
-22	2.200 TO 2.299
-23	2.300 TO 2.399
-24	2.400 AND HIGHER
-25	1.950 TO 1.999

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4. DAMAGE LIMITS PER SPEC 32-014
3. a. SOLDER SCREEN FRONT USING ARTWORK PER DWG 11428
   b SOLDER SCREEN BACK USING ARTWORK PER DWG 11432
2. a. SCREEN FRONT USING ARTWORK PER DWG 011550
   b ALUMINUM SCREEN BACK USING ARTWORK PER DWG 011657
   c. SILVER SCREEN BACK USING ARTWORK PER DWG 011655
1. MATERIAL: FABRICATE USING 011558 WAFER

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
PARTS LIST			

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE: ±
FRACTIONS DECIMALS ANGLES
X .XX ±
XX ±.01
XXX ±.005
BREAK ALL SHARP EDGES
.010 .030
REMOVE ALL BURRS
DIMENSIONS PER USASY14.5
FINISH

CONTRACT NO

APPROVALS	DATE
DRAFTSMAN M.T.S.	7-3-80
CHECKED Jerry Spencer	7/16/80
DESIGNED	
ENGINEER	
APPROVED	

ARCO Solar, Inc.

CELL – SOLAR 4.05 DIA
W/ ALUMINUM BACK

SIZE	ITEM NO	DRAWING NO	REV
C	104	011886	B

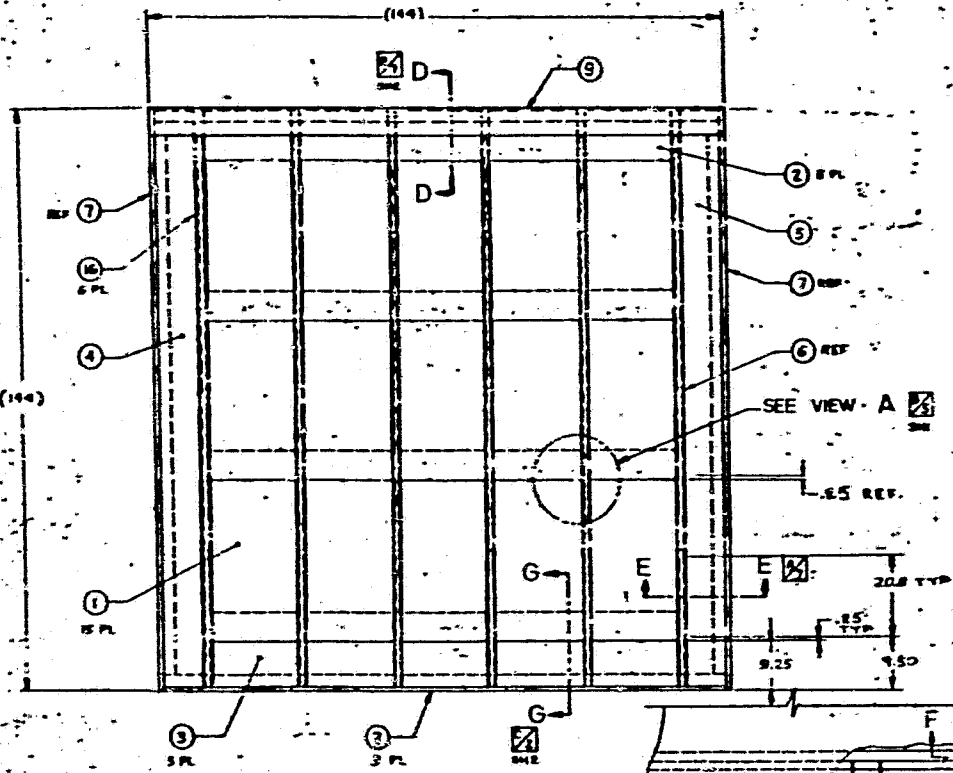
SCALE 1:1 WEIGHT SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	

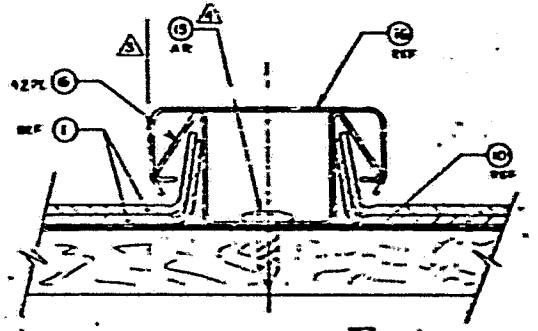
DO NOT SCALE DRAWING

011886

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE
	A	REVISED PER EC 005	
	B	REVISED PER EC 006	



PLAN VIEW



SECTION B-B

SCALE: 2/1

VIEW A

SCALE: 1/4

	6	220	011891-1	BATTEN	
	AR	320	700913-01	[illegible]	
	5	322	700914-02	STRIPE PAINT "PEEL"	
	30	322	700914-01	WIRE MARK (YELLOW)	
	6	210	011896	WIRE RACEWAY PLATE	
	1	210	012440	RIDGE COVER	
	1	210	012443	CLOSURE "2"	
	3	210	012444	STARTER	
	42	210	011890-1	CLIP BATTEN	
	1	210	012436	SIDE FLASH PANEL-RIGHT	
	1	210	012435	SIDE FLASH PANEL-LEFT	
	5	210	012438	FLASH PANEL-LOWER	
	5	210	012437	FLASH PANEL-UPPER	
	15	004	012421	[illegible]	
	QTY	SIZE	DRAWING OR SPECIFICATION	DESCRIPTION OR IDENTIFYING NO.	

PARTS LIST

- P AVERAGE - TBD
- S NOMINAL OPERATING VOLTAGE 24 V
- 4 SCREWS INSTALLED WITH IMPACT DRIVER
- 5 SHADOW CONSTRAINT 001
- 6 CAD PL STEEL, SUGGESTED SOURCE: DIAMOND TOOL SUPPLY
- 7 FIELDCUT FLANGES TO FIT STARTER (ITEM 7) OR CLOSURE (ITEM 8).

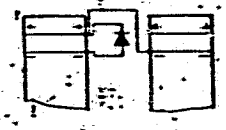
NOTES UNLESS OTHERWISE SPECIFIED

ARCO Solar, Inc.

