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Quarterly Technical Report

No. 6329-6

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

September 30, 1982

Contract 956205

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Approved by:

Nick Mardesich
Manager, Advanced Programs

SPECTROLAB, INC.
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Sylmar, California 91342

November 1982

The 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.

ABSTRACT/SUMMARY

Solar cells without AR coating achieved efficiencies of 10.5% with the Type A Mo/Sn/TiH paste. Curve shape, series resistance, and shunt resistance are all excellent and comparable to silver paste controls. Other pastes were not successful.

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Section 1.0

INTRODUCTION

The objective of this contract is the optimization, evaluation, and demonstration of a novel metallization applied by a screen printing process. The process will be evaluated on both CZ and non-CZ silicon wafers.

Section 2.0

TECHNICAL DISCUSSION

Procurement delays and vendor error delayed the receipt of square pattern screens. The inefficient round pattern was used to test additional paste formulation.

The pastes are 80-85% solids using vehicle #3347. The metal content in parts by weight follows:

Type	TFS #	Sylvania 280-325 Mo	Atlantic Equipment Engineers SN 266 Sn	Ferro Plant PX-41 TiH
A	DP-E570	19.5	80.0	0.5
B	DP-E571	50.0	49.5	0.5
C	DP-E572	70.0	29.5	0.5
D	DP-E573	49.0	49.0	2.0
E	DP-E574	48.0	48.0	4.0

Eight cells of each paste type as well as silver controls were manufactured. The cells of each type were divided into four groups (of 2 each). The four groups were processed as follows:

1) 18"/1 min. 500°C prefire, 1 min. 575°C H_2 fire
2) 18"/min. 500°C prefire, 1 min. 600°C H_2 fire
3) 9"/min. 500°C prefire, 1 min. 575°C H_2 fire
4) 9"/min. 500°C prefire, 1 min. 600°C H_2 fire

The results of this matrix are shown in Table 1. The best silver control had V_{oc} = 601, I_{sc} = 700, I_{500} = 500, and I_{450} = 586.

Table 1

Paste Type	Pre-Fire Speed @ 500°	Fire Temp. @ 1 min.	Cell #	V_{oc}	I_{sc}	I_{500}	I_{450}
A	9"	575	1	600	701	482	569
A	9"	575	2	598	677	390	490
A	9"	600	3	601	700	469	553
A	9"	600	4	597	696	458	548
A	18"	575	5	603	702	450	543
A	18"	575	7	599	560	286	359
A	18"	600	6	598	701	440	530
A	18"	600	8	602	703	461	550
B	9	575	9	600	687	377	488
B	9	575	11	598	676	297	398
B	9	600	10	600	689	369	478
B	9	600	12	597	644	282	371
B	18	575	13	602	681	345	451
B	18	575	14	602	681	331	438
B	18	600*	15	598	686	409	515
B	18	600*	16	596	692	389	497
C	9	575	20	594	617	194	266
C	9	575	17	589	369	109	150
C	9	600	19	592	668	246	345
C	9	600	18	587	300	90	123
C	18	575	21	597	684	305	415
C	18	575	23	598	667	285	388
C	18	600	22	600	687	350	463
C	18	600	24	596	680	347	453
D	9	575	26	598	684	330	447
D	9	575	25	599	681	320	429
D	9	600	28	598	676	328	435
D	9	600	27	599	678	351	455
D	18	575	31	596	686	346	464
D	18	575	29	598	682	336	448
D	18	600	32	601	691	378	441
D	18	600	30	600	694	393	502
E	9	575	33	596	668	260	356
E	9	575	34	596	639	229	312
E	9	600	35	596	674	265	363
E	9	600	36	598	677	262	417
E	18	575	37	597	672	295	396
E	18	575	38	598	669	286	385
E	18	600	39	597	690	333	440
E	18	600	40	600	685	318	420

These cells have no AR coating. The best silver solar cell has an efficiency of 9.3% and a fill factor of 0.627. The best Mo/Sn, Cell #1 from Group A has a fill factor of 0.609 and an efficiency of 9.0%. If the cells were AR coated, efficiency would rise to ~ 12.3% and 11.9% respectively.

From these results it was decided to continue work using only Type A paste. Four-inch screens were received but were of poor quality. Additional screens were ordered.

A lot of cells was processed using the screens. The front pattern metallization is shown in Figure 1. Cells were prefired at 500-550°C at a belt speed of 18" minutes. They were then fired at 575°-625° for 39-90 seconds. Silver controls were processed at the same time.

Figures 2 and 3 show the best Mo/Sn and Ag cells. The Mo/Sn cell was made using paste Type A with a 200 mesh 1 mil emulsion screen. The Ag cell was made with the same screen. The Mo/Sn cell was prefired at 500°C in an 18" zone at 18"/min. belt speed. It was then fired in H_2 for 90 seconds at 600°C.

