

DRL 175

DOE/JPL-956205-83/4
Distribution Category UC-63

Quarterly Technical Progress Report

No. 6329-15

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

June 30, 1983

Contract 956205

Prepared by:

Alexander Garcia III

Approved by:



Nick Mardesich
Manager, Advanced Programs

SPECTROLAB, INC.
12500 Gladstone Avenue
Sylmar, California 91342

August 1983

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.

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

ABSTRACT/SUMMARY

A non-lead frit paste was received from Thick Film Systems Inc. and evaluated. The results were not promising. Additional work was done on a two-step process where the bulk of the metallization is Mo/Sn but a small ohmic pad is silver. This approach was successful. A new matrix of paste formulations was developed with JPL and Electrink, Inc. personnel. A series of 12 pastes was ordered from Electrink, Inc.

Section 2.0

TECHNICAL DISCUSSION

A non-lead frit paste was ordered from Thick Film Associates #DP-F523. The paste was the same as the Type F paste except the new frit was substituted for the old type. Table 1 shows the characteristics of cells made with this paste. Figures 1-4 show Cells 83, 79, 81, and 85, respectively. As the time of sintering lengthened from 1.5, 5, 10, to 15 minutes at 600°C, the cells first improve as the series resistance decreases, then degrade as shunting occurs. Lower sintering temperatures led to very high series resistance and poor electrical characteristics (Figure 5). Soldering was unsuccessful on these cells.

Thick Film Systems would not supply exact formulations of their proprietary frits. Future pastes will be ordered from Electrink who have agreed to furnish exact formulations.

In view of the difficulties in soldering to the Mo/Sn pastes several experiments were conducted using a two step screen-printing procedure. One step would put down a small silver paste soldering pad and the other the Mo/Sn grid pattern.

The first experiment was done using paste F503. The cells were printed with the front metallization pattern missing the ohmic pad. The 600°C prefire at 18"/min. was then performed. Silver paste was printed on the ohmic pads overlapping the Mo/Sn paste. The cells were fired in the IR furnace at 48"/min. with an 18" zone at 400°C and a 24" zone at 750°C. The cells were next

Table 1

<u>Cell</u>	<u>Prefire</u>		<u>Gas</u>	<u>Fire</u>		<u>V_{oc}</u>	<u>I_{sc}</u>	<u>I₅₀₀</u>
	<u>Temp.</u>	<u>Belt</u>		<u>Temp.</u>	<u>Time</u>			
41082-70	600	18	H ₂	600	1.5	593	643	351
41082-79	600	18	H ₂	600	5.0	595	646	416
41082-81	600	18	H ₂	600	10.0	591	665	360
41082-85	600	18	H ₂	600	15.0	592	667	353
41082-83	600	18	H ₂	550	15.0	580	654	291

