SAND80-1568
Unlimited Release
UC-62

150 kW_e Solar Irrigation Project Test and Evaluation Plan

Leroy E. Torkelson

Prepared by Sandia Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550 for the United States Department of Energy under Contract DE-AC04-76DP00789

Printed August 1980

Sandia National Laboratories

2900-Q(3-80)

Issued by Sandia Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America

Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $4.50; Microfiche $3.00

SAND80-1568
Unlimited Release
Printed August 1980

150 kW_e SOLAR IRRIGATION PROJECT TEST AND EVALUATION PLAN

L. E. Torkelson
Experimental Systems Operations Division 4721
Sandia National Laboratories
Albuquerque, NM 87185

ABSTRACT

The 150 kW_e Solar Irrigation Project at Coolidge, Arizona consists of a 23,000-ft^2 line focus collector subsystem, a 30,000-gallon thermal storage subsystem, and a 150 kW_e power generation unit.

The purpose of this document is to present the plan for the facility's testing and evaluation, a description of the facility, and the objectives of the project. Detailed test plans and a schedule are included.

150 kW_e SOLAR IRRIGATION

PROJECT

TEST AND EVALUATION PLAN

APPROVALS:

PROJECT MANAGER
SANDIA LABORATORIES

SOLAR ENERGY PROJECTS DEPARTMENT
SANDIA LABORATORIES

PROJECT MANAGER
UNIVERSITY OF ARIZONA

GOVERNMENT TECHNICAL REPRESENTATIVE
DOE/ALO

5/19/80

DIVISION OF CENTRAL SOLAR TECHNOLOGY
DOE/HQ

CONTENTS

ILLUSTRATION

TABLES

150 kW_e SOLAR IRRIGATION PROJECT TEST AND EVALUATION PLAN

Scope

This document defines the plan for test and evaluation of the 150 kW_e Solar Irrigation Project at Coolidge, Arizona. The testing will commence at the completion of construction checkout of the project. The tests defined by this plan will last for approximately 1 year. It is contemplated that additional operational testing will follow, but its exact nature is undefined at this point in time.

Specifically, this document defines the objectives, responsible organizations, types and duration of tests, test schedules, data requirements, and data reduction and analysis requirements for the tests.

Description and Background

The 150 kW_e Solar Irrigation Project is part of the Solar Thermal Program supported by the Department of Energy (DOE). The 150 kW_e Solar Irrigation Project undertakes the design, construction, and operation of a solar thermal electric power plant. The primary objective of the Solar Thermal Program is "to provide a sound technological and industrial base on which a viable solar thermal power industry can be founded." This will be accomplished by establishing a high confidence in the technical and cost readiness of solar thermal concentrating collector systems in industrial process heat, cogeneration, electric energy, and other application sectors.

The objectives of the 150 kW_e Solar Irrigation Project are as follows:

1. To provide private industry the opportunity to participate, both as manufacturer and user, in solar technology development,
2. To prepare a detailed design of a solar-powered experimental facility to provide 150 kW_e of electrical power to be fed into a local utility grid to offset the load of operating deep well irrigation pumps,
3. To construct the facility in accordance with the prepared design and install it on a farm near Coolidge, Arizona, and
4. To operate the facility in an actual farm environment and gather data on the facility's performance.

The project is the world's largest solar thermal power plant. A preliminary design study was undertaken early in 1977 by three contractors and completed in August 1977. The project site was selected in February 1977 and is the Dalton Cole farm south of Coolidge, Arizona. On the basis of the conceptual design competition, Acurex Corporation was selected as the prime contractor for this project, as well as the supplier of the solar collectors. The major subcontractors to Acurex are Sundstrand Corporation and Sullivan and Masson Consulting Engineers. Sundstrand is the supplier of the Organic Rankine Cycle (ORC) power generation unit. The team of Sullivan and Masson and Acurex was responsible for the detail design task.

A schematic diagram of the 150 kW_e Solar Irrigation Project is shown in Figure 1. Basically, the Acurex collectors heat Caloria HT-43 heat transfer oil to 288°C (550°F). The oil is then transferred to thermal storage or moved directly to the vaporizer where toluene is superheated for use by the Organic Rankine Cycle power generation unit.

