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10 MWe Solar Thermal Central Receiver Pilot Plant: 1983 Operational Test Report

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10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT:

1983 OPERATIONAL TEST REPORT

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ABSTRACT

The design and construction of the world's largest solar thermal central receiver electric power plant, the 10 MWe Solar Thermal Central Receiver Pilot Plant, "Solar One," located near Barstow, California, were completed in 1982. The plant continued in the two-year experimental Test and Evaluation phase throughout 1983.

Experiences during 1983 have shown that all parts of the plant, especially solar unique ones, operated 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. All operational modes were tested and plant automation activities began in earnest.

This report contains (1) a brief description of the plant system; (2) a summary of the year's experiences; (3) topical sections covering preliminary power production, automation activities, and receiver leak repairs; (4) a monthly list of principal activities; and (5) operation and maintenance costs.

SOLAR THERMAL TECHNOLOGY
FOREWORD

The research and development described in this document was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. The goal of the Solar Thermal Technology Program is to advance the engineering and scientific understanding of solar thermal technology, and to establish the technology base from which private industry can develop solar thermal power production options for introduction into the competitive energy market.

Solar thermal technology concentrates solar radiation by means of tracking mirrors or lenses onto a receiver where the solar energy is absorbed as heat and converted into electricity or incorporated into products as process heat. The two primary solar thermal technologies, central receivers and distributed receivers, employ various point and line-focus optics to concentrate sunlight. Current central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Parabolic dishes up to 17 meters in diameter track the sun in two axes and use mirrors or Fresnel lenses to focus radiant energy onto a receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Concentrating collector modules can be used alone or in a multi-module system. The concentrated radiant energy absorbed by the solar thermal receiver is transported to the conversion process by a circulating working fluid. Receiver temperatures range from 100^{o}C in low-temperature troughs to over 1500^{o}C in dish and central receiver systems.

The Solar Thermal Technology Program is directing efforts to advance and improve promising system concepts through the research and development of solar thermal materials, components, and subsystems, and the testing and performance evaluation of subsystems and systems. These efforts are carried out through the technical direction of DOE and its network of national laboratories who work with private industry. Together they have established a comprehensive, goal directed program to improve performance and provide technically proven options for eventual incorporation into the Nation's energy supply.

To be successful in contributing to an adequate national energy supply at reasonable cost, solar thermal energy must eventually be economically competitive with a variety of other energy sources. Components and system-level performance targets have been developed as quantitative program goals. The performance targets are used in planning research and development activities, measuring progress, assessing alternative technology options, and making optimal component developments. These targets will be pursued vigorously to insure a successful program.

System experiments provide valuable data on capital cost, performance, and operations and maintenance of complete solar thermal systems. The system experiments are conducted with major participation from solar equipment manufacturers and potential users. These experiments lead to the establishment of technical feasibility, to the development of a valuable cost and performance data base, to technology transfer which can be used in private sector decisions, and to the identification of future research and development needs.

The current system experiment in the Central Receiver Development Program is the 10 MWe Solar Thermal Central Receiver Pilot Plant in Barstow, California. The objective of this experimental pilot plant is to test the various subsystems and analyze the performance of the components. Evaluation of data provides information to industry to support decisions regarding designs and economics of central receiver systems. The work also identifies areas where future central receiver research and development could lead to significant performance improvements and increased capabilities.

10MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT:

1983 OPERATIONAL TEST REPORT
EXECUTIVE SUMMARY

This document reports the operational test experience for the 10 MWe Solar Central Receiver Pilot Plant (Solar One) near Barstow, California, during calendar year 1983. The main 1983 objectives for the 10 MWe Solar Central Receiver Pilot Plant Evaluation and Test Phase included completion of intersystem mode testing, initiation of plant automation and continued power production.

The Pilot Plant test program covers three phases: start-up, the two-year experimental Test and Evaluation Phase, and the three-year Power Production Phase; 1983 was the first full year in the two-year experimental Test and Evaluation Phase.

A Summary of 1983 Activities at Solar One

During calendar year 1983, the objectives for the 10 MWe Solar Central Receiver Pilot Plant Evaluation and Test Phase included completion of intersystem mode testing, initiation of plant level automation, and continued power production.

All of the major modes of operation were functionally demonstrated during 1983. By the end of the year, Modes 1, 5, 6, and 8 were released to SCE for routine operations. Automation activities included integration of the separate system controllers under the control of a main operational control system computer. Many power design points were achieved during 1983, however, the requirement to deliver 10 MWe net for 4 hours on Winter Solstice was not realized.

Receiver tubing leaks were encountered and repaired. The cause of the leaks is unknown and investigation continues.

Programs were initiated to reduce the parasitic power requirements during non operating periods and improve component performance during operation. Although the plant began to "breakeven" on electrical generation, 1983 was only a start toward energy production goals.