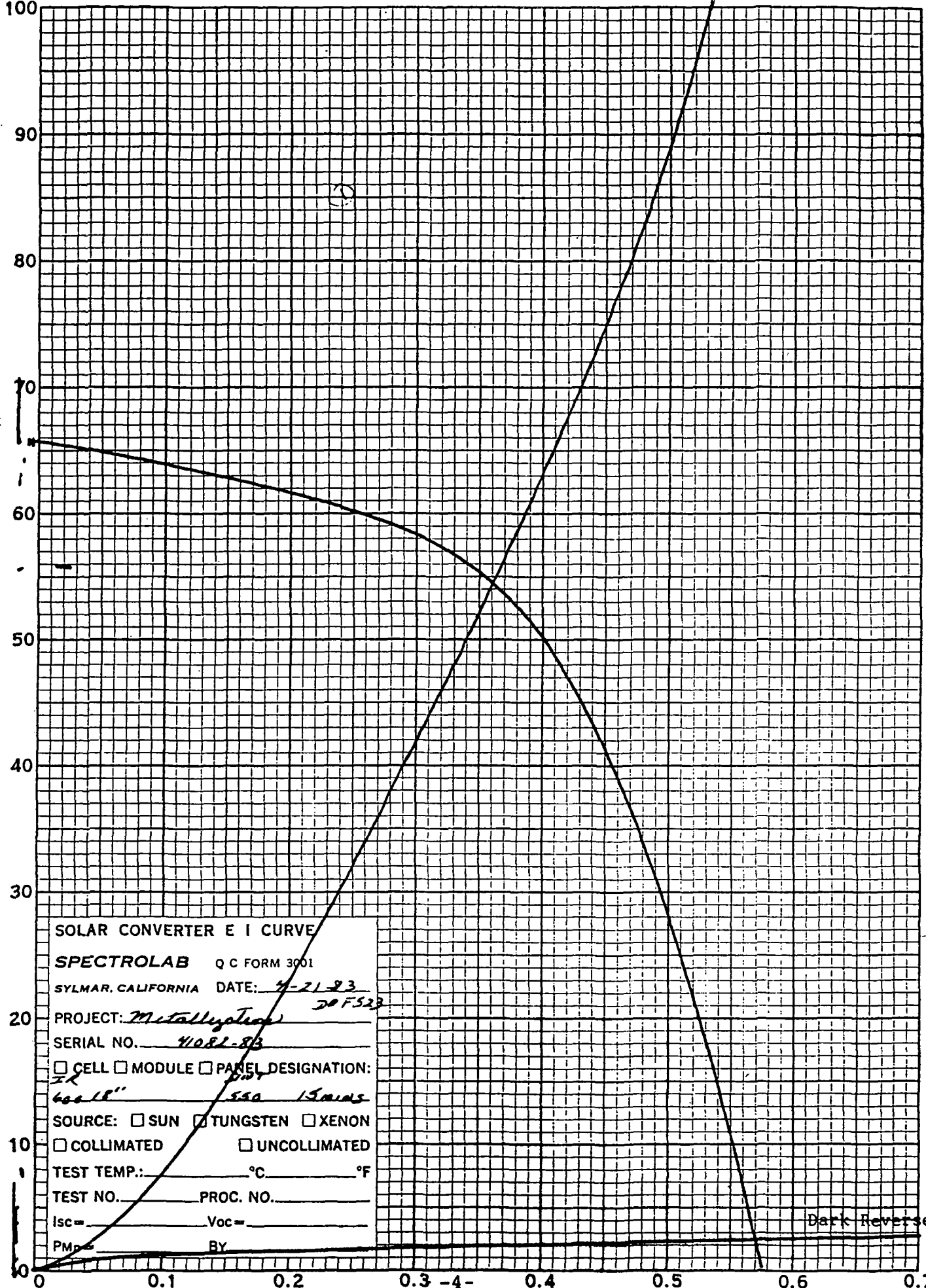
Figure 1

Dark Forward

Light
[V

CURRENT (MA. X 10)

Dark Curves x 1 mA



SOLAR CONVERTER E I CURVE

SPECTROLAB Q C FORM 3001

SYLMAR, CALIFORNIA DATE: 4-21-83

PROJECT: Metallization

DF523

SERIAL NO. 41081-83

CELL MODULE PANEL DESIGNATION:

60018" 550 15mins

SOURCE: SUN TUNGSTEN XENON

COLLIMATED UNCOLLIMATED

TEST TEMP.: °C °F

TEST NO. PROC. NO.