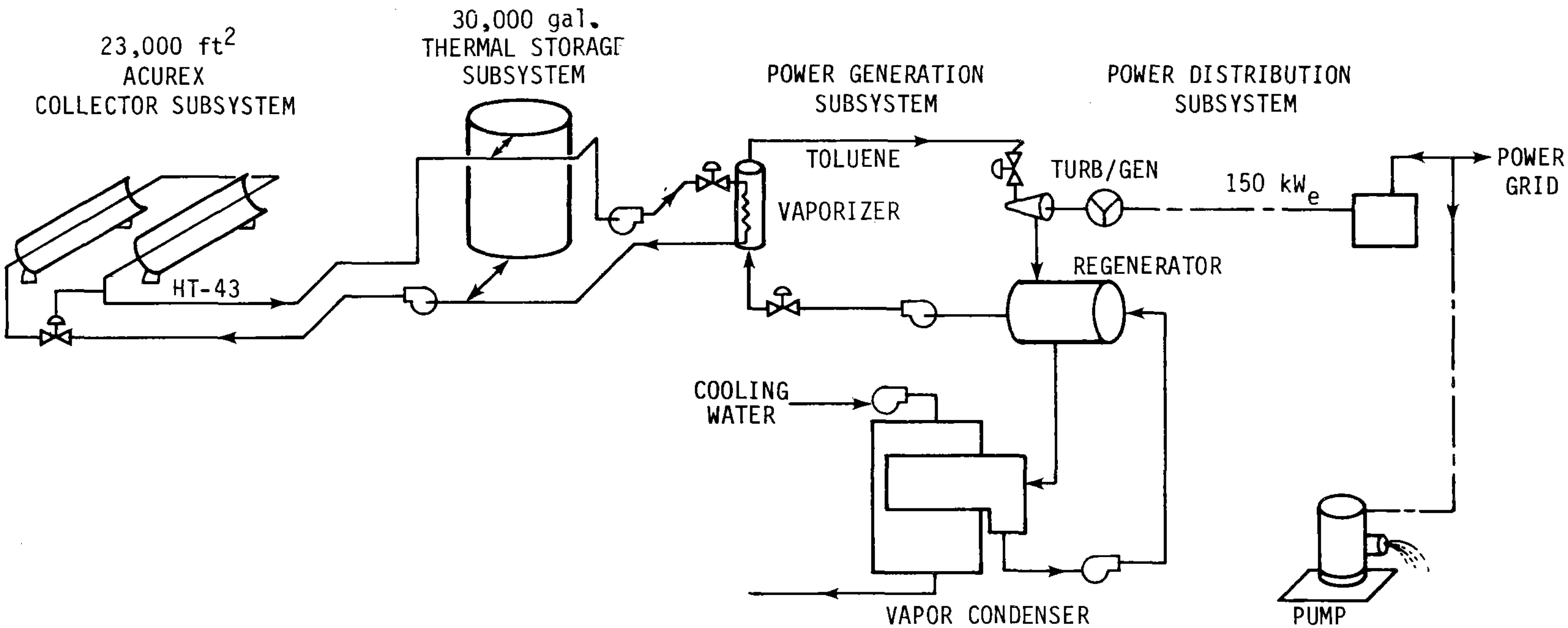

Figure 1. Schematic Diagram of the 150 kW_e Solar Irrigation Project

Test Objectives

This 1-year test program has been subdivided into two phases. The first phase, the subsystem characterization phase, will have a duration of approximately 4 months, with the exception of the collector subsystem tests which will continue all year and be devoted to checking out and determining the operational characteristics of each individual subsystem. The second phase, the system operation phase, will occupy the remainder of the year and will entail the operation of the complete system on a daily basis to demonstrate its capabilities.

Subsystem Characterization Phase

This phase will begin with an evaluation of the thermal storage subsystem. Its thermal loss characteristics will be determined along with the characteristics of its thermocline. Next, the system safety interlocks and malfunction lockouts will be checked out. Then, the entire system will be brought on line, and the operational characteristics of the individual subsystems will be determined. Further, this phase will be devoted to developing and verifying operational and maintenance procedures for the system.

System Operation Phase

During this phase, the entire system will be in operation daily with the goal of delivering the maximum possible electrical energy to the power grid. To achieve this goal, a variety of operational techniques will be investigated. For example, during periods of consistently sunny days, the ORC subsystem's electrical output will be adjusted to a rate that will allow it to operate continuously, 24 hours per day, to avoid the losses associated with starting it up and shutting it down. This technique will be compared to operation of the ORC subsystem at its peak efficiency as energy is available.

