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Photovoltaics Program
Technology Development and Applications
Lead Center

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Photovoltaic Systems Test Facilities: Existing Capabilities Compilation

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March 1, 1982

Prepared for
U.S. Department of Energy
Through an Agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

(JPL PUBLICATION 81-14, REVISION 1)

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ABSTRACT

Photovoltaic Systems Test Facilities (PV-STFs) are used to evaluate complete photovoltaic systems, subsystems, and their interfaces. This report presents a general description of PV-STFs presently operated under the U.S. Department of Energy's National Photovoltaics Program, as well as descriptions of a number of privately operated facilities reflecting current understanding of those having test capabilities appropriate to PV hardware development. A summary of specific, representative test capabilities at the system and subsystem level is presented for each listed facility. This compilation indicates the range of system and subsystem test capabilities presently available to serve the needs of both the National Photovoltaics Program and the private sector photovoltaics industry.

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CONTENTS

EXECUTIVE SUMMARY 1

I. INTRODUCTION 1-1

A. BACKGROUND 1-1

B. SCOPE 1-1

C. DEFINITIONS 1-2

II. PHOTOVOLTAIC SYSTEMS TEST FACILITY DESCRIPTION 2-1

A. CHARACTERISTICS OF THE PHOTOVOLTAIC SYSTEMS TEST FACILITY . . . 2-1

B. PHOTOVOLTAIC SYSTEMS TEST FACILITY IMPLEMENTATION 2-1

III. PHOTOVOLTAIC SYSTEMS TEST FACILITIES: EXISTING CAPABILITIES 3-1

Figure

2-1. Generalized Photovoltaic System 2-1

Tables

1. Facility Information: U.S. DOE Photovoltaics Program Centers 2

2. Photovoltaic Test Facilities: Private Laboratories 3

3-1. General Facility Information: U.S. DOE Photovoltaics Program Centers 3-2

3-2. General Facility Information: Private Laboratories 3-3

3-3. Systems Test Capabilities: Photovoltaics Program Centers . . . 3-4

3-4. Collector Test Capabilities: Photovoltaics Program Centers . . 3-5

3-5. Power Conditioner Test Capabilities: Photovoltaics Program Centers 3-8

3-6. Storage Test Capabilities: Photovoltaics Program Centers . . . 3-11

3-7. Collector Test Capabilities: Private Laboratories 3-12

3-8. Power Conditioner Test Capabilities: Private Laboratories . . 3-15

3-9. Storage Test Capabilities: Private Laboratories 3-18

EXECUTIVE SUMMARY

To meet the objectives of the U.S. Department of Energy's National Photovoltaics Program, a number of evaluation, environmental, and performance tests of photovoltaic systems, subsystems, and major system components will be required during the next several years. This report is a description of test facilities identified as currently available to support anticipated Program system-level test activities. It also lists test capabilities at the subsystem and major component levels where these activities directly support programmatic system test requirements. Many of these facilities are presently available to support photovoltaics development activities within the private sector.[1]

Eleven test installations have been identified and surveyed to provide data summarizing their test capabilities. Of the eleven queried, four are Photovoltaics Program centers and seven are private testing laboratories. Tables 1 and 2 present an overview of these facilities.

Several other test facilities were identified as having PV-related test capabilities. These include the Florida Solar Energy Center, Hawaii Natural Energy Institute, Southern Solar Energy Center, and the Southwest Research Institute. These facilities have not been detailed in the present document, either because their availability to the Program is uncertain, or their emphasis is upon thermal technologies, "outside-the-fence" testing, or product certification. The latter activities lie beyond the scope of the current Photovoltaics Program.

The four Photovoltaics Program centers presently operate facilities with system-level test capabilities. This means that complete photovoltaic systems, consisting of array, power processing units, controls, and storage where appropriate, can be installed and operated to permit evaluation of system performance characteristics in a realistic environment. The Program centers also operate facilities for testing separate subsystems. Taken together, the system and subsystem level test results permit verification of system and subsystem design, performance, and interface requirements, as well as validation of performance models and design methodologies.

The private laboratories surveyed report test capabilities covering a wide range of environmental and accelerated life testing appropriate to the development requirements of photovoltaic subsystems and components. Although none of these laboratories presently exhibit system-level test capability, these facilities nevertheless represent a substantial resource available to support important elements of the overall system development effort.