Isc = Voc =

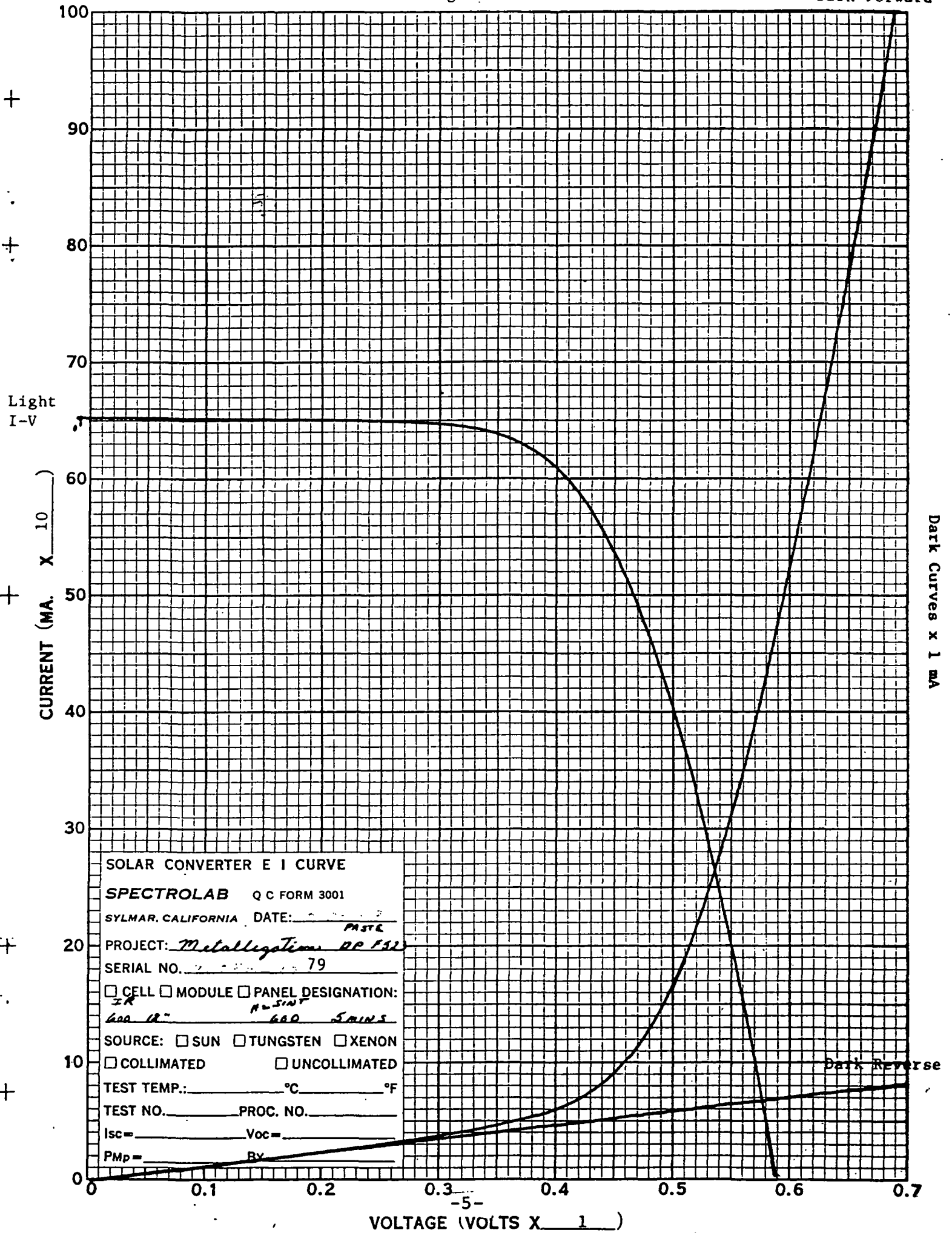
PM = BY

Dark Reverse

VOLTAGE (VOLTS X 1)

Figure 2

Dark Forward



SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
 SYLMAR, CALIFORNIA DATE: _____
 PROJECT: *Metallization DP F32*
 SERIAL NO. *79*
 CELL MODULE PANEL DESIGNATION:
3A *600 12"* *N=51"* *600 5MIN*
 SOURCE: SUN TUNGSTEN XENON
 COLLIMATED UNCOLLIMATED
 TEST TEMP.: _____ °C _____ °F
 TEST NO. _____ PROC. NO. _____
 Isc = _____ Voc = _____
 PMP = _____ BY _____

Figure 3

Dark Forward

Light
I-V

CURRENT (MA. X 10)

Dark Curves x 1 mA

SOLAR CONVERTER E I CURVE

SPECTROLAB Q C FORM 3001

SYLMAR, CALIFORNIA DATE: 7-21-83

PROJECT: Metallization DP F523

SERIAL NO. 41082-81

CELL MODULE PANEL DESIGNATION:

IR 600 18" 1" x 512" 600 10mils

SOURCE: SUN TUNGSTEN XENON

COLLIMATED UNCOLLIMATED

TEST TEMP.: °C °F

TEST NO. PROC. NO.

Isc Voc

Pmp BY

VOLTAGE (VOLTS X 1)

