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10 MWe Solar Thermal Central Receiver Pilot Plant: 1982 Operational Test Report

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10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT:

1982 OPERATIONAL TEST REPORT

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ABSTRACT

The design and construction of the world's largest solar thermal central receiver electric power plant were completed in 1982. Start-up was accomplished, and the plant began the two-year experimental Test and Evaluation phase.

Experiences during 1982 have shown that all parts of the plant--especially solar unique ones--operate as well as or better than expected. It was possible to incorporate routine power production into the Test and Evaluation phase because plant performance yielded high confidence.

The million killowatt-hours net, generated while the plant was grid-connected, are an indication of the successful start-up and test experience in 1982. During 1982, the transfer of the plant to operation by utility personnel was also accomplished. Events reported here are not unique to utility operations; an important lesson learned is that solar technology is amenable to operation in conventional utility practices.

This report contains (1) a brief description of the plant system; (2) a summary of the year's experiences; and (3) a monthly list of principal activities and operation and maintenance costs.

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SUMMARY

During calendar year 1982, the objectives for the 10 MWe Solar Central Receiver Pilot Plant included completion of construction, start-up of the major systems, and transition into the two-year Test and Evaluation phase.

The plant transitioned from construction-related activities to testing operations without difficulty. Programmatically, construction ceased with turbine roll on April 12, 1982.

Functionally, during the 3.5-month start-up testing stage, 5-day test operations were conducted by the Department of Energy (DOE). Major activities included activation of the thermal storage system and completion of the stand-alone receiver and turbine-generator testing. On the utility side, a contingent of start-up personnel were retained to initiate operations, which is normal practice within the Southern California Edison (SCE) system.

Satisfactory completion of the start-up stage produced an unplanned result--the release of the plant for restricted production on weekends, without technical supervision. As a result, the potential for 7-day-per-week operation was realized sooner than expected. The major portion of the week (5 days) was reserved for testing and evaluation.

Four of the eight major modes of operation were functionally demonstrated during CY1982. These include direct power generation using receiver-supplied steam (Mode 1), storage charge (Mode 5), storage extraction (Mode 6), steam dump system operation (Mode 8), and warm plant standby (Mode 7).

Modes 1, 5, and 7 were released to SCE for routine operation. Interim procedures were available for storage extraction. Final procedures await turbine modification planned in CY1983.

Successes at the plant were literally clouded by poor weather in 1982. Low monthly direct normal energy and daily peak power were experienced in Daggett, California, as at other solar plant locations throughout the world. However, higher than mean average rainfall maintained the cleanliness of the heliostat field.

Throughout CY1982, progress at the plant has shown that conventional planning and staffing can be applied to this "new" technology. No fundamental technical limitations were identified. Solar-unique portions of the plant required less than budgeted maintenance costs. Conventional portions of the plant consumed a greater than expected quantity of the maintenance budget. Overall, the under expenditures on the solar side balanced the extra expenditures on the conventional side.

10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT:

1982 OPERATIONAL TEST REPORT

This document reports the operational test experience for the 10 MWe Solar Central Receiver Pilot Plant near Barstow, California, during calendar year 1982. It includes summaries of testing and start-up experience. Specific test reports which present detailed test analysis are planned.

Objectives

The pilot plant (Figure 1), also known as Solar One, is a joint venture between the Department of Energy (DOE) and the Associates (Southern California Edison, principal, the Los Angeles Department of Water and Power, and the California Energy Commission). The primary objectives of the project are:

-- to establish the technical feasibility of a solar thermal power plant of the central receiver type and to identify areas where research and development may lead to significant performance improvements and increased capabilities.

-- to obtain development, production, operating, and maintenance cost data to (a) support private sector decisions to invest in solar central receiver energy systems, and (b) to identify areas where research and development may most effectively be applied to reduce costs and extend areas of application of such systems.

-- to determine the environmental impacts of the construction, operation, and maintenance of solar thermal central receiver plants.

These objectives are being met through the extensive collection and evaluation of technical and cost data (including data on production, operation, maintenance, environmental, and life-cycle costs). The data will be made available for use by electric utilities, industrial firms, and private sector groups. DOE's Solar Thermal Technology Program, as well as other federal, state, and local entities, will also have access to the information for defining long-term, high-risk, high-payoff research that should appropriately be supported by public funds.

System Description

The pilot plant delivers 10 MWe peak of electric power to the Southern California Edison (SCE) distribution grid. This power level is the net output of the plant after all plant operating requirements, excluding storage, are subtracted when the plant operates solely from insolation for a period of either:

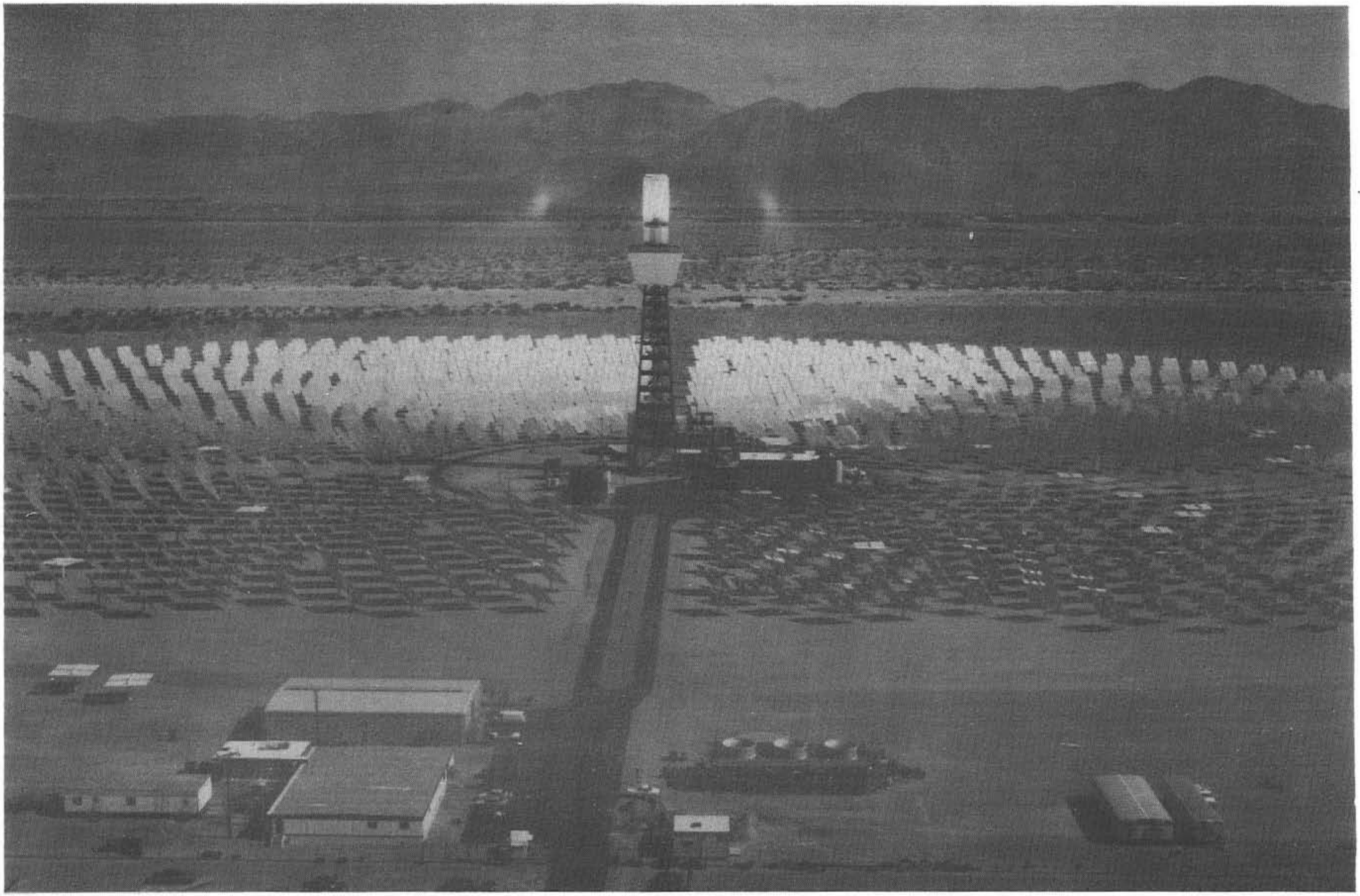


Figure 1. 10 MWe Solar Thermal Central Receiver Pilot Plant

1. at least four hours on the least favorable clear day of the year (December 21).

2. at least eight hours on the most favorable clear day of the year (June 21).

The storage charging rate was sized to accept the equivalent thermal power necessary to operate the turbine-generator at the rated 10 MWe net power output level. When operating solely from a fully charged thermal storage system, the plant delivers a minimum of 28 MWhe of electrical energy to the grid. The maximum net power is 7 MWe when the plant operates solely from the thermal storage system.

The pilot plant consists of solar facilities, turbine-generator facilities, and miscellaneous support facilities. A brief description of each system follows. Major systems are shown in Figure 2. (For a more detailed description, refer to Pilot Plant System Description RADL 2-1, available from the National Technical Information Center.)

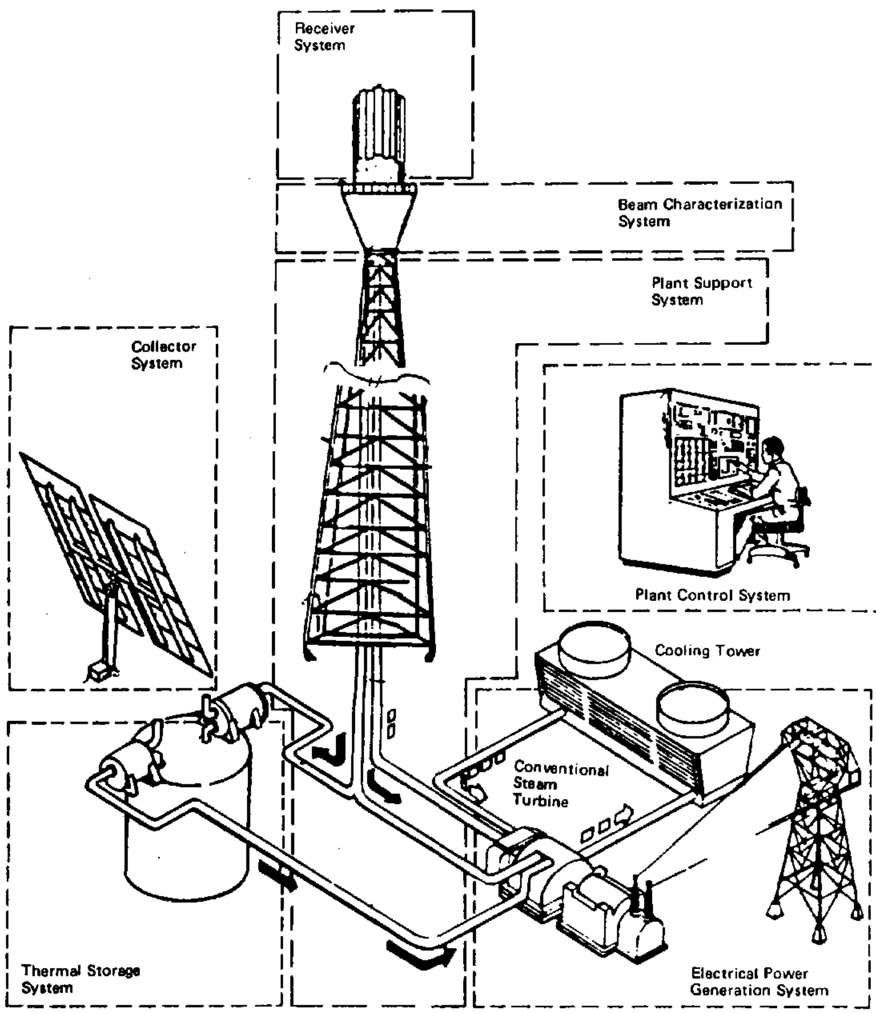


Figure 2. Schematic of Major Plant Systems

Solar Facilities

The pilot plant has several solar-unique facilities:

(1) Collector System: The collector system is an array of 1818 individually controlled reflectors (heliostats) that direct the available insolation onto an elevated receiver. The heliostats are located in a circular field array that surrounds the receiver tower.

(2) Receiver System: The receiver system consists of equipment to pump water to the top of a tower where an array of 24 panels, 6 preheaters, and 18 once-through boiler-generators comprise the cylindrical steam boiler. Redirected solar energy is focused by the heliostats onto the external surface of the boiler. The dry, superheated steam from the boiler is returned to the ground level within this system for delivery to other systems.