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[1]The Residential Experiment Stations (RES) currently operated as part of the Photovoltaics Program have not been included in this compilation. The RESs were established for the purpose of conducting operational experiments on a set of prototype systems of fixed configurations. The System Test Facility (STF) is designed to accept and test systems and subsystems in a manner which permits frequent configuration changes. The two existing RESs may eventually be adapted for more general use as STFs. Options presently under consideration include their direct availability for use by private industry.

Table 1. Facility Information: U.S. DOE Photovoltaics Program Centers

Managing Agency	Location	Application[a]	Maximum Power, kW
Jet Propulsion Laboratory	Pasadena, California	RS, R, I	10
Lewis Research Center	Cleveland, Ohio	RS (U)	30
MIT/Lincoln Laboratory	Lexington, Massachusetts	RS, R, I (U)	10
Sandia National Laboratories	Albuquerque, New Mexico	RS, R, I CS (U)	150

[a]RS - Remote - Stand Alone
R - Residential
I - Intermediate
CS - Central Station
(U) - Utility Interface Capability

Table 2. Photovoltaics Test Facilities: Private Laboratories

Company	Location	Comments
Acton Energy Laboratory	Acton, Massachusetts	Test procedures are generated using customer-provided test plans. Solar thermal experience. Facility size: 3200 m^2
Approved Engineering Test Laboratories	Encino, California	A general purpose environmental test laboratory; sand, dust, vibration, shock, etc. AETL is a division of National Technical Services Co. and has five sites in southern California with varying capabilities and size
AVCO Environmental Testing Laboratories	Wilmington, Massachusetts	Environmental testing capabilities include climatic test facilities for temperature, humidity, salt fog, sand, dust, and fungus; AVCO has other general environmental test capabilities, including a seismic test facility
DSET Laboratories, Inc.	Phoenix, Arizona	Performance, reliability and durability testing of photovoltaic materials, components, and subsystems. Solar measurements; radiometric measurements of artificial light sources. Six remote sites and a seventh planned
Franklin Research Center	Philadelphia, Pennsylvania	Non-proft. Facility size: 19,000 m^2. Experience relative to tracking and control of electrical output and utility interface. Some research relative to development of thermal collectors
Structural Dynamics Research Corp.	Milford, Ohio	Facility size: 800 m^2. Mechanical and structural engineering consulting company; primarily failure and fatigue through analysis and testing.
Wyle Laboratories	Huntsville, Alabama	Environmental testing capabilities include accelerated power conditioner testing to 27 kW DC; load capability to 100 kW

SECTION I

INTRODUCTION

A. BACKGROUND

In the development of new sources of energy for the United States, assessment of the terrestrial photovoltaic (PV) option has been only recently initiated. As in most new technology programs, early PV system development efforts have relied extensively on modeling and simulation to assist in designing operational systems prior to their deployment. Despite such analyses, any newly-developed technology may experience unforeseen problems, particularly in the interactions between subsystems, and between the system and the operating environment. To identify and address such problems prior to actual system deployment, some form of testing and evaluation of full-scale prototype systems under realistic operating conditions is essential.

In recognition of this need, an early step taken by the National Photovoltaics Program was to initiate a planning activity whose purpose was to ensure the availability of test facilities adequate to the requirements of the Program. Participating in this activity were representatives of the principal Program centers involved in photovoltaic technology development and testing.

One of the first steps taken in this planning process was to compile information about PV systems test facilities both available for, and appropriate to, the specific testing requirements of Program-sponsored system development efforts. Included were facilities within the Photovoltaics Program centers, as well as state-supported and private facilities. The first STF Existing Capabilities Compilation, issued by the Jet Propulsion Laboratory in August 1981, summarized the collected PV-STF information and addressed the question of future Photovoltaics Program PV-STF requirements.

The present compilation has been updated to reflect recent substantial revisions in the National Photovoltaics Program structure and funding level. The current Photovoltaics Program is based on (1) an allocation of resources which will require the pursuit of considerably fewer technology options, (2) technology transfer to the private sector at an earlier stage of the development sequence, and (3) greater reliance on industry at all levels of technical decision-making. Accordingly, it should be noted that many of the facilities included in this revised compilation are currently available to the PV industry at large, while continuing to serve those activities directly supported by the Program.

