OUTDOOR PERFORMANCE TESTING OF THIN-FILM DEVICES

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The Advanced Systems Research Group supports the PV AR&D project by providing outdoor (global) testing of PV cells, submodules, modules, and arrays. The group also provides in-house engineering and analysis to identify and determine how technical issues such as cell/module/system adaptations, long-term stability, reliability, economics, materials availability, safety, and environmental impacts affect the development and ultimate use of advanced PV thin film, innovative cell and material technologies.

A major thrust of the research effort is to develop and utilize instrumentation and procedures for monitoring and analyzing PV cells and submodules including outdoor performance and stability testing and life-cycle accelerated stress testing. Through testing and simulation, researchers can identify problems that require further laboratory research and can help to focus, as well as support, advanced PV systems research.

To accomplish the above, the SERI outdoor PV test facility was established in 1982. The facility is located directly west of SERI's field test laboratory building in Golden, Colorado. The group has designed testing systems and analysis procedures for, and has tested, numerous amorphous silicon thin film submodules provided by SERI subcontractors and has performed long-term outdoor stability tests on CdS/$CuInSe_2$ and hydrogen passivated silicon solar cells. A significant contribution from this facility over the past year was the testing of large-area amorphous silicon submodules which supported the achievement of major milestones in the DOE/SERI PV Program.

The outdoor testing operations are presently divided into four functional areas: (1) Outdoor Performance Testing; (2) Stability Performance Testing; (3) Accelerated Stress Testing, and (4) Systems Simulation Testing. The following provides an overview of outdoor performance and stability testing capabilities at SERI, selected test results and performance trends.

- Outdoor Performance Testing: This activity includes the measurement of PV cell and submodule I-V characteristics in an outdoor environment under sunlight. Figure 1 illustrates typical test and measurement data and information recorded during a test program. The mainstay of the testing system is an HP 3054A data system (Figure 2) controlled by an HP 9836 computer. A specially designed test bed (Figure 3), with temperature control capabilities, vacuum hold down provisions, motor controlled light shutter, and calibrated pyranometer, can accommodate cells and submodules ranging in sizes up to .61 meteres (2 ft) by 1.1 meters (3.5 ft). A unique testing capability has been incorporated into this system which makes it possible to simultaneously test and measure individual cell I-V characteristics of series connected cells on a submodule substrate.

C-3

Over 200 tests have been performed on various thin-film submodules in the last two years. Selected test results are provided in Table 1 illustrating the range in submodule sizes (active areas) tested and corresponding performance data obtained during outdoor tests. Test results taken from Table 1 (efficiency and fill factor) are plotted against time (Figure 4) and submodule active area (Figure 5) illustrating performance trends.

Stability Performance Testing: A variety of testing systems are being utilized for long-term performance and stability measurements of cells and submodules. These systems include a hermetically sealed test chamber purged with nitrogen for outdoor stability exposure tests of cells and is monitored by an HP 3054A data system controlled by an HP 85 computer. Two additional outdoor test beds, which can accommodate large submodules and modules ranging in sizes up to .61 meters (2 ft) by 1.1 meters (3.5 ft) have provisions for temperature and environmental control during testing and are controlled and monitored by an HP 3054A or Acurex Autodata Ten/10 data systems. Recent testing utilizing these systems included outdoor stability testing of CdS/$CuInSe_2$ and hydrogen passivated silicon solar cells. Selected stability performance test results are illustrated by Figures 6 and 7 for a CdS/$CuInSe_2$ solar cell and by Figure 8 for a hydrogen passivated silicon solar cell.

Advanced PV Systems Research — Outdoor Testing

Typical Test and Measurement Data and Information Recorded during a Testing Program

- Date of test
- Time of test
- Test specimen I.D. number
- Insolation before and after test
- Temperature
- Area
- I_{sc} (short circuit current)
- V_{oc} (open circuit voltage)
- P_{max} (maximum power output)
- Current at P_{max}
- Voltage at P_{max}
- Current at V_{oc}
- Voltage at I_{sc}
- Efficiency
- Fill factor
- I-V curve and listing of data points
- Solar spectral response curve and listing of data points

