N84-34031 9950-941

DRL 175

DOE/JPL-956205-84/17
Distribution Category UC-63

Quarterly Technical Progress Report

No. 6329-24

on the

DEVELOPMENT OF METALLIZATION PROCESS

FSA Project, Cell and Module Formation Research Area

For the Period Ending

March 31, 1984

Contract 956205

Prepared by:

Alexander Garcia III

Approved by:

Nick Mardesich
Nick Mardesich
Manager, Advanced Programs

SPECTROLAB, INC.
12500 Gladstone Avenue
Sylmar, California 91342

July 1984

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.

ABSTRACT/SUMMARY

New pastes were evaluated that contained additives to aid in the silicon to metallization contact. None were completely successful. Pastes were evaluated using a heated stage SEM at Microscopy Research, Inc. This equipment shows promise for future evaluations.

TABLE OF CONTENTS

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

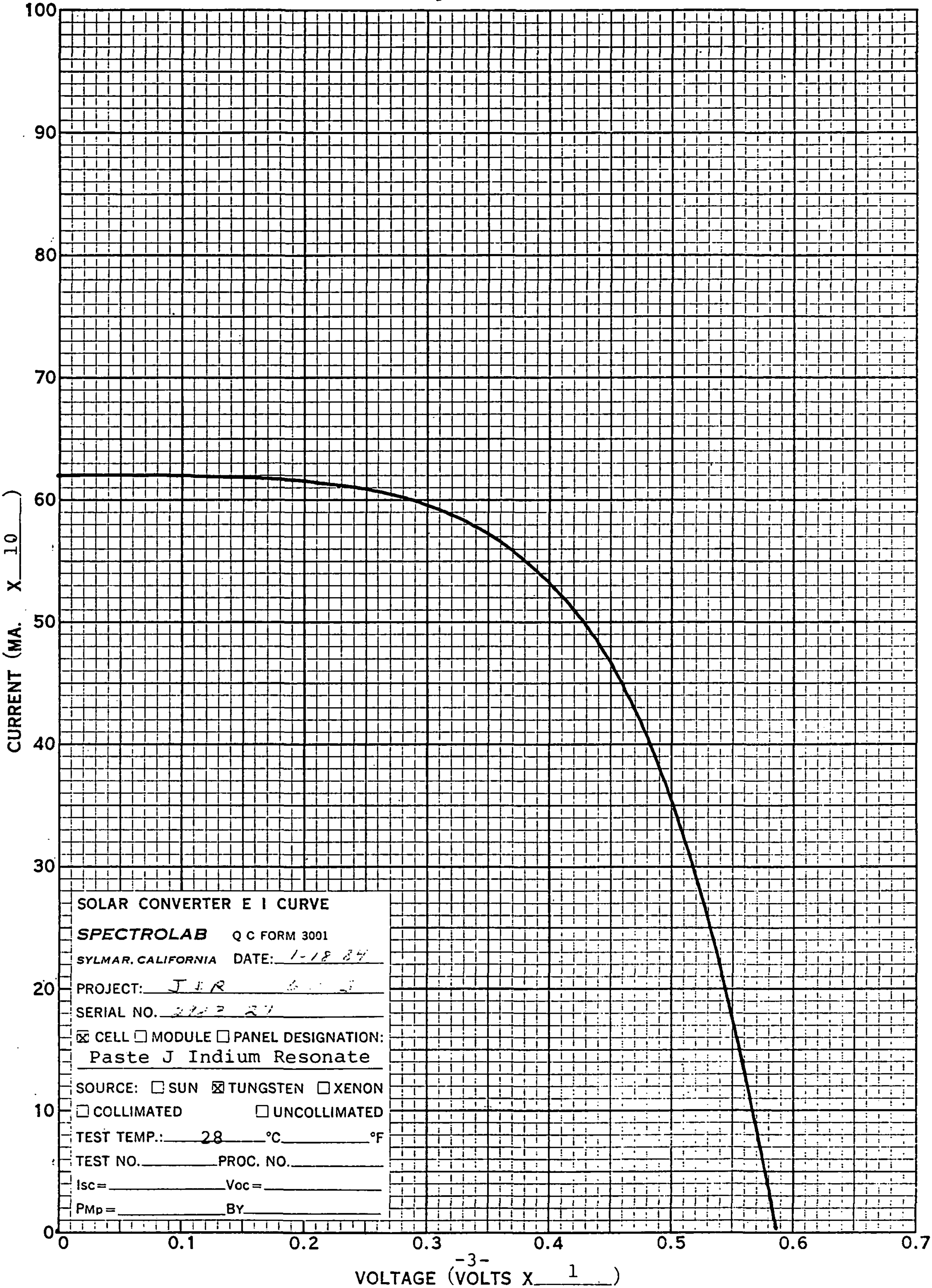
TECHNICAL DISCUSSION

A series of experiments were done using pastes modified with indium resinate solution A2307 (Englehard-Electro Metallics, East Newark, NJ) and silver resinate solution 9144. Pastes E, J, and L were modified by adding 1% by weight of the resonates. The cells were processed as usual and then sintered at 650°C for 5 minutes in H_2. The J paste showed the best results with indium resonate added. Figures 1-4 show the light and dark IV curves for the best two cells using indium and silver resonates respectively.

Further experiments using the J paste with indium resonate at higher sintering temperatures produced better cells. The best cell was produced by sintering at 700°C for 5 minutes. Figures 5 and 6 show the light and dark curves of this cell. The production of good cells using this process was not reproducible about half of the cells produced were shunted as is shown in Figures 7 and 8. The better cells were still not solderable. Attempts to fine tune times and temperatures of sintering were not successful.