B. SCOPE

The PV-STF characteristics summarized herein include the test capabilities of primary interest in the development of photovoltaic systems for all appplications areas: remote stand-alone, small roof-mounted,

medium-size, and large ground-mounted systems. Test capabilities are characterized as follows:

(1) Facility capacity/rating: maximum power handling capability, thermal capacity, storage capacity, etc.

(2) Test level: total system, subsystem, or major system component.

(3) Capacity to test in grid-connected mode, stand-alone, or both.

(4) Specific measurement capability as to type and capacity, where applicable.

This compilation lists several facilities whose primary capabilities are in subsystem and component testing (environmental and accelerated life). Although not strictly a part of system-level testing, subsystem and component testing constitute important elements of the overall system development process. Additionally, most testing of established products is performed at the subsystem and component levels. As more is learned about PV system-subsystem interactions and how to better model and simulate those interactions, testing at the subsystem and component levels is expected to assume an increasingly important role relative to system-level testing.

C. DEFINITIONS

Terms used in this compilation are defined below:

(1) Photovoltaic Systems Test Facility (PV-STF): A facility that tests and evaluates the performance of total PV systems, subsystems, and their interfaces.

(2) Subsystem Test Facility: A facility that tests and evaluates the performance of PV subsystems. Currently, there are three subsystems: array, power processing, and energy storage.

(3) Component Test Facility: A facility that tests and evaluates the performance of major PV system components, such as PV modules and inverters, which are elements of subsystems. Component testing includes environmental and accelerated-life testing.

(4) Environmental Testing: Testing that attempts to identify the mechanisms of failure caused by extremes of loads induced by environmental forces, either acting alone or in combination.

(5) Accelerated-Life Testing: Testing that attempts to accelerate long-term degradation effects and, in so doing, correlate that degradation with time.

(6) Program Center Test Facilities: Facilities that are directly owned or sponsored by the Federal Government and are a part of the National Photovoltaics Program.

(7) Non-Programmatic Facilities: Test facilities that are either owned and operated by a state or agency thereof or are privately owned. These facilities are available to the Program on a contract basis as required.

SECTION II

PHOTOVOLTAIC SYSTEMS TEST FACILITY DESCRIPTION

A. CHARACTERISTICS OF THE PHOTOVOLTAIC SYSTEMS TEST FACILITY

For purposes of this document, the principal characteristic of the PV-STF that distinguishes it from a typical full-scale system demonstration is that the facility is adaptable to a variety of PV system configurations, rather than dedicated to the evaluation of a single, specific design. Ideally, a PV-STF will be able to test various combinations of PV modules and arrays, including flat-plate or concentrator, PV and thermal, (whether side-by-side or combined), and accommodate either stand-alone or grid-interactive system designs. Additionally, the PV-STF should be capable of accepting configuration changes rapidly enough to permit practical retesting and evaluation. This latter characteristic is termed "breadboarding."

B. PHOTOVOLTAIC SYSTEMS TEST FACILITY IMPLEMENTATION

The following are key elements in the implementation of PV-STFs:

(1) PV System Configuration: In its most general form, a photovoltaic (or more properly, photovoltaic/thermal) system is configured as shown in Figure 2-1. Both electrical and thermal systems are