Throughout 1983, operation of the plant showed 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 cost of the plant operations were within budget.

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 scheduled outage, time during which scheduled work was performed and forced outage, time periods when test or power production activities were planned but malfunctions prevented operation; and finally, weather outage time, daylight hours during which weather precluded operation. The 1983 experience at Solar One is shown on Figure ES-1.

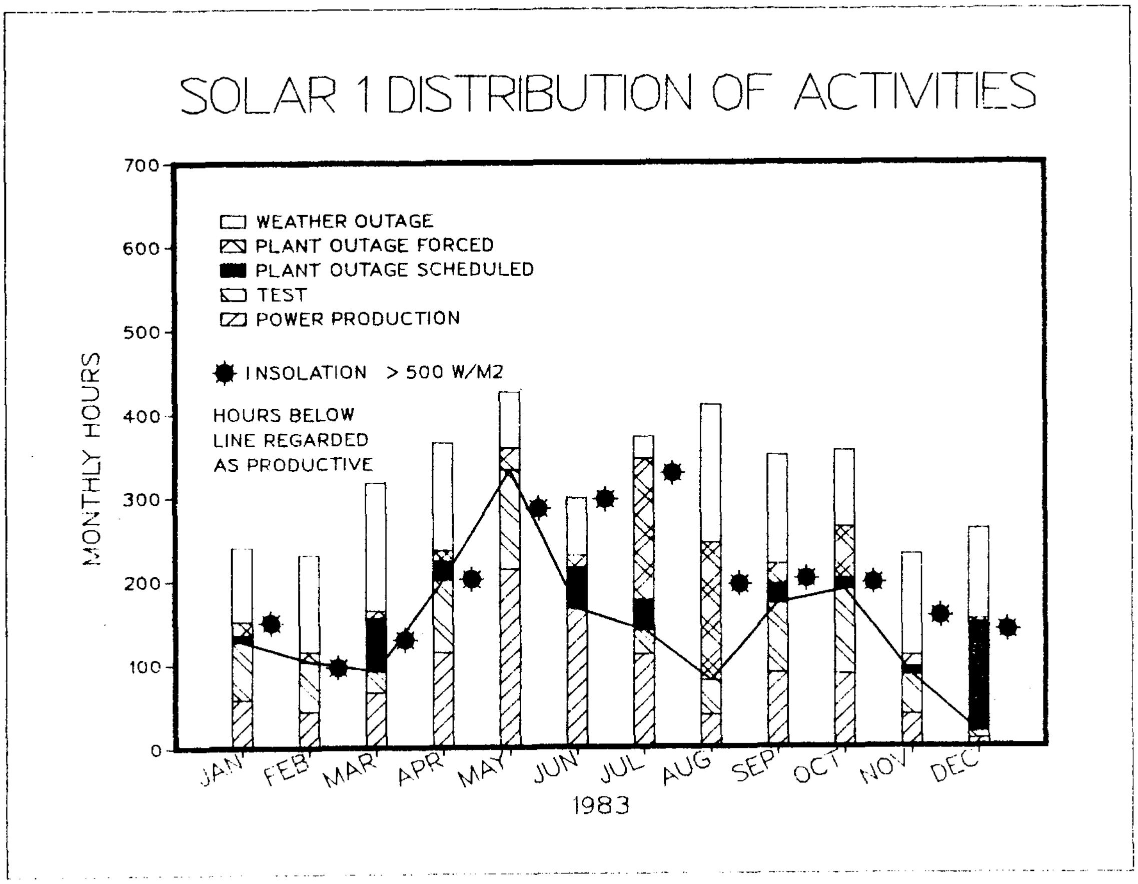

Figure ES-1

The major planned activities for 1983 included performance verification of most plant systems, continuation of plant automation, and establishment of operations and maintenance (O&M) cost baselines. The status of the verification of principal performance verification objectives is summarized in the following tables, ES-1 and ES-2.

Table ES-1

STATUS OF THE VERIFICATION OF PRINCIPAL TECHNICAL OBJECTIVES AT 1983 YEAR-END.

10.0 MWe net from receiver supplied steam.	10.4 MWe
7.0 MWe from storage system for four hours •	7.1 MWe net for four hours, (7.3 peak).
Plant operable at 2 MWe •	Operable to 1.0 MWe
95 per cent heliostat availability •	Better than 97 per cent
Operation at insolation above 690 watts/sq. meter •	Operates above 300 watts/sq. meter
Plant transitions among all modes •	Complete
Automatic control of separate systems	Demonstrated 1983
Automatic control of the integrated plant	Scheduled 1984
Evaluation of all modes:	
Modes 1, 2, 5, 6	Complete
Modes 3, 4, 7	Scheduled 1984
10MWe for 4 hours Winter Solstice •	Not achieved

• Design requirement.