(3) Thermal Storage System: The thermal storage system transfers energy from steam to oil for sensible heat storage in an oil-rock media that is contained within a single cylindrical tank. Retransfer of thermal energy from oil back to steam is accomplished within this system. The system is capable of performing both transfer operations simultaneously. The thermal storage system is sized to include the auxiliary energy needed by other systems as well as the energy stored for reconversion to electric power.

(4) Beam Characterization System: The beam characterization system permits rapid and automatic measurement and characterization of the flux delivered by any single heliostat.

Turbine-Generator Facilities

The major components of the turbine-generator facilities are:

(1) Turbine-Generator: The turbine is an automatic admission, condensing unit. The high-pressure steam available from the receiver system (950°F, 1465 psia nominal) for 10 MWe net is supplied to the high-pressure inlet valves, and the low-pressure steam available from the thermal storage system (529°F, 385 psia nominal) for 7 MWe net is supplied to the low-pressure automatic admission port.

(2) Circulating Water System: This system includes the equipment that provides coolant for the condenser, mechanical draft wet cooling tower, pumps, and make-up water supply.

(3) Condensate and Feedwater System: This system includes the condenser, feedwater heaters, deaerator, pumps, and full-flow polishing demineralizer.

(4) Electrical System: The electrical system connects the generator through the facility main-power transformer to the transmission system for distribution of power to the grid. The electrical system also includes the internal plant electrical distribution.

Miscellaneous Support Facilities:

The miscellaneous support facilities provide the overall plant control, interconnection, and utilities for plant integration. A brief description of each system of the common-use facilities follows.

(1) Plant Control System: The plant control system (PCS) is a computerized supervisory system which responds to operator or automatic direction to provide integrated plant control. The PCS controls the functions of plant start-up, shutdown, operation and mode changes, and contains capabilities for emergency actions on a plant basis. The PCS consists of the plant operational control subsystem (OCS) and a dedicated data acquisition system (DAS) which records engineering and scientific data for plant evaluation.

(2) Plant Support System: The plant support system (PSS) provides for interconnection of the major systems, utility distribution throughout the plant, and the necessary facilities such as roads, lighting, buildings, security, and communications.

Overview of the Test Program

The test program covers three phases: start-up, the two-year experimental Test and Evaluation phase, and the three-year Power Production phase.

Start-up is that time period between turbine roll (April 12, 1982), which signifies construction completion, and the beginning of the two-year experimental Test and Evaluation phase (August 1, 1982). During start-up, the receiver system testing continued and the activation of the thermal storage system was initiated.

The two-year test period will enable the pilot plant to demonstrate stable, controlled operation in each of the steady-state operational modes and provide data for performance evaluation. In addition to the operation modes, preliminary power production, transitions, and emergency shutdowns will be demonstrated. Furthermore, this phase will be devoted to verifying the operational and maintenance procedures for the plant. This period lasts from August 1, 1982, to August 1, 1984.

The three-year period of power production will be devoted to demonstrating the viability of the pilot plant as a reliable source of electrical busbar energy. Plant reliability, maintenance, and operational characteristics will be evaluated in this phase. Special tests will be performed; some of these tests may include commercial plant evaluations, environmental impact, safety studies, and technical improvement and cost reduction evaluation. However, specific tests will be defined in the future by DOE and SCE near the end of the two-year experimental test phase.

Management of the Test and Evaluation Phase

Responsibility for the pilot plant start-up operational test activities was delegated to the DOE San Francisco Operations Office Solar Energy Division (SED) by the Division of Solar Thermal Energy Systems, DOE/HQ. On behalf of DOE, Sandia National Laboratories serves as Technical Manager with subcontractors, principally Martin Marietta, and the Solar Facilities Design Integrator (McDonnell Douglas, prime; Stearns-Roger; and Rocketdyne Division, Rockwell International). Test management, technical support, and test documentation are provided.

Testing is required during the two-year experimental period to verify the technical feasibility of design as well as the equipment and systems performance. Data acquired during the following three years of operation will be used to demonstrate and verify the operational performance of the plant, define actual operating and maintenance requirements, confirm commercial system cost projections, and provide direction to technical improvement and major cost reduction efforts. Throughout the five-year program, engineering measurements will be made in conjunction with intermediate inspections and evaluations to observe any degradation of components.

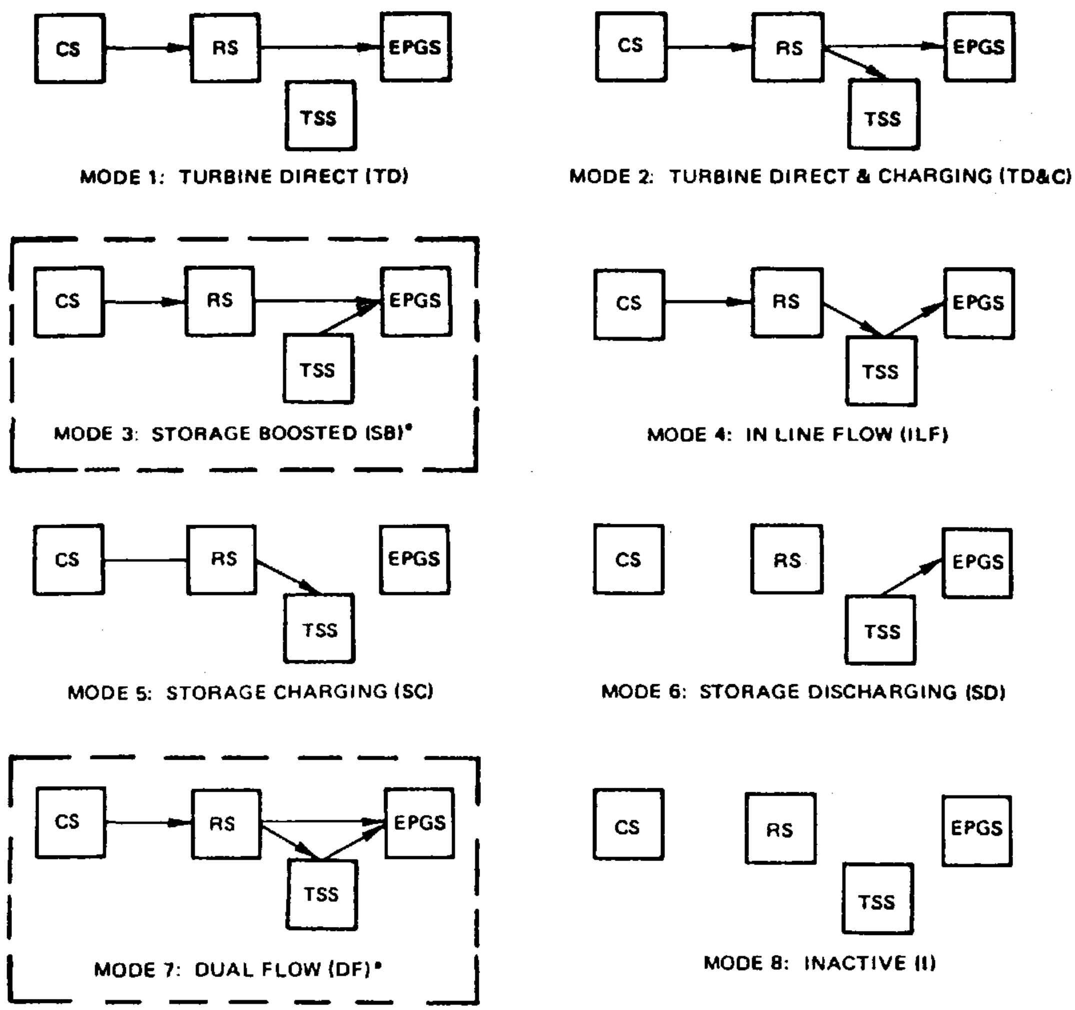
Plant operation is being evaluated in all operating modes under manual, semi-automatic, and automatic plant control options. The five active operating and two engineering test and transition modes (see Figure 3) will be tested using one or more of the following control combinations: manual, or clear- or cloudy-day automatic control. Collector modulation can be incorporated and operated to support any of the control modes. To maximize the energy produced, plant operation, other than testing, will be performed in a sun-following strategy, that is, using as much sunlight energy as possible.

Description of the 1982 Test Schedule

The scheduled activities for 1982 are shown in Figure 4. During the transition period, the major construction work was completed. Start-up testing designates an interim period when construction work clean-up was completed and SCE start-up forces finished their work.

During this interim stage, start-up and construction forces left the site; SCE personnel decreased from 60 to 35. A similar decrease occurred on the technical support side. Until the plant was released for weekend power production, all start-up operations were restricted to 8-hour days and 5-day weeks, although SCE operations staffed the plant 7 days per week on a 24-hour-per-day basis.

The two-year Test and Evaluation phase began on August 1. SCE operations took control of the plant, and the DOE construction project office was closed. DOE established an on-site project director and SCE R&D provided on-site representation. During August the SCE operators also qualified to operate the plant in Mode 1 without technical assistance, thereby providing the "weekend power production" milestone and 7-day-per-week function of the plant, weather permitting.



Mode 1	Turbine Direct:	Receiver-generated steam directly powers the turbine.
Mode 2	Turbine Direct and Charging:	Receiver-generated steam powers the turbine and charges storage.
Mode 3	Storage Boosted:	Steam from the receiver and storage powers the turbine.
Mode 4	In-Line Flow:	Receiver steam charges storage, while storage steam is stimultaneously discharged powering the turbine.
Mode 5	Storage Charging:	Receiver steam charges the storage system.
Mode 6	Storage Discharging:	Steam generated by the storage system is used to power the turbine.
Mode 7	Charging and Storage Boosted:	A combination of Modes 2 and 3 (probably only achieved during transitions).
Mode 8	Inactive	Major systems are standing by for operation.