Figure 1

Amorphous Silicon Test — Data & Control System

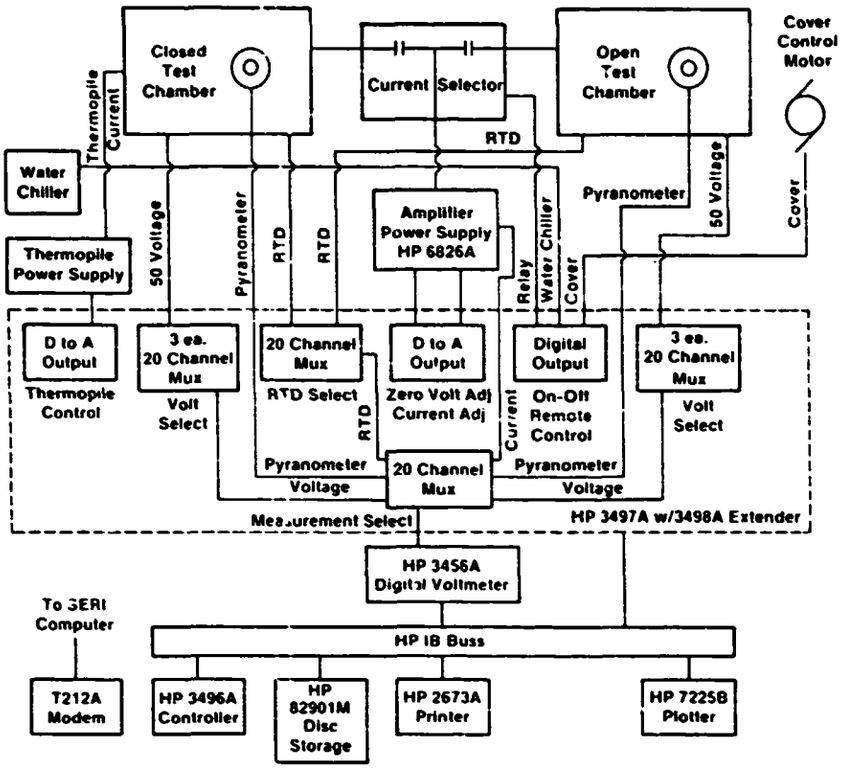
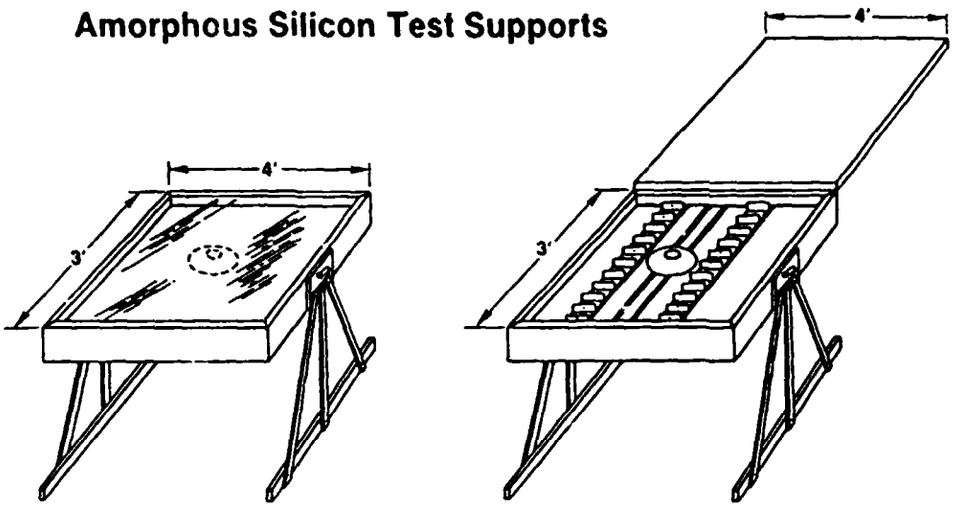


Figure 2

Amorphous Silicon Test Supports



Closed Chamber
Glass Cover
Dry N_2 Purge
Temperature Control 10° - 60° C
Pyranometer
RTD Temperature Measurements
Module Space
2 ea. 1' × 2-1/2'
or 1 ea. 2' × 3-1/2'
Contacts for 50 Cells

Open Chamber
Remote Control Lid and Light Shutter
Pyranometer
RTD Temperature Measurements
Module Space
2 ea. 1' × 2-1/2'
or 1 ea. 2' × 3-1/2'
Contacts for 50 Cells