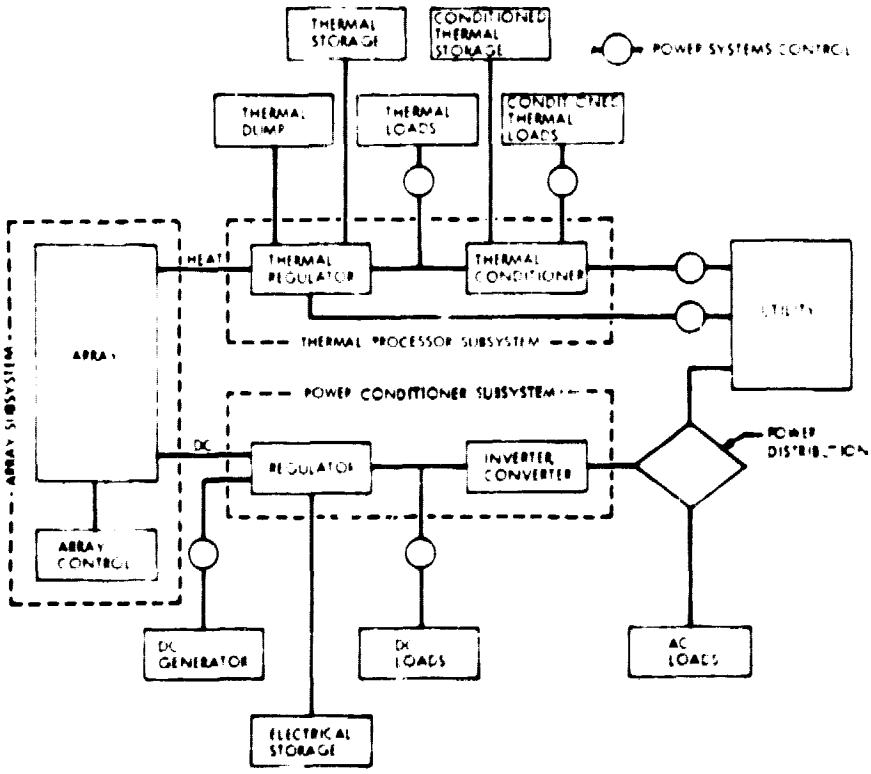

Figure 2-1. Generalized Photovoltaic System

involved. It should be noted that current systems concepts for most applications are considerably simpler than this general configuration, involving only the electrical system elements. Medium-size system concepts (commercial and industrial applications) presently exhibit the greatest diversity, due to the potential value of both electrical and thermal energy in this sector, and the potential for either concentrator or flat-plate designs. To support the development of a technology characterized by a large variety of practical system forms and applications, it is clearly of value for a PV-STF to be highly adaptable, allowing quick reconfiguration of its test bed to accommodate and test a different system once testing of a previous system is complete.

(2) Test Procedures and Equipment: In the development and comparative evaluation of multiple system concepts, commonality of test equipment and procedures is essential. With several PV-STFs in different climates testing a variety of photovoltaic systems, uniformity of test methods is essential to ensure valid comparison of results. The National Photovoltaics Program has supported the development of such test methods with the cooperation of private laboratories, industry, government, and public interest groups. The results to date appear in Interim Performance Criteria for Photovoltaic Energy Systems, a document published by the Solar Energy Research Institute.[2] These results are expected to provide a uniform basis for subsequent development of industry-wide test procedures and standards for evaluation of PV systems.

(3) Data Acquisition and Processing: Typical kinds of information provided by a PV-STF include efficiency for various modes of operation, initial reliability estimates, transient response characteristics, assessment of system modeling and simulation, assessment of control strategies, and stability evaluation. Timely analysis and dissemination of the results of programmatic systems testing and evaluation performed in PV-STFs are expected to enhance the worth of these data.

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[2] Interim Performance Criteria for Photovoltaic Energy Systems, SERI/TR-742-654, R. DeBlasio, et. al., December 1980. This document, issued by the Solar Energy Research Institute, Golden, Colorado, for the U.S. Department of Energy, presents interim results of efforts "to identify, develop, and promulgate performance criteria and test methods for photovoltaic solar energy conversion systems."

SECTION III

PHOTOVOLTAIC SYSTEMS TEST FACILITIES: EXISTING CAPABILITIES

This section summarizes, in tabular form, the information collected on PV system, subsystems, and major component testing facilities. Addressed are general facility information as well as representative testing capabilities. The information contained in the following tables is not intended as an exhaustive description of the capabilities of each facility, nor does it purport to indicate what tests are appropriate for particular system or subsystem development activities. Rather, the included information is intended primarily to illustrate the general range of capabilities provided by each facility. Inquiries regarding more specific test capability or facility availability should be directed to the appropriate facility contact (see Tables 3-1 and 3-2).

The compiled information is contained in four sections, as follows:

(1) Summary Tables: Table 3-1 summarizes the information obtained for the National Photovoltaics Program Centers. Locations, contacts, application sector capabilities, maximum power handling capability and, where available, initial and annual costs are shown.

Table 3-2 summarizes the capabilities of private laboratories.

(2) System Test Capabilities: Table 3-3 delineates the capabilities of those facilities that have total system testing capacity. These capabilities are broken down by major subsystem; i.e., array, power conditioner, and storage.

(3) Subsystems Test Capabilities - Photovoltaics Program Centers: Tables 3-4 through 3-6 present detailed descriptions of the test capabilities of the Program field centers.