Table ES-2

SIGNIFICANT 1983 MILESTONES

Continuous synchronization to the grid for 33 hours	June, 1983
Peak power output of 12.1 MWe net, Mode 3	June, 1983
Total storage capacity of 41.3 MWe-h net	June, 1983
Peak single day energy of 104 MWe-h net, using stored plus incident solar energy	June,1983
Peak single day energy of 78.5 MWe-h net while synchronixed, incident solar energy only	May, 1983
Peak single day energy of 62 MWe-h net , 24 h basis	May, 1983

Plant Automation

Solar One is unique in the electric utility industry because it is automatically controlled by a Master Control System consisting of an Operational Control System computer which supervises the operation of the plant's two thousand microprocessors. Information on plant operation is provided to the operator on color-graphic video displays.

Throughout 1983, an alteration of the control systems was initiated whereby centralized plant level control of plant systems would be realized. The goal was to have the plant operate automatically throughout the day.

By the end of 1983, most hardware changes had been accomplished, and the programmed start-up/shut-down transitions had been demonstrated for Modes 1, 5 and 6. It is difficult to quantitively demonstrate the effect of plant automation, but the following favorable trends can be inferred:

* Net electrical energy generated increased dramatically when compared to 1982. This was aided by faster start-ups and longer plant operation due to automation.

* Parasitic load both off and on line was reduced.

* Operator work load was decreased as evidenced by fewer operators and less overtime when compared to 1982.

To gauge utilization of the available solar resource, turbine synchronizing time, and synchronization time plus test time, are plotted as a fraction of the time insolation was above 500 watts per square meter in Figure ES-2. 500 watts per square meter was selected as a minimum operational threshold for evaluation purposes. Favorable trends are observed in both until June. In June testing was curtailed to allow the power production engineering test. From July through most of August the receiver leak problems curtailed most plant operations. This was also the case during November and December.