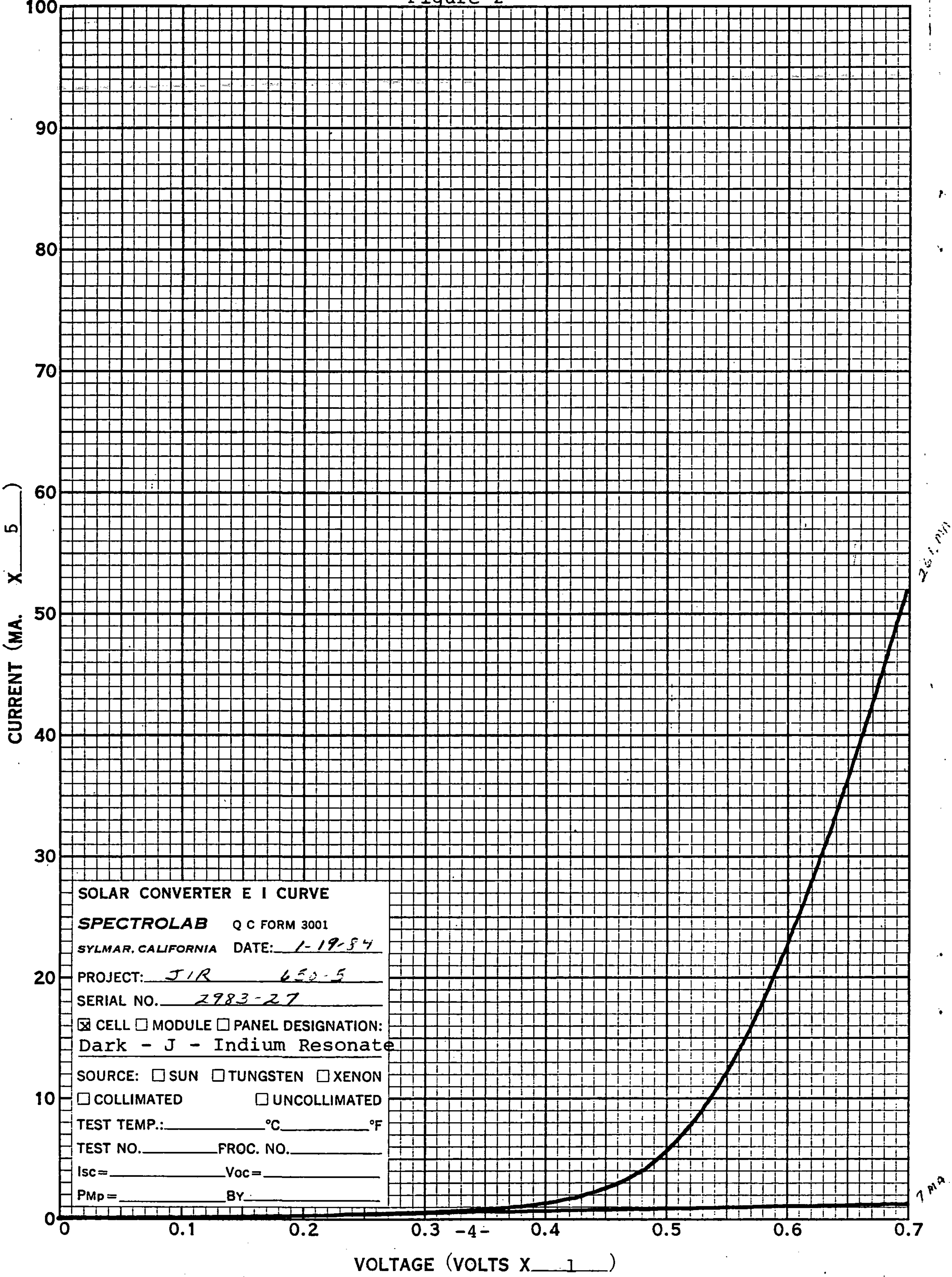
Three new pastes were received from Electrink formulated using silver neodecanoate. The formulations are shown in Table 1. An extensive matrix of experiments using prefire belt speed of 18-54"/min. at 400°C and sintering temperatures of 500-700°C

Figure 1



CURRENT (MA. X 10)
VOLTAGE (VOLTS X 1)
0 10 20 30 40 50 60 70 80 90 100
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 1-18-84
PROJECT:
SERIAL NO.
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Paste J Indium Resonate
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 2



100
90
80
70
60
50
40
30
20
10
0
CURRENT (MA. X 5)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
261 mA
7 MA
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 1-19-84
PROJECT: JIR 650-5
SERIAL NO. 2983-27
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Dark - J - Indium Resonate
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 3