The Mo/Sn metallization has a blue-gray color after the prefire which becomes metallic after firing similar to screen-printed silver. If the prefire is at a lower temperature, the initial color is brown and cells show more series resistance.

The two cells shown in Figure 2 have the following characteristics:

Cell		V_{oc}	I_{sc}	I_{500}	P_{max}	FF	E
1728M-90	(Mo/Sn)	.601	.678	.596	.229	.73	10.5%
1728M-72	(Ag)	.601	.680	.600	.302	.74	10.6%

Neither cell has an AR coating.

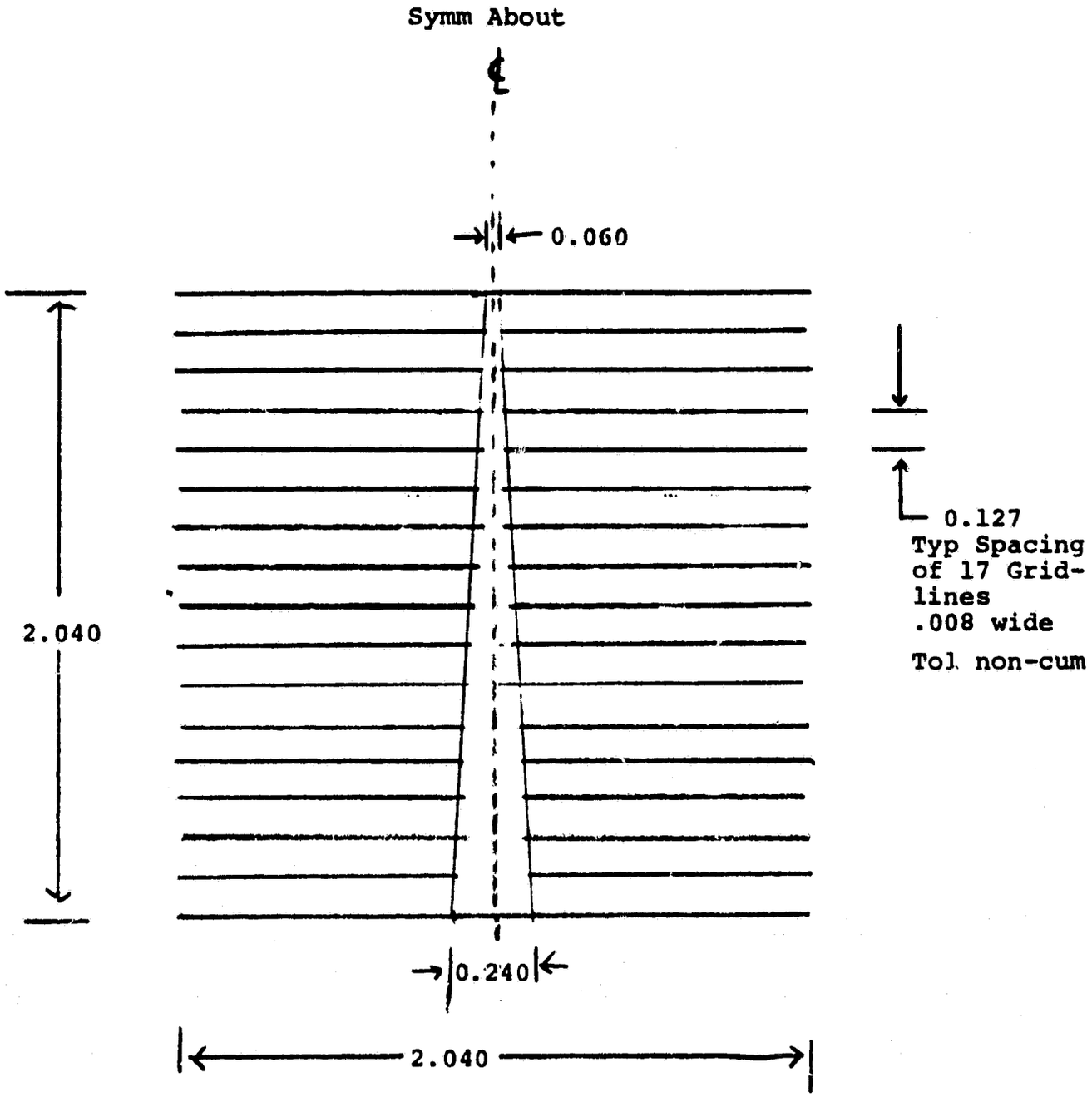
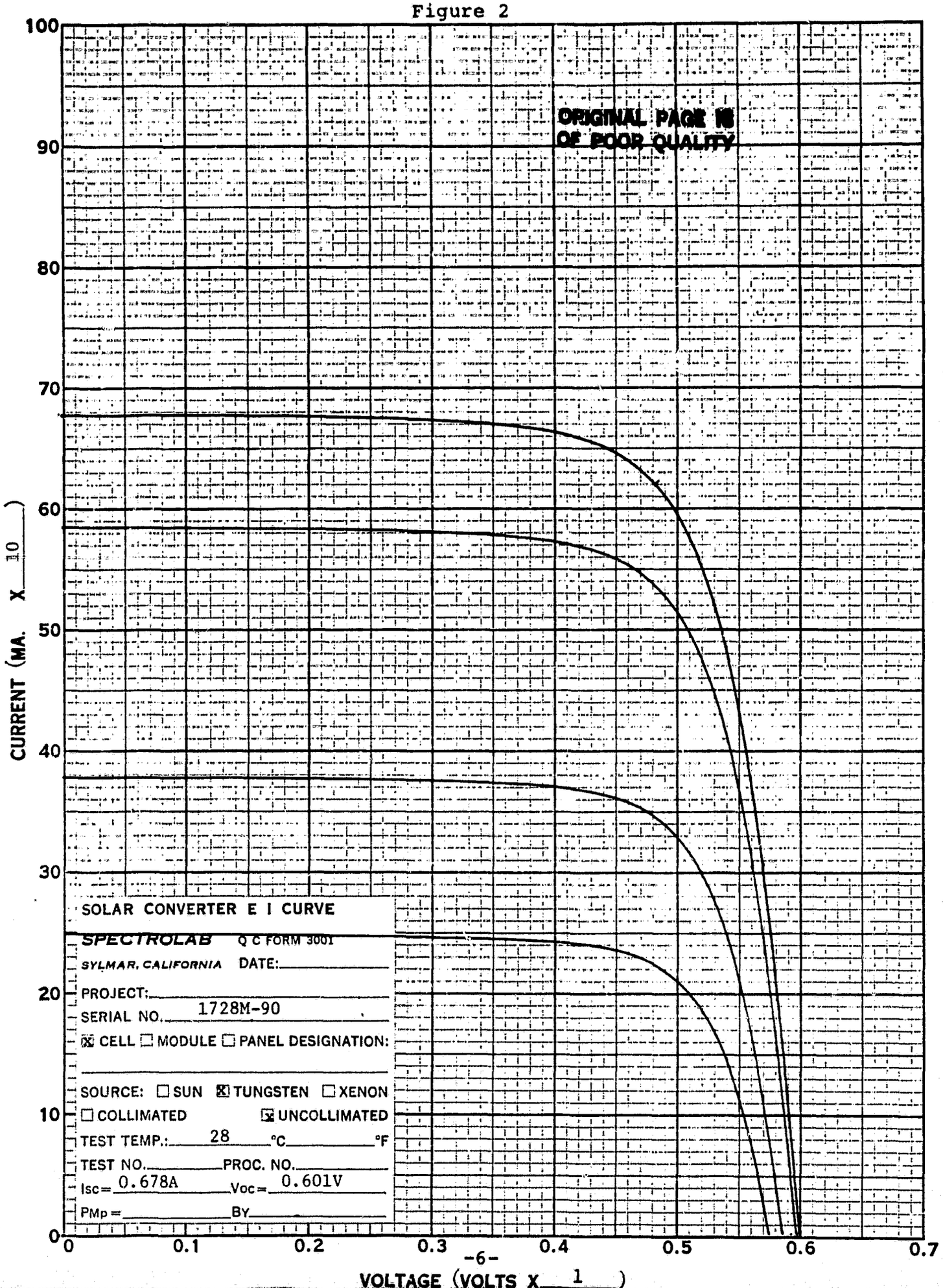