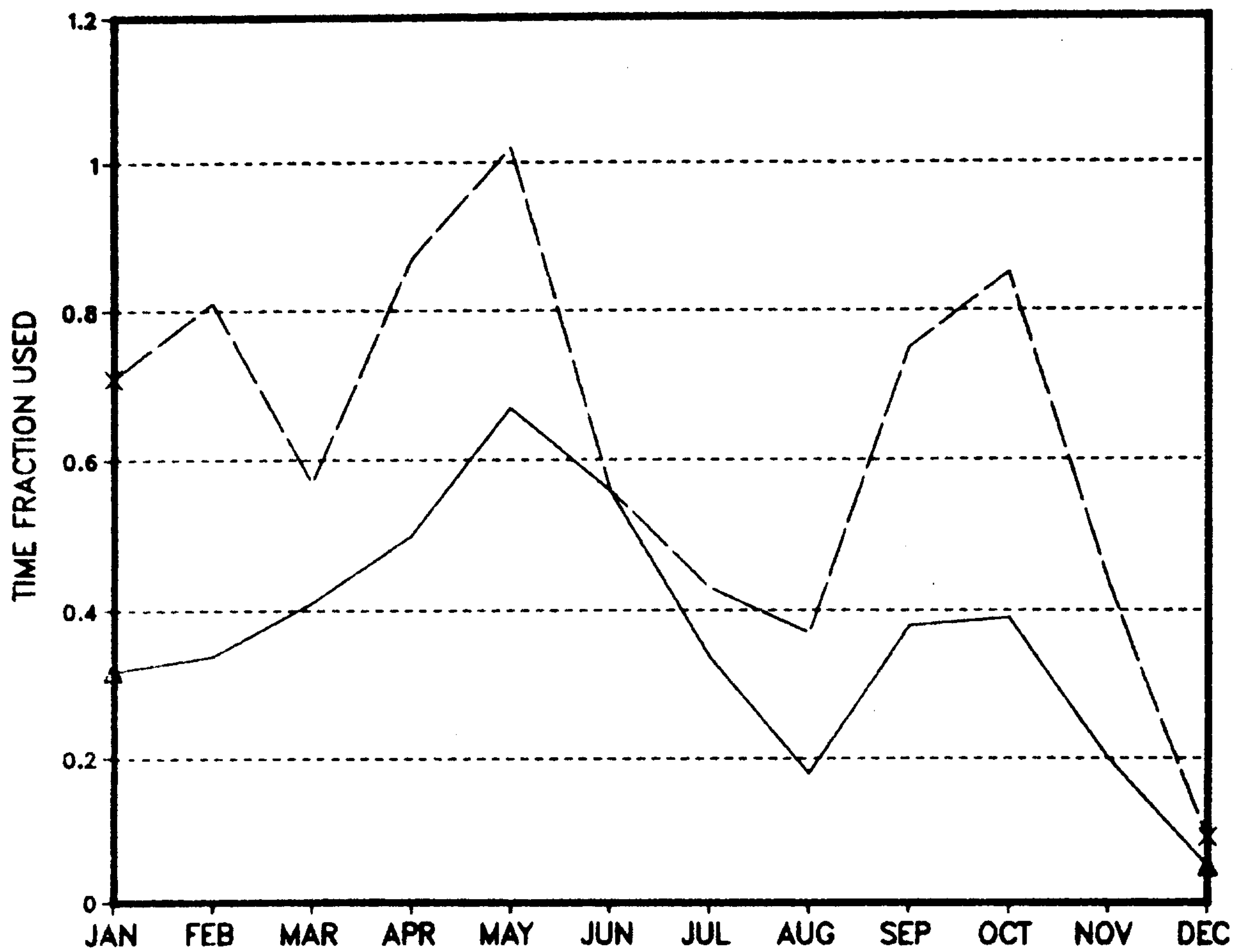

Figure ES-2. Compared to time the insolation was above 500 watts per square meter, the dashed curve is the fraction of available time used for testing and power production. The solid curve is the fraction of useable time that the turbine was synchronized.

Electricity Production

Figure 3 shows the historical cumulative energy production net while synchronized at the pilot plant during 1983. Through mid July the monthly rate of energy production continued to increase. Following July a decrease in the rate of production resulted from equipment failures and poor weather.

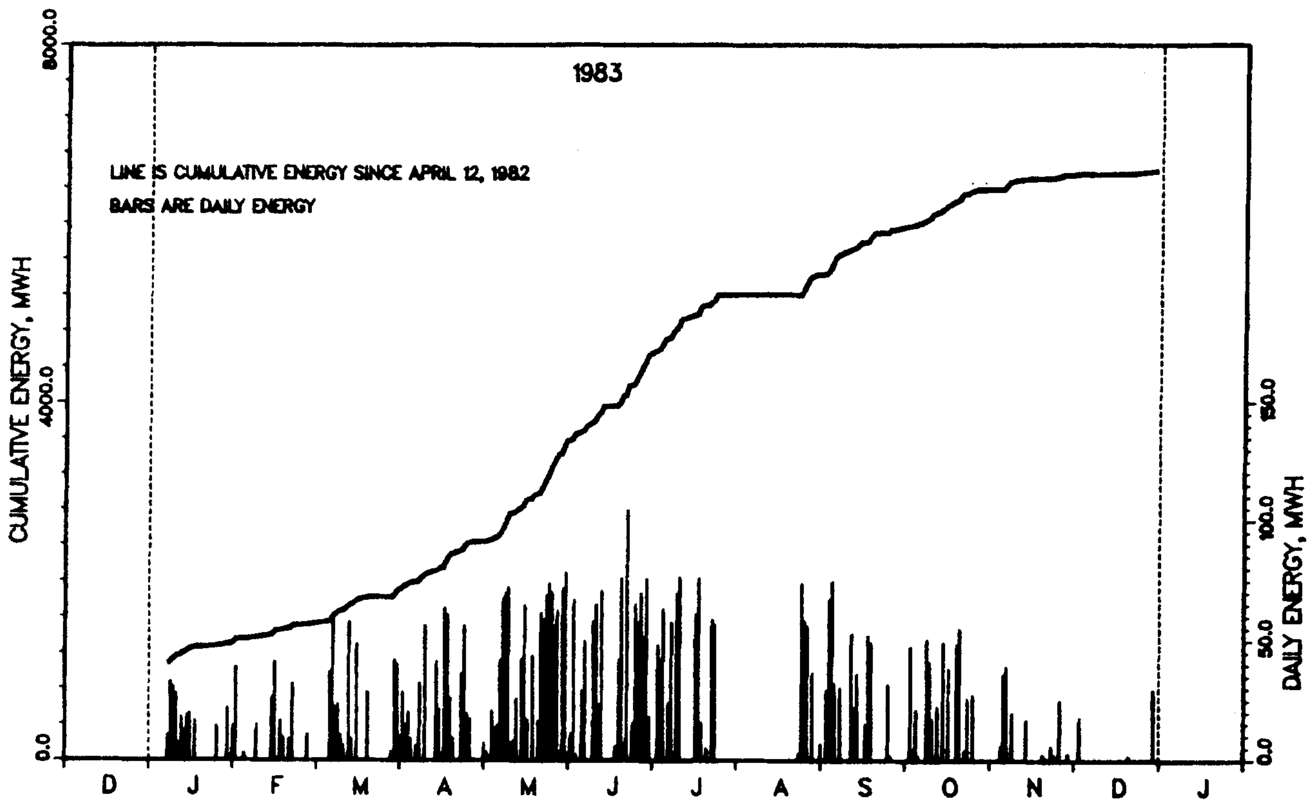

Figure ES-3 - Net Energy Production while Synchronized