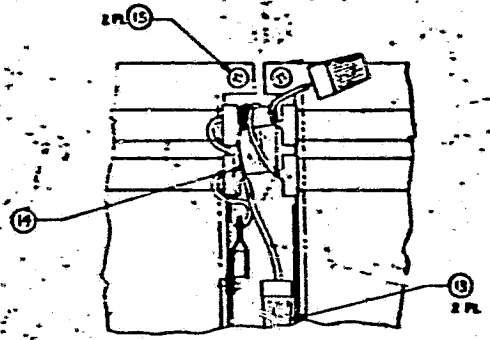
INTERFACE CONTROL DRAWING
ASI RESIDENTIAL MODULE
INSTALLATION

D 050 012441

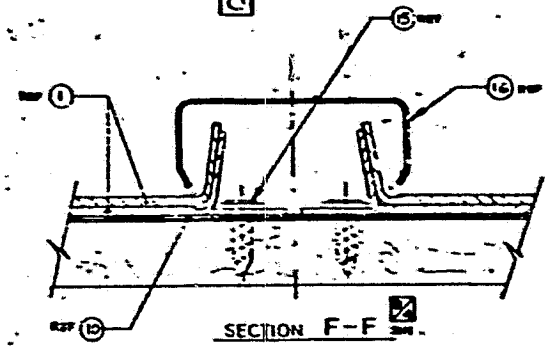
012441



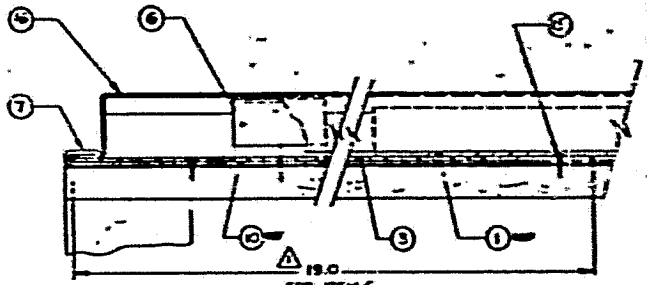
SCHEMATIC OF VIEW C



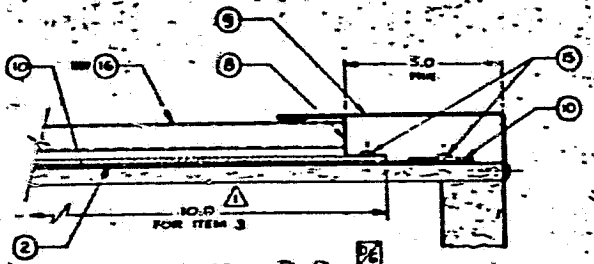
VIEW C
SCALE: FULL



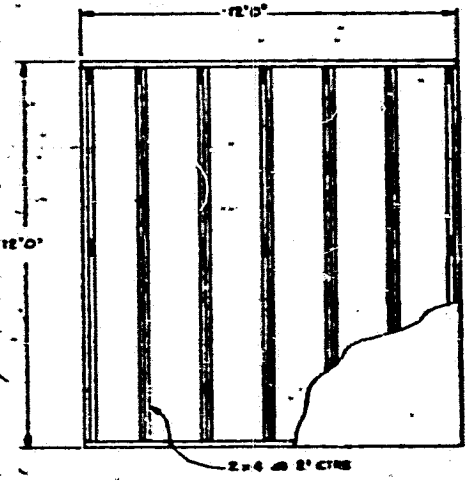
SECTION F-F
SCALE: 2/1



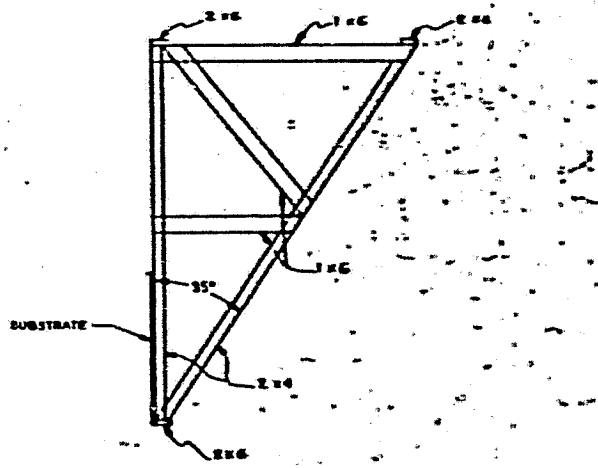
SECTION G-G
SCALE: NONE

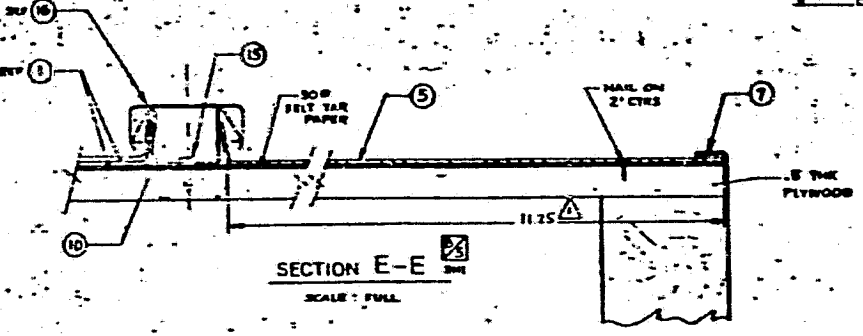


SECTION D-D
SCALE: 1/2
ROTATED 90°



TYPICAL SUBSTRATE SUPPORT FRAME
SCALE: 1/2" = 1'



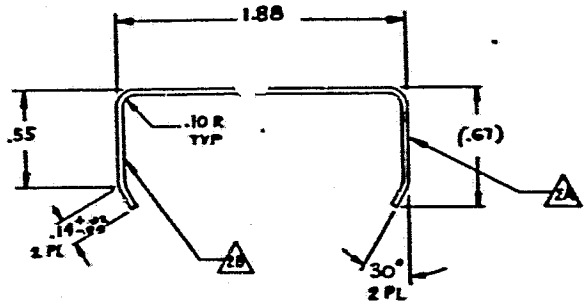


SECTION E-E
SCALE: FULL

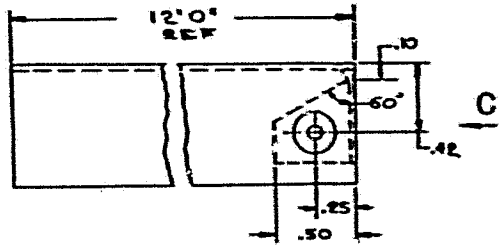
ARCO Solar, Inc.	
INTERFACE CONTROL DRAWING ASI RESIDENTIAL MODULE INSTALLATION	
SIZE D	012441