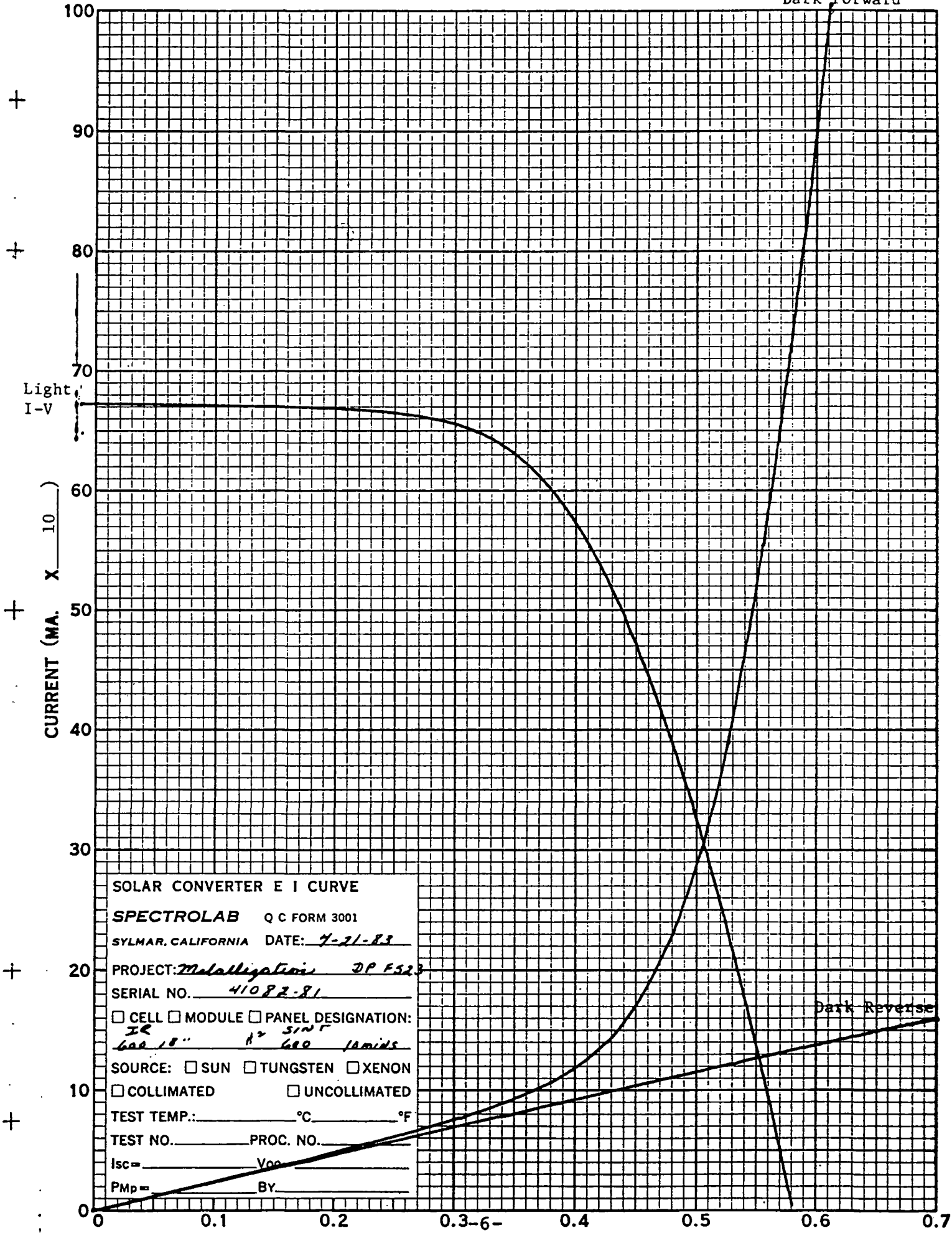


Figure 4

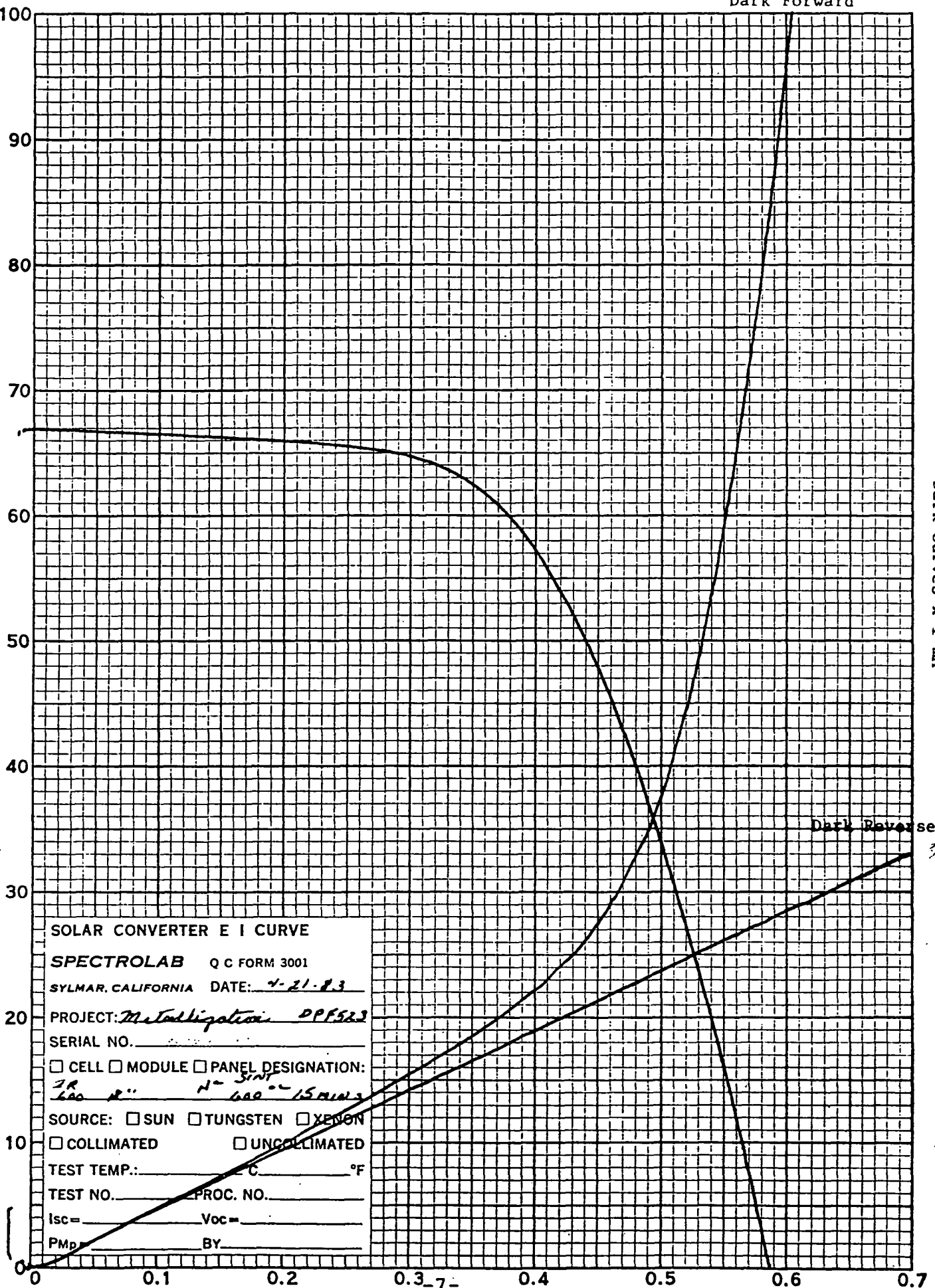
Dark Forward

Light
I-V

CURRENT (MA. X)