*Engineering Test and Transitory Modes

Figure 3. Plant Operational Modes
(a) Steady-State Operating Modes

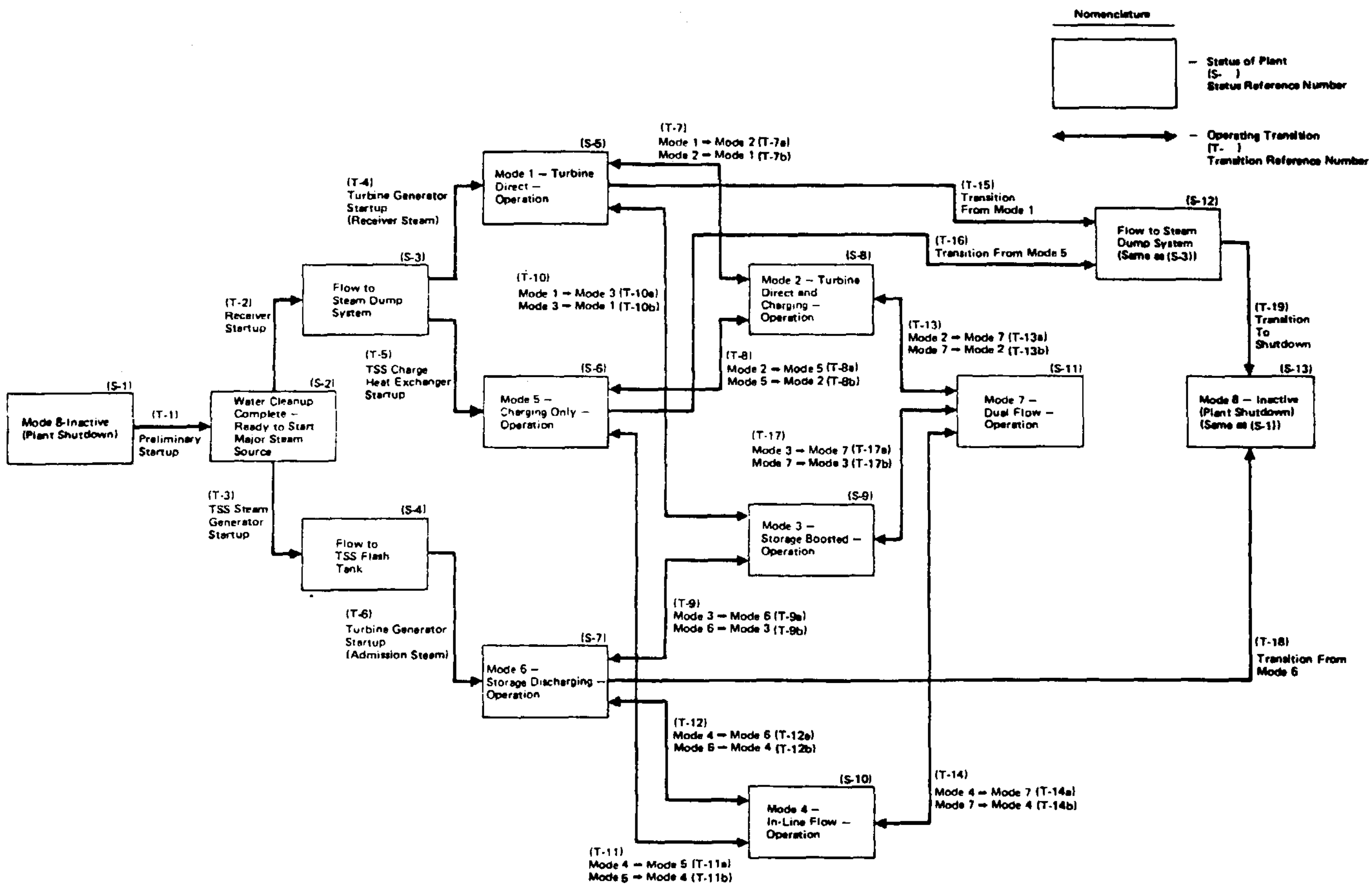


Figure 3. Plant Operational Modes
(b) Preliminary Operational Flow Diagram

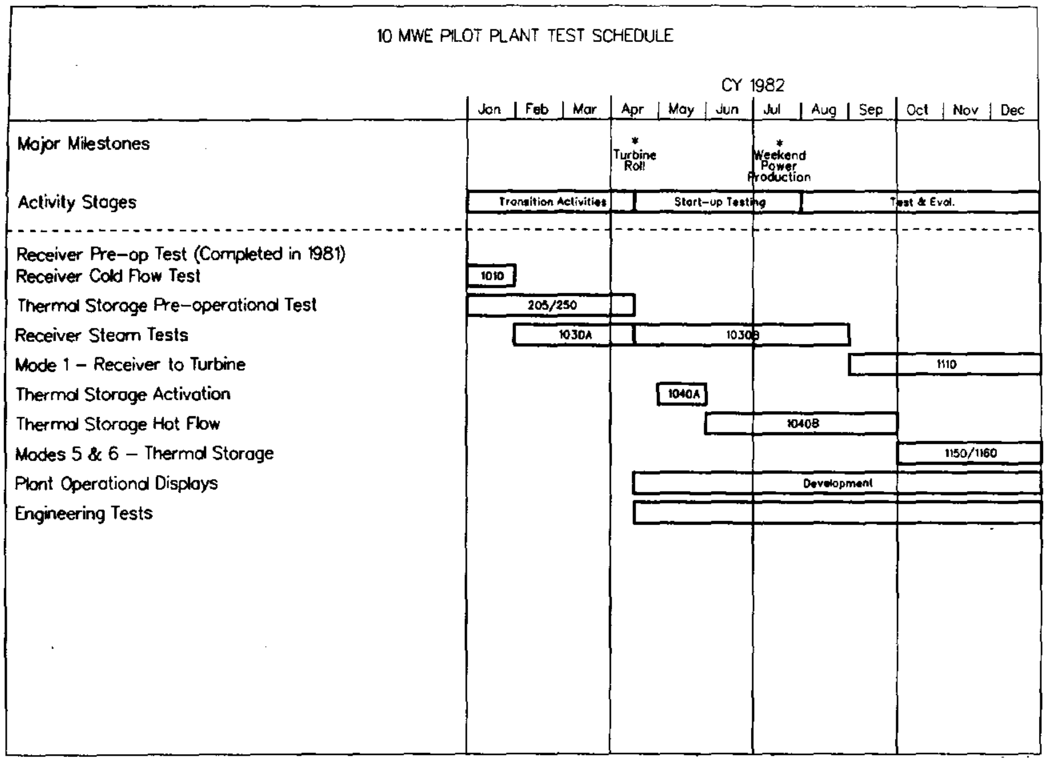


Figure 4. 1982 Test Schedule

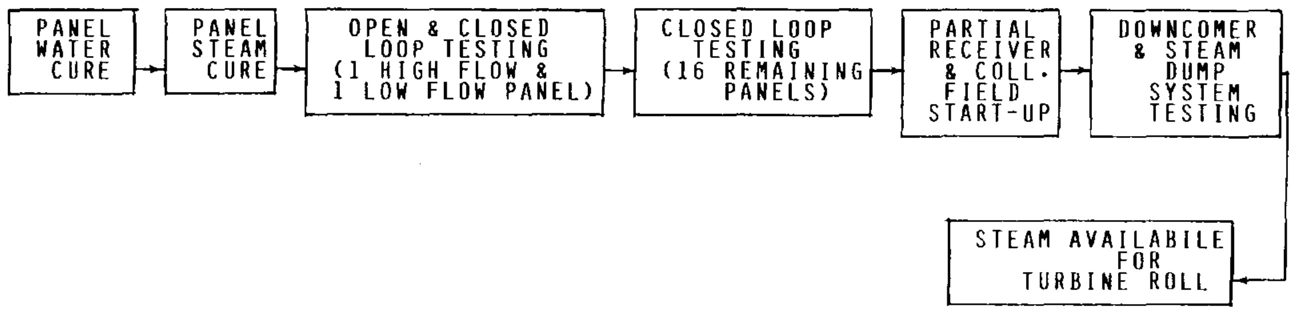
Tests are numbered so that those in the 1000 series represent stand-alone system tests. The 1100 series refers to intersystem testing in the major operating modes: 1110 is Mode 1, and 1150 and 1160 are Modes 5 and 6. (See Figure 3 for a schematic of the operating modes.) All 1100 series tests were initially scheduled for completion by June 1982. However, construction delays and resource depletion precluded this from occurring. The performance test 1100 series were deferred into the Test and Evaluation phase, as were completion of the receiver and thermal storage preoperational tests 1030B and 1040.

Test 1030A and B is shown functionally in Figure 5. The result of this test is a fully functioning receiver as a freestanding unit. Automatic control of all 18 boiler panels and 6 preheater panels has been demonstrated, and start-up and shutdown were fully demonstrated and controlled. Division of the test into two portions allowed the timely achievement of turbine roll, a programmatic milestone.

Figure 6 is a simplified schematic depicting the principal thermal circulation paths of the pilot plant. Shaded portions indicate those paths which were operative at the time of turbine roll. Through test 1030B, the receiver system was tested at all operative steam conditions. Concurrent complete activation of the turbine system, especially feedwater heaters, was accomplished.

During much of test 1030, major portions of steam flow followed the receiver downcomer path through the steam dump system. A modulating isolation valve, PV1001, controlled steam flow and pressure from the receiver to the condenser.

(a) Test 1030A



(b) Test 1030B

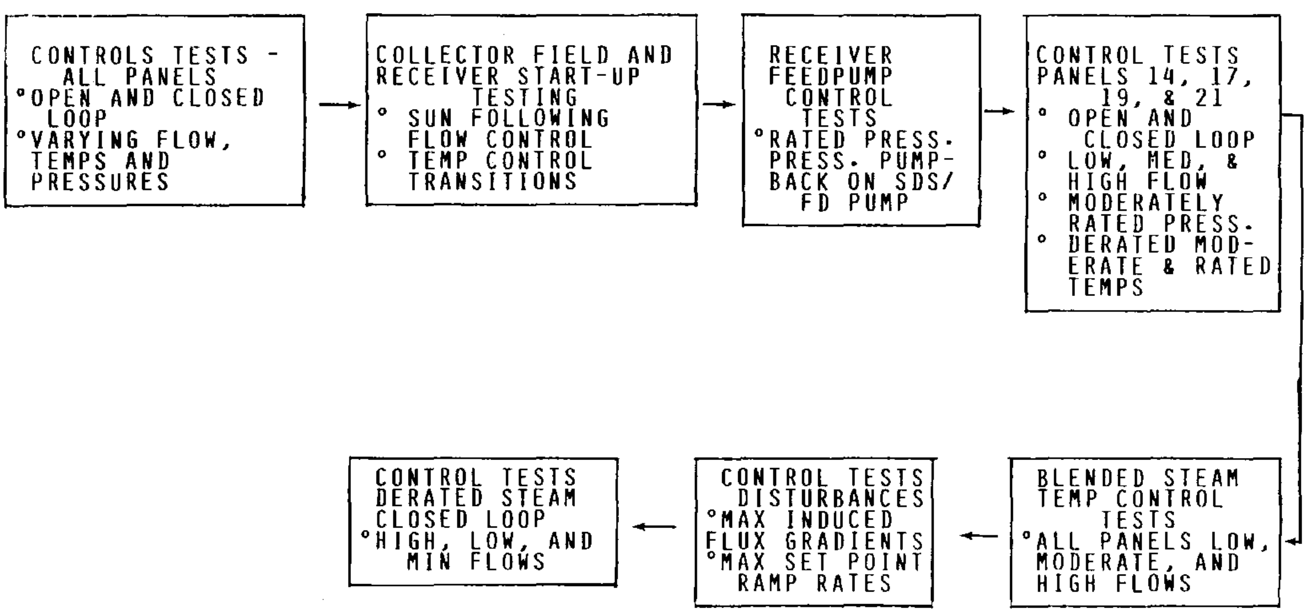


Figure 5. Block Diagram of Test 1030

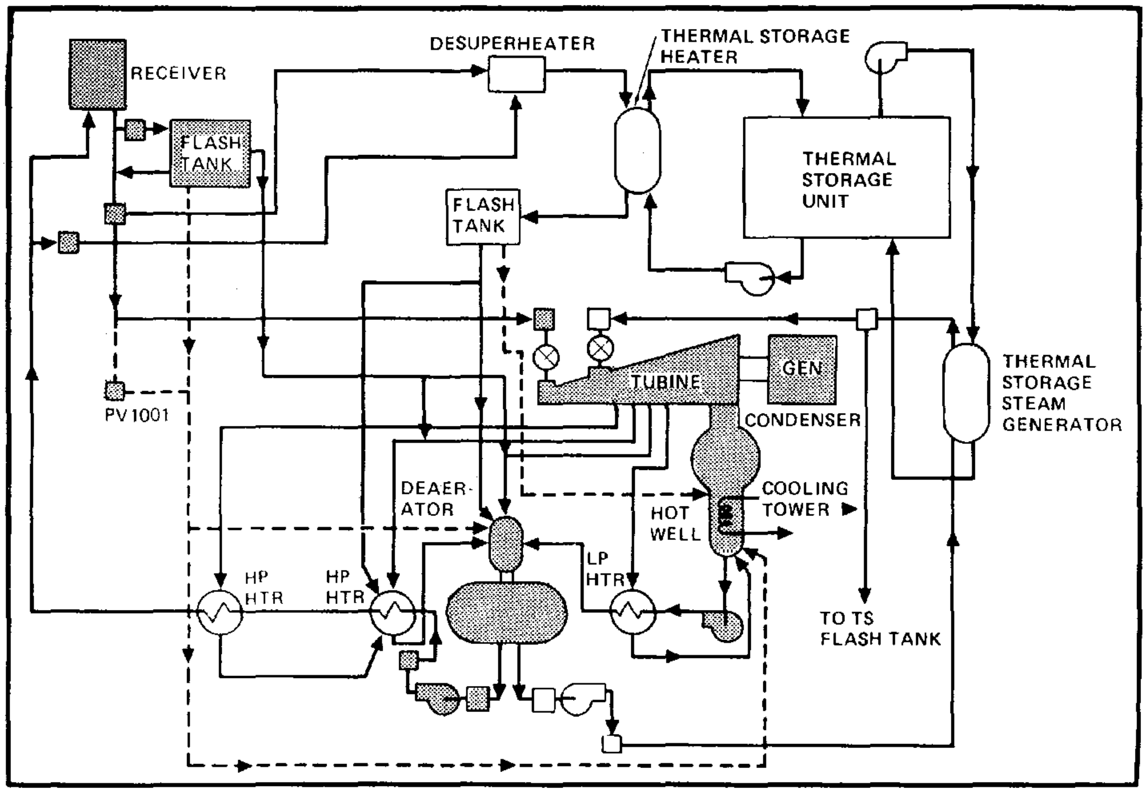


Figure 6. System Schematic of Major Thermal Flow Paths

Similarly, tests 1040A and 1040B were developed. The thermal storage oil and sensible heat media were preheated and controls functionally checked during part A, using a rental boiler. (See Figure 7.) The 1040B portion used receiver-generated steam to charge the storage tank. Both charge and extraction control testing were performed throughout the testing to deliver the thermal storage system fully operative as a freestanding unit at test completion. The character of both 1030B and 1040 tests changed due to the availability of the turbine generator. It became possible to perform much of the 1030B testing with the turbine connected to the grid. The turbine was necessary for 1040 extraction tests to vent the generated steam.

Satisfactory experience during the 1030 and 1040 testing provided the basis for weekend power production. Such power production was within limited constraints. Test 1110 provided full performance verification of the receiver-turbine systems. The complete test matrix included variations in steam temperature and pressure, different load points, investigation of power ramp rates, and simulated and actual cloud transient responses.