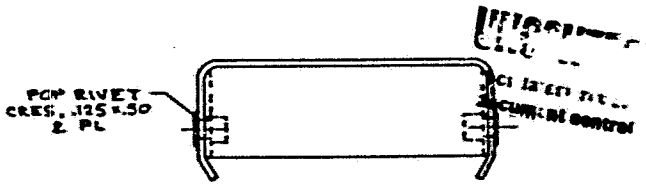
011690

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	B	REDRAWN WITH CHANGES PER E.O. 173	9-16-80	[illegible]
	C	REVISED PER EO 187	1-9-81	[illegible]
	D	REVISED PER EO 213	1-30-81	[illegible]



-02
(OPEN END)





VIEW C

-01
(CLOSED END)

4 SOURCE: ARCHITECTURAL END PRODUCTS
SAN DIEGO, CALIF

3. LENGTH OF BATTEN: 12'0" ± .12
CLOSED AT ONE END -01
OPEN AT BOTH ENDS -02

2 FINISH:
A. BOND OUTSIDE OF BATTEN WITH .0015 THICK TEDLAR FILM, COLOR CHARCOAL, NO. 1 SOBLEC
B. INSIDE TO HAVE A CLEAR EPOXY WASH, .0004 THK. MAX

1 MATL: 24 GAGE, ZINC GALVANIZED STEEL SHEET PER ASTM-A-446, GRADE A, G-90

NOTES: UNLESS OTHERWISE SPECIFIED

012078	HAWAII
012441	3 PL
012059	3 LONG T
011760	3 LONG T
NEXT ASSY	USED ON
APPLICATION	

QTY IN DD	ITEM NO	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
PARTS LIST			

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS 1/8 — DECIMALS X — XX = .03 XXX = — ANGLES X XX' = 1°
BREAK ALL SHARP EDGES C10 MAX
REMOVE ALL BURRS
DIMENSIONS PER USASY14.5
FINISH 2
DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS		DATE
DRAWN	N. S.	9-18-80
CHECKED	[illegible]	9-22-80
DESIGN	N. S.	9-18-80
ENGINEER	[illegible]	1-27-81
APPROVED	[illegible]	[illegible]

ARCO Solar, Inc.

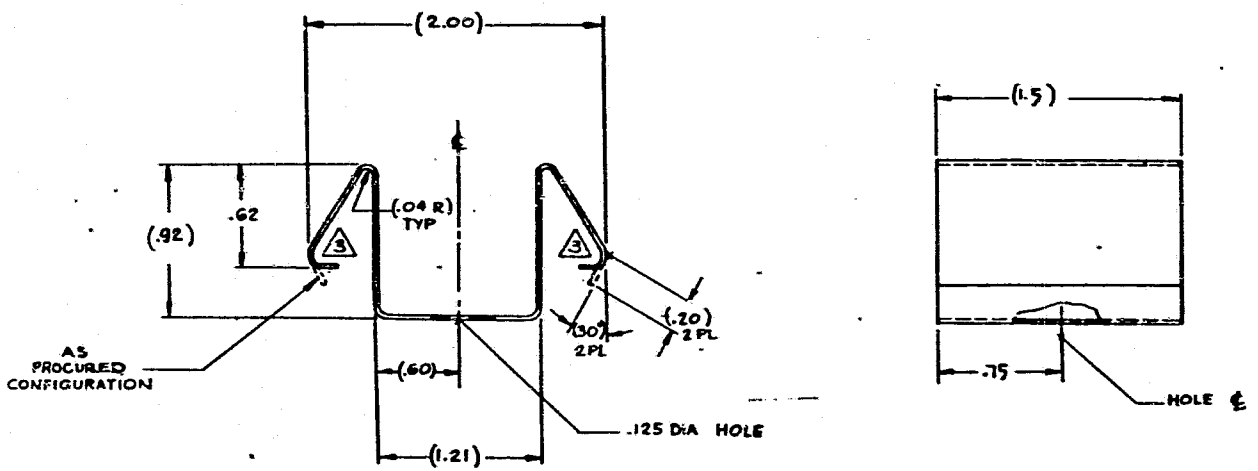
BATTEN
ASI RESIDENTIAL MODULE

SIZE	FSCM NO.	DRAWING NO.	REV.
C	270	011691	D

SCALE 2/1 WEIGHT — SHEET 1 OF 1

011690

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		RELEASE PER DRN 272	3-16-81	



—01 SHOWN

ALTERED PART

3 FORM TO SHAPE SHOWN.

2. SOURCE: ARCHITECHTURAL ENG. PRODUCTS SAN DIEGO, CA. PART NO. BC-1

1. MATL: . 24 GAGE ZINC GALVANIZED STEEL SHEET, PER ASTM-A-446, GRADE A, G-90

NOTES:

QTY REQD	FSCM NO.	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
			PARTS LIST
011760	1 LONG I		
012491	1 PL		

NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE: ±
FRACTIONS 1/X — DECIMALS X = .1 XX = .03 XXX = .010 ANGLES X XX° = 1°
BREAK ALL SHARP EDGES GID
REMOVE ALL BURRS
DIMENSIONING PER USASY14.5
FINISH

DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS	DATE
DRAFTSMAN Klaus C	2-4-80
CHECKER Larry Zerby	2/24/80
DESIGNER Klaus C	2-4-80
ENGINEER	2.19.80
	2.22.80
APPROVED	2-22-80

ARCO Solar, Inc.