Dark Curves x 1 mA

Dark Reverse

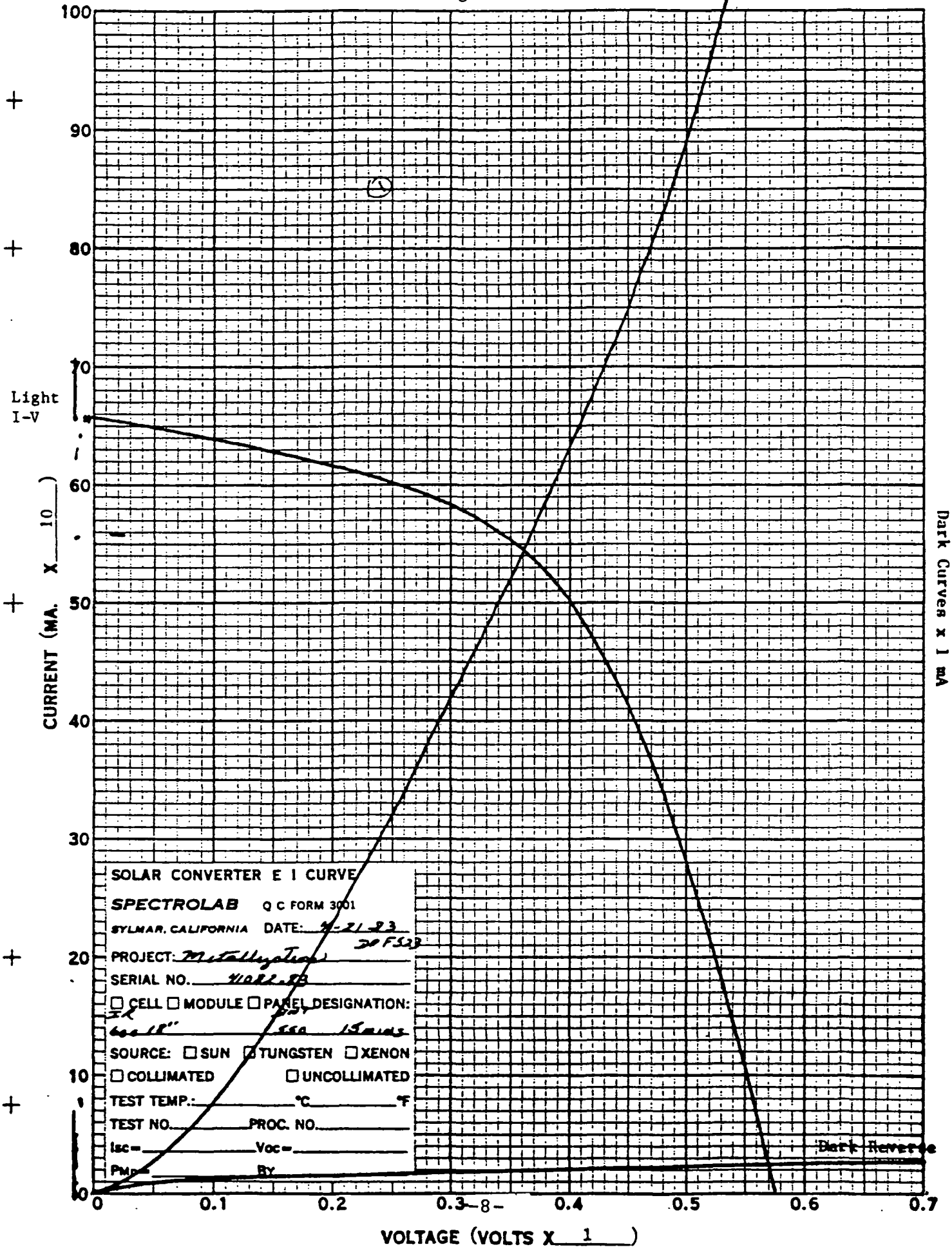


SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 4-21-83
PROJECT: Metallization PPF523
SERIAL NO. _____
 CELL MODULE PANEL DESIGNATION:
3R 600 R" N= 3INT 600 ~ 15 MIN
SOURCE: SUN TUNGSTEN XENON
 COLLIMATED UNCOLLIMATED
TEST TEMP.: _____ °C _____ °F
TEST NO. _____ PROC. NO. _____
Isc= _____ Voc= _____
PMP _____ BY _____

VOLTAGE (VOLTS X 1)

Figure 5

Dark Forward



Dark Curves x 1 mA

SOLAR CONVERTER E I CURVE
 SPECTROLAB Q C FORM 3001
 SYLMAR, CALIFORNIA DATE: 7-21-63
 PROJECT: Metallography 20 F523
 SERIAL NO. 41022-83
 CELL MODULE PANEL DESIGNATION:
60 x 18" SSA 15 mins
 SOURCE: SUN TUNGSTEN XENON
 COLLIMATED UNCOLLIMATED
 TEST TEMP.: _____ °C _____ °F
 TEST NO. _____ PROC. NO. _____
 I_{sc} = _____ V_{oc} = _____
 P_{mp} _____ R_y _____

Dark Reverse

fired in H_2 for 5 minutes at $600^\circ C$. The best cell had the following characteristics when tested by contacting the Mo/Sn metallization: $V_{oc} = .586$, $I_{sc} = .650$, $I_{500} = .448$. When the cell was contacted on the Ag pad the I_{sc} fell to .080. There is no ohmic contact between the two metallization types. Cells were also processed with 500 and $400^\circ C$ prefire temperatures, but had similar characteristics. Interconnects were successfully soldered to the ohmic pad.