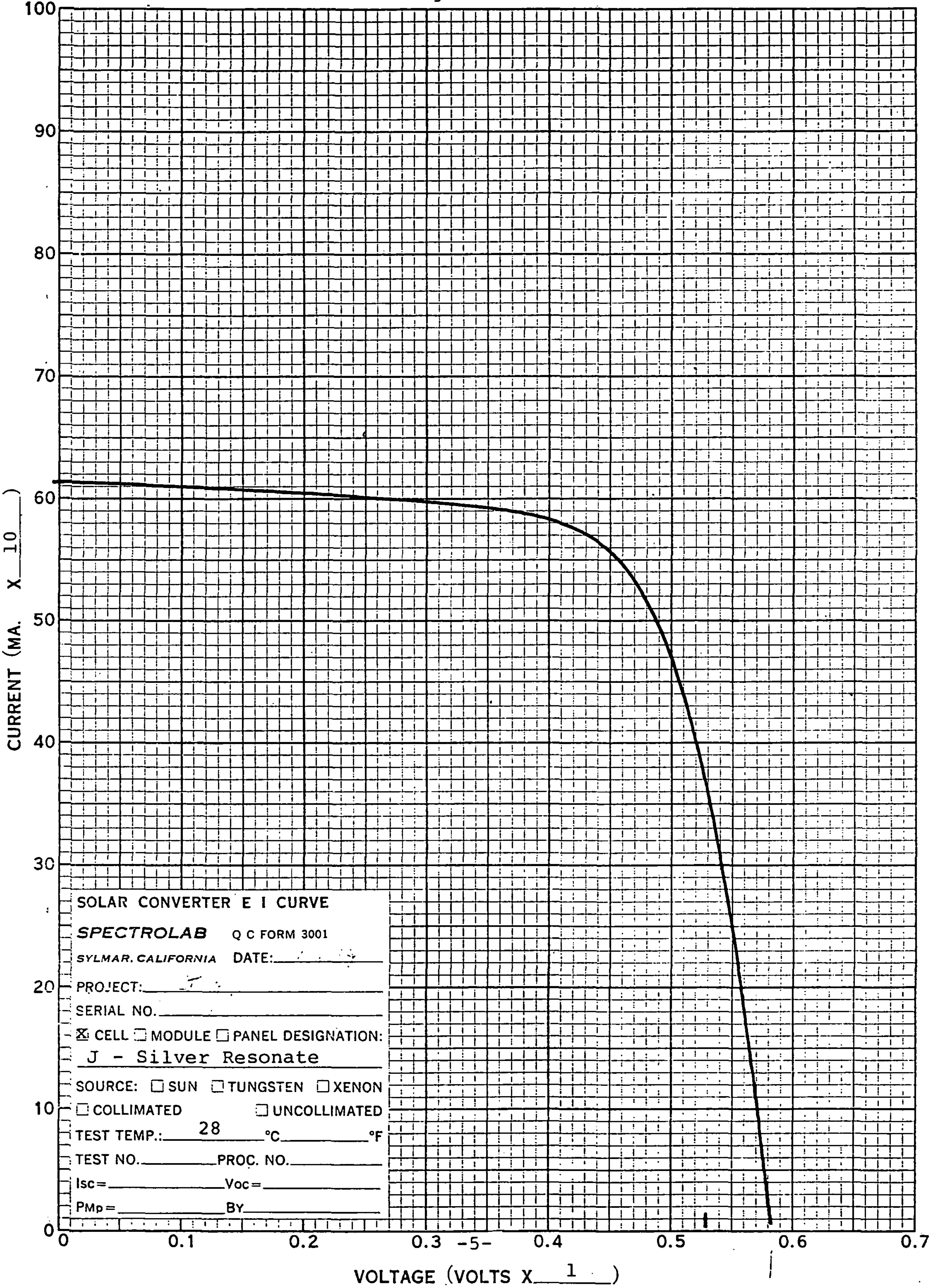
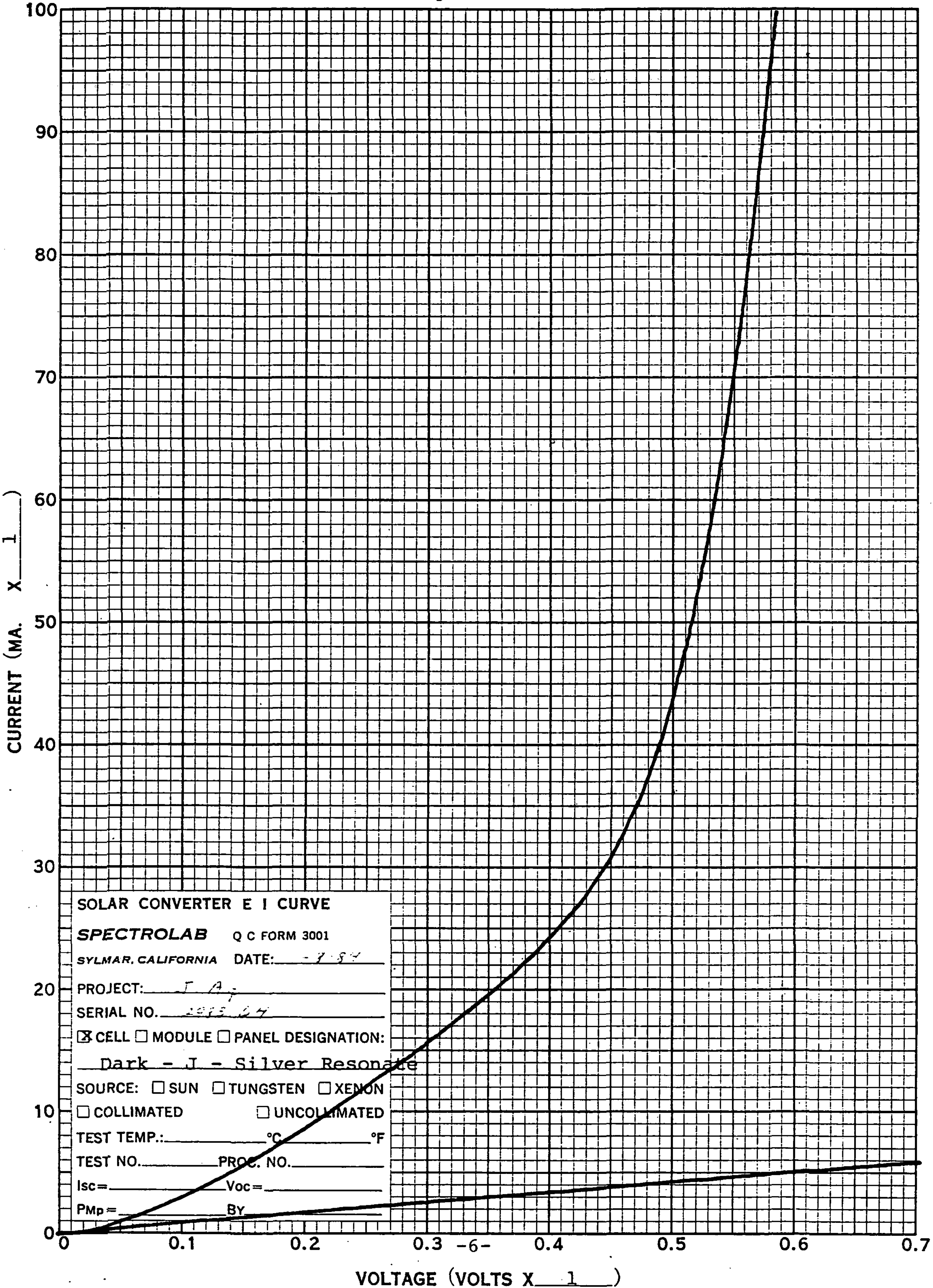
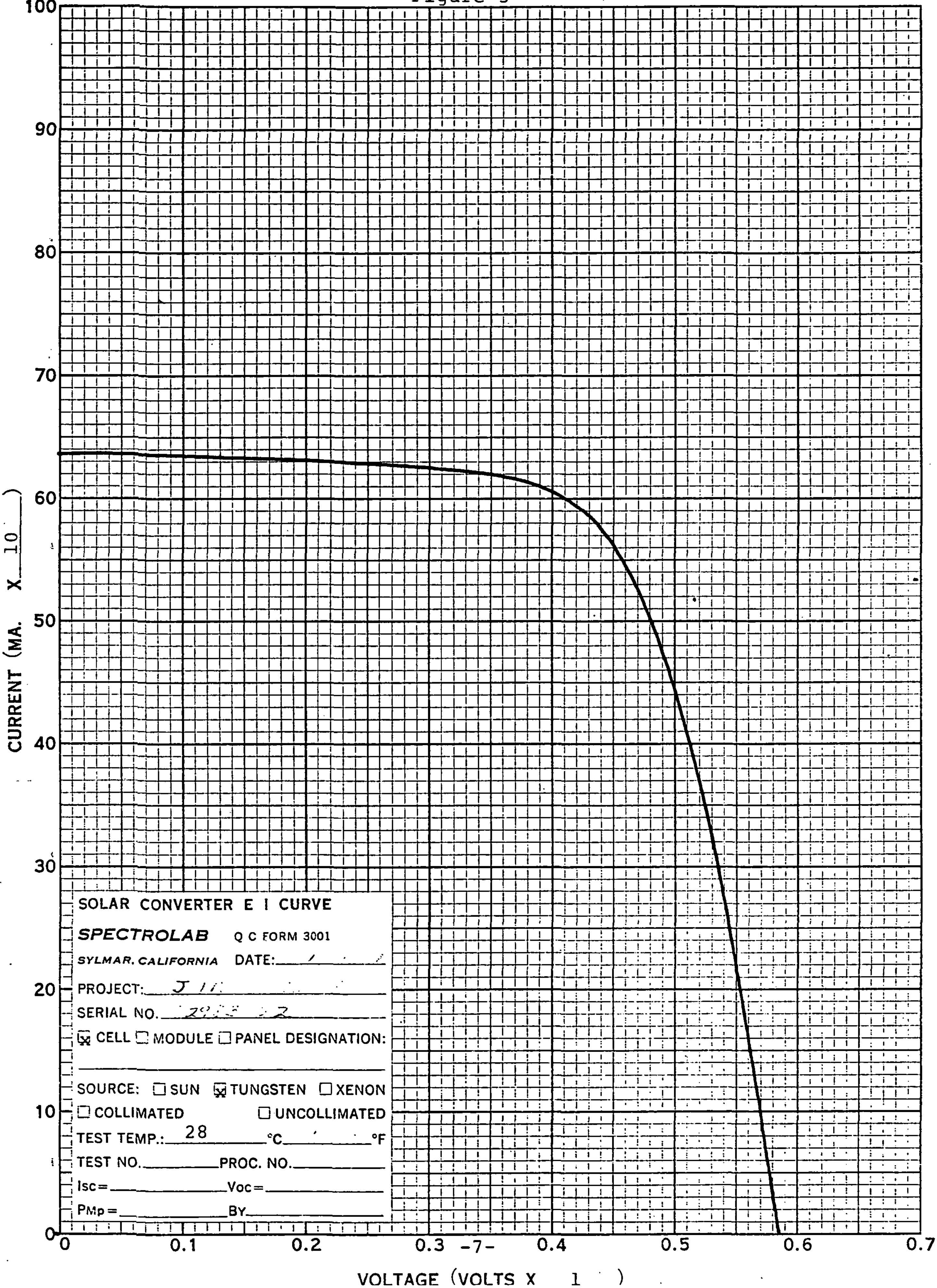