Figure 3

PV Thin-Film Submodule Outdoor Performance Test Results

Sample Code No.	Material Type	Date Meas.	Time Meas.	Insolation W/m^2	Cell Temp. C^o	Isc (ma)	V_{oc} (volts)	FF (%)	Eff. (%)	Active Area (cm^2)	Dimensions (cm)
AS1	Amorphous Si	5/24/83	P.M.	957	39.0	70.9	15.3	51.2	4.6	126.9	---
AS2	"	5/24/83	P.M.	896	39.2	110.5	26.0	48.5	4.4	350.0	---
AS3	"	6/23/83	P.M.	1047	39.0	69.7	21.1	45.1	4.3	149.0	---
AS4	"	8/2/84	A.M.	923	36.3	66.1	15.1	58.1	6.1	102.4	21 x 10
• AS5	"	9/28/84	A.M.	1205	35.8	319.9	23.7	54.5	5.0	693	30 x 30
• AS6	"	9/28/84	A.M.	1049	36.1	314.9	23.1	57.0	5.5	722.4	30 x 30
AS7	"	2/7/85	A.M.	1182	32.1	341.5	22.7	57.1	5.1	733	30 x 30
AS8	"	2/8/85	P.M.	906	44.2	62.1	11.1	64.3	5.9	82.5	21 x 21

o Test Site Location: SERI Advanced PV Systems Outdoor Test Facility - Golden, Colorado

o Insolation Measurement Uncertainty: ±5% (Global)