Another set of experiments was done using paste type F503 to which was added 3% Ag3347 silver paste. The cell was first printed with the Mo/Sn, prefired at $600^\circ C$, and fired in H_2 at $500^\circ C$ for 5 minutes. The silver paste was printed and fired as before. The cell was tested and it was found to have an $I_{500} = .250$, however there was ohmic continuity between the silver and Mo/Sn metallizations. The cell was then resintered several times for five minutes but continued to degrade. Figures 6 and 7 show typical cells. Sintering at higher temperatures destroyed the contact between the metallizations as is seen in Figure 8.

After meeting with JPL personnel a matrix of paste types was constructed to be manufactured by Electrink Inc. Two types of frits will be investigated, one with barium and strontium #494, and one without #90. Both frits are lead free. The formulations will also be prepared with and without Teflon powder. Two different vehicles will also be tested, a conventional cellulosic vehicle V-38 and an acrylic vehicle V-26. As controls pastes will also be prepared without frit and with lead borosilicate frit. The following table summarizes the pastes:

<u>Paste</u>	<u>Frit (Pb)</u>	<u>Frit 90</u>	<u>Frit 494</u>	<u>Teflon</u>	<u>V-26</u>	<u>V-38</u>
A			X		X	
B			X	X	X	
C		X			X	
D		X		X	X	
E			X			X
F			X	X		X
G		X				X
H		X		X		X
I	X				X	
J	X					X
K					X	
L						X