Engineering tests seek to explore specific aspects of Solar One. Some examples are beam safety studies, heliostat characterization, and meteorological studies. Further studies will be defined throughout the two-year Test and Evaluation phase.

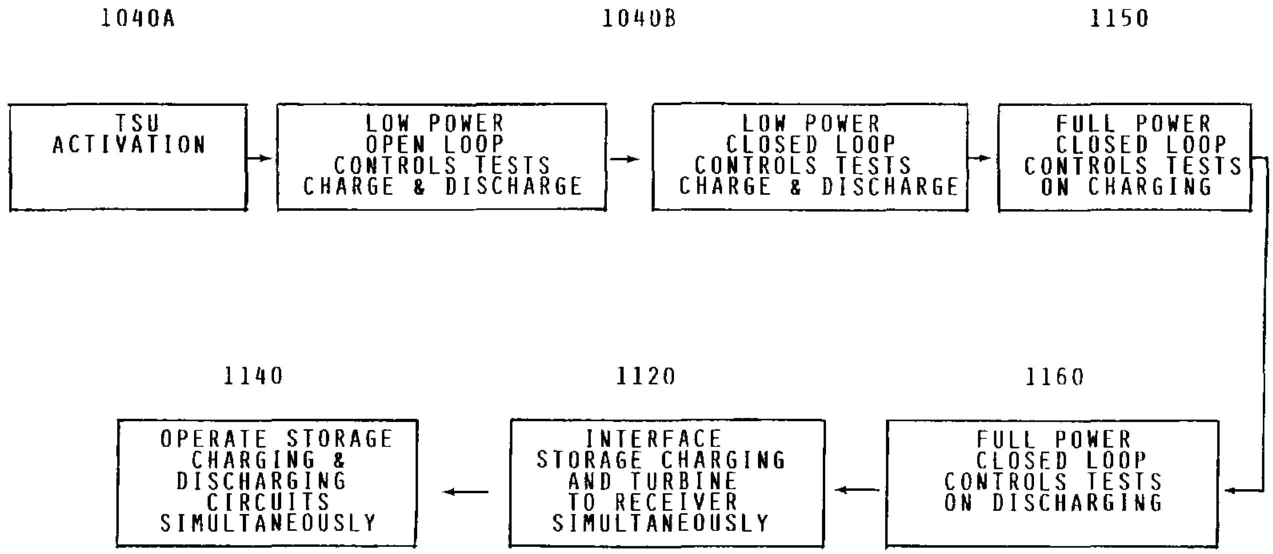


Figure 7. Block Diagram of Thermal Storage System Testing

Plant operational displays (PODs) will enhance the existing plant control system. Control and display of plant operations are provided at the system level (receiver, thermal storage, electric power generating system, and plant support systems). Operating data for each system are displayed on four separate cathode ray tubes (CRTs). The POD will allow all system data to be displayed upon two CRTs; performance data will also be displayed. These improvements are a first step toward demonstrating single operator plant control.

Activities at Solar One

The major activities during 1982 have been activation of the plant's systems. To measure productive work associated with the plant, the following are monitored on a daily basis: power hours, that is, the time during which the turbine is connected to the grid; test hours, the time during which testing was conducted; plant outage time, those daylight hours during which the plant could not support testing or power production; and finally, weather outage time, daylight hours during which weather precluded operation. (If weather and plant outages occurred, they are logged separately.) Start-up hours indicate the time devoted to starting the receiver system; that is, the time from directing the heliostats upon the receiver (or sunrise, whichever was later) to achieving superheated steam from the downcomer. Unless the primary purpose of the start-up was start-up testing, these hours are not counted as "productive." The historical experience at Solar One is shown on Figure 8. Below the trend line are productive activity hours (power production and testing). Nonproductive activities are shown above the trend line.

Total hours increase from June through September, reflecting the start of weekend power production and the availability of the thermal storage subsystem for testing.

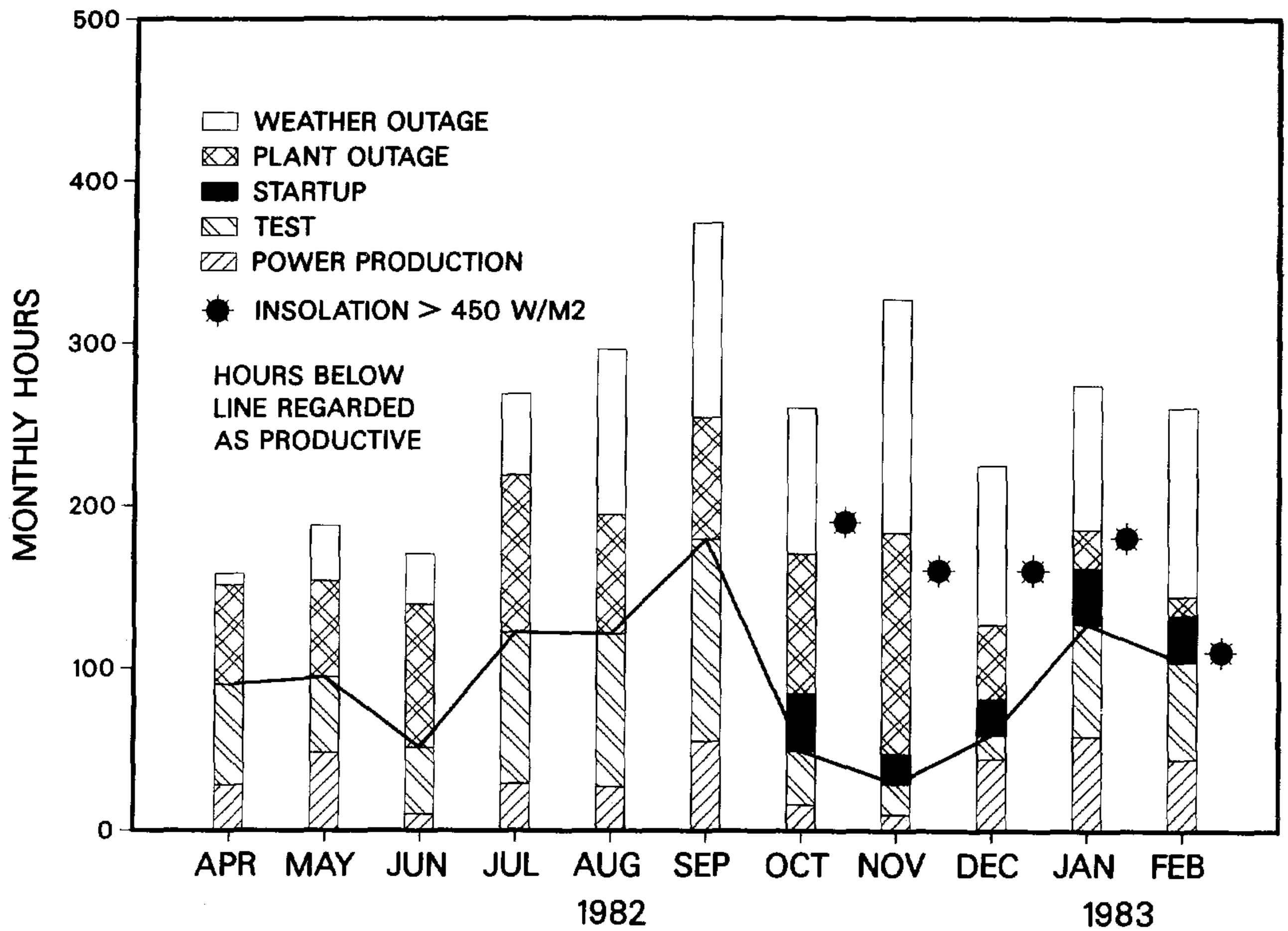


Figure 8. Distribution of Monthly Activities

Design criteria call for the plant to be operative above 450 W/m^2. From October 1982 through February 1983, the monthly hours during which the insolation exceeded this value are also shown. A favorable trend is evident; that is, from October, utilization of available sunlight hours has steadiliy increased to better than 90 percent in February 1983. This increase is reflected also in solar and plant availability for test and power production in Figure 9 (note these are not conventional availability figures, but rather as defined on the figure).

Throughout the period of operation, the direct normal insolation has been significantly below previously measured average values. This is most clearly shown in Figure 10, where direct normal insolation values for 1976 (baseline year), 1981, 1982, and the first two months of 1983 are shown. Measurements displayed were obtained in 1976, 1981, and part of 1982 at the SCE Service Center in Barstow, approximately 11 miles from the site. Site values for April 1982 through February 1983 are also shown. In 1982, the direct normal insolation was approximately 25 percent lower than in 1976; the first two months of 1983 show a reduction of approximately 10 percent compared to 1982.

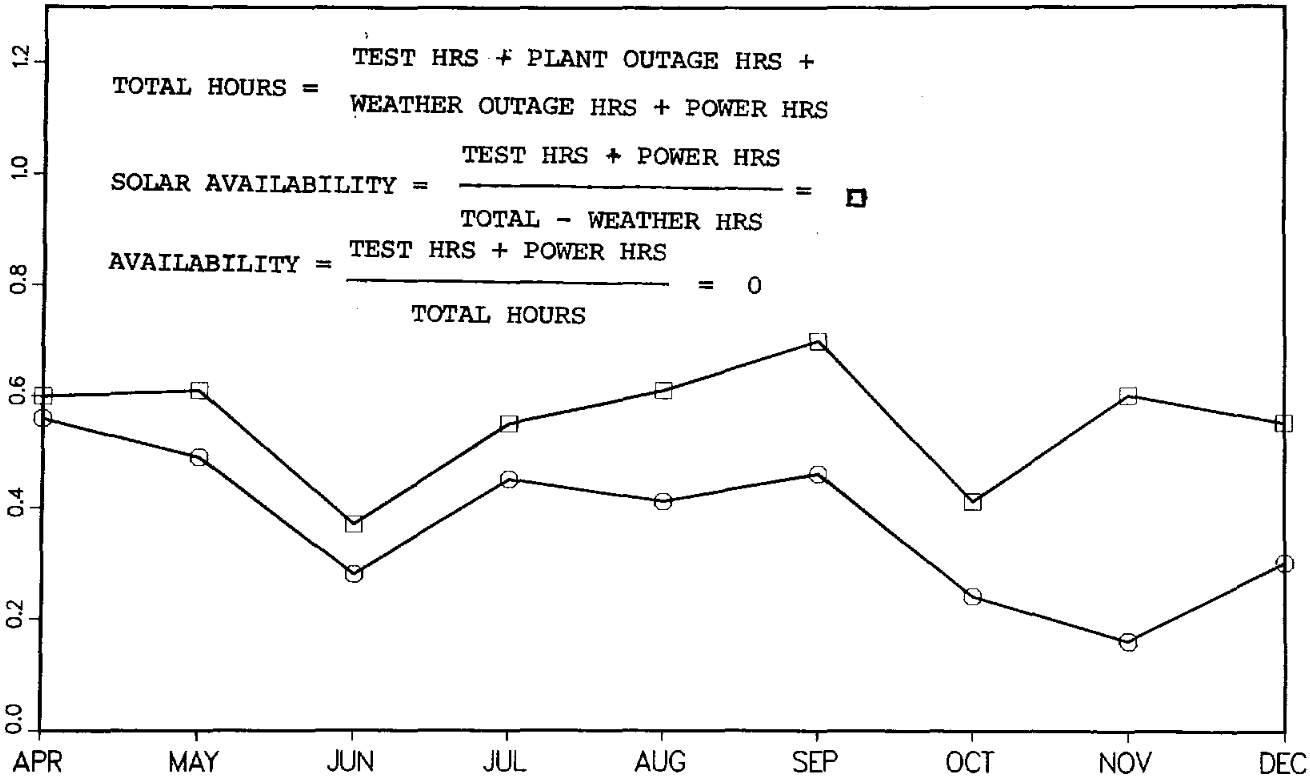


Figure 9. Monthly Solar and Plant Availability (1982)