(4) Subsystems Test Capabilities - Private Laboratories: Tables 3-7 through 3-9 give a detailed description of the test capabilities of the private laboratories surveyed.

Table 3-1. General Facility Information: U.S. DOE Photovoltaics Program Centers

Managing Agency	Location	Phone/Contact	Application[a]	Maximum Power kW	Initial Cost, $K (year)	Annual Cost, $K
Jet Propulsion Laboratory	Pasadena, California	(213) 577-9440 R. Baisley (213) 177-9161 J. Graf	RS, R, I	10		
Lewis Research Center	Cleveland, Ohio	(216) 433-6295 (FTS) 294-6295 W. Masica	RS	30		
MIT/Lincoln Laboratory	Lexington, Massachusetts	(617) 862-5500, ext. 7973 S. E. Forman	RS, R, I	10	250 (1978)	50-65
Sandia National Laboratories	Albuquerque, New Mexico	(FTS) 844-0112 H. J. Gerwin	RS, R, I, CS	150	500 (1976)	600

[a]RS - Remote - Stand Alone
R - Residential
I - Intermediate
CS - Central Station

Table 3-2. General Facility Information: Private Laboratories

Company	Location	Phone/Contact	Comments
Acton Energy Laboratory	533 Ma[illegible] treet Acton, Ma[illegible]achusetts 01720	(617) 263-2933 Mr. Russell Levin	Test procedures are generated using customer-provided test plans. Solar thermal experience. Facility size: 3200 m^2
Approved Engineering Test Laboratories (AETL)	15720 Ventura Blvd. Encino, California 91436	(213) 783-5985 Mr. A. Edelstein, or (213) 306-3994 Mr. David Pelk	A general purpose environmental test laboratory; sand, dust, vibration, shock, etc. AETL is a division of National Technical Services Co. Capabilities vary from site to site. AETL has five sites in southern California with varying capabilities and size
AVCO Environmental Testing Laboratories	201 Lowell Street Wilmington, Massachusetts	(617) 657-2222 Mr. Harry Zoglia Mr. Al Koch	Environmental testing capabilities include climatic testing facilities for temperature, humidity, salt fog, sand, dust, and fungus
DSET Laboratories, Inc.	Box 1850 Black Canyon Stage Phoenix, Arizona 85029	(602) 465-7356 Mr. Matt Rupp	Performance, reliability, and durability testing of photovoltaic materials, components, and subsystems. Six remote sites and a seventh planned
Franklin Research Center (FRC)	20th and Parkway Philadelphia, Pennsylvania 19103	(215) 448-1591 Mr. Charles Belsterling	Non-profit. Facility size: 19,000 m^2. Experience relative to tracking and control of electrical output and utility interface. Some research relative to development of thermal collectors
Structural Dynamics Research Corp. (SDRC)	200 Eastman Drive Milford, Ohio 45515	(513) 576-2400 Mr. Garth Wiley	Facility size: 800 m^2. Mechanical and structural engineering consulting company; primarily failure and fatigue through analysis and testing
Wyle Laboratories	7800 Governors Dr. West Huntsville, Alabama 35807	(205) 837-4411 Mr. David Christensen	Environmental testing capabilities include accelerated testing, power conditioner testing to 27 kW DC; load capability to 110 kW

Table 3-3. Systems Test Capabilities: Photovoltaics Program Centers

Facility	Facility Size	Array				Power Conditioner		Utility Connection, kVA	Storage		Load	
		Flat Plate	Concentrator	Tracking Accuracy	Thermal	DC Rating, kW	AC Rating, kVA		Type	Rating, kWh	Static, kW	Reactive, kVA
Jet Propulsion Laboratory	10 acres (RS, R, I)	Yes	3500 Suns	± 0.05 deg 2-Axis	50 gpm at 150 psi	10	10	No	Batteries	130 amp-h	Yes	Yes
Lewis Research Center	12,000 m^2 (RS)	Yes	100 Suns	-	-	30	30 ± 0.8 PF	30	Batteries, Redox	48 10	50	30 Cap 15 Ind
MIT Lincoln Laboratory	750 m^2 (RS, R, I)	Yes	3 Suns	-	(ASHRAE)	2.5	10	10	Batteries, Flywheel	750 Experi-mental	10	3
Sandia National Laboratories	930 m^2 (RS, R, (I, CS)	Yes	1500 Suns	± 0.08 deg	60 kBtu/h Cooling	10	180 ± 0.8 PF, 3ϕ	180	Batteries	24	150	228