BATTEN CLIP, ASI RESIDENTIAL MODULE

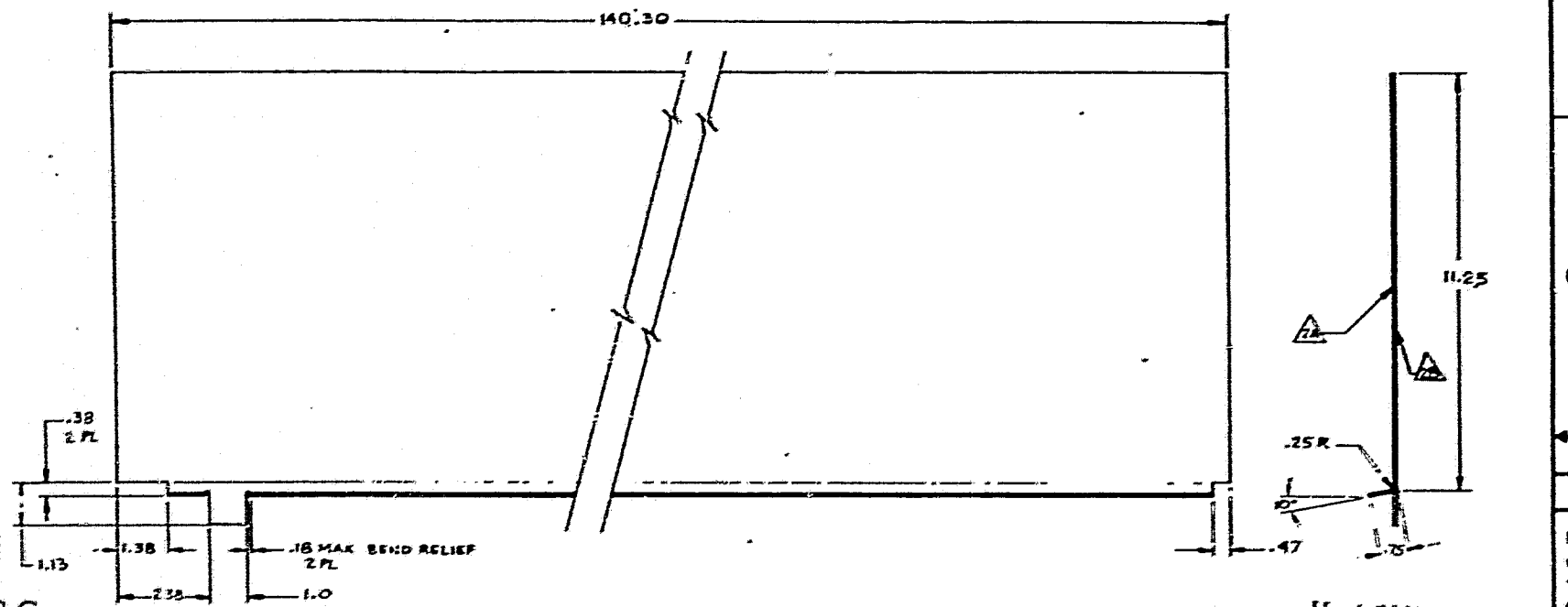
SIZE		DRAWING NO.	REV.
C	270	011690	—

SCALE 2/1 WEIGHT SHEET 1 OF 1

069110

012435

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		FOR PROD PER EO 127	1-5-87	
	A	REVISED PER EO 213	1-30-87	



QTY REQD	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
		PARTS LIST	

UNLESS DIMENSIONAL SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS ±
DECIMALS .X ±.1 .XX ±.05 .XXX ±
ANGLES ±
BREAK ALL SHARP EDGES .01 - .030 MAX
REMOVE ALL BURRS
DIMENSIONS PER ANSI Y14.5

CONTRACT NO

APPROVALS	DATE
DRAFTSMAN M.T.	12/2/87
CHECKED	
DESIGNED	
ENGINEER K. Gaston	12/2/87

FINISH: A

ARCO Solar, Inc.

SIDE BLANK PANEL - LEFT

SIZE	FSCM NO	DRAWING NO	REV
C	.10	012435	A

MATERIAL	PART NO
.051	BPL9402

APPLICATION

DO NOT SCALE DRAWING

SCALE 1 OF 1 SHEET 1 OF 1

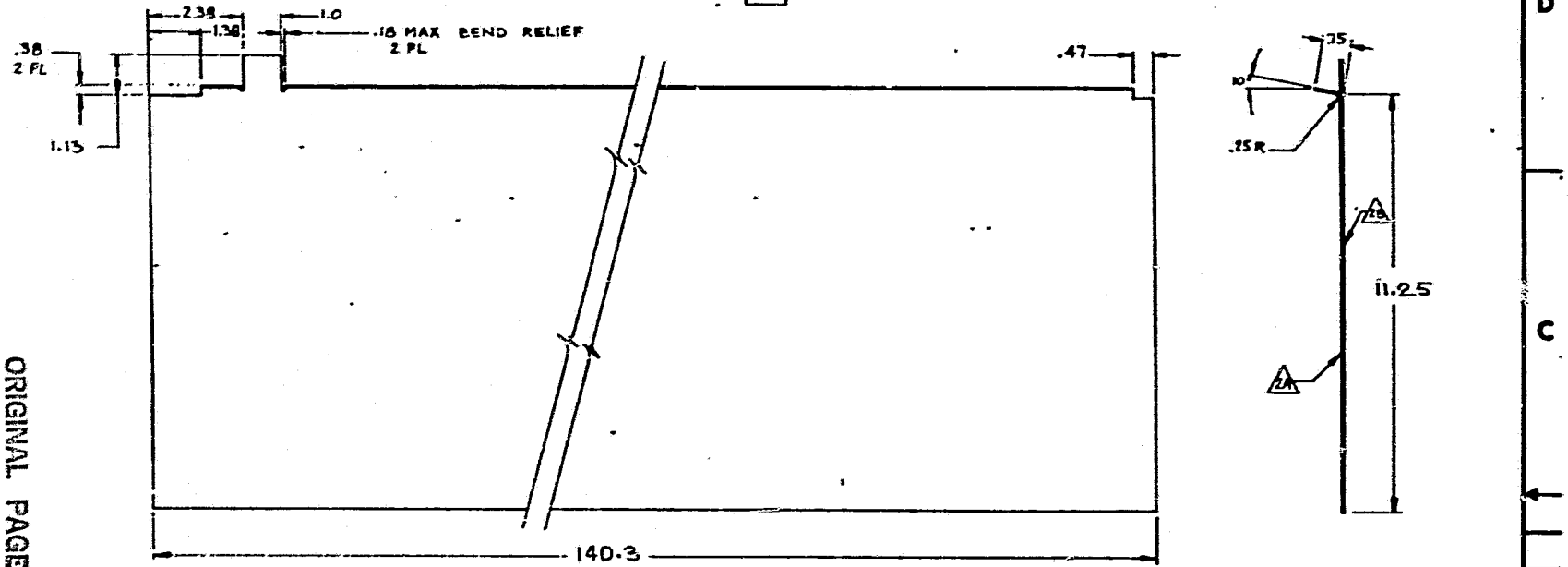
A
1. FINISH: A. BOND TOP OF PAN WITH .005 THICK TEDLAR FILM, COLOR CHARCOAL NO #30BL300
B. PAN SIZE TO MAKE A CLOSE FIT WITH THE MOD