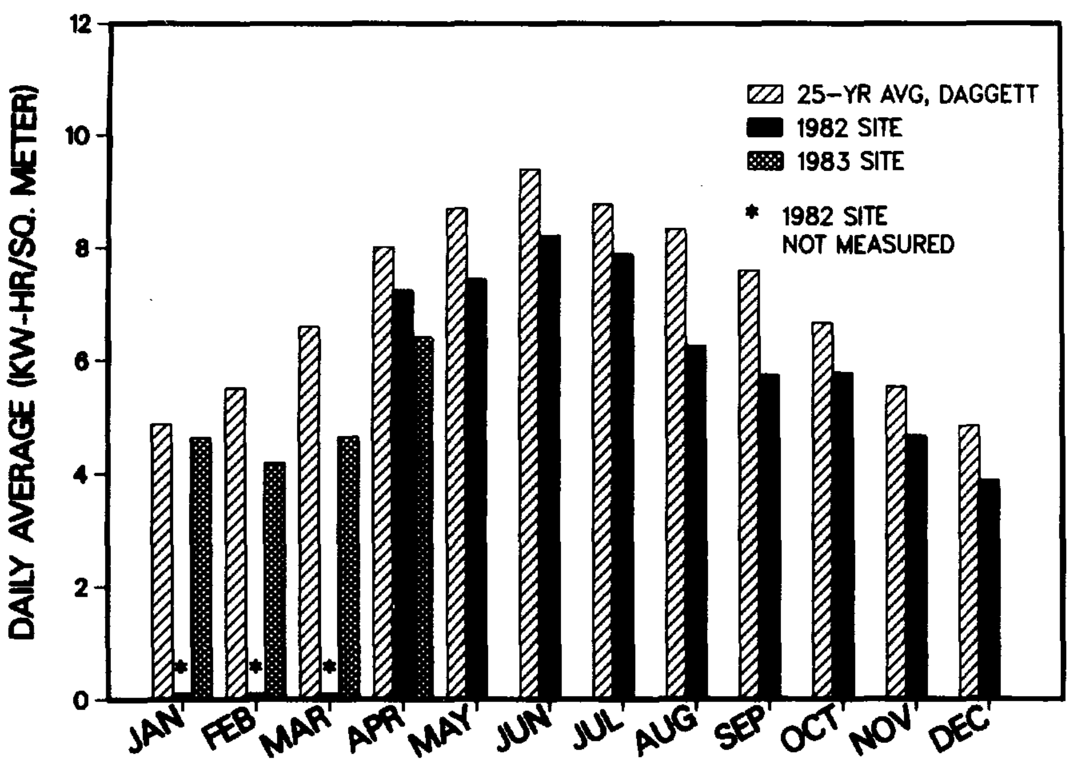


Figure 10. Monthly Direct Normal Insolation Comparison

Part of the explanation for low total insolation is the above-normal rainfall in the Barstow area during 1982. From January through November, 55 occurrences of rain were observed for a total of 4.9 inches. This can be compared to the 1956 - 1970 eleven-month average of 3.25 inches per year on 23 occurrences.

The satisfactory use of the available insolation assisted in achieving a number of planned test goals. These activities are listed in Table 1.

Table 1

1982 TEST ACTIVITIES

Planned	Accomplished
Receiver start-up (1030)	Complete
Storage activation and start-up (1020/1040)	Complete
Mode 1 performance (receiver steam to turbine direct)	Complete
Modes 5 & 6 performance testing (storage charge and discharge)	10% Complete
	BCS testing and enhancements - functional
	SCE operator training for weekend power production
	Supplemental turbine generator testing
	Steam dump valve thermal performance testing
	Beam safety measurements

In the context of the overall test objectives, progress has been made in achieving all the goals. An abbreviated summary is shown in Table 2.

Table 2

STATUS OF PRINCIPAL TECHNICAL OBJECTIVES

Design	Observed
10 MWe net in Mode 1	10.4 MW
7 MWe net in Mode 6	7.3 MW
Operation above 450 W/m^2	Operation above 300 W/m^2
Operable at 2 MWe net	Operated at 500 kW net
95% of the heliostats operable	Achieved
Plant capable of transitions between all modes	Functionally demonstrated
Energy design points	To be demonstrated
Operation in all modes	Demonstrated
Evaluation of all modes	
Mode 1	Complete
Modes 5 & 6	Scheduled 1983
Modes 2, 3, 4, 7	Scheduled 1983, 1984
Automatic Control Separate System	Scheduled 1984
Integrated Plant Control	Scheduled 1984

Several equipment difficulties have slowed testing at Solar One. These are primarily equipment failures, which are listed in Table 3.

Table 3

EQUIPMENT DIFFICULTIES

Source	Solution
Receiver panel distortion (one)	All receiver panel support structures lengthened. Minimum flow limit raised. Controller and flowmeter electronics relocated.
Steam dump valve failure	Valve internals replaced and valve body trace-heated.
Uncontrolled roll of turbine on admission steam	Interim operating changes followed by modification in May 1983.
Thermal storage heat exchanger steam and oil leaks	Gasket repairs to solve oil and steam leaks systematically being investigated - repair scheduled.
Underground piping leaks	Thrust blocks omitted during construction now installed. Some service water piping replaced.
Mirror corrosion due to entrapped water	Heliostat stow changed to mirror vertical position. Corrosion rates being monitored. Additional vents installed in some heliostats.

Turbine roll overspeed conditions existed when starting from admission steam. Over nine months of evaluation were conducted by the vendor, and several periods of special testing were required to verify a design defect. The repair has been promised for mid-1983.

Some of these equipment failures were quite detrimental to plant operations. For example, the steam dump valve precluded high steam pressure and mass flow receiver operation for two weeks. However, flow through the receiver flash tank system allowed operation of the thermal storage charging system. Similarly, the availability of two 50 percent thermal storage charge and extraction trains allowed isolation of one train for repair while a second was in operation. The inherent flexibility of the plant design contributed to the favorable performance record.

Power Production

Although the primary goal during CY1982 was plant start-up and initiation of the two-year Test and Evaluation phase, limited power production was realized from April through December. Graphically, this is displayed in Figure 11, which shows daily and cumulative net energy production while the plant was synchronized to the grid. May was the peak power production month because the insolation energy was high and receiver systems testing was the main focus of activity. Production picked up again in August with authorization to operate on weekends. Weather and Equipment outages in October and November limited weekend operation; however, December shows a marked improvement due to Mode 1 performance testing and dedication of the plant to power production during the holiday season. Thus, in spite of shorter insolation hours, December was the second best month for electrical production during 1982.

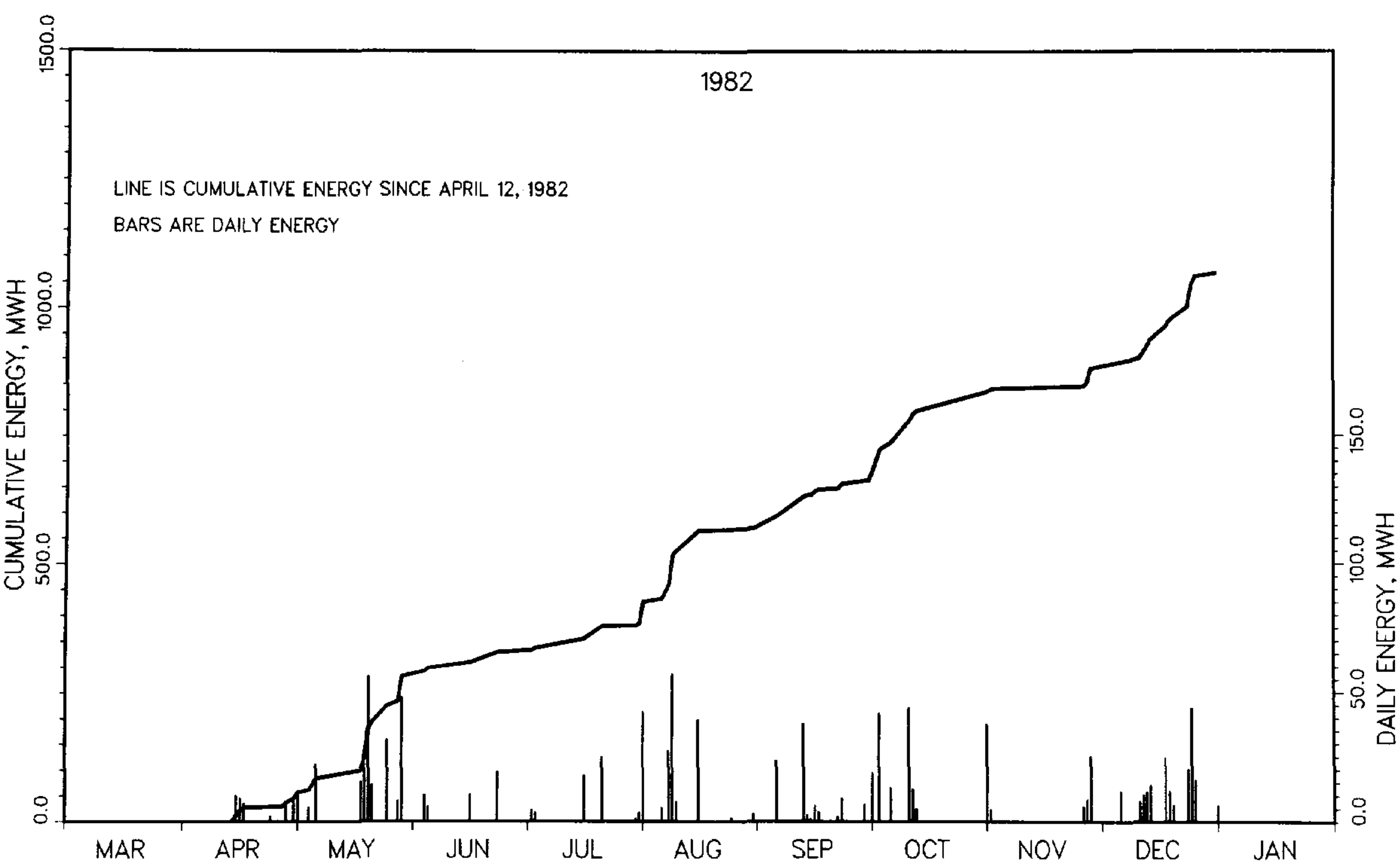


Figure 11. 1982 Net Electrical Production

The success of the test program is due to the efforts of a broad spectrum of organizations. The principals are identified below:

-- The Department of Energy: major funding and administrative control

-- Southern California Edison: operation of Solar One and equipment maintenance

-- Sandia National Laboratories: technical management and plant evaluation

-- Subcontractors:

- ° Martin Marietta: heliostat system control development

- ° McDonnell Douglas Astronautics Corporation: test management and reporting, data processing, and control automation

  and their subcontractors:

  - ° Rocketdyne: receiver and thermal storage system test support

  - ° Stearns-Roger: balance of plant test support

  - ° University of Houston: field aimpoint strategy development

Monthly Operational and Maintenance Highlights

This section describes major construction, testing, and operations and maintenance (O&M) activities at the pilot plant during 1982. Appendix A contains monthly O&M cost data; a summary of the cost data is provided in Table 4.

Table 4

April - December 1982

O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	165.2	3.1	13.6	8.4	190.3
OPERATIONS	609.7	71.8	4.4	7.7	692.8
MISC. NONPRODUCTIVE COST	56.9	6.1	22.8	7.8	92.7
MAINTENANCE					
Supervision/Indirect	81.5	89.8	23.1	47.8	208.9
Control System	47.5	31.0	24.1	5.1	108.0
Receiver System	17.6	1.7	32.9	20.0	72.1
Thermal Storage System	30.5	12.5	14.7	23.3	80.2
Collector System	18.0	0.8	0.5	0.6	19.9
EPGS System	44.5	20.7	25.8	37.3	128.3
Miscellaneous	33.7	10.5	24.0	15.0	83.2
Total Maintenance	273.3	167.0	145.1	149.1	700.6
SUBTOTAL	1104.8	247.1	185.9	173.0	1616.4
Injuries & Damages					3.4
Division O.H.					202.1
TOTAL DIRECT					1883.1
Workmen's Comp.					27.5
Payroll Tax					141.2
Pension & Benefits					212.2
Admin. & General					243.7
TOTAL INDIRECT					624.6
GRAND TOTAL					2507.7

January

Construction--Riveting of 5400 selected mirror modules was completed. These modules had a manufacturing-process defect that occurred during bonding of the module doubler plate to the back of the module. A stud was mounted into the module doubler and now holds each module assembly to the support truss. (Because of poor adhesive mixing, 69 modules detached from the heliostats.) The repair proved effective.

A thermal storage tank leak was repaired by welding a circular patch over an imperfection in a 3/8-inch-thick floor plate.

Plant exterior systems were declared operative, and major mechanical subcontractors were demobilized.

Testing--Interfacing of the Heliostat Array Controller (HAC) and the data aquisition system computer began. Minor difficulties were found with the interface.

Receiver system testing was the major immediate activity. A reduced test scope was identified to achieve turbine roll (net generation of electrical power) by the end of April. Delays in clean-up of the system piping were caused by a freeze, which damaged some equipment required for receiver operations.

February

Construction--Restoration of the thermal storage system tank foundation completed the tank leak repair. The tank and heat exchangers were blanketed with nitrogen to minimize oxidation of system piping and heat exchangers.

Field inspection of the piping systems disclosed a number of pipe hangers and snubbers which required adjustment. Installation of electrical cable tray covers on the tower and pipe racks was completed.

Collector field lightning protection was completed. Field control wiring has a ground sheath and an outer rodent shield. This modification grounded the rodent shield to the junction box on each heliostat in order to minimize the potential of induced voltage spikes. No heliostat mirror modules failed during the month; the riveting appeared to be effective.