CURRENT (MA. X 10)
100
90
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO.
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
J - Silver Resonate
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

Figure 4



CURRENT (MA. X 1)
VOLTAGE (VOLTS X 1)
0
10
20
30
40
50
60
70
80
90
100
0.1
0.2
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.
CELL
MODULE
PANEL DESIGNATION:
Dark - J - Silver Resonate
SOURCE:
SUN
TUNGSTEN
XENON
COLLIMATED
UNCOLLIMATED
TEST TEMP.:
°C
°F
TEST NO.
PROC. NO.
Isc=
Voc=
PMp=
BY

Figure 5



100
90
80
70
60
50
40
30
20
10
0
CURRENT (MA. X 10)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE:
PROJECT:
SERIAL NO.
☒ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 6

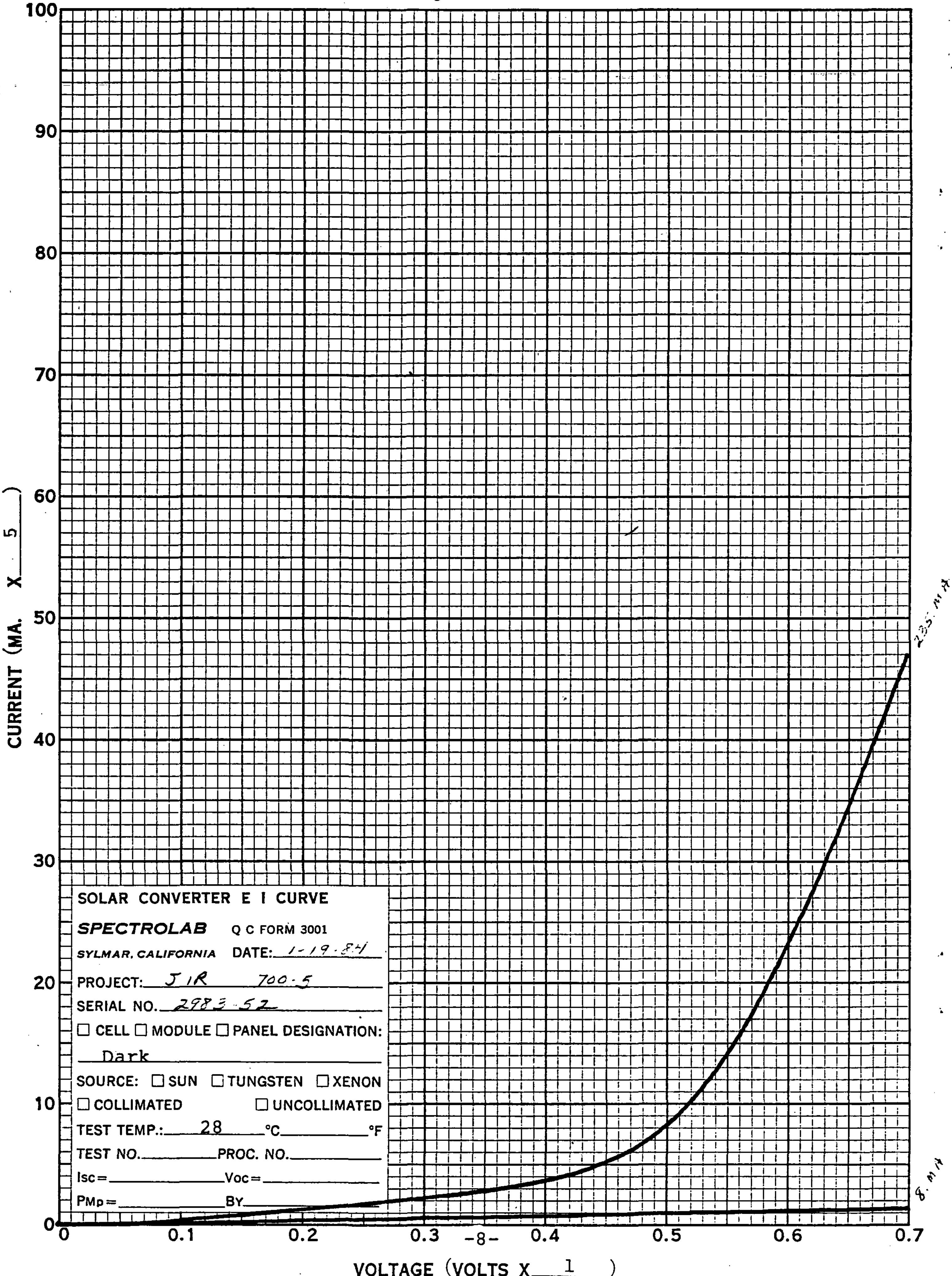
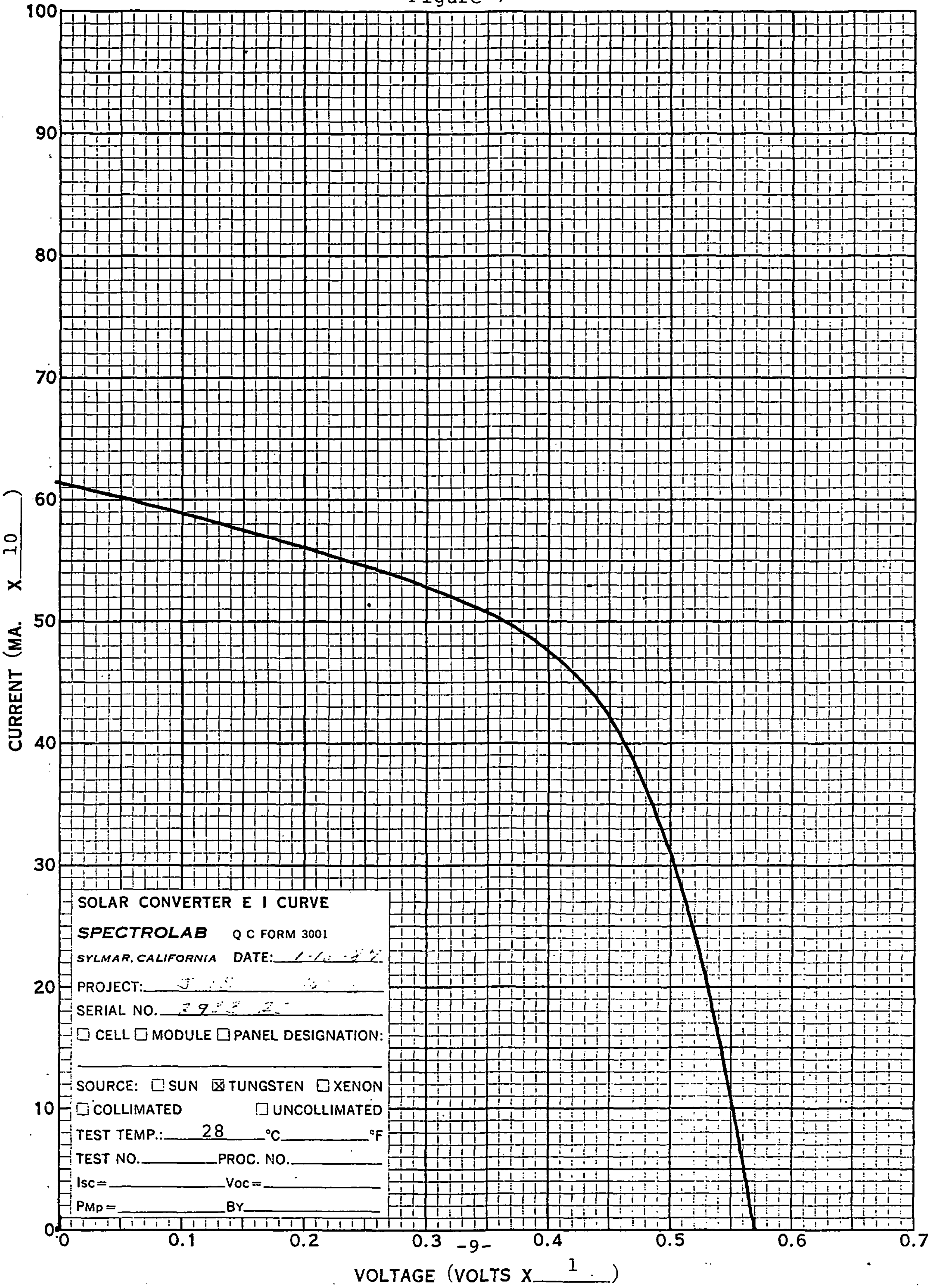
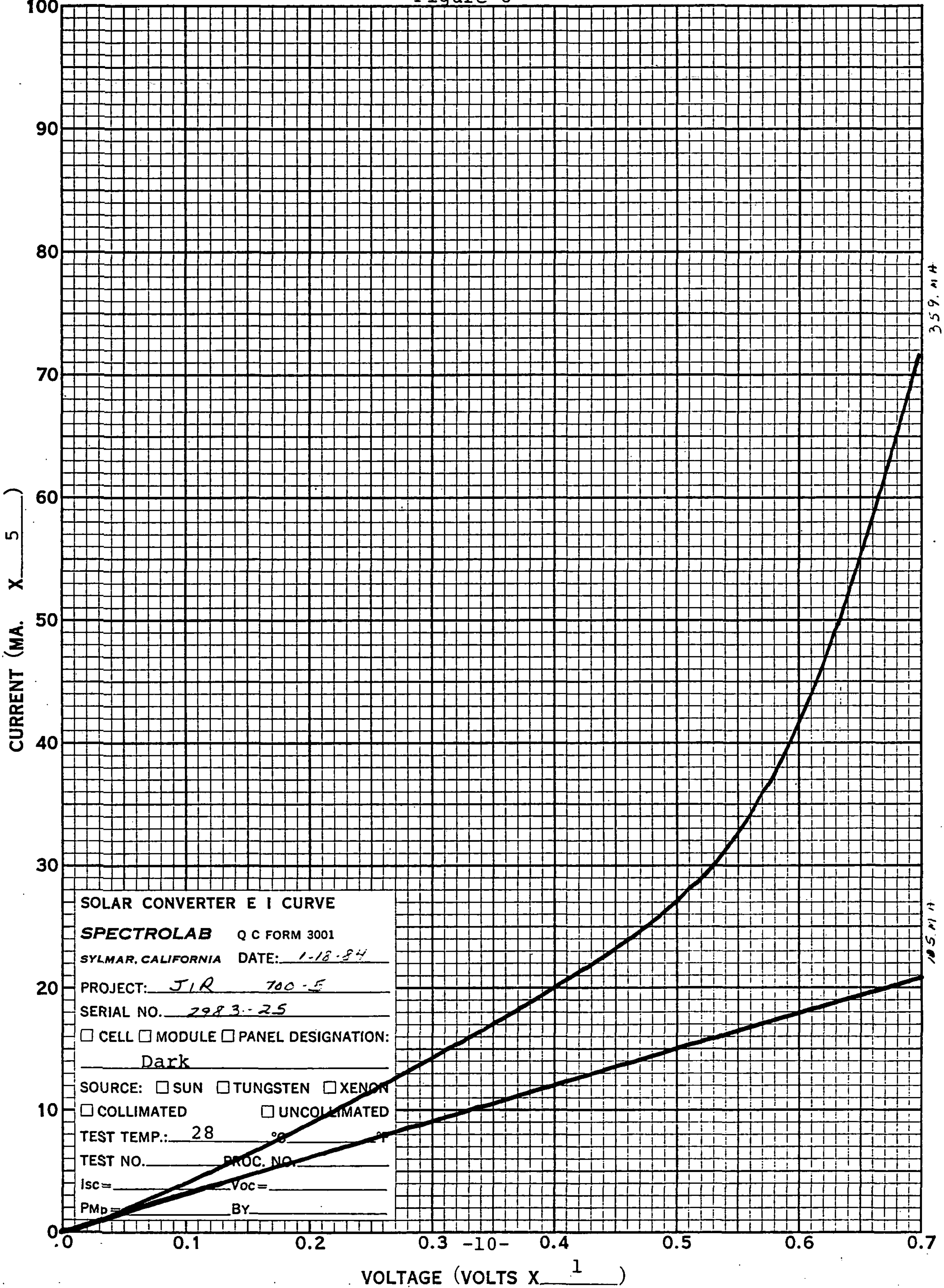

CURRENT (MA. X 5)
VOLTAGE (VOLTS X 1)
100
90
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
235 MA
8 MA
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 1-19-84
PROJECT: JIR 700-5
SERIAL NO. 2983-52
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Dark
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 7