Table 3-4. Collector Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
I. Qualification				
(Environmental)	(RS, R, I)	(RS)	(RS, R, I)	(RS, R, I, CS)
A. Controlled				
1. Rain	Yes	--	Yes	--
2. Humidity	Yes	--	--	Yes
3. Salt Fog	Yes	--	--	Yes
4. Hail	Yes	--	--	Yes
5. Fire (UL790/723)	--	--	ASTM D635	Yes
6. Shipping/Handling	--	--	--	Yes
7. Wind/Vibration (UL997)	Yes	--	--	Yes
8. Temperature Cycling	-65°C to 150°C	--	-70°C to 200°C	-65°C to 120°C
9. Size Limits	4 x 4 ft	--	Temp - 3 x 3 x 3 ft; other, 4 x 8 ft	4 x 10 ft
B. Natural (NE, SE, MW, etc.)	SW, High Desert	Midwest	NE	SW, High Desert

Table 3-4. (Cont'd) Collector Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
II. Performance				
A. Capability	(RS, R, I)	(RS)	(RS, R, I)	(RS, R, I, CS)
1. Flat Plate	Yes	Yes	Yes	Yes
2. Concentrator (Suns)	3500	100	3	1500
3. Tracking Accuracy	± 0.05 deg	--	--	± 0.08 deg
4. Simulator (size)	4 x 8 ft	4 x 8 ft	5 x 5 ft	--
5. Thermal				
a. Cooling	50 gpm at 150 psi	--	Yes	60k Btu/h
b. Storage	--	--	40 gal	--
c. Fluid Loop	--	--	100°C, 1 gpm	90°C, 12 gpm
d. ASHRAE				
i. Storage	--	--	--	--
ii. Collector	--	--	Yes	Yes

Table 3-4. (Cont'd) Collector Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
B. Measurement				
1. Simulator				
a. Temperature (Module)	Yes	Yes	Yes	Yes
b. Hot Box	4 x 4 ft, -65°C at 150°C	--	4 x 4 ft, 150°C	--
c. Irradiance	150 MW/cm^2	Pulsed, 10^4 MW/cm^2 Steady, 150 MW/cm^2	85-110 MW/cm^2	105 MW/cm^2
2. Insolation				
a. Direct	Yes	Yes	Yes	Yes
b. Diffuse	Yes	Yes	--	--
c. Total	Yes	Yes	Yes	Yes
d. UV	--	--	Yes	--
3. IV Curves				
a. Manual	Yes	Yes	Yes	--
b. Automatic	Yes	Yes	Yes	Yes
4. Load				
a. Dynamic Sweep	Auto and Manual	Manual	Auto and Manual	Auto and Manual
b. Static	Manual	Yes	Yes	Yes

Table 3-5. Power Conditioner Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
I. Environmental				
A. Temperature				
1. Min-Max	-55°C to 200°C	--	3 x 3 x 3 ft -70°C to 200°C	-65°C to 120°C
2. Cycling	Yes	--	Yes	Yes
3. Dwell	Yes	--	Yes	Yes
B. Humidity	Yes	--	--	Yes
C. Vibration	Yes	--	Yes	Yes
D. Noise				
1. Acoustic	Yes	--	--	Yes
2. External EMI	Yes	--	--	Yes
3. Internal EMI	Yes	Yes	--	Yes

Table 3-5. (Cont'd) Power Conditioner Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
II. Performance				
A. DC				
1. Rating	10 kW, 400 V	30 kW, 600 V	2.5 kW, 400 V	10 kW, 375 V
2. Switch Rating	600 V, 100 amp	240 V, 125 amp	--	600 V, 100 amp
B. AC				
1. Rating (kVA, V, PF)	10, 240, 0.8	30, 240, ± 0.8	10, 240, 1	180, 440, 0.8
2. Commutation	Line and Self	Line and Self	Line and Self	Line and Self
C. Load Variation	Yes	Yes	Yes	Yes
D. Input Variation	Yes	Yes	Yes	Yes
E. Functional Tests				
1. Short-Circuit	Yes	Yes	Yes	Yes
2. Lightning	Yes	--	--	Yes
3. Internal Switching	Yes	Yes	Yes	Yes
4. External Switching	Yes	Yes	Yes	Yes
5. Controls	Yes	Yes	Yes	Yes
6. Temperature	Yes	Yes	Yes	Yes