Figure 1

FRONT METALLIZATION PATTERN

Figure 2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VOLTAGE (VOLTS X 1)
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0.1
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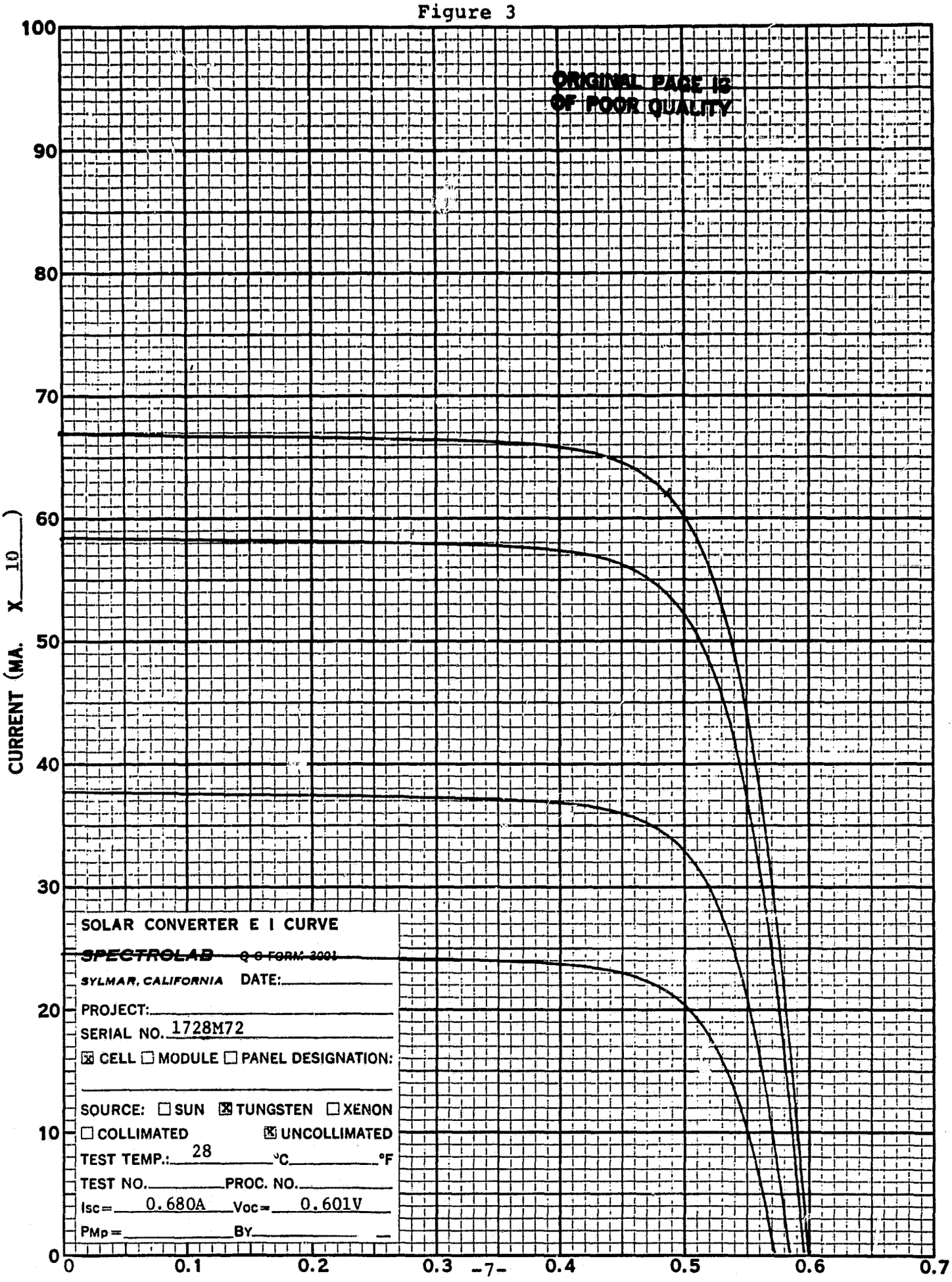
0.3
0.4
0.5
0.6
0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO. 1728M-90
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☒ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc = 0.678A Voc = 0.601V
PMp = BY

Figure 3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0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO. 1728M72
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☒ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc= 0.680A Voc= 0.601V
PMp= BY

Section 3.0

CONCLUSIONS AND RECOMMENDATIONS

Work will continue exclusively on the Type A paste. Cells made with this paste have characteristics almost identical to silver paste cells.

Section 4.0

ACTIVITIES PROJECTION

At the request of JPL the contract was redirected to include the evaluation of indium tin oxide (ITO) conductive AR coatings. This evaluation necessitated a no-cost extension of the contract. A new Milestone Chart and Deliverable Schedule is shown on the following page.

SPECTROLAB
a subsidiary of Hughes Aircraft Co

MILESTONE CHART AND DELIVERY SCHEDULE

SHEET 1 OF 1
DATE 11/24/82
REVISION 1

ITEM OR TASK	DESCRIPTION
	Final Mo/Sn Metallization Selected
	Prototype Cells Fabricated
	Front Soldering Process Finalized
	Front Demonstration Cells Fabricated
	ITO on Metal Initial
	Prototype Cells ITO on Metal
	Metal on ITO Initial
	Prototype Metal on ITO Cells
	Initiate Metallization Tests
	Finish Metallization Tests
	Metallization System on WEB
	Metallization System on Semix
	Program Plan
	Monthly - Technical
	Monthly - Financial
	Quarterly - Technical
	Final
	Documentation Specification
	Economic Evaluation

A M J J A S O N D J F M A M J J A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Draft
Final

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NOTES

CUSTOMER JPL

PROGRAM METALLIZATION PROCESS

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