CURRENT (MA. X 10)
VOLTAGE (VOLTS X 1)
0
10
20
30
40
50
60
70
80
90
100
0
0.1
0.2
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.
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc = Voc =
PMp = BY

Figure 8



100
90
80
70
60
50
40
30
20
10
0
CURRENT (MA. X 5)
.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
359. mA
105 mA
SOLAR CONVERTER E I CURVE
SPECTROLAB
Q C FORM 3001
SYLMAR, CALIFORNIA
DATE: 1-18-84
PROJECT: JIR 700-5
SERIAL NO. 2983-25
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Dark
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: 28 °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

Table 1

NEW PASTES

Paste Composition

	P (F-83)	Q (F-84)	R (F-85)
TiH_2	.40	.44	.40
Mo	14.70	15.99	14.70
Tin	58.78	63.91	58.78
Frit 450	6.46	0	0
Frit 494	0	0	6.46
Silver Neodecanoate Solution	5.48	5.48	5.48
Vehicle V38	14.18	14.18	14.18

Frit Composition

	450	494
K_2O	1.80	2.20
Na_2O	2.36	2.03
CaO	5.98	9.35
MgO	.32	.41
PbO	31.72	-
BaO	-	11.19
SrO	-	6.08
Al_2O_3	3.50	5.09
B_2O_3	13.76	7.99
SiO_2	40.56	55.66
MP	827°C	771°C

Table 1 - Continued

Vehicle

α-Terpineol	43.62
Butyl Carbitol Acetate	43.62
Ethyl Cellulose N-14	9.76
Thixatrol ST	3.00

Materials Sources

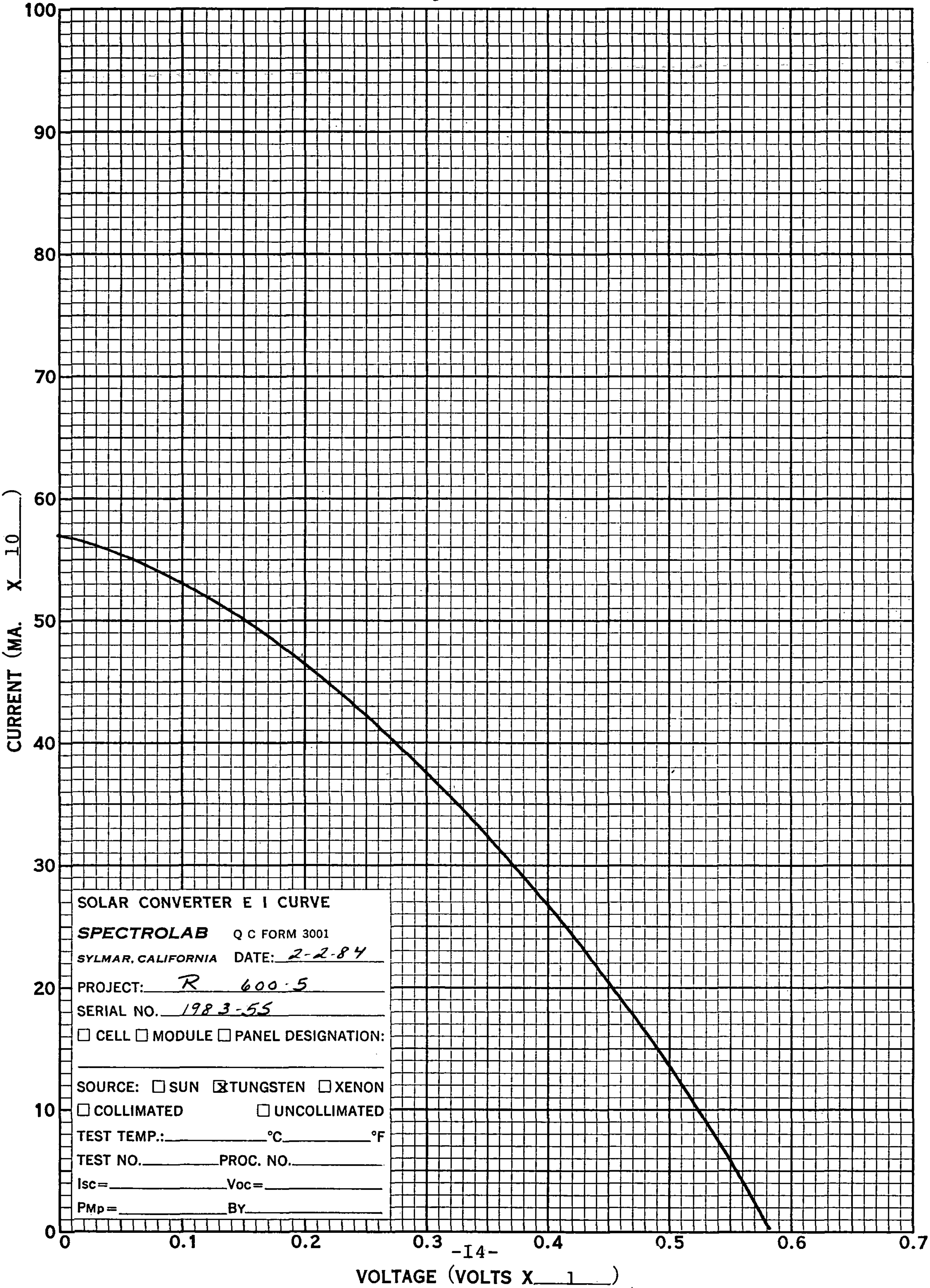
Material	Manufacturer Designation	Source
Titanium Hydride (TiH_2)	77113	Alfa-Ventron, Danvers, MA
Molybdenum Powder	280/325	GTE Sylvania, Towanda, PA
Tin Powder 325 Mesh	00352	Alfa-Ventron, Danvers, MA
α-Terpineol	TX75	MCB Chem. Cincinnati, OH
Butyl Carbitol Acetate	-	Orange Co. Chem., Santa Ana, CA
Ethyl Cellulose	N-14	Hercules, Wilmington, DE
Thixatrol (thickener)	ST	NL Industries, Heightstown, NJ
Molebdenum Oxide (MoO_3)	102882	Alfa-Ventron, Danvers, MA
Titanium Resinate	9428	Englehard Ind., E. Newark, NJ
Trichloroethylene	-	Orange Co. Chem., Santa Ana, CA
Carbitol Acetate	-	Orange Co. Chem., Santa Ana, CA
Borane Pyridine	89150	Alfa-Ventron, Danvers, MA

was unsuccessful. The best cell is shown in Figures 9 and 10. Additionally, sintering was attempted by simple heating on a hot plate to cause the neodecanoate to act as sintering agent. This attempt was also unsuccessful.

A visit was made to Microscopy Research Laboratories, Inc. in Sommerville, New Jersey. This company has a controlled atmosphere SEM with a heated sample stage. Figure 11 shows a schematic of the instrument. The sample is placed in a sample holder and can be exposed to any gas at up to 5 torr while being heated and observed via the SEM. Video tapes of the SEM image are made as the sample is being heated.