• Encapsulated

Table 1

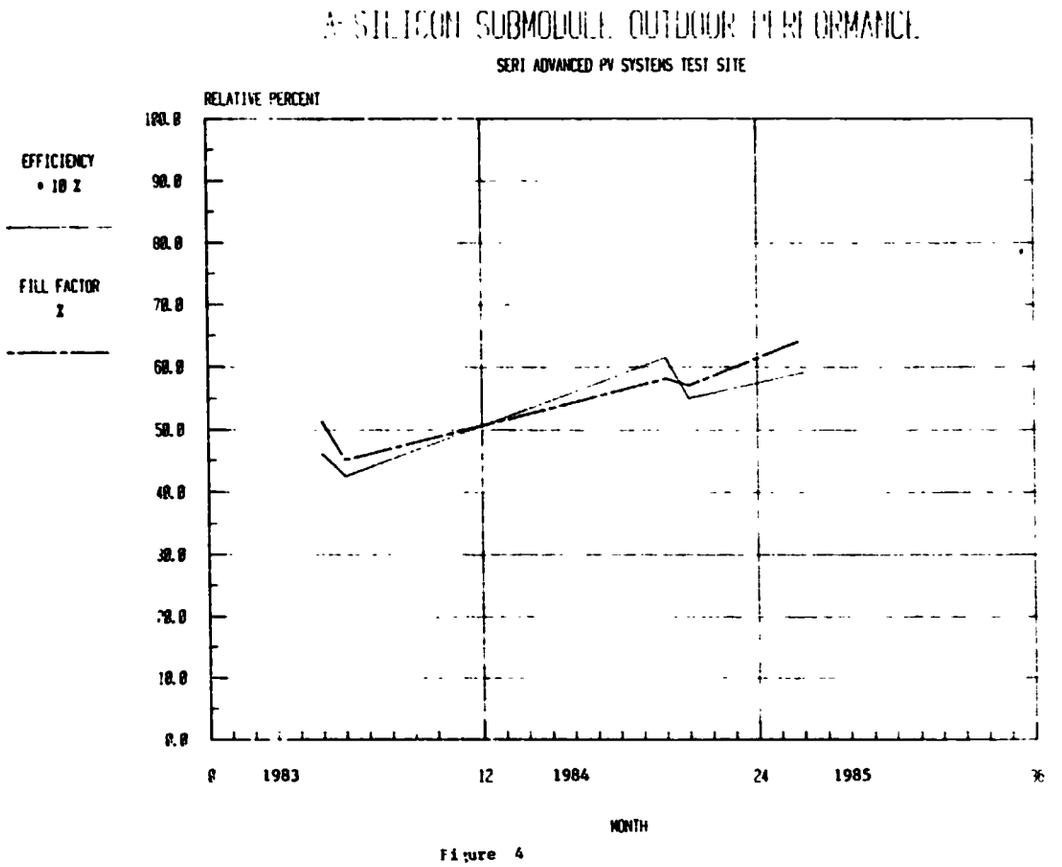


Figure 4

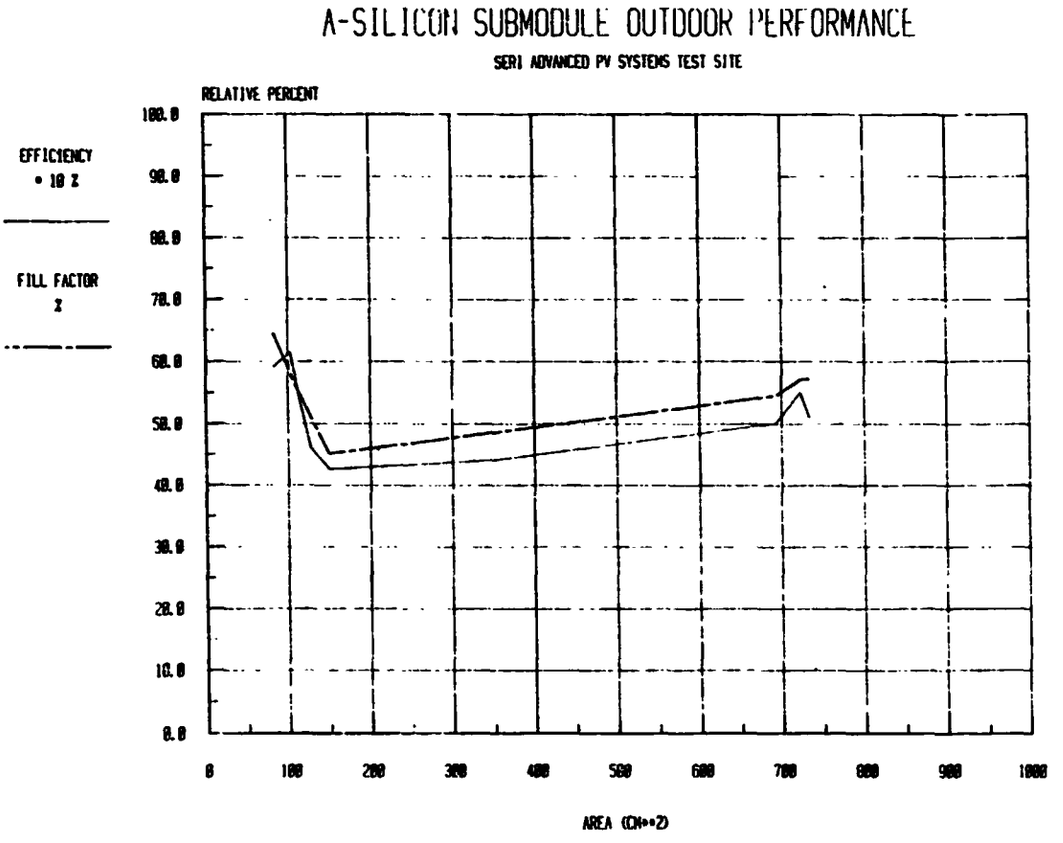

A-SILICON SUBMODULE OUTDOOR PERFORMANCE
SERI ADVANCED PV SYSTEMS TEST SITE
RELATIVE PERCENT
EFFICIENCY
• 10 Z
FILL FACTOR
Z
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
100
200
300
400
500
600
700
800
900
1000
AREA (CM**2)