1. 24 GAGE 5052 ANNEALED ALUMINUM SHEET PER ASTM-B-209, ALLOY 5052

NOTES: UNLESS OTHERWISE SPECIFIED

012436

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		RELEASE FOR PROD. PER EO 187	12-81	
	A	REVISED PER EO 213	1-30-81	



012436

QTY REQD	ITEM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION

PARTS LIST

FINISH: A BOND TOP OF PAN WITH 001STHK TEDLAR FILM, COLOR CHARCOAL NO.150BL30SC;
B BACK SIDE TO HAVE A CLEAR EPOXY WASH, 0002 THK MAX
1 24 GAGE [illegible]

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS DECIMALS ANGLES
BREAK ALL SHARP EDGES
REMOVE ALL BURRS
DIMENSIONS PER ANSI Y14.5
FINISH A
DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS	DATE
DRAFTSMAN	
CHECKER	
DESIGNER	
ENGINEER	12-31
APPROVED	1-6-81

ARCO Solar, Inc.

SIDE BLANK PANEL—RIGHT

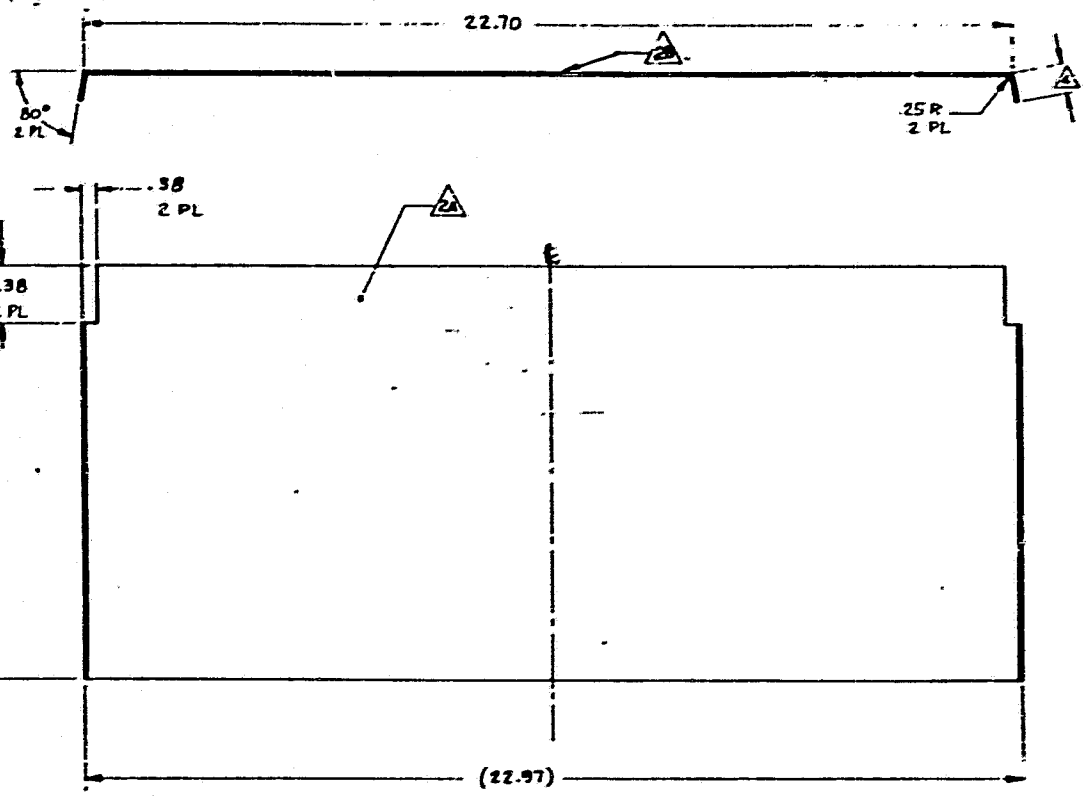
SIZE	FSCM NO	DRAWING NO	REV
C		012436	A

012491 PL05502
APPLICATION

SCALE [illegible] WEIGHT [illegible] SHEET 1 OF 1

012437

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		RELEASE FOR PROD PER EO 189	1-8-81	
	A	REVISED PER EO 213	3-31-81	



3. THE ACTUAL VALUE OF THE SIDE FLANGES TO BE DETERMINED BY THE WIDTH OF THE RAW STOCK ($24.00^{+.25}_{-.00}$) AND THE PAN HELD TO 22.70 ± .03. BOTH FLANGES TO BE EQUAL WITHIN ±.03.

2. FINISH: A BOND TOP OF PAN WITH .0015THK TEDLAR FILM, COLOR CHARCOAL NO 150BL30CC
   B BACK SIDE TO HAVE A CLEAR EPOXY WASH, .0004 THK MAX

1. 24 GAGE, [illegible] GALVANIZED STEEL SHEET [illegible] ASTM-A-526, GRADE A, [illegible]

UNLESS OTHERWISE SPECIFIED

QTY PER CAR	FSCM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
			PARTS LIST

DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS DECIMALS ANGLES
X ± .1
XX ± .03
XXX ±
BREAK ALL SHARP EDGES .010 .020
REMOVE ALL BURRS
DIMENSIONS PER USASY14.5

CONTRACT NO

APPROVALS	DATE
DRAFTSMAN C. Body	1/8/81
CHECKER	
STRESS	
ENGINEER K. Gruber	1/8/81
APPROVED	

ARCO Solar, Inc.