Figure 6

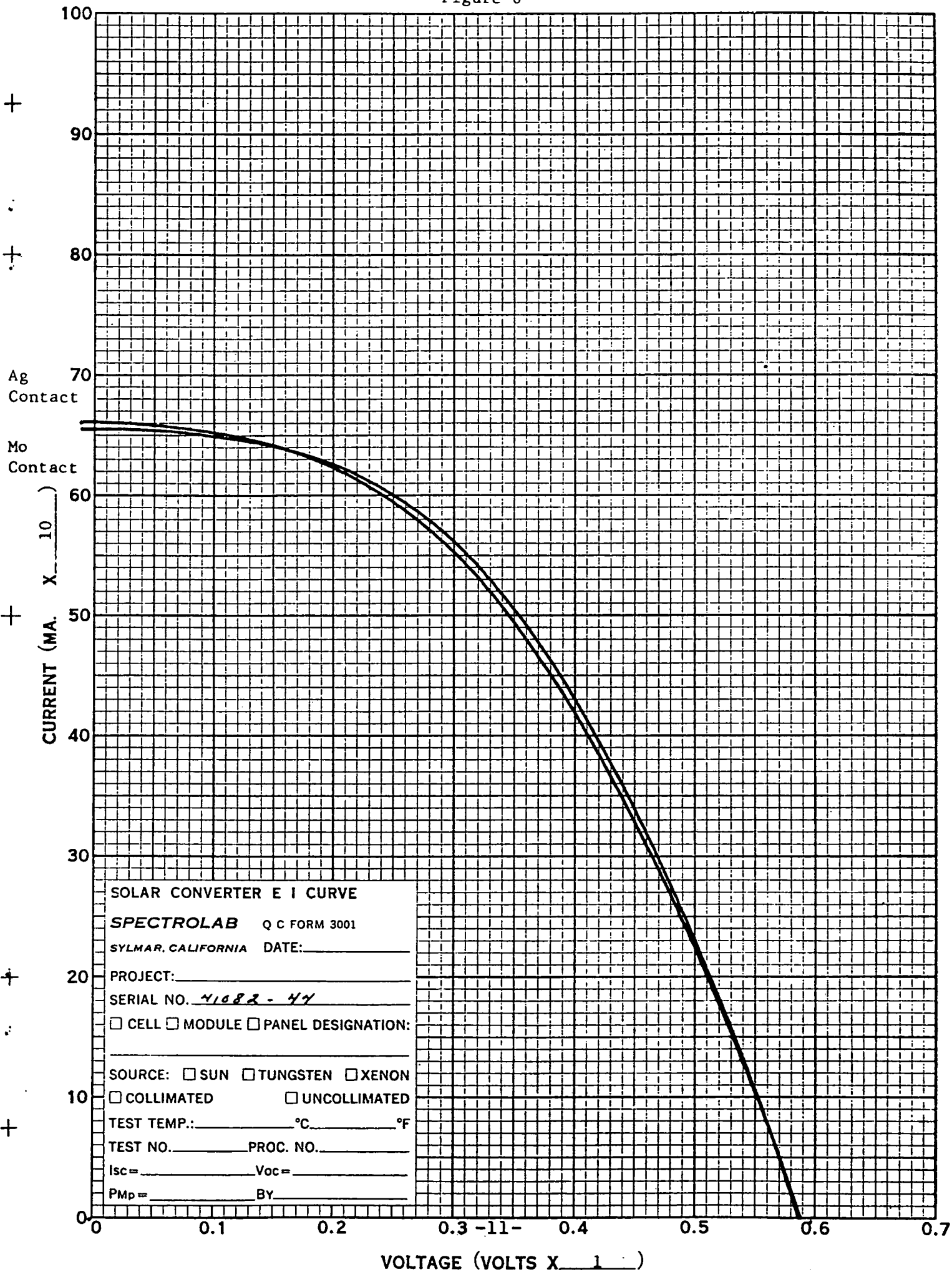


Figure 7

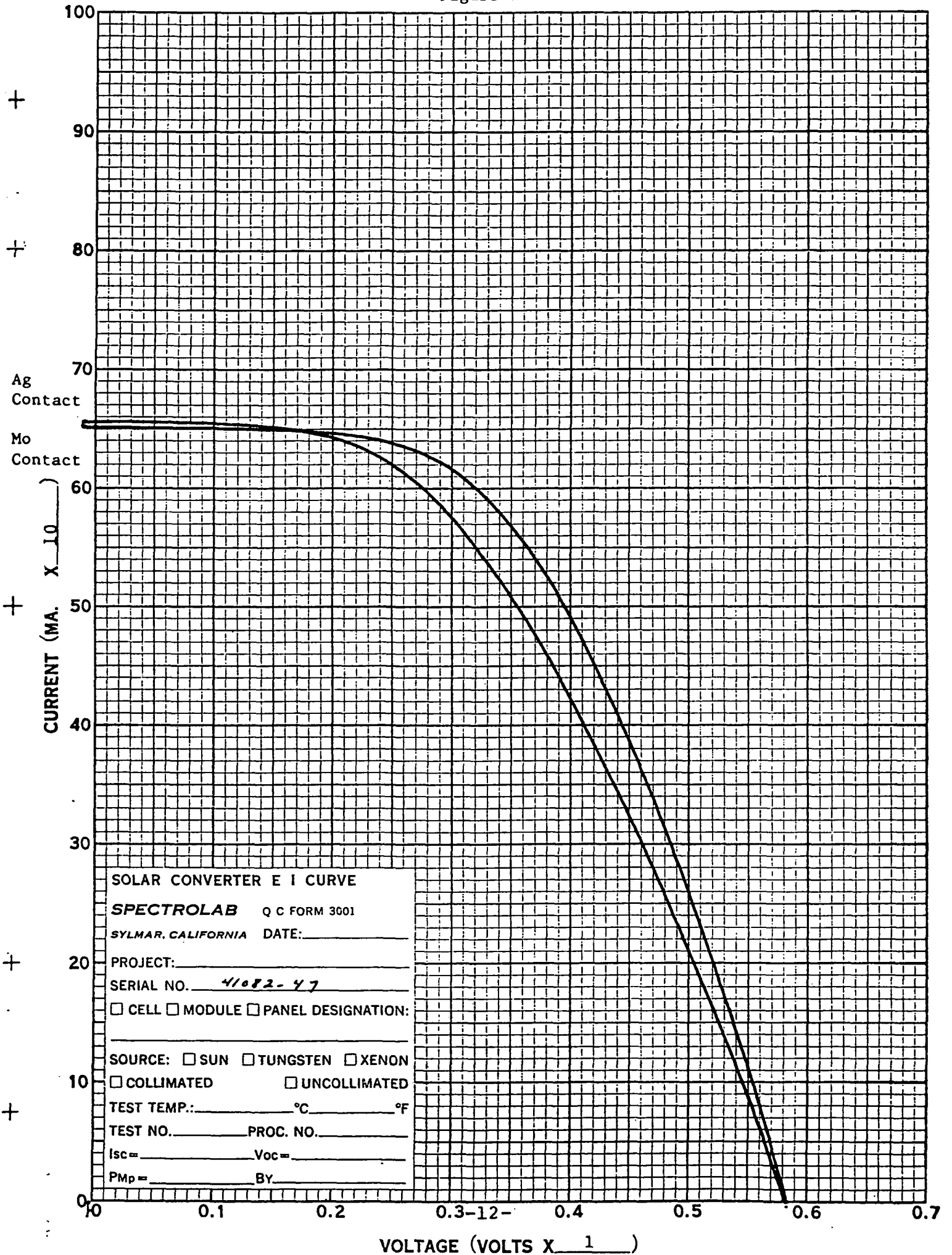
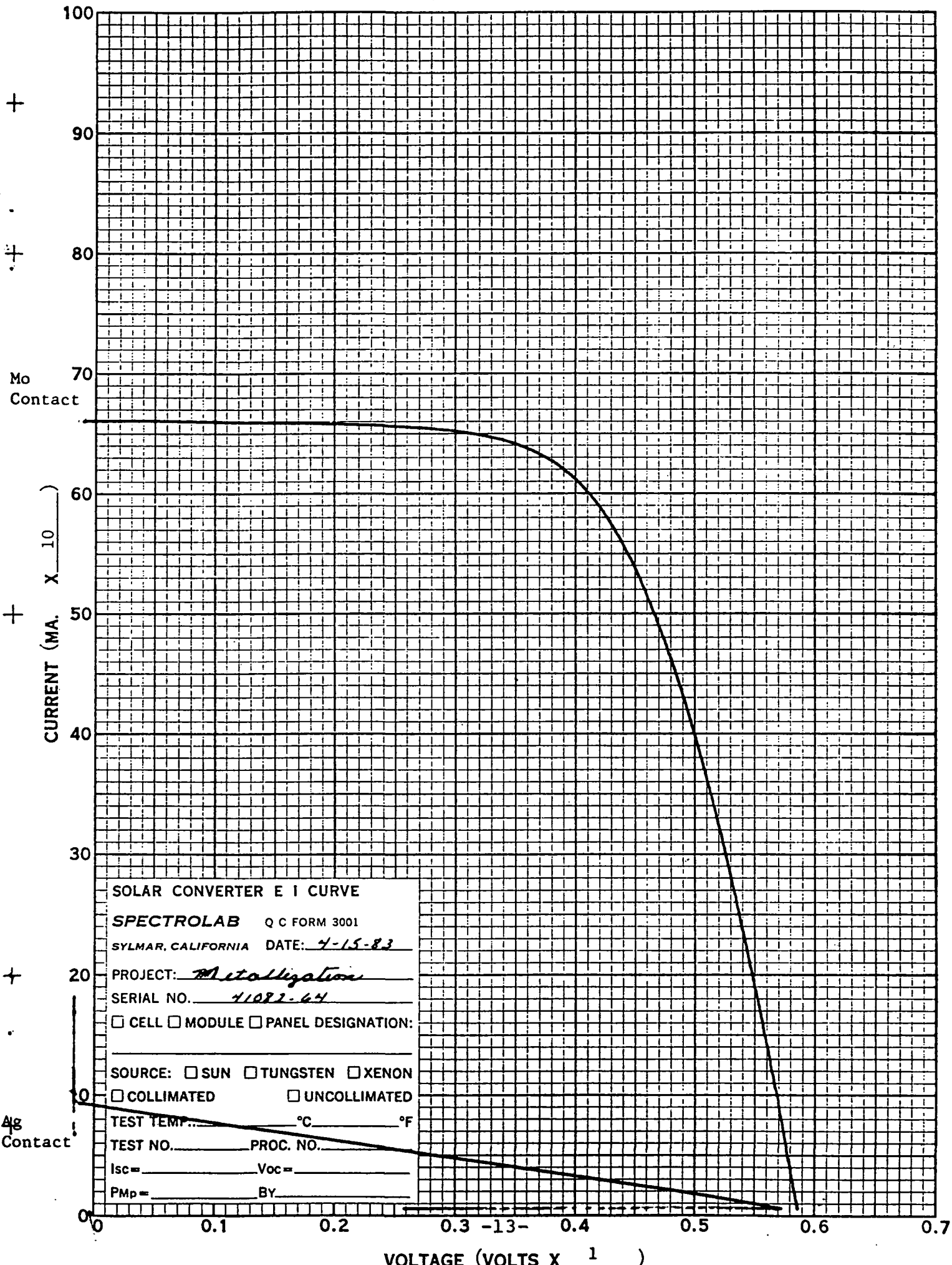