Figure 5

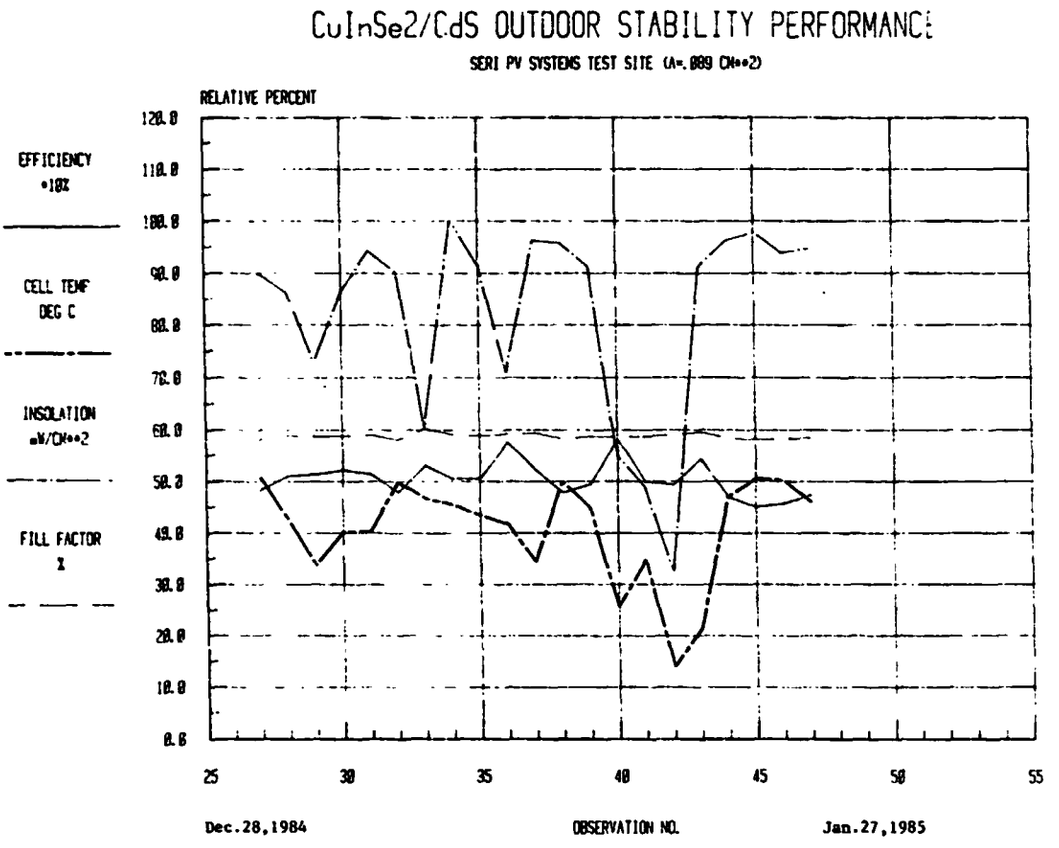

CuInSe2/CdS OUTDOOR STABILITY PERFORMANCE
SERI PV SYSTEMS TEST SITE (A=.009 CM**2)
RELATIVE PERCENT
EFFICIENCY *10%
CELL TEMP DEG C
INSOLATION mW/CM**2
FILL FACTOR %
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25
30
35
40
45
50
55
Dec.28,1984
OBSERVATION NO.
Jan.27,1985