BLANK PANEL-UPPER

MATERIAL		
012391	SPEC 951252	
FINISH 3		
APPLICATION		

DO NOT SCALE DRAWING

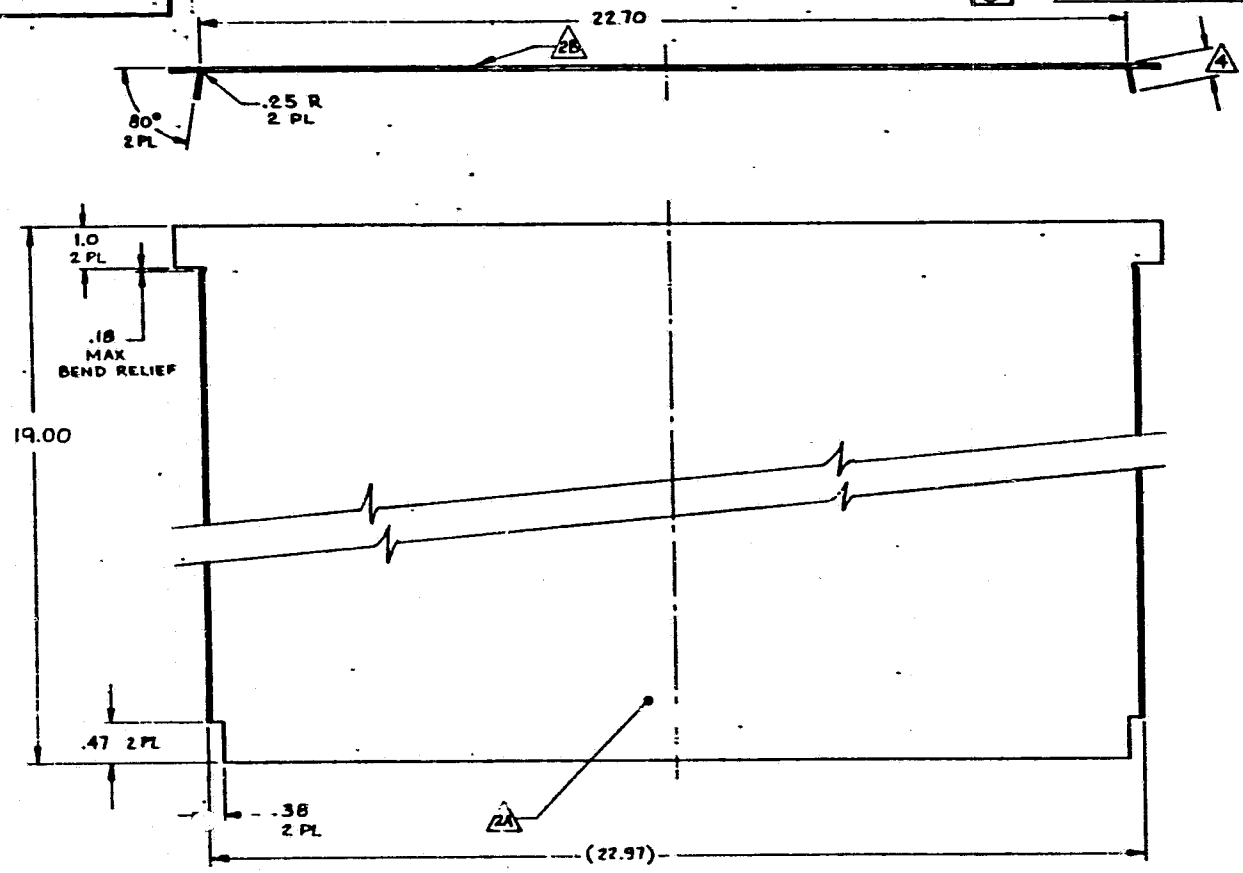
SIZE	DRAWING NO	REV
C	012437	A

SCALE 1/4 | SHEET 1 OF 1

012437

012438

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		RELEASE FOR PROD PER ECO 157	1-2-81	
	A	REVISED PER ECO 213	1-30-81	
	B	REVISED PER ECO 246	2-26-81	



3\ THE ACTUAL VALUE OF THE SIDE FLANGES TO BE DETERMINED BY THE WIDTH OF THE RAW STOCK (24.00 +.25 −.00) AND THE PAN HELD TO 22.10±.03. BOTH FLANGES TO BE EQUAL WITHIN ±.03

2\ FINISH: A. BOND TOP OF PAN WITH .005THK TEDLAR FILM, COLOR CHARCOAL NO.150BL30CC.

B. BACK SIDE TO HAVE A CLEAR EPOXY WASH, 1 MIL THK MAX.

1. MATL: 24 GAGE, [illegible] GALVANIZED STEEL SHEET TEL ASTM-A-446, GRADE 4, G-90

UNLESS OTHERWISE SPECIFIED

QTY REQD	FSCM NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION
			PARTS LIST

012441	JPL9[illegible]472	
NEXT ASSY	USED ON	
APPLICATION		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS 1/X — DECIMALS X .1 XX .03 XXX — ANGLES X° X'' X'''
BREAK ALL SHARP EDGES .010 REMOVE ALL BURRS
DIMENSIONS PER USASY14.5
FINISH 3
DO NOT SCALE DRAWING

CONTRACT NO

APPROVALS	DATE
DRAFTSMAN [illegible]	12-3-80
CHECKER	
DESIGNER	
ENGINEER [illegible]	[illegible]
APPROVED [illegible]	[illegible]

ARCO Solar, Inc.

BLANK PANEL — LOWER

SIZE	FSCM NO	DRAWING NO	REV
C	270	012438	C

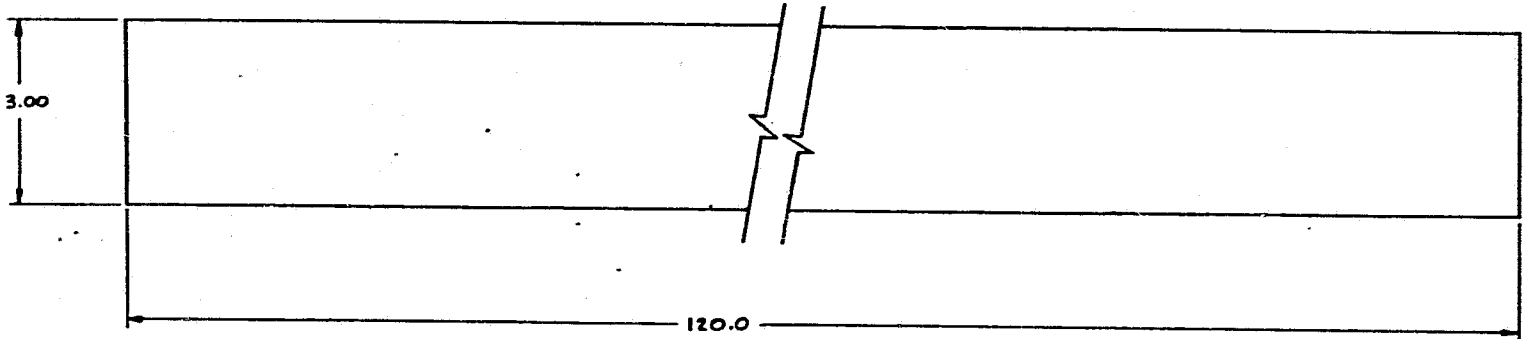
SCALE [illegible] WEIGHT SHEET 1 OF 1

012438

ORIGINAL PAGE IS
OF POOR QUALITY

011796

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		RELEASE PER DRN 272	3-16-81	