Overall system performance will be monitored daily to provide data for future system designs and a comparison with the DOE specification requirements. The characteristics of the individual subsystems will be closely checked periodically to monitor any degradation so that the effects of the individual subsystems on the overall system performance can be monitored.

For both phases of testing, records will be kept to document operational procedures and changes, maintenance procedures and changes, and to maintain a record of repairs and associated downtimes. The records will differentiate between activities required to support operating subsystems and to support the instrumentation. Man-hours and spare parts costs for the operation and maintenance of the system will be established.

Test Objectives within Each Subsystem

Collector Field Subsystem -- The test objectives are as follows:

1. Determine overall subsystem performance characteristics,
2. Determine parasitic electrical energy requirements,
3. Determine optimum starting time,
4. Determine control system characteristics,
5. Determine subsystem performance degradation with time,
6. Determine washing cycle requirements,
7. Determine the operating and maintenance characteristics,
8. Compare the actual characteristics to design targets,
9. Determine thermal losses both during steady-state operation and during overnight cool-down, and
10. Determine optical property degradation of the collectors with time.

ORC Subsystem -- The test objectives are as follows:

1. Determine subsystem performance at design conditions,
2. Determine subsystem performance at off-design conditions,
3. Determine boiler efficiency under a variety of operating conditions,
4. Determine the energy available from the condenser,

5. Determine the parasitic electrical energy consumed,
6. Determine the thermal energy required to start the ORC subsystem,
7. Determine the subsystem performance degradation with time,
8. Determine the operating and maintenance characteristics, and
9. Compare the actual characteristics to the design goals.

Thermal Storage Subsystem -- The test objectives are as follows:

1. Determine the thermal loss from the subsystem,
2. Determine the growth rate of the thermocline under steady-state conditions,
3. Determine the stability of the thermocline under transient conditions,
4. Determine a technique for flushing the thermocline from the storage tank and the frequency required,
5. Determine the operating and maintenance characteristics,
6. Compare the actual characteristics to the design goals, and
7. Determine the subsystem performance degradation with time.

Responsibilities

The University of Arizona, under contract to Sandia National Laboratories, will be responsible for the following:

1. Operating the system in accordance with this test plan,
2. Data reduction and analysis,
3. Providing Sandia with the raw data for analysis,
4. Writing the test reports,
5. Maintaining the system with the help of Acurex and Sundstrand on a subcontract basis, and
6. Maintaining the visitor center and conducting prearranged tours.

The Acurex Corporation, under contract to Sandia National Laboratories, will be responsible for the following:

1. Reviewing this test plan for the purpose of assuring that the required data will be made available to confirm the theoretical models used in the design of Coolidge and
2. Providing the design targets for the various subsystems for verification by the test results.

Tests

This section presents a detailed description of the tests to be conducted, the data to be collected, and the data reduction required. Table 1 presents a test matrix for the subsystem characterization phase. Table 2 presents a test matrix for the system operation phase. Following the tables are the detailed test plans for each test to be conducted.

TABLE 1

Subsystem Characterization Test Matrix

Test	Objective	Results
Thermal Storage Subsystem		
1. 24-Hour Thermal Loss Test	Study thermal losses from storage tank.	Percentage of stored energy lost in a 24-hour period will be determined. The heat loss paths will be defined and quantified.
2. Thermocline Lifetime Test	Study the thermocline under steady-state conditions.	The growth rate of the thermocline will be determined. The thermal losses associated with the thermocline will be defined.
3. Thermocline Stability Test	Study the stability of the thermocline under transient conditions.	The quantity of 400°F oil that can be added to top of the storage tank without upsetting the thermocline will be determined. Similarly for hot oil added to the bottom.
4. Thermocline Flushing Test	Find a suitable technique for removing the thermocline from the storage tank.	A technique for utilizing the low-grade energy contained in the thermocline using the ORC subsystem will be established. Also, the removal frequency required will be determined.