Figure 8



Section 3.0

CONCLUSIONS AND RECOMMENDATIONS

There are no conclusions or recommendations to report for the period.

Section 4.0

ACTIVITIES PROJECTION

During the next quarter the matrix of paste formulations will be evaluated. The work on ITO coatings over the metallization will not begin until a more successful process is found. A Milestone Chart follows.

MILESTONE CHART AND DELIVERY SCHEDULE

SHEET 1 OF 1
 DATE 4/13/83
 REVISION

ITEM OR TASK	DESCRIPTION	A	M	J	J	J	D	J	F	M	A	N	J	J	A	S	O	N	D
10	FRONT METALLIZATION	▼																	
11	Initial Formulation	▼																	
12	Re-Formulations				▼														
13	IPO on Metal						▼												
14	Metal on ITO																		
15	Two Step Process								▼										
20	DEMONSTRATION RUN & EVALUATION																		
30	TESTING	▼																	
31	Electrical Characteristics	▼																	
32	Adhesion						▼												
33	Humidity																		
34	Contact Resistance									▼									
40	NON-CZ PROCESSES																		
50	MANAGEMENT	▼																	
	Program Plan	▲																	
	Monthly Technical Report		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Monthly Financial Report		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	Quarterly Technical Report																		
	Process Specifications																		
	Economic Evaluation																		
	Prototype Cell Deliveries																		
	Final Report																		

NOTES: JEF PROPULSION LABORATORY CUSTOMER PROGRAM RETRIBUTION

LEGEND: Q-