Table 3-5. (Cont'd) Power Conditioner Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
III. Measurement				
A. Array Simulation	2 kW	--	--	10 kW and 75 kW
B. Load Simulation				
1. Static	10 kW, 240 V	50 kW, 250 V	10 kW, 240 V	150 kW, 240 V
2. Reactive	5 k VA, 240 V, ± 0.8 PF	30 kVA Cap., 15 kVA Ind., 240 V, ± 0.8 PF	--	228 kVA, 240 V, ± 0.5 PF
3. Overload	--	--	--	--
4. Incremental Load	Yes	Continuous kW	Continuous kW	3.3 amp, 1 kW
5. Wattmeters	Yes	Yes	Yes	Yes
6. Auto Data Rate	Yes	5 kHz	12 channels/sec	14/sec

Table 3-6. Storage Test Capabilities: Photovoltaics Program Centers

	JPL	Lewis	MIT-LL	Sandia
I. Environmental				
A. Temperature				
1. Min-Max	-55°C to 200°C	--	--	-65°C to 200°C
2. Cycling	Yes	--	--	Yes
3. Dwell	Yes	--	--	Yes
B. Water Loss	Yes	--	Yes	Yes
C. Hydrogen Accumulation	Yes	--	--	--
II. Performance				
A. Batteries	130 amp-h, 15 kWh	48 kWh	750 kWh	24 kWh
1. Constant Discharge	--	--	2.5 kW, 20 amp	24 kW, 100 amp
2. Constant Charge	200 V, 150 amp	130	130 V, 150 amp	320 V, 1[illegible] amp
B. Flywheel	--	--	36-in. dia	--
C. Pumped Hydro	--	--	--	--
D. Other	--	Redox, 10 kWh	--	--
III. Measurement				
(Volts, amps, shunts)	Yes	Yes	Yes	Yes

Table 3-7. Collector Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
I. Qualification							
(Environmental)							
A. Controlled	Small Components	Modules and Panels					
1. Rain	--	Yes	Yes	Yes	--	--	Yes
2. Humidity	--	Yes	Yes	Yes	--	--	Yes
3. Salt Fog	Small Chamber	Yes	Yes	--	--	--	Yes
4. Hail	--	Yes	Yes	--	--	--	Yes
5. Fire (UL790/723)	--	Yes	--	--	--	--	Yes
6. Shipping/Handling	--	Yes	Yes	Yes	--	Yes	Yes
7. Wind/Vibration (UL997)	Seismic Vibration	Yes	Seismic Vibration	--	--	Seismic Vibration	Yes
8. Temperature Cycling	Small Chamber	-150°C to 350°C	Yes	-30°C to 70°C	--	--	Yes
9. Size Limits	--	25 x 40 x 12 ft	18 x 18 x 18 ft	1 x 3 ft	--	--	12 x 24 ft
B. Natural							
(NE, SE, NW, etc.)	--	SW/So. Calif. 10 x 14 ft		SW; Remote Sites All Regions	--	--	SE

Table 3-7. (Cont'd) Collector Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
II. Performance							
A. Capability							
1. Flat Plate	--	Yes	--	Yes	--	--	Yes
2. Concentrator (Suns)	--	--	No	100	--	--	60
3. Tracking Accuracy	--	--	--	$\pm$ 0.1°	--	--	$\pm$ 1.25 deg
4. Simulator (size)	--	Yes	--	6 x 10 ft	--	--	4 x 8 ft
5. Thermal							
a. Cooling	--	Yes	Yes	25 kW	--	--	20 kW
b. Storage	--	Yes	--	540 MJ/day	80 gal	--	300 gal
c. Fluid Loop	--	Yes	--	10°C to 316°C, 0-10 gpm	93°C	--	4°C to 315°C, 10 gpm
d. ASHRAE	--	Yes	--	93-77, 94-77 95-81, 96-80	--	--	--
i. Storage	--	Yes	--	Yes	--	--	Yes
ii. Collector	--	Yes	--	Yes	--	--	Y[illegible]