The construction of the heliostat field was completed and Martin Marietta demobilized its field forces.

Testing--For the first time, solar radiation was redirected to the receiver. Steam curing of the absorptive paint on the receiver was completed at month's end. Significant solar testing was delayed by poor weather.

The Data Acquisition System (DAS) was operated and supported testing. This separate computer system was designed to gather data on site and to display part of it in real time. The balance is recorded on disks or transmitted in real time to McDonnell Douglas Astronautics in Huntington Beach (MDAC-HB) over high-speed data links. Due to poor telephone communications, the high-speed links did not function properly; data was transferred to tape and transported by courier to Huntington Beach.

March

Construction--Piping earthquake snubbers and hangers were adjusted and minor piping changes were completed. Insulation of piping was near completion. Final electrical work was completed on the meteorological system.

Testing--Start-up of a portion of the receiver was demonstrated. Open- and closed-loop control testing was performed. Each of the receiver's 18 boiler-superheaters is independently controlled. Although time-of-day insolation affects each panel differently, experience indicated that enough symmetry existed so that control constants from a representative panel could be loaded into other panels without significant modification. Each panel's operating temperatures, pressure, and flows were monitored by test engineers in real time to verify that design parameters were not exceeded. Principal concerns were that maximum backside metal temperature not exceed 1100°F and lateral gradients not exceed 300°F for sustained periods. At the end of the month, a turbine roll date of April 15 was predicted.

Panel Warpage--On March 31, receiver panel #5 was observed to have a "warp." The deformation is sinesoidal with a period of approximately 20 feet and an amplitude of approximately 7 inches. Receiver performance was not impaired, and the panel is still in operation.

Apparently, the panel overheated from loss of water flow during start-up. As part of the start-up procedure, flow valves are set at fixed flow rates. When the water temperature is sufficient, the water flow is shifted to panel temperature control. During this transition, the "zero" flow output signal of the flowmeter corresponded to approximately 700 lb/hr. Since the control setpoint of the flow valves was set at 600 lb/hr, the flowmeter signal commanded the flow valve to close. This "bias" error in the flowmeter was detected, and flow was restored from the control room--but apparently not in time. Three actions were initiated:

1. To accommodate future errors in bias, minimum flow was set at 1200 lb/hr in all panels.

2. The flowmeter bias error was observed to be maximum during mid-morning start-up. When the receiver is brought up "with the sun," the components thermally equilibrate and reduce flowmeter bias error. This preferred start-up is followed whenever possible.

3. The electronics which condition the flowmeter signals were modified to reduce coupling through ground loops.

4. Flowmeters with increased temperature compensation were received and installed after turbine roll.

Warpage occurred when the expanding panel hit the support structure. Original thermal design called for 3.5 inches of panel expansion; allowance for 4.7 inches was made in fabrication design. The support modification allowed 8 inches of panel expansion. Testing was continued with the new guidelines and not delayed for completion of the modification.

Data Acqusition System--The immediate need for data to support receiver testing caused a freeze on DAS software changes. Changes to DAS were itemized and prioritized into two catagories: those immediately required to support testing, and the balance which could be deferred until after turbine roll.

Thermal Storage System--A cost trade analysis showed that preliminary warmup of the thermal storage system oil with a supplemental boiler would be effective. The alternate was to wait for the availability of receiver-supplied steam. Procurement of a rental boiler was begun; it would be fueled with excess storage system oil media.

Heliostat System--The plant has two heliostat array controllers (HACs): a prime, and a backup which monitors the prime. If the backup identifies a problem, it will take over, a process defined as a "failover." A susceptibility to electrical noise caused failovers which, although not affecting operations, caused considerable consternation. In the worst-noise case, both HACs failed over and control of the heliostat was taken over by heliostat field controllers (HFCs) which command the heliostats to a stow position. Design of a noise filter was started to ameliorate the failovers.

April

Test Activities--The turbine-generator was synchronized to the SCE grid at 15:09 hours on April 12, 1982. For several hours, the turbine produced 1.2 MW net electrical output. Test personnel monitored receiver, heliostat, and turbine-generator performance parameters as this was largely a manually controlled operation. Receiver steam test 1030A was completed on April 16, and test 1030B began. The primary difference between the two tests was that the A control tests were directed toward individual panel control and the B series integrated all panel controls into a system control scheme; that is, desired receiver output conditions were specified and the control system directed each panel to provide individual steam output conditions to achieve the final receiver-steam parameters.

With completion of construction-funded activities, testing personnel went from seven-day to five-day per week operations.

A rental boiler was moved to the site to prewarm the Thermal Storage System (TSS) media.

Maintenance Activities--The maintenance staff was filled to budget levels (nine people) and maintenance training continued; however, work on most plant equipment continued under SCE start-up labor jurisdiction.

Problems with equipment included:

- Generator air cooler temperature control valve and generator temperature detectors did not function correctly. No permanent damage was incurred.

- Receiver tower main steam lines seismic restraints were found to be bound, the steam lines were galled, and support "I" beams were deformed.

- Some receiver panel flowmeters were replaced with temperature-compensated units in order to stabilize their bias setpoints.

- Receiver panel inlet filters were inspected several times and found to be clean.

- Several condensate pump trips were caused by a defective hotwell level transmitter.

- A ground fault was discovered in the TSS charging oil pump 302 inverter.

Programmatic--A subcontract from Sandia Livermore (SNLL) with Martin Marietta, Denver, was placed for the continuation of software engineering support.

Completion of the Construction Activities--During April 1982 the pilot plant underwent a DOE programmatic transition from the construction phase to the experimental Test and Evaluation phase. Changes which occurred were:

- Dissolution of the DOE Solar One 10 MWe Project Office (STMPO).

- Establishment of a DOE Site Operations Office.

- Testing over a five-day work week instead of a seven-day work week.

To support the testing and research portion of the program, SCE R&D provided on-site and off-site support.

ACTIVITY	CONSTRUCTION PHASE	EXPERIMENTAL TEST & EVALUATION PHASE
DOE Major Contractors	Martin Marietta (heliostats) - Solar Facilities Design Integrator (SFDI) - McDonnell Douglas Astronautics (prime & subs) - Rocketdyne (storage & receiver) - Stearns-Roger (balance of plant) - University of Houston (analysis)	Sandia National Laboratories Subcontractors: - Martin Marietta Aerospace Corp., - McDonnell Douglas (prime) Subcontractors: - Rocketdyne Stearns-Roger
Construction Management	Townsend & Bottum	
Project Management	DOE Solar One 10 MWe Project Office	DOE/SAN Site Office
Technical Support	- Aerospace - Energy Technology Engineering Center - Sandia National Laboratories	
Technical Management		Sandia National Laboratories

May

Construction Activities--The construction manager of Townsend & Bottum began a final equipment audit in preparation for demobilization. Plant support modifications were completed early in May allowing the resumption of maximum temperature receiver testing. Repair of the piping restraints and deformed tower structural steel which supports the main steam piping was completed. Construction activities were essentially completed in May.

Testing Activities--Thermal storage media conditioning began with installation of a portable rental boiler. The boiler was fueled with excess Caloria HT-43, the liquid heat transfer and storage media. Preheating the oil media eliminates water entrapped in the sand and rock.

Receiver testing examined full power start-up and operation to rated temperature and pressure (960°F, 1465 psig). All panels except number 16 were operated in panel metal temperature control. Operation was restricted for this panel due to a high lateral temperature gradient. Instrument checks disclosed that two thermocouples were interchanged at a junction box and the panel gradient was within acceptable limits. The receiver preoperational test was estimated to be 33 percent complete; 110 of 130 test hours were accomplished with little data analysis.

Small amounts of mirror corrosion were sighted at the plant. Water had been identified as a contributor, for it was found in mirror modules which had been opened for inspections. In an attempt to find water without destroying the mirror modules, an x-ray technique was used to examine four modules with corrosion. This nondestruction technique proved successful.

Turbine-generator testing was completed for main steam operation. A peak net output of 9.02 MWe net was achieved and, due to low insolation and the number of heliostats out of service, it was clear that the full 10.0 MWe capacity was presently unattainable; the major single factor precluding 10 MWe operation was that the heliostat field reflectivity had decreased to 78 percent, compared with a 90 percent original value.

Operating Highlights--SCE operators placed the plant in weekend service on May 27, 1982, unassisted by test engineers. Operation was limited to maintaining systems in a warm standby basis.

The first of the two TSS charging and extraction trains were water cleaned on May 25, 1982.

Maintenance Activities--Maintenance of major equipment included the following:

- The 18 receiver boiler panels and 2 of the preheat panels were modified to allow increased axial expansion. This task was performed by Rocketdyne personnel with remaining construction funds.

- Seismic restraints for the receiver main steam lines were replaced.

June

Testing Activities--Thermal storage media conditioning was completed mid-month, and the rental boiler used for heating was removed. The storage tank media was uniformly 350-370°F. Concurrently, receiver-supplied steam was introduced into the thermal storage system, initiating the second part of the thermal storage system preoperational test 1040B.

Receiver testing proceeded on schedule. A two-day plant shutdown was scheduled to relocate electronic equipment within the receiver core area. A combination of a high-temperature environment and loosened electrical ground wires was causing excessive noise in panel flowmeter and control valve wiring.

Dust storms continued through the month and heliostat reflectivity dropped to 73 percent, thereby reducing the possibility of obtaining 10 MWe net. SCE considered bringing an insulator wash truck to rinse some heliostats.

A simulated cloud transient test was conducted. The receiver stayed on line with an 80 percent step reduction in field power for five minutes and an 80 percent step increase. These power steps took approximately one minute. Receiver steam was directed to the thermal storage system for the first time.

Operating Highlights--Southern California Edison requested that consideration be given to running the plant on weekends without technical supervision. The request was occasioned by the successful receiver and turbine testing. A review committee was formed to assess the readiness of the plant and operating personnel. Operating procedures were reviewed and SCE personnel were observed as they started the plant. As a result, the plant was released for weekend power production on a limited basis; technical personnel were to observe operations for an interim period starting in mid-July.

The generator experienced a high temperature excursion on June 22, 1982.

The turbine-generator tripped off the line at 13:01 hours on June 24, 1982, on generator undervoltage.

Maintenance Activities--Maintenance of major equipment included the following:

- Heliostat Array Controller (HAC) software was revised to preclude failover on loss of collector field power.

- PV 1001 (steam dump to condenser) was discovered to have a broken actuator piston.

- The turbine-generator system underwent dynamic testing by the SCE Apparatus Department.

- A station auxiliary load kilowatt-hour meter was installed and functioning.

July

A major component failure of a large steam dump valve which isolates receiver steam downcomer flow from the condenser occurred on July 3. This valve is a regulating valve which can open rapidly to divert steam from the turbine to the condenser if a steam supply malfunction should occur. Valve internals failed. As a result, turbine operation was impossible and receiver operation was limited to flow through the flash tank system. (This procedure is normally used for start-up. Flow is limited to 50,000 lbs/hr and a maximum pressure of 625 psig). The valve manufacturer determined that failure was a result of high temperature gradients associated with initial start-up. After replacement of the valve internals, procedures were defined to warm up the valve gradually. Between forty-five and ninety minutes were added to the start-up time, allowing the dump valve to equilibrate with the steam.

A full power attempt was made on July 15. Only 7.8 MWe net were realized. Major differences between design and actual were heliostat reflectivity (0.75 vs. 0.89 design), low insolation (904 vs. 973 design), and 1728 operable heliostats vs. 1818. In addition, a 0.5 MWe unaccountable loss was found to be caused by an open condensate drip line. Maintenance corrective actions were initiated.

Operating Highlights--The thermal storage system charging train underwent activation on July 7-8, 1982.

The Beam Characterization System (BCS) was placed in automatic operation and functioned by operating personnel.

On July 12, 1982, a passing thunderstorm caused several 33 kV line voltage excursions. No equipment damage or failure occurred.

Maintenance Highlights--Maintenance of major equipment included the following:

- The receiver steam dump valve was repaired on July 11, 1982, and was test-operated on July 12 and July 16 in the presence of the valve manufacturer.

- The storage system, valves, and heat exchangers leaked on the oil and water side.

- Receiver panels 8, 13, 14, and 19, and 21 inlet filter gaskets were replaced as a result of leaks.

- Repair of out-of-service heliostats was initiated with the arrival of additional spare heliostat control boards. Heliostat rinsing was begun using an insulator wash truck; over 1000 heliostats were washed in this manner. The cleanliness of the mirrors was finally resolved with a rain wash at the month's end.

- Downcomer drip and drain line components, traps, etc., were examined for proper functioning.

- Thermal storage testing was inhibited with the failure of the extraction feedwater pump. Repair of the pump casing required approximately a week. Testing of thermal storage extraction trains was delayed because the heat exchangers required frequent blowdown to maintain water quality standards.