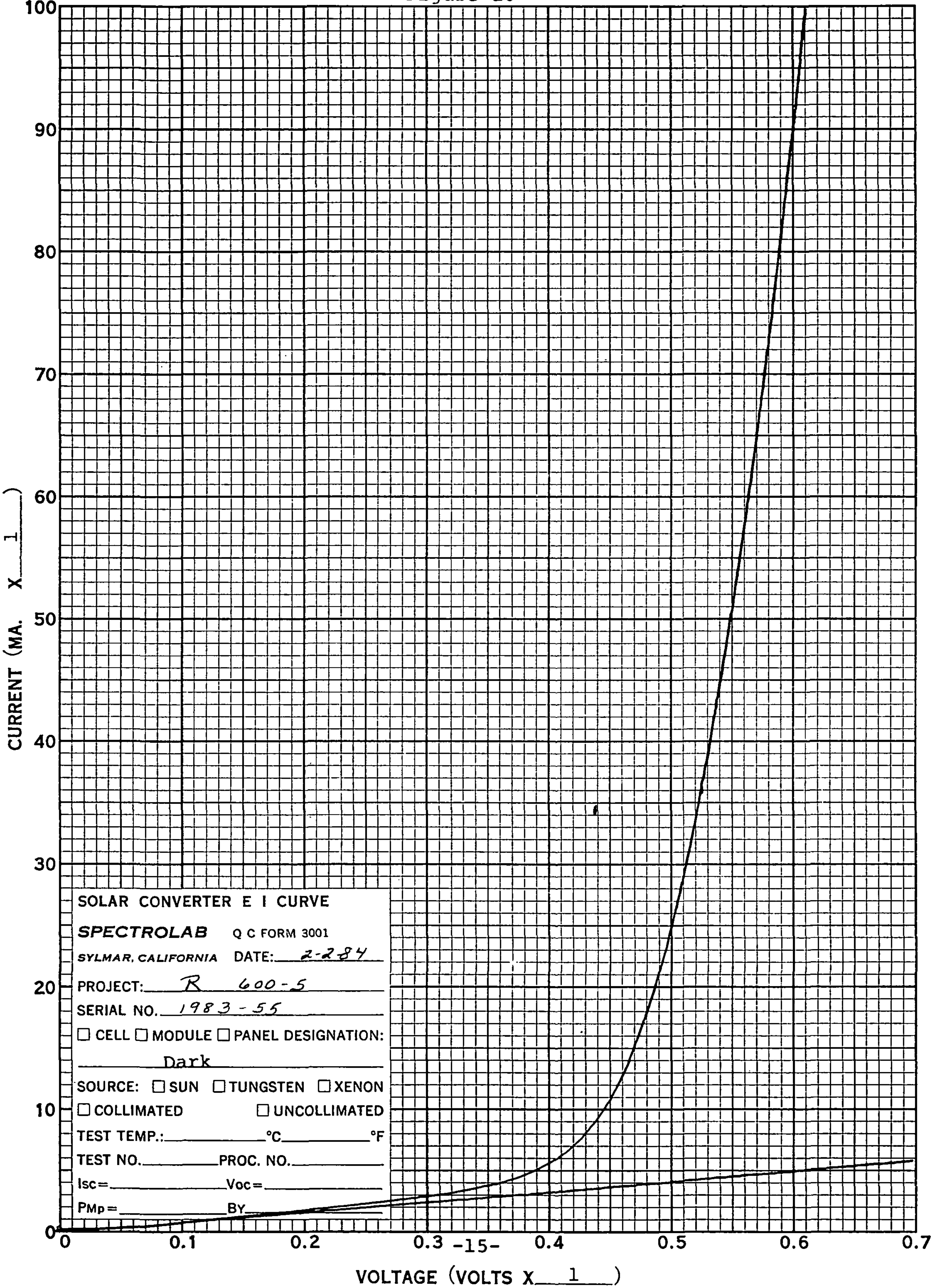
A sample of the dryed J paste was observed with the instrument. Initially an O_2 was introduced and the sample heated to $\sim$500°C, tin particles melted to globules at $\sim$230°C but did not wet surrounding particles. The sample was returned to room temperature and H_2 introduced to the sample. The sample was heated slowly to $\sim$800°C. The sample showed minor changes until a temperature of $\sim$700°C was reached when a rapid wetting and movement of the particles was seen. A well sintered continuous structure was formed. Figures 12 and 13 show SEM photographs before and after this redistribution.

Figure 9



100
90
80
70
60
50
40
30
20
10
0
CURRENT (MA. X 10)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB
Q C FORM 3001
SYLMAR, CALIFORNIA
DATE: 2-2-84
PROJECT: R 600-5
SERIAL NO. 1983-55
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
SOURCE: ☐ SUN ☒ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

Figure 10



CURRENT (MA. X 1)
100
90
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
VOLTAGE (VOLTS X 1)
SOLAR CONVERTER E I CURVE
SPECTROLAB Q C FORM 3001
SYLMAR, CALIFORNIA DATE: 2-2-84
PROJECT: R 600-5
SERIAL NO. 1983-55
☐ CELL ☐ MODULE ☐ PANEL DESIGNATION:
Dark
SOURCE: ☐ SUN ☐ TUNGSTEN ☐ XENON
☐ COLLIMATED ☐ UNCOLLIMATED
TEST TEMP.: °C °F
TEST NO. PROC. NO.
Isc= Voc=
PMp= BY