QTY REQD	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
			PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE ±
FRACTIONS 1/X — DECIMALS X .1, XX .05, XXX .010 ANGLES X XX' —
BREAK ALL SHARP EDGES .010 .030
REMOVE ALL BURRS
DIMENSIONS PER USASI Y14.5
FINISH
DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS		DATE
DRAFTSMAN	Kim S.	5-6-80
CHECKER	[illegible]	2-17-81
DESIGNER	K. S.	5-6-80
ENGINEER	[illegible]	2-17-81
APPROVED	[illegible]	1-7-81

ARCO Solar, Inc.

WIRE RACEWAY PLATE, RESIDENTIAL MODULE

SIZE	FSCM NO.	DRAWING NO.	REV.
C	270	011796	—

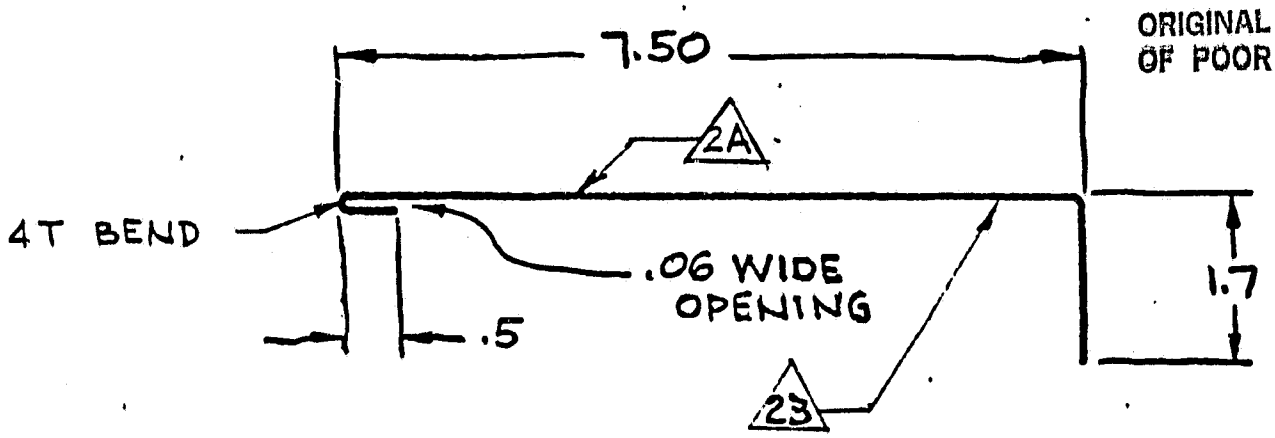
SCALE FULL SIZE WEIGHT SHEET 1 OF 1

011760	J LONG I
C - - 1	JPL
NEXT ASSY	USED ON
APPLICATION	

1. MATL: . 24 GAGE ZINC GALVANIZED STEEL SHEET PER ASTM-A-446, GRADE A, G-90

NOTES: UNLESS OTHERWISE SPECIFIED

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
			RLSE. FOR PROD PER EO 187	1-8-81	
		A	REVISED PER EO 213	1-31-81	



ORIGINAL PAGE IS OF POOR QUALITY

3. LENGTH : 12' 0"

2. FINISH : A. .0015 THICK TEDLAR FILM, COLOR LEAD CHARCOAL #150BL30CC ON SIDE SHOWN

B. OPPOSITE SIDE TO HAVE A CLEAR EPOXY WASH .0004 THICK MAX.

1. MATERIAL : 24 GAGE STEEL SHEET PER ASTM-A-446-76 GRADE "A" G-90 ZINC GALVANIZED

NOTES ! UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOL RANGES ARE ±
FRACTIONS DECIMALS ANGLES
1/X .X ±
.XX ±
.XXX ±.03

BREAK ALL SHARP EDGES
REMOVE ALL BURRS
DIMENSIONS PER USAS Y 14.5

FINISH

NEXT ASSY | USED ON

CONTRACT NO.

APPROVALS	DATE
DRAFTSMAN M. JS.	12-30-80
CHECKER	
DESIGNER	
ENGINEER Cramer	1-8-81

ARCO Solar, Inc.

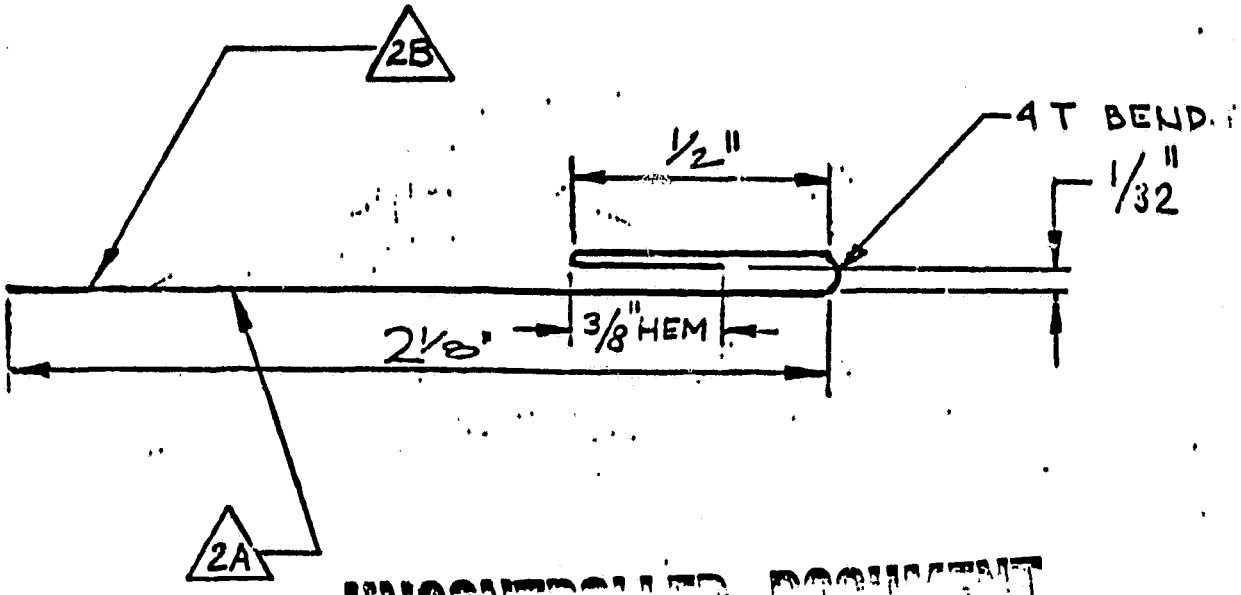
RIDGE COVER

SIZE	DRAWING NO.	REV
A	270 012440	A

SCALE 1/2 WEIGHT SHEET OF

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
012441	J.P.L.		REL FOR PROD PER EO 192	1-8-81	
		A	REVISED PER EO 213	1-31-81	