- Power supply to the plant is by means of a 33 kV line. During a five-day period, voltage variations caused interruptions in this supply eight times. These variations exceeded allowable supply tolerances of the computer systems (which shut down as a result) and interrupted testing. Improvements to allow automatic switch-over to the backup 4 kV line were made by SCE.

August

Testing--On August 6, the thermal storage tank was charged to its rated value, 575°F, for the first time.

Aerial and ground beam safety tests were performed to validate calculated eye hazards above and around the plant for various heliostat configurations. The tests measured light intensity with a video camera. Preliminary results indicated that present operational safety procedures are satisfactory. Sandia is preparing a formal report which will document the results of the tests.

One hundred random heliostat mirrors were checked by x-ray for water in the heliostat honeycomb area. Analysis showed that approximately 60 percent of the heliostats tested contained some water. A large number of heliostats showed mirror corrosion; however, this represents a negligible loss of reflective area (on the order of 0.002 percent).

On August 24, the turbine reached a net load of 3.4 MWe on thermal storage (TSS) admission steam for the first time on two extraction trains. Turbine throttle conditions were 213 psig, 507°F, and 63 klb/hr. Oil flow was 209 klb/hr at 525°F.

While the TSS tank was charging on August 26, the plant weathered two severe insolation drops, from 750 W/m^2 to 25 W/m^2. Both receiver and TSS remained in service.

Operating Activities--An effort was made during August to determine the maximum plant generation capability using receiver steam. Despite a calculated load of 12 MWe gross, the maximum achieved was 7.0 MWe gross. An investigation of the heliostat reflectivity, receiver absorption coefficient, receiver radiant and convective losses, piping losses, and turbine system efficiency revealed that steam losses due to bypass and drain leaks were responsible for the power derating. After the leaks were repaired, the plant reached the rated 10 MWe net load.

On August 15, a turbine net load of 9.9 MWe was achieved with a parasitic load of 0.9 MWe. Insolation was 882 W/m^2 with 1739 heliostats in service. Turbine throttle conditions were 949°F, 1526 psig, and 99 klb/hr.

The receiver main steam dump valve to the condenser required an extensive warm-up period, thereby delaying start-up because of temperature differentials across the valve body. Heat tracing was installed to maintain the valve body at 400°F during start-up. A transient temperature study was made.

While the turbine was operating on TSS admission steam, a bypass steam leak through the intermediate turbine shaft packing gland caused turbine speed control and synchronization problems. Admission steam stop valves were used for throttling until the leak was fixed.

Maintenance Highlights--Oil and steam leaks developed in the thermal storage charging train subcooler and extraction boiler end flanges, respectively. Both leaks were temporarily stopped by tightening end flange bolts. The leaks were apparently caused by daily start-up and shutdowns. Leaks in the receiver panels were also attributed to the same cause.

While the TSS extraction steam and feedwater lines were being cleaned, the hot well was contaminated by high iron concentrations of up to 1000 ppb. The entire system was cleaned by blowing down for several days.

September

Testing--Activities for the month of September emphasized transitions from receiver to storage operation. Testing of the control systems was performed during storage charge and discharge. During the month, it became evident that a serious problem existed while attempting to roll the turbine on admission (storage-supplied) steam. If the specified procedure was followed, the turbine would accelerate to an excess of 3000 RPM with the first introduction of steam.

On September 23, the turbine transitioned successfully from receiver steam supply, to receiver and extraction simultaneous steam supply, to extraction steam supply only. Then the mode transitions were successfully accomplished in the reverse order. Pressure control was transferred from the turbine to the steam source and back to the turbine. Some logic control problems required operator intervention; however, in general the control system performed well.

Operating Highlights--Although the main objective for September was testing of the TSS charging and extraction systems, September was the third highest production period (after May and August). This level was achieved despite the highest number of testing hours and the most time lost due to overcast skies for any month since plant operation began in April 1982.

With the auxiliary oil pump instead of the electric boiler, the thermal storage system began supplying all plant auxiliary steam systems. The use of the TSS to provide the auxiliary steam is a part of the normal operating procedure. In addition, the electric boiler had multiple circuit breaker and electrode failures.

On September 15-16, the turbine averaged a net load of 0.9 MWe for 11.8 hrs on TSS extraction steam. The thermal storage tank discharged from 85 percent to 20 percent full charge capacity. The thermal storage tank charge level is the percentage of oil above 550°F.

On September 17, the turbine achieved a net load of 4.5 MWe on extraction steam with both extraction trains at 50 percent oil flow.

On September 29, the turbine achieved a net load of 5.6 MWe on both TSS extraction trains.

Maintenance Highlights--Flowmeter electronics on the TSS skids were moved to a remote location because of local high ambient temperatures. This is consistent with a previous design change in which the receiver flowmeter electronics were relocated from the receiver core area to an environmentally controlled remote station.

The vendor attributed recurring steam flange leaks on the TSS extraction and charging trains to daily thermal cycling. The flange gaskets were replaced and the flange bolts tightened to higher torque values during the next maintenance outage.

The receiver core was modified to accommodate a skyclimber (a short work platform suspended by wire cable, suitable for lifting two people) to inspect the receiver boiler panels. The Pyromark paint on the surface of the boiler panels was in satisfactory condition after six months of receiver operation.

The Data Acquisition System (DAS) had signal noise problems when communicating with the heliostat field. Loose connections in the heliostat tracking motors were tightened, which seemed to solve the problem. Diagnostic testing continued.

Contract construction crews installed missing thrust blocks and fire hydrant pads for the fire protection system.

The TSS condensible heptane tank stores heptane liquid and vapor created in the thermal storage tank during charging operations. The 300-gallon heptane tank was discovered to be undersized, so a portable 6000-gallon tank was connected to the existing heptane tank to store excess liquid heptane for salvage. A nitrogen blanket is required, since analysis revealed the heptane condensate has a flash point of 70°F.

October

Testing Highlights--Testing on the TSS control loops was limited because of forced outages and overcast skies for over two weeks. The forced outages were caused by gland seal exhauster pump and Heliostat Array Controller (HAC) failures.

The turbine was rolled on TSS extraction steam to evaluate high-pressure to low-pressure turbine shaft packing as recommended by the turbine manufacturer. The test was performed to establish the corrective measures needed to provide turbine speed control during extraction steam start-up.

The problem manifests itself as an overspeed of the turbine motor when steam is first introduced into the intermediate stage via the admission port. To provide cooling of the high pressure stage when the admission port is in operation, an internal steam bypass allows steam entry into the high pressure stage. This occurs regardless of the admission port control valve settings. Between the high and intermediate stages, a rotary shaft seal (gland seal) isolates the two stages. When attempts are made to roll from admission steam, the seal is subjected to a high pressure differential, which blows steam through the seal at sufficient mass flow to overspeed the turbine, e.g., it free-rolls in excess of 3000 RPM whereas the starting specification calls for a roll and hold to 1000 RPM for warmup. (The overspeed condition does not exist on the main steam inlet because the steam must pass through the main control valves first; thus steam mass flow is controlled.)

On October 10, the generator reached a new high net load of 10.4 MWe on receiver steam with an auxiliary load of 1.0 MWe. The insolation was 954 W/m^2 with 1763 heliostats in service. Turbine throttle conditions were 950°F, 1520 psig, and 103 klb/hr.

On October 11, the receiver supplied steam to the turbine and TSS charging trains as a stable operating mode for the first time. The turbine operated at 6.3 MWe net with an auxiliary load of 1.1 MWe. The steam and oil flows to the charging trains were 25 and 13 klb/hr, respectively. Steam flow was limited due to silica and iron contamination.

Operating Highlights--Despite losing half the month, October was the second highest generation period since operations began in April.

Heliostat Array Controller failures were thought to be caused by noise in the station ground system and direct current noise, as previously reported. Martin Marietta installed a noise filter on the HAC and continued diagnostic testing.

The receiver main steam dump valve required excessive warm-up time and delayed start-up. Heat tracing was installed to maintain the value at 400°F, but thermostat and thermocouple failures delayed testing. Preliminary test results indicated that the heat tracing would eliminate the warm-up time and decrease start-up delays.

On October 9, the Thermal Storage System contaminated the entire plant feedwater, steam, and condensate system with silica and iron carryover from one of the extraction boilers. The extraction boiler and TSS flash tank were isolated and cleaned by blowdown over a four-day period. The hot well, deareator, and the receiver system were cleaned by the normal start-up procedure. (The hot well, the deareator, the receiver are cleaned sequentially by blowing down and going through the in-line demineralizers.)

Maintenance Highlights--Five of sixty-four heliostat field controllers (HFC) were replaced when the crystal element controlling the input/output communication frequency to the heliostat array controller computer failed. The defective crystal chips were replaced.

The gland seal exhauster pump failed twice. Solids in the service water plating on the pump rotor and case caused the pump to sieze. A temporary condensate supply replaced the service water as the quenching water for the gland seal spray chamber. A permanent condensate supply was installed during the next maintenance outage.

Elbows in the PVC waste water line from the TSS area drains appeared to fail when thermal expansion of a 400-foot straight section of the waste line occurred. The expansion was caused by the TSS boiler and subcooler leaking hot condensate into the drains, to a sump, and into the waste line. The water temperature 400 feet from the sump was 110°F. Schedule 80 fittings replaced the defective schedule 40 elbows.

All 4 kV circuit breakers were found to trip when an Interlock Logic System (ILS) input/output card was replaced. The card appears to ground when it is removed, causing a discrete logic system trip. A factory representative investigated the problem. The 4 kV circuit breakers carry most of the station auxiliaries except for certain control computers, which are on an uninterruptable power supply.

November

Testing Highlights--The Thermal Storage Unit (TSU) was fully charged before a scheduled two-week outage and isolated to study the natural thermal energy degradation over the two-week period. Preliminary results indicated an average 0.11 thermal megawatt loss per hour, which is better than the design loss of 0.12 thermal megawatt per hour. The temperature of the oil in the top of the tank dropped from 575°F to 550°F, approximately four percent; the temperature in the bottom of the tank decayed from 476°F to 397°F, 17 to 20 percent, in the 19-day period. The temperature decay was relative to an average ambient temperature of 60°F.

During the planned outage, selected receiver boiler panels had Pyromark paint removed from the edge tubes to reduce temperature gradients across the respective panels. Absorptivity readings were subsequently taken on all panels. The maximum absorptivity reading was 0.93 on three south-facing preboiler panels; the minimum was 0.91 on two north-facing boiler panels.

The plant backup 4 kV power supply was modified so that the plant can now restart on the 4 kV if the primary 33 KV power supply is lost. This change significantly improves plant reliability.

On November 30, the plant did not suffer wind damage as a consequence of 70 mph winds. The plant is designed to withstand 90 mph winds.

Maintenance Highlights--The following major items were worked on during the outage:

- New boiler panel inlet strainer gaskets were installed.

- Eight major receiver control valves were repaired for leaks.

- The TSS feedwater pump was rebuilt by the manufacturer to return pump tolerances to the original specifications.

- Both charging subcoolers had their channel box cover gasket replaced and the cover bolts tightened to 4800 ft-lb.

- Both extraction boiler tube bundles were pulled out seven inches to repair the steam leaks past the shell-side tubesheet gaskets. One gasket was wrapped with "grapfoil" and the other replaced with a carbon/stainless steel gasket. Both boilers were thermally cycled and the bolts retorqued to 368 ft-lb.

- Eight tube leaks that were found in the charging subcoolers were seal welded.

- Sample lines were installed on the TSS extraction boilers and flash tank.

- Inspection of the turbine rotating element showed no unusual conditions.

- Inspection of the main and admission stop valve strainers showed no debris or fouling. The admission stop valve plug and seat ring were dye tested for wear. None was found, even though it had been used to throttle for admission steam start-up speed control.

An overspeed sensing relay on the turbine failed when its contacts burned, forcing the turbine out of service until the relay was replaced.

Inadvertent 4 kV system circuit breaker trips were traced to retaining clips that grounded when an Interlock Logic System (ILS) logic card was removed. All logic cards were modified to eliminate the problem.

December

Testing Highlights--Performance verification during the "worst design case," Winter Solstice, was the primary goal for December. Preliminary results indicate the plant meets the design performance criteria despite the low insolation level, 867 W/m^2, which limited load to 10.1 MWe gross for 90 klbs/hr flow at 1460 psi and 1000°F. Work continued on automating the Thermal Storage System (TSS) charg'ng train controls which were 70 percent complete.

On December 20, the turbine reached a net load of 6.0 MW on admission steam, with an auxiliary load of 0.9 MW and an oil flow of 100 klb/hr at 540°F. Test coordinators believe the turbine would have reached the 7.0 MWe net design load if the oil had been at the 575°F rated design temperature.