Figure 6

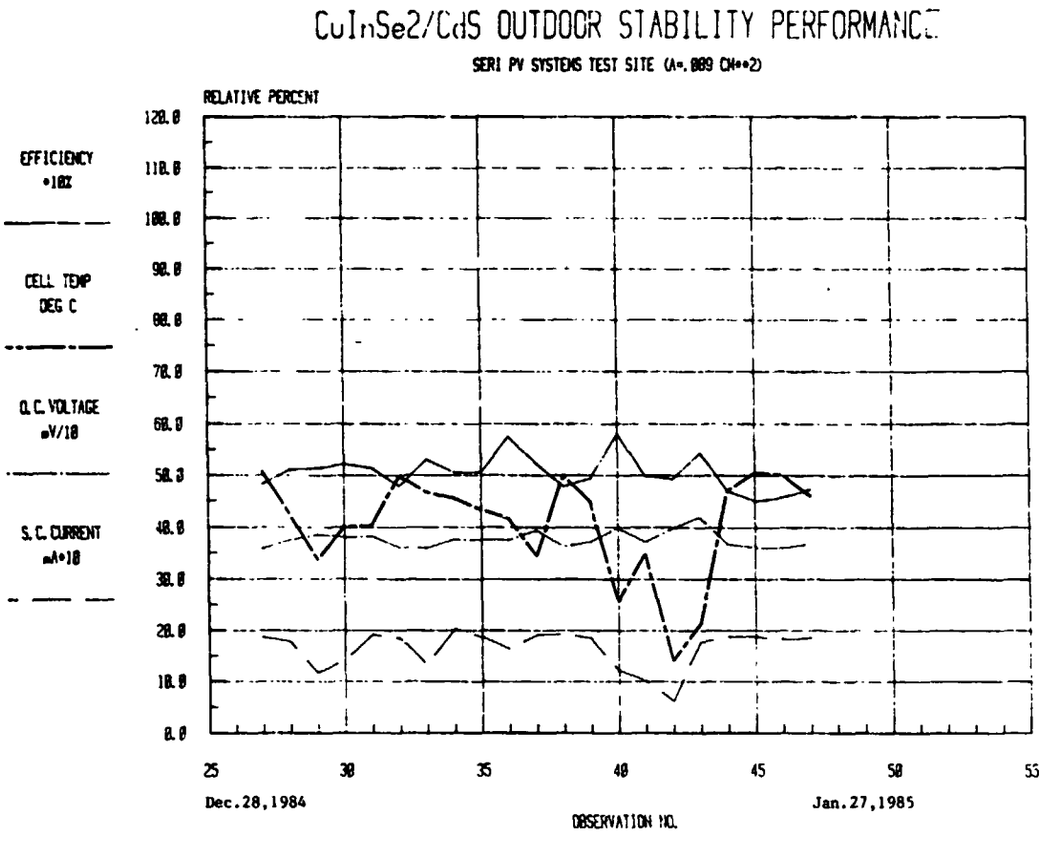

CuInSe2/CdS OUTDOOR STABILITY PERFORMANCE
SERI PV SYSTEMS TEST SITE (A=.089 CM**2)
RELATIVE PERCENT
EFFICIENCY
*10%
CELL TEMP
DEG C
O.C. VOLTAGE
mV/10
S.C. CURRENT
mA*10
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
25
30
35
40
45
50
55
Dec.28,1984
Jan.27,1985
OBSERVATION NO.

Figure 7

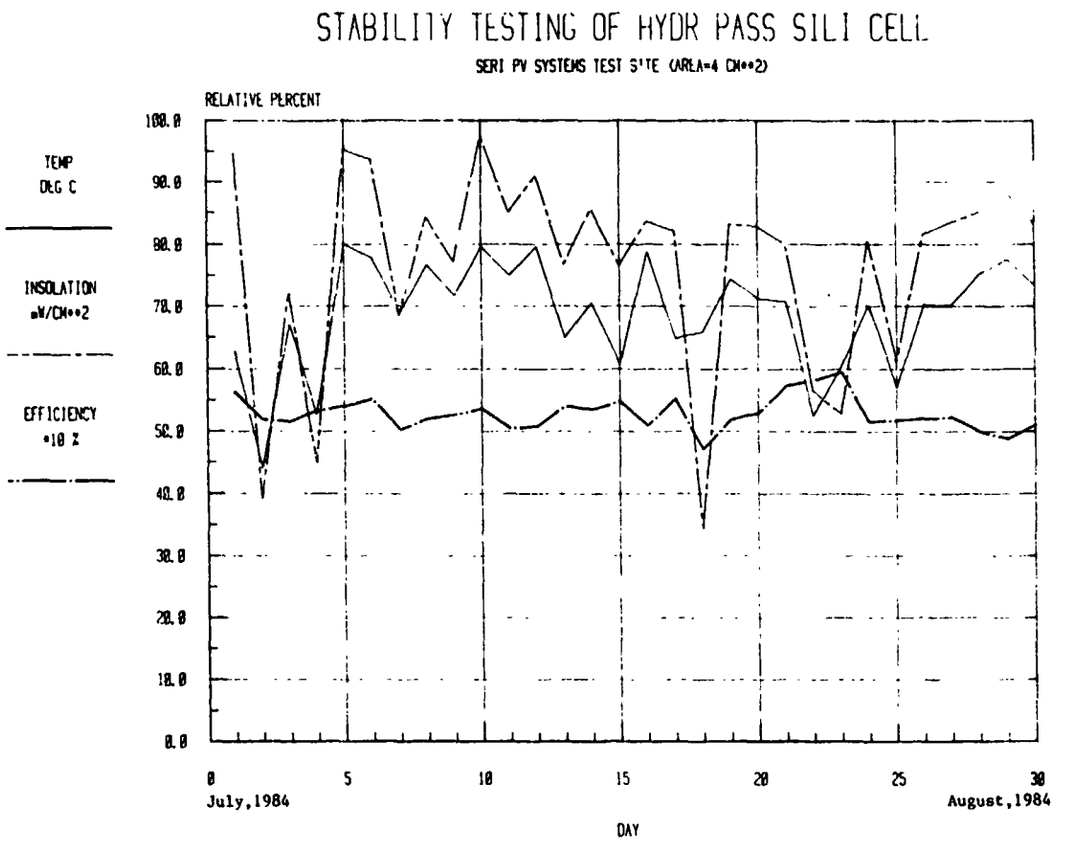

STABILITY TESTING OF HYDR PASS SILI CELL
SERI PV SYSTEMS TEST SITE (AREA=4 CM**2)
RELATIVE PERCENT
TEMP
DEG C
INSOLATION
mW/CM**2
EFFICIENCY
*10 %
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
5
10
15
20
25
30
July,1984
August,1984
DAY

Figure 8

DISCUSSION

LESK: I have seen some very high insolation values. You had one at 1200 W/m^2 with reflection from clouds adding on to a clear beam. Was that a special circumstance for that one, or will something else give it that high a value?

DE BLASIO: That is typical at our test facility on a clear summer day. There we average 1100, 1150, 1200, even up to 1240. Hard to believe, but it's true.