TABLE 1 (Continued)

Test	Objective	Results
System Start-Up		
1. System Safety Interlocks and Malfunction Lockouts Test	Determine a technique for checking the system safety interlocks and malfunction lockouts.	A technique will be so determined, and they will be checked out and calibrated.
2. Collector Automatic Tracking System Test	Check out and calibrate the collector automatic tracking system.	The collector automatic tracking system will be put into operation.
3. Collector Field Subsystem Fluid Bypass Controls Test	Check out and calibrate the fluid bypass controls for the collector field subsystem.	The fluid bypass controls will be put into operation.
4. Collector Field Subsystem Automatic Fluid Temperature Control System Test	Check out and calibrate the automatic fluid temperature control system for collector field subsystem.	The automatic fluid temperature control system will be put into operation.
5. ORC Subsystem Start-Up Test	Check out and start up the ORC subsystem.	The ORC subsystem will be put into operation.

TABLE 1 (Continued)

Test	Objective	Results
Collector Field Subsystem		
1. All-Day Subsystem Test	Determine overall subsystem performance.	Seasonally, the following subsystem characteristics will be determined: a. Efficiency vs. time of day b. All-day thermal efficiency c. All-day energy collection d. Start-up time required e. Parasitic electrical energy consumed during start-up and steady-state operation
2. Control System Characteristics Test	Determine control systems characteristics under a variety of conditions.	The subsystem controls characteristics will be monitored under the following conditions: a. Start-up b. Steady-state operation c. Transient cloud cover d. Shutdown
3. Starting Time Test	Determine optimum starting time.	The starting time that will maximize the net system output will be determined for each month.
4. Subsystem Performance Degradation Test	Determine performance degradation with time.	Subsystem performance will be continually monitored to determine degradation rate.
5. Washing Cycle Test	Study the effects of washing cycle frequency.	Seasonally, the subsystem will be monitored to determine performance degradation as a function of washing frequency.

TABLE 1 (Continued)

Test	Objective	Results
Fluid Loop		
1. Steady-State Thermal Loss Test	Study the steady-state thermal losses of the various fluid loops.	The steady-state thermal loss rate and the thermal capacity of the various loops will be determined. Receiver losses will be separated out.
2. Overnight Thermal Loss Test	Study the overnight thermal losses of the various fluid loops.	The overnight losses will be determined and sources of thermal syphoning will be defined.
3. Parasitic Loss Test	Study the electrical energy consumed by the pumps in the various loops.	The all-day electrical energy consumption of the pumps in various loops will be monitored.

TABLE 1 (Continued)

Test	Objective	Results
ORC Subsystem		
1. Subsystem Overall Performance Test	Determine overall subsystem performance under a variety of operating conditions.	The subsystem overall performance will be determined for the following conditions: a. Design conditions b. 1/2 design Caloria flow rate c. 1/4 design Caloria flow rate d. Repeat with 500°F Caloria
2. Boiler Efficiency Test	Determine boiler efficiency.	The flow rates and temperature changes in the Caloria and toluene will be recorded during test No. 1. This data will be used to calculate boiler efficiency.
3. Waste Energy Test	Determine quantity of low-grade energy available from the condenser.	The properties of the toluene will be monitored at the inlet and exit of the condenser to determine the energy available.
4. Parasitic Energy Consumption Test	Determine parasitic energy consumed by the subsystem.	The electrical energy consumed by the various electrical devices in the subsystem will be determined.
5. Start-Up Test	Determine thermal energy required to start up the subsystem.	The Caloria flow rate and temperature into the vaporizer will be determined and the start-up energy calculated from it.

TABLE 2

System Operation Test Matrix

Test	Objective	Results
1. Maximum System Output	Maximize the daily net energy output of the system.	Daily energy output will be monitored for a variety of Caloria flow rates to the ORC subsystem. This data will allow the selection of the optimum Caloria flow rate.
2. System Normal Operational	Maximize the system operating time.	Data will be collected daily to monitor the overall system performance and that of the individual subsystems.