ORIGINAL PAGE IS
OF POOR QUALITY



3. LENGTH: 12'0"

2. FINISH: A. .0015 THICK TEDLAR FILM, COLOR CHARCOAL No.150BL30CC ON SIDE SHOWN.
B. OPPOSITE SIDE TO HAVE A CLEAR EPOXY WASH .0004 THICK MAX.

1. MATERIAL: 24 GAGE STEEL SHEET PER ASTM-A-446 GRADE A, G-90 ZINC GALVANIZED.

NOTES: UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE: ±
FRACTIONS 1/X ± 1/16 | DECIMALS X.X ± .1, X.XX ± .01, X.XXX ± .005 | ANGLES X° ± 1°

BREAK ALL SHARP EDGES .010 - .030
REMOVE ALL BURRS
DIMENSIONS PER USASI Y 14.5

FINISH 2

DO NOT SCALE DRAWING

CONTRACT NO.

APPROVALS	DATE
DRAFTSMAN R.S.	5-8-80
CHECKER	
DESIGNER	
ENGINEER	1-8-81
	1-9-81

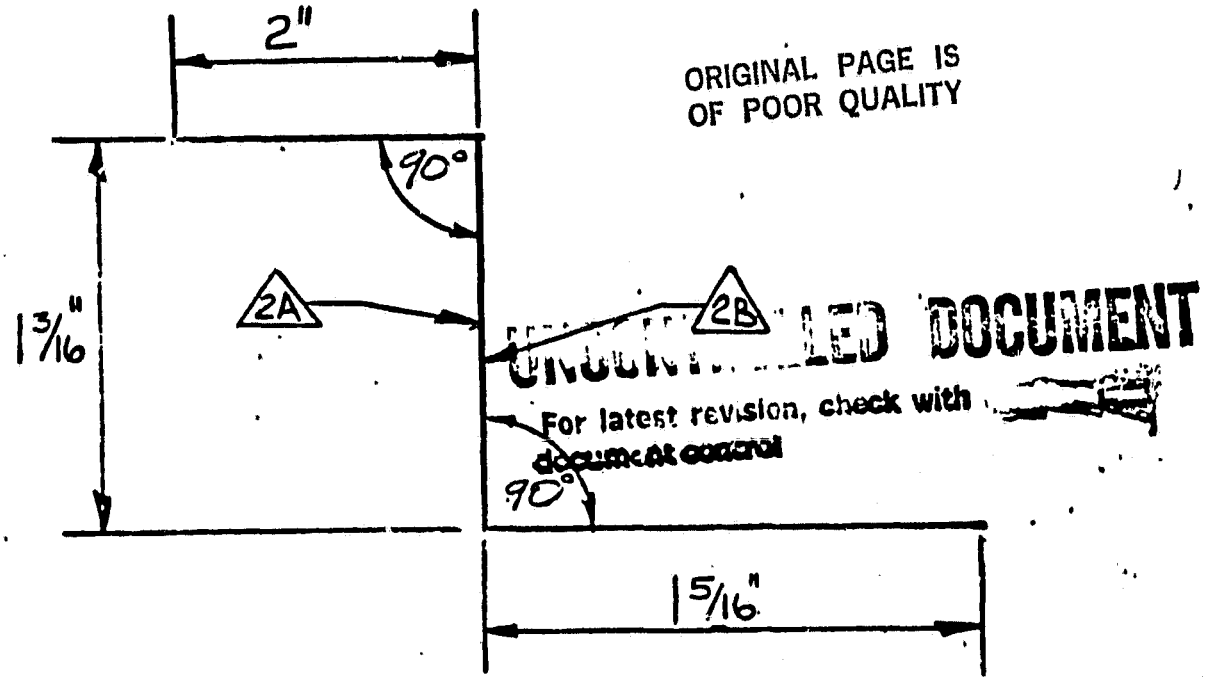
ARCO Solar, Inc.
Subsidiary of Atlantic Richfield Company
20554 Plummer Street Chatsworth California 91311 (213) 998-0551

STARTER

SIZE	FSCM NO.	DRAWING NO.	
A	270	012444	A

SCALE NONE | WEIGHT | SHEET 1 OF 1

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
012441	JPL		REL. FOR PROD. PER EO 192	1-8-81	DWH
		A	REVISED PER EO 213	1-30-81	E.H.B.



3. LENGTH: 12' 0"

2. FINISH: A. .0015 THICK TEDLAR FILM, COLOR CHARCOAL #150BL30CC ON SIDE SHOWN.
B. OPPOSITE SIDE TO HAVE A CLEAR EPOXY WASH .0004 THICK MAX.

1. MATERIAL: 24 GAGE STEEL SHEET PER ASTM-A-446-76 GRADE "A" G-90 ZINC GALVANIZED.

NOTES:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE. FRACTIONS DECIMALS ANGLES 1/X X .X ± X XX ± .XX ± .XXX ±	CONTRACT NO.		ARCO Solar, Inc. Subsidiary of Atlantic Richfield Company 20554 Plummer Street Chatsworth California 91311 (213) 998-0667
	APPROVALS	DATE	
	DRAFTSMAN M.T.	1/8/81	'Z' CLOSURE
	CHECKER		
BREAK ALL SHARP EDGES .01C .03D REMOVE ALL BURRS DIMENSIONS PER USASI Y 14.5	DESIGNER		
	ENGINEER	1-8-81	SIZE A · FSCM NO. 270 · DRAWING NO. 012443 · REV A
FINISH	APPROVED	1-8-81	SCALE · WEIGHT · SHEET 1 OF 1
DO NOT SCALE DRAWING			