Operating Highlights--On December 13 and 14, level surges in the TSS extraction boiler level transmitter reference legs caused several boiler trips. The reference legs were modified to eliminate the surge problem.

TSS extraction boiler isolation valves will be installed to prevent steam/feedwater system contamination due to dissolved solid carryover from the extraction boilers. In addition, a sample system will be installed to monitor the extraction boiler blowdown and superheated steam, as well as the TSS flash tank condensate.

The TSS extraction boilers are being used instead of the station electric auxiliary boiler to supply auxiliary steam in order to reduce the plant auxiliary electrical load. Also, a smaller auxiliary TSS feedwater pump is being used instead of the main TSS feedwater pump for the same reason.

SCE operators were certified to operate TSS single train charging. This procedure allowed blanketing the plant with TSS steam at night over the Christmas holidays without McDonnell Douglas supervision.

There were 248 hours available for test activities in December. December was the second highest generation period after May, despite a 40 percent weather outage. The delay in receiving the generator speed sensing relay and delays due to poor extraction boiler water chemistry accounted for the unscheduled outage hours.

Maintenance Highlights--Due to intermittent oil leaks in the TSS charging trains, all flange bolts were retorqued in the TSS area.

Cracks were discovered in the annular shell fillet weld to the channel box tubesheet on both TSS extraction boilers. The boilers are a double tubesheet design with a longitudinal space between the tubesheets. The failure mechanism is thought to be differential expansion between the stainless steel tubes and the carbon steel annular shell or differential radial expansion between the two tubesheets. No repairs were required since the annulus does not provide significant support to the tubes.

A trip relay was installed to close the main steam dump valve on high temperature downstream of the steam dump desuperheater. This will prevent superheated steam from damaging the condenser.

Small pieces of grapfoil tape, which was used in sealing receiver panel flowmeter flanges, temporarily fouled the receiver feedwater inlet strainer and water sampling lines. The strainer and lines remained clear after cleaning.

Continuous steam leakage into the electronic portion of three TSS flowmeters resulted in failures. The flowmeters were removed and sent back to Rampo for modification and repair.

APPENDIX A

MONTHLY O & M COST SUMMARIES

This Appendix contains monthly operations and maintenance cost data for April through December 1982.

Construction activities culminated with turbine roll in April 1982. Beginning with that month, Southern California Edison's operating and maintenance reports are included. Although plant status was programmatically changed in April from construction to operational, a number of construction activities continued. The cost to support these activities is contained within the monthly O&M cost summaries. SCE costs are categorized as follows:

Field Costs	-	Includes plant supervision, engineering, accounting, clerical, office supplies, and miscellaneous indirect expenses.
Operations	-	Includes total cost of operating expenses and staff.
Miscellaneous	-	Includes station supplies and rentals, nonproductive safety and job training, and site security costs.
Maintenance	-	Includes total cost of maintenance expenses and staff allocated to major plant subsystems.
Overheads	-	Includes costs associated with direct labor plus company administrative and general expenses.

Table A-1

April 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	4.9	-	1.8	2.4	9.1
OPERATIONS	59.4	.8	-	.7	60.1
MISC. NONPRODUCTIVE COSTS	8.0	-	-	.6	8.6
MAINTENANCE					
Supervision/Indirects	7.3	7.6	1.0	.2	16.1
Control System	1.8	.8	-	-	2.6
Receiver System	-	-	-	-	-
Thermal Storage System	.6	-	6.3	-	6.9
Collector System	1.9	-	-	.1	2.0
EPGS System	1.7	-	-	5.2	11.9
Miscellaneous	1.7	-	-	.2	1.9
SUBTOTAL	88.8	11.6	9.4	9.4	119.2
Injuries & Damages					.8
Division O.H.					22,5
TOTAL DIRECT					142.6
Workman's Comp.					
Payroll Tax					8.7
Pension & Benefits					30.9
Admin. & General					9.8
			A&G Adjustment		<2.9>
GRAND TOTAL					189.1

Table A-2

May 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	12.8	.5	3.2	.3	16.8
OPERATIONS	101.8	-	-	.4	102.2
MISC. NONPRODUCTIVE COSTS	10.3	.2	.1	.3	10.9
MAINTENANCE					
Supervision/Indirects	7.0	29.0	1.2	.2	11.3
Control System	8.0	-	.5	.3	8.8
Receiver System	2.2	-	.1	.5	2.8
Thermal Storage System	.9	-	.6	1.3	2.8
Collector System	3.0	.6	-	.3	3.9
EPGS System	5.5	1.4	.1	3.7	10.7
Miscellaneous	5.4	.7	-	.1	6.2
Total Maintenance	32.0	31.7	2.5	2.5	46.5
SUBTOTAL	156.9	6.3	5.8	7.4	176.4
Injuries & Damages					.9
Division O.H.					30.2
TOTAL DIRECT					207.5
Workman's Comp.					
Payroll Tax					13.0
Pension & Benefits					45.9
Admin. & General					12.1
			(AUDIT ADJUSTMENT)		(.3)
GRAND TOTAL					278.2

Table A-3

June 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	16.8	-	2.2	-	19.0
OPERATIONS	59.1	.8	-	.2	60.1
MISC. NONPRODUCTIVE COSTS	8.2	-	2.5	.1	10.8
MAINTENANCE					
Supervision/Indirects	6.2	9.2	8.0	-	16.2
Control System	2.3	.1	.1	.5	3.0
Receiver System	1.6	-	-	-	1.6
Thermal Storage System	2.1	1.0	.9	.6	3.7
Collector System	2.5	-	.1	-	2.6
EPGS System	8.8	.1	-	.8	9.7
Miscellaneous	2.6	.7	-	-	3.3
Total Maintenance	26.1	10.2	1.9	1.9	40.1
SUBTOTAL	110.2	11.0	6.6	2.2	130.0
Injuries & Damages					.6
Division O.H.					19.6
TOTAL DIRECT					150.2
Workman's Comp.					
Payroll Tax					8.2
Pension & Benefits					29.2
Admin. & General					10.7
GRAND TOTAL					198.3

Table A-4

July 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	9.9	-	2.3	-	12.2
OPERATIONS	57.1	9.5	-	4.7	71.3
MISC. NONPRODUCTIVE COSTS	6.1	.3	3.6	-	10.0
MAINTENANCE					
Supervision/Indirects	9.3	5.0	1.0	-	15.3
Control System	3.8	5.5	4.3	-	13.6
Receiver System	4.2	-	-	3.7	7.9
Thermal Storage System	5.7	.2	-	-	5.9
Collector System	2.6	.1	-	-	2.7
EPGS System	2.9	1.3	.2	1.1	5.5
Miscellaneous	4.2	-	.3	-	4.5
Total Maintenance	32.7	12.1	5.8	4.8	55.4
SUBTOTAL	105.8	21.9	11.7	9.5	148.9
Injuries & Damages					.4
Division O.H.					17.8
TOTAL DIRECT					167.1
Workman's Comp.					
Payroll Tax					7.6
Pension & Benefits					26.8
Admin. & General					7.3
GRAND TOTAL					208.8

Table A-5

August 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	18.2	2.1	-	-	20.3
OPERATIONS	60.8	30.6	-	-	91.4
MISC. NONPRODUCTIVE COSTS	4.6	3.6	.2	-	8.4
MAINTENANCE					
Supervision/Indirects	12.2	13.2	3.8	17.7	46.9*
Control System	4.6	.1	3.7	-	8.4
Receiver System	2.1	.1	4.2	.1	6.5
Thermal Storage System	6.4	1.6	1.6	4.0	13.6
Collector System	.2	.1	.1	.2	.6
EPGS System	4.5	.3	2.0	-	6.8
Miscellaneous	3.0	1.8	-	-	4.8
Total Maintenance	33.0	17.2	15.4	22.0	87.6
SUBTOTAL	116.5	53.5	15.6	22.0	207.7
Injuries & Damages					1.5
Division O.H.					18.6
TOTAL DIRECT					227.8
Workman's Comp.					.4
Payroll Tax					8.0
Pension & Benefits					25.6
Admin. & General					17.4
GRAND TOTAL					279.2

* Reflects approximately $27,000 of start-up costs.

Table A-6

September 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	21.0	-	1.8	.6	23.4
OPERATIONS	72.3	1.5	4.4	1.0	79.2
MISC. NONPRODUCTIVE COSTS	4.6	.5	5.9	.1	11.1
MAINTENANCE					
Supervision/Indirects	9.3	3.7	2.4	10.7	26.1
Control System	4.6	12.7	1.7	3.6	22.6
Receiver System	1.1	.1	28.1 *	8.4	37.7
Thermal Storage System	4.5	1.5	1.4	4.7	12.1
Collector System	1.5	-	.3	-	1.8
EPGS System	2.7	5.2	8.7	11.2	27.8
Miscellaneous	4.3	1.1	7.8	2.9	16.1
Total Maintenance	28.0	24.3	50.4	41.5	144.2
SUBTOTAL	125.9	26.3	62.5	43.2	257.9
Injuries & Damages					(.6)
Division O.H.					20.3
TOTAL DIRECT					277.6
Workman's Comp.					1.6
Payroll Tax					10.0
Pension & Benefits					24.7
Admin. & General					67.1
GRAND TOTAL					381.0

* This reflects a late billing for start-up expenses.

Table A-7

October 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	22.6	0.2	0.6	3.1	26.5
OPERATIONS	55.4	3.6	-	0.3	59.3
MISC. NONPRODUCTIVE COSTS	4.6	0.5	1.8	1.8	8.7
MAINTENANCE					
Supervision/Indirects	10.7	3.7	1.6	10.5	26.5 *
Control System	6.2	0.2	8.6	0.3	15.3
Receiver System	3.4	0.7	0.5	4.4	9.0
Thermal Storage System	3.1	0.4	2.4	5.4	11.3
Collector System	1.7	-	-	-	1.7
EPGS System	4.7	1.2	2.9	1.8	10.6
Miscellaneous	3.9	1.3	13.4 *	5.2	23.8
Total Maintenance	33.7	7.5	29.4	27.6	98.2
SUBTOTAL	116.3	11.8	31.8	32.8	192.7
Injuries & Damages					
Division O.H.					23.1
TOTAL DIRECT					215.8
Workman's Comp.					1.0
Payroll Tax					9.3
Pension & Benefits					26.1
Admin. & General					38.0
GRAND TOTAL					290.2

NOTES: Overhead amounts are derived from a combination of rates for start-up and O&M expenses.

* Reflects start-up expenses.

Table A-8

November 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	33.7	.1	1.5	1.9	37.2
OPERATIONS	83.5	13.8	-	.4	97.7
MISC. NONPRODUCTIVE COSTS	6.0	.2	5.7	3.3	15.2
MAINTENANCE					
Supervision/Indirects	13.2	5.7	2.3	1.9	23.1
Control System	9.9	.8	3.3	.7	14.7
Receiver System	2.3	.5	-	1.6	4.3
Thermal Storage System	3.9	6.7	1.0	4.4	16.1
Collector System	1.7	-	-	-	1.7
EPGS System	7.7	1.1	1.7	11.8	22.3
Miscellaneous	4.4	.1	1.3	3.6	9.4
Total Maintenance	43.1	14.9	9.6	24.0	91.6
SUBTOTAL	166.3	29.1	16.8	29.6	241.7
Injuries & Damages					(.2)
Division O.H.					29.5
TOTAL DIRECT					271.1
Workman's Comp.					1.8
Payroll Tax					13.0
Pension & Benefits					34.8
Admin. & General					61.2
GRAND TOTAL					381.8

Table A-9

December 1982 O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	25.3	0.2	0.2	0.1	25.8
OPERATIONS	60.3	12.0	-	-	72.3
MISC. NONPRODUCTIVE COSTS	4.5	0.8	3.0	0.7	9.0
MAINTENANCE					
Supervision/Indirects	6.3	12.7 **	1.8	6.6	27.4
Control System	6.3	10.8	1.9	-	19.0
Receiver System	0.7	0.3	-	1.3	2.3
Thermal Storage System	3.3	1.1	0.5	2.9	7.8
Collector System	2.9				2.9
EPGS System	4.5	6.9	9.9 *	1.7	23.0
Miscellaneous	4.2	4.8	1.2	3.0	13.2
Total Maintenance	28.2	36.6	15.3	15.5	95.6
SUBTOTAL	118.3	49.5	18.7	16.3	202.8
Injuries & Damages					
Division O.H.					20.4
TOTAL DIRECT					223.2
Workman's Comp.					1.0
Payroll Tax					8.3
Pension & Benefits					23.1
Admin. & General					45.2
GRAND TOTAL					300.8

* These expenses are abnormally high because previous start-up costs are included.

** This includes an amount for stocking the warehouse with miscellaneous materials (e.g., nuts, bolts, etc.).

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