CONTROLLED ATMOSPHERE SCANNING ELECTON MICROSCOPY

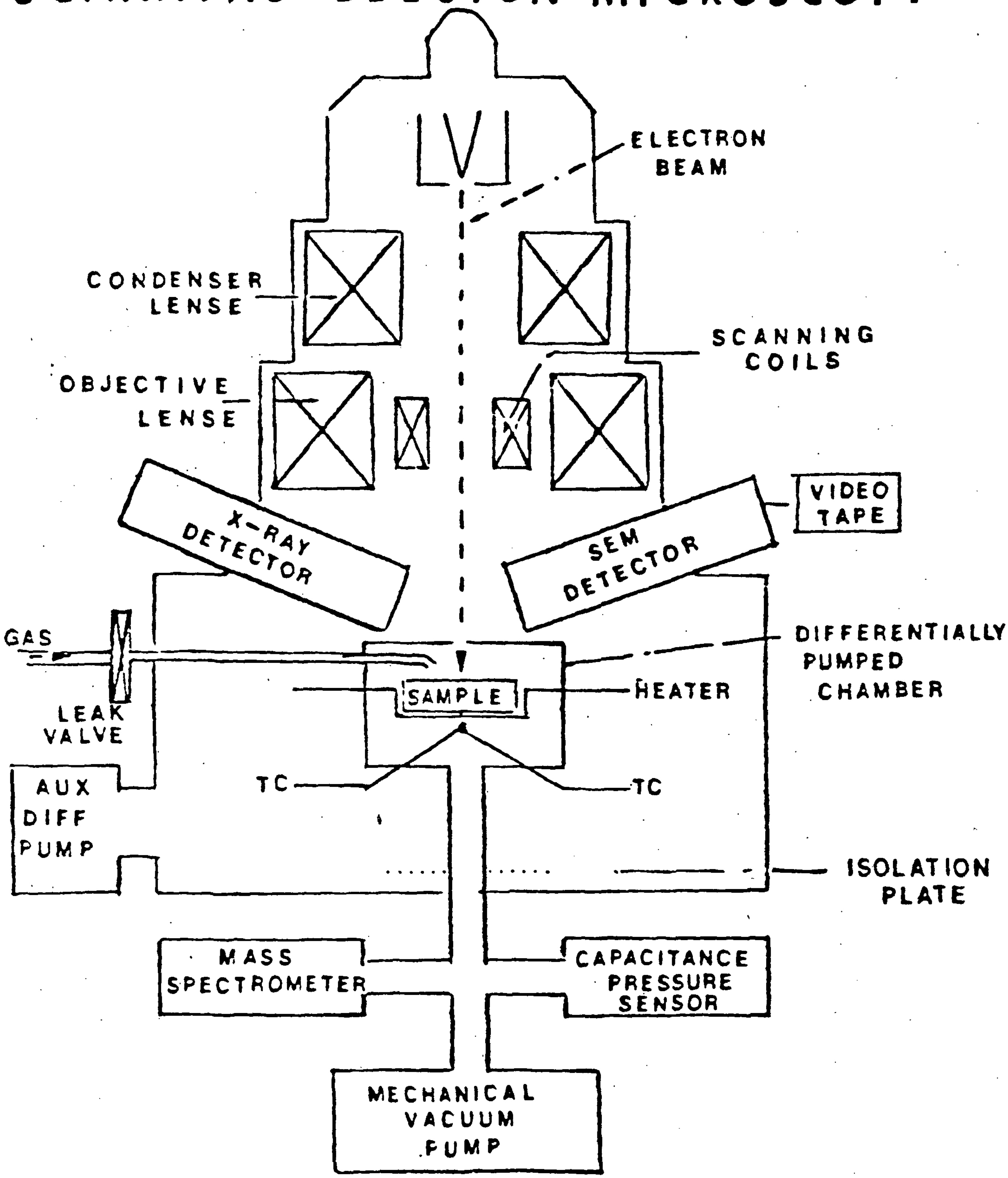


Figure 11

MICROSCOPY RESEARCH LABORATORIES, INC.

Figure 12

PASTE J, 3000X, PRIOR TO HEATING

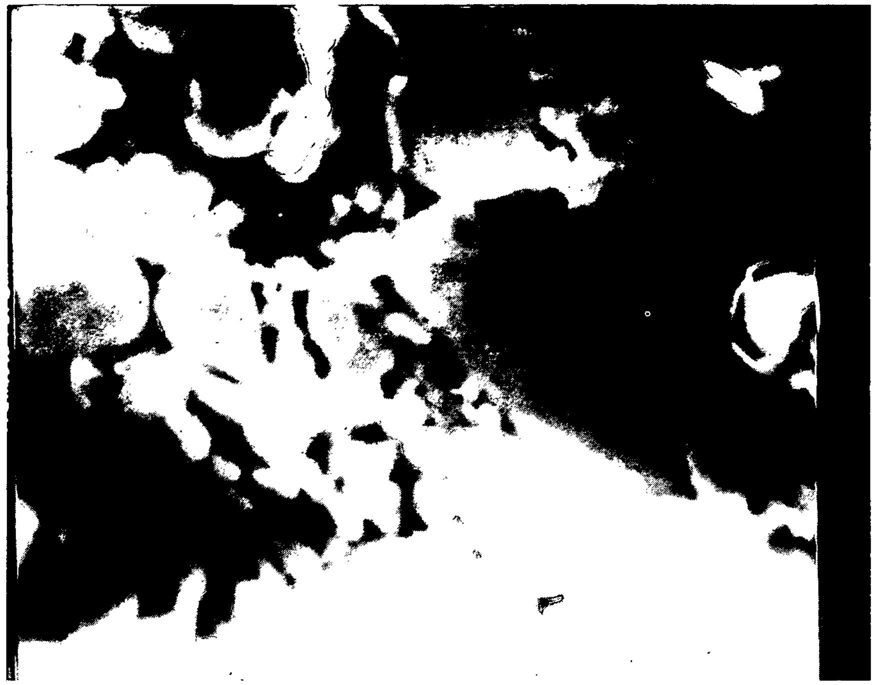
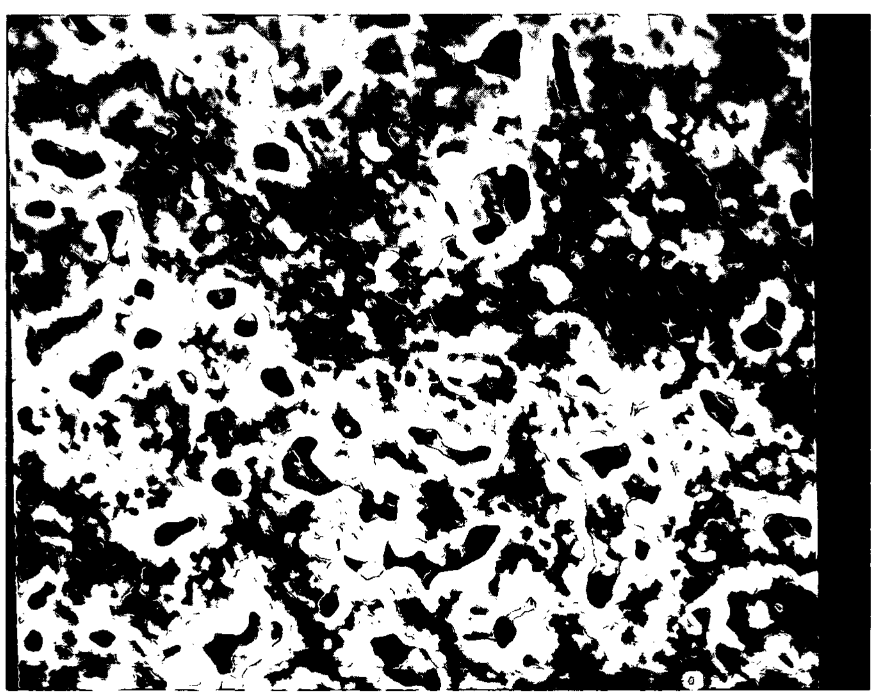


Figure 13

PASTE J, 3000X, AFTER HEATING



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 additional pastes will be evaluated. Work on the two-step process will continue and the molybdenum oxide paste will be reevaluated.