Thermal Storage Tests

1. Determine 24-hour thermal loss from full tank.
   a. Maintain tank at 204°C (400°F) for 24 hours.
   b. Heat storage to 288°C (550°F) while measuring flow rate, inlet oil temperature (T_{in}), and outlet oil temperature (T_{out}). Integrate data to determine thermal input.
   c. Read all tank thermocouples inside and out and thermocouples on attached pipelines every 3 hours during cool-down.
   d. Let tank cool for 24 hours with no flow into or out of it.
   e. Take final reading on all tank and attached plumbing thermocouples.
   f. Replace hot oil in tank with 204°C (400°F) oil while recording flow rate, T_{in} and T_{out}. Integrate data to determine thermal output.
2. Determine thermocline steady-state lifetime.
   a. Fill tank half full of 288°C (550°F) hot oil.
   b. Monitor thermocouples on side of tank and thermocouple probes every few hours for 2 days.
3. Thermocline stability.
   a. Cool tank down to 204°C (400°F).
   b. Fill tank half full of 288°C (550°F) oil.
   c. Pump 1000 gallons of hot oil from the top of the tank into the bottom of the tank.
   d. Record effect on thermocline by monitoring the tank's vertical thermocouple probe.
   e. Repeat pumping oil from the bottom of tank into the top of the tank.
4. Determine frequency that the thermocline must be removed and how to remove it for daily storage tank operation.

System Start-Up Tests

1. Devise the required technique and confirm that all the system safety interlocks and malfunction lockouts are operational.

2. Manually override the collector field subsystem fluid temperature controls and establish full flow through the collector field. Set the bypass controls to return the fluid to the thermal storage tank.
3. Put one collector loop at a time into focus and calibrate its automatic tracking system. With the first loop tracking automatically, move on to the second loop, and so on.
4. When all loops are tracking automatically, manually switch the bypass controls to begin recirculating the fluid through the collector field. Calibrate the bypass controls so that the fluid will be directed to the thermal storage tank when it reaches 260°C (500°F).
5. Manually adjust the fluid flow rate to maintain 288°C (550°F) outlet temperature.
6. Calibrate the automatic fluid temperature control system so that it will maintain 288°C (550°F) outlet fluid temperature when in the fully automatic mode.
7. Initiate the vaporizer Caloria pump, verify proper Caloria temperature and flow rate at the vaporizer, and start up the turbine.

Collector Field Subsystem Tests

Seasonally determine the following:

1. Subsystem efficiency versus time of day.
2. All-day thermal efficiency.
3. All-day energy collection.
4. Start-up time required.
5. Optical properties of the collectors.

   Subject to these conditons:

   a. Freshly washed reflectors and receiver tubes.
   b. 1 week after washing.
   c. 2 weeks after washing.
   d. 1 month after washing.
   e. 2 months after washing.

In addition, seasonally determine:

1. Optimum starting time and fluid flow rate during start-up.
2. The solar insolation level required for "break-even" operation of the subsystem.
3. Parasitic energy used during start-up and steady state.
4. Response to transient cloud cover.
5. Control system characteristics during
   a. Start-up,
   b. Steady-state operation,
   c. Transient operation, and
   d. Shutdown.
6. The performance degradation rate by comparing current data to previous data.

Daily record the following:

1. When mirrors and receiver tubes were washed.
2. When mirrors and receiver tubes were rain-washed.
3. Turn-on time and stop time.

In addition to the above, after a rain, record the start-up time during the next day of operation. This will indicate the effect of the rain dampening the insulation on the pipelines.

<u>Fluid Loop Tests</u>

1. Determine the steady-state thermal losses.
   Pump hot oil from storage through the various fluid loops with the collectors out of focus and the turbine not running.

   Record the following:

   a. Time to reach steady state.
   b. Flow rates.
   c. Temperature readings throughout the system.

   Calculate the following:

   a. Steady-state thermal loss rate of the various portions of the loops (separate receiver losses from header and piping losses).

b. Determine the thermal capacity of the loops as follows:
   1. Determine the total thermal energy put into the loops during test.
   2. Subtract losses that occurred during steady-state operation.
   3. Subtract estimated losses during warm-up.

2. Determine overnight thermal losses.
   The morning after a normal day's operation, monitor all thermocouples in the various loops and estimate the overnight thermal losses as a fraction of the thermal capacity calculated above. Document the sources of thermal syphoning.
3. Determine electrical energy consumed by the various pumps in the loops during a normal day's operation for the various seasons. Separate morning start-up parasitics from steady-state parasitics.

ORC Tests

1. Determine ORC performance at design conditions as specified by Sundstrand.
2. Repeat No. 1 but with minimum possible hotwell temperature.
3. Determine the effects of varying inlet oil temperature and flow rate on ORC performance as follows:

   a. Operate at 1/2 design Caloria flow rate.
   b. Operate at 1/4 design Caloria flow rate.
   c. Repeat with 260°C (500°F) Caloria.

4. Determine minimum inlet oil temperature and flow rate to keep the ORC running and keep its performance at that level.
5. Determine the efficiency of the boiler during the above-mentioned tests by observing flow rates, temperatures, and changes in temperature of the fluids passing through the boiler.
6. Determine the energy available from the vapor condenser by measuring the flow rate and the change in thermal properties of the toluene passing through the vapor condenser.
7. Determine the parasitic electrical energy consumed by the

ORC by measuring the power consumed by its various components during above-mentioned tests.

8. Determine the amount of energy put into the ORC system by the Caloria in order to start it up.
9. Determine the water usage rate of the vapor condenser under a variety of conditions.
10. Periodically monitor the subsystem's performance to determine its rate of degradation and the frequency of cleaning required by the vapor condenser.

Normal Systems Operations Tests

1. The collector field subsystem will be operated with an outlet temperature of 288°C (550°F).
2. A variety of flow rates of Caloria to the vaporizer will be investigated to determine the flow rate that will maximize the net electrical energy output on a daily basis for different seasons.
3. The thermocline in the storage tank will be removed periodically, as determined by the thermal storage tests. The effect on the system of doing so will be determined and documented.
4. The system will be operated on sunny days whenever possible. Operation will not stop due to a malfunction of an automatic control system if control can be maintained manually. When possible, routine maintenance and repairs will normally be done on cloudy days or at night.
5. During a rain shower, the collectors will be turned upward to be cleansed by the rain water.
6. Routine collector washing will be defined after the test results from the first part of the Collector Field Subsystem Tests are concluded.
7. Determine the optical properties of the collector subsystem on a periodic basis and, if possible, before and after an unusual occurrence (i.e., rain, dust storm), after washing, before washing, etc.

8. The following data will be recorded on tape whenever the system is operating.

- Collector field inlet and outlet temperatures
- Collector field flow rate
- Collector loop outlet temperatures
- Solar insolation (NIP)
- Ambient air temperature
- Wind speed
- Vaporizer inlet and outlet temperatures
- Vaporizer flow rates
- Electrical power output

In addition, at the end of each day the following will be recorded:

- kWh_e output of the system
- kWh_e consumed by the system
- Peak kW_e consumed by the system
- Turn-on and stop times of the system

9. The following calculated values will be determined daily:

- Integrated NIP
- Integrated thermal output of the field
- Daily collector efficiency
- Daily system efficiency
- Peak collector efficiency
- Energy input by the gas-fired heater

10. Monthly calculate the availability of the collector field subsystem and ORC subsystem when defined as follows:

Collector field subsystem availability: Percentage of time when the solar insolation is above the "break-even" level and the collectors are in operation.

ORC subsystem availability: Percentage of time the ORC was operating when sufficient energy was available at the vaporizer from the Caloria.

Maintenance

1. Incorporate the Weekly Operational Maintenance Report (see page 27) into the monthly report. Nonrecurring operational maintenance and test maintenance will simply be logged in the facility log book.
2. Prepare a maintenance schedule for all routine maintenance required by the various components.
3. Collector washing will be a maintenance item.

WEEKLY OPERATIONAL MAINTENANCE REPORT

Recurring Costs Required For Facility Operation*

Week**	COLLECTOR FIELD			POWER			FLUID SYSTEM		
	Operator mh	Services	Parts	Operator mh	Services	Parts	Operator mh	Services	Parts
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

*Nonrecurring operation costs, testing costs, etc., will be logged in record books.

**Week 1 corresponds to 1-15-80 start.

Schedule

FY 80 Major Milestones	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1. Subsystem Characterization		∇A	∇B	∇C	∇D							∇E
2. System Operation					∇A							∇B

1A Complete Thermal Storage Subsystem Tests

1B Complete System Start-Up Tests

1C Complete Fluid Loop Tests

1D Complete ORC Subsystem Tests

1E Complete Collector Field Subsystem Tests

2A Begin System Operation Tests

2B Complete System Operation Tests

DISTRIBUTION:
TID-4500-R66, UC62 (268), 6/80

Acurex Aerotherm
485 Clyde Avenue
Mountain View, CA 94042
Attn: H. L. Morse

Argonne National Laboratory (2)
9700 South Cass Avenue
Argonne, IL 60439
Attn: W. W. Schertz
R. Winston

Barber Nichols Engineering
6325 W. 55th Avenue
Arvada, CO 80022
Attn: R. G. Olander

Battelle Memorial Institute
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
Attn: K. Drumheller

Bechtel National, Inc.
P.O. Box 3965
50 Beale Street
San Francisco, CA 94119
Attn: E. Y. Lam

Boeing Space Center
M/S 86-01
Kent, WA 98131
Attn: Steven Duzick
Al Lunde

Congressional Research Service
Library of Congress
Washington, DC 20540
Attn: H. Bullis

DSET
Black Canyon Stage
P.O. Box 185
Phoenix, AZ 85029
Attn: Gene A. Zerlaut

Del Manufacturing Co.
905 Monterey Pass Road
Monterey Park, CA 91754
Attn: M. M. Delgado

Desert Research Institute Energy
Systems Laboratory
1500 Buchanan Blvd.
Boulder City, NV 89005
Attn: J. O. Bradley

Honorable Pete V. Domenici
Room 405
Russell Senate Office Bldg.
Washington, DC 20510

EPRI
3412 Hillview Avenue
Palo Alto, CA 94303
Attn: J. E. Bigger

E-Systems, Inc., Energy Tech. Center
P.O. Box 226118
Dallas, TX 75266
Attn: R. R. Walters

Edison Electric Institute
90 Park Avenue
New York, NY 10016
Attn: L. O. Elsaesser,
Director of Research

Energetics
833 E. Arapohoe Street, Suite 202
Richardson, TX 75081
Attn: Gary Bond

Energy Institute
1700 Las Lomas
Albuquerque, NM 87131

Florida Solar Energy Center
300 State Road, Suite 401
Cape Canaveral, FL 32920
Attn: C. Beech
D. Block

General Atomic
P.O. Box 81608
San Diego, CA 92138
Attn: Alan Schwartz

General Electric Co.
P.O. Box 8661
Philadelphia, PA 19101
Attn: A. J. Poche

DISTRIBUTION (Continued)

Georgia Institute of Technology
Atlanta, GA 30332
Attn: J. D. Walton

Georgia Power Company
270 Peachtree, P.O. Box 4545
Atlanta, GA 30302
Attn: Walter Hensley

Hexcel
11711 Dublin Blvd.
Dublin, CA 94566
Attn: George P. Branch

Jet Propulsion Laboratory (2)
4800 Oak Grove Drive
Pasadena, CA 91103
Attn: Dr. M. K. Selcuk
V. C. Truscello

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
Attn: M. Wallig

Lawrence Livermore Laboratory
University of California
P.O. Box 808
Livermore, CA 94500
Attn: W. C. Dickinson

Los Alamos Scientific Lab. (3)
Los Alamos, NM 87545
Attn: J. D. Balcomb
C. D. Bankston
D. P. Grimmer

Honorable Manuel Lujan
1324 Longworth Building
Washington, DC 20515

Martin Marietta Aerospace
P.O. Box 179
Denver, CO 80201
Attn: Paul Brown

McDonnell Douglas Astronautics Co.
5301 Bolsa Avenue
Huntington Beach, CA 92647
Attn: J. B. Blackmon
D. Steinmeyer

Motorola Inc.
Government Electronics Division
8201 E. McDowell Road
P.O. Box 1417
Scottsdale, AZ 85252
Attn: R. Kendall

NASA-Lewis Research Center
Cleveland, OH 44135
Attn: R. Hyland

New Mexico State University
Solar Energy Department
Las Cruces, NM 88001

Oak Ridge National Laboratory (2)
P.O. Box Y
Oak Ridge, TN 37830
Attn: S. I. Kaplan
W. R. Mixon

Office of Technology Assessment
U.S. Congress
Washington, DC 20510
Attn: Henry Kelly

Omnium G
1815 Orangethorpe Park
Anaheim, CA 92801
Attn: S. P. Lazzara

PRC Energy Analysis Company
7600 Old Springhouse Road
McLean, VA 22102
Attn: K. T. Cherian

Honorable Harold Runnels
1535 Longworth Building
Washington, DC 20515

Honorable Harrison H. Schmitt
Room 1251
Dirksen Senate Office Bldg.
Washington, DC 20510

Scientific Atlanta, Inc.
3845 Pleasantdale Road
Atlanta, GA 30340
Attn: A. Ferguson

DISTRIBUTION (Continued)

Solar Energy Research Institute (8)
1536 Cole Blvd.
Golden, CO 80401
Attn: B. L. Butler
M. D. Cotton
B. P. Gupta
D. Hayes
F. Kreith
J. Thornton
K. Touryan
N. Woodley

Solar Energy Technology
Rocketdyne Division
6633 Canoga Avenue
Conoga Park, CA 91304
Attn: J. M. Friefeld

Solar Kinetics Inc.
P.O. Box 10764
Dallas, TX 75207
Attn: G. Hutchinson

Southwest Research Institute
P.O. Box 28510
San Antonio, TX 78284
Attn: D. M. Deffenbaugh

Stanford Research Institute
Menlo Park, CA 94025
Attn: Arthur J. Slemmons

Sun Gas Company
Suite 800, 2 No. Pk. E
Dallas, TX 75231
Attn: R. C. Clark

Sundstrand Electric Power
4747 Harrison Avenue
Rockford, IL 61101
Attn: A. W. Adam

Suntec Systems Inc.
2101 Wooddale Drive
St. Paul, MN 55110
Attn: L. W. Rees

Swedlow, Inc.
12122 Western Avenue
Garden Grove, CA 92645
Attn: E. Nixon

TRW, Inc.
Energy Systems Group of TRW, Inc.
One Space Park
Bldg. R4, Room 2074
Redondo Beach, CA 90278
Attn: J. M. Cherne

Texas Tech University
Dept. of Electrical Engineering
P.O. Box 4709
Lubbock, TX 79409
Attn: J. D. Reichert

U.S. Department of Energy (3)
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185
Attn: G. N. Pappas
C. B. Quinn
J. Weisiger

U.S. Department of Energy (2)
Agricultural & Industrial
Process Heat
Conservation & Solar Application
Washington, DC 20545
Attn: W. W. Auer
J. Dollard

U.S. Department of Energy
Division of Energy Storage
Systems
Washington, DC 20545
Attn: J. Gahimer

U.S. Department of Energy (7)
Division of Central Solar Technology
Washington, DC 20545
Attn: G. W. Braun
H. S. Coleman
M. U. Gutstein
G. M. Kaplan
L. Melamed
J. E. Rannels
R. L. San Martin

U.S. Department of Energy
San Francisco Operations Office
1333 Broadway, Wells Fargo Bldg.
Oakland, CA 94612
Attn: R. W. Hughey

DISTRIBUTION (Continued)

University of New Mexico (2)
Department of Mechanical Eng.
Albuquerque, NM 87113
Attn: W. A. Cross
M. W. Wilden

Western Control Systems
13640 Silver Lake Drive
Poway, CA 92064
Attn: L. P. Cappiello

Westinghouse Electric Corp.
P.O. Box 10864
Pittsburgh, PA 15236
Attn: J. Buggy

1472 L. G. Rainhart
1500 W. A. Gardner
1520 T. J. Hoban
1530 W. E. Caldes
1550 F. W. Neilson
1552 O. J. Burchett
2300 J. C. King
Attn: K. L. Gillespie, 2320

2323 C. M. Gabriel
2324 R. S. Pinkham
2326 G. M. Heck
3161 J. E. Mitchell
3600 R. W. Hunnicutt
Attn: H. H. Pastorius, 3640
3700 J. C. Strassell
4000 A. Narath
4231 J. H. Renken
4700 J. H. Scott
4710 G. E. Brandvold
4713 B. W. Marshall
4714 R. P. Stromberg
4715 R. H. Braasch
4719 D. G. Schueler
4720 V. L. Dugan
4721 J. V. Otts (20)
4722 J. F. Banas
4723 W. P. Schimmel
4725 J. A. Leonard
4730 H. M. Stoller
5510 D. B. Hayes
5520 T. B. Lane
5810 R. G. Kepler
5820 R. E. Whan
5830 M. J. Davis
5840 H. J. Saxton
5844 F. P. Gerstle
8100 W. J. Spencer
8124 R. J. Gallagher
8450 R. Wayne
8450 T. T. Bramlette
8451 P. Eicker
8452 A. C. Skinrood
8453 W. G. Wilson
8266 E. A. Aas
3141 T. L. Werner (5)
3151 W. L. Garner (3)
For DOE/TIC
(Unlimited Release)

Org.	Bldg.	Name	Rec'd by *	Org.	Bldg.	Name	Rec'd by

* Recipient must initial on classified documents.