Table 3-7. (Cont'd) Collector Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
B. Measurement							
1. Simulator							
a. Temperature (Module)	--	Yes	--	Yes	--	--	Yes
b. Hot Box	--	Yes	--	4 x 8 x 1 ft	--	--	4 x 8 x 2 ft
c. Irradiance	--	Yes	--	125 MW/cm^2	--	--	100 W/cm^2
2. Insolation							
a. Direct	--	Yes	--	Yes	--	--	Yes
b. Diffuse	--	Yes	--	Yes	--	--	Yes
c. Total	--	Yes	--	Yes	--	--	Yes
d. UV	--	Yes	--	Yes	--	--	Yes
3. IV Curves							
a. Manual	--	Yes	--	--	--	--	--
b. Automatic	--	Yes	--	Yes	--	--	Yes
4. Load							
a. Dynamic Sweep	--	Yes	--	Yes	--	--	Yes
b. Static	--	Yes	--	Yes	--	--	Yes

Table 3-8. Power Conditioner Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
I. Environmental							
A. Temperature							
1. Min-Max	--	-70°C to 175°C	-73°C to 538°C	--	Yes	--	-85°C to 150°C
2. Cycling	--	Yes	Yes	--	Yes	--	Yes
3. Dwell	--	Yes	Yes	--	Yes	--	Yes
B. Humidity	--	Yes	Yes	--	Yes	--	Yes
C. Vibration	--	Yes	Yes	--	Yes	--	Yes
D. Noise							
1. Acoustic	Yes	Yes	--	--	Yes	--	Yes
2. External EMI	Yes	Yes	--	--	Yes	--	--
3. Internal EMI	Yes	Yes	--	--	--	--	--

Table 3-8. (Cont'd) Power Conditioner Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
II. Performance							
A. DC							
1. Rating	--	--	--	--	--	--	27 kW, 90 V
2. Switch Rating	--	Yes	--	--	Yes	--	90 V, 300 amp
B. AC							
1. Rating	--	--	--	--	--	--	90 kVA, 480 V, ± 0.8 PF
2. Commutation	--	Line and Self	--	--	--	--	Line and Self
C. Load Variation	--	Yes	--	--	--	--	Yes
D. Input Variation	--	Yes	--	--	--	--	Yes
E. Functional Tests							
1. Short-Circuit	--	Yes	--	--	--	--	Yes
2. Lightning	--	Yes	--	--	--	--	Yes
3. Internal Switching	--	Yes	--	--	--	--	Yes
4. External Switching	--	Yes	--	--	--	--	Yes
5. Controls	--	Yes	--	--	--	--	Yes
6. Temperature	Small Chamber	Yes	--	--	--	--	Yes

Table 3-8. (Cont'd) Power Conditioner Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
III. Measurement							
A. Array Simulation	--	--	--	--	--	--	Yes
B. Load Simulation							
1. Static	--	100 kW	--	--	--	--	Yes, Variable V
2. Reactive	--	480 V, 3ϕ	--	--	--	--	90 kVA , 480 V $\pm$ 0.8 PF
3. Overload	--	Yes	--	--	--	--	Yes
4. Incremental Load	--	Yes	--	--	--	--	--
5. Wattmeters	--	Yes	--	--	--	--	Yes
6. Auto Data Rate	--	1 kHz	--	--	--	--	Yes

Table 3-9. Storage Test Capabilities: Private Laboratories

	Acton	AETL	AVCO	DSET	FRC	SDRC	Wyle
I. Environmental							
A. Temperature							
1. Min-Max	--	70°C to 170°C	-73°C to 538°C	--	--	--	-85°C to 150°C
2. Cycling	--	Yes	Yes	--	--	--	Yes
3. Dwell	--	Yes	Yes	--	--	--	Yes
B. Water Loss	--	Yes	--	Yes	--	--	Yes
C. Hydrogen Accumulation	--	Yes	--	Yes	--	--	Yes
II. Performance							
A. Batteries							
1. Constant Discharge	--	--	--	3 kW, 150 amp	--	--	30 kW, 200 amp
2. Constant Charge	--	--	--	Yes	--	--	60 V, 100 amp
B. Flywheel	--	4-ft dia	--	--	--	Yes	--
C. Pumped Hydro	--	200 psig 20-ft dia x 31 ft	--	--	--	--	--
D. Other	--	--	--	--	Compressed Air	--	--
III. Measurement							
(Volts, amps, shunts)	--	--	Yes	Yes	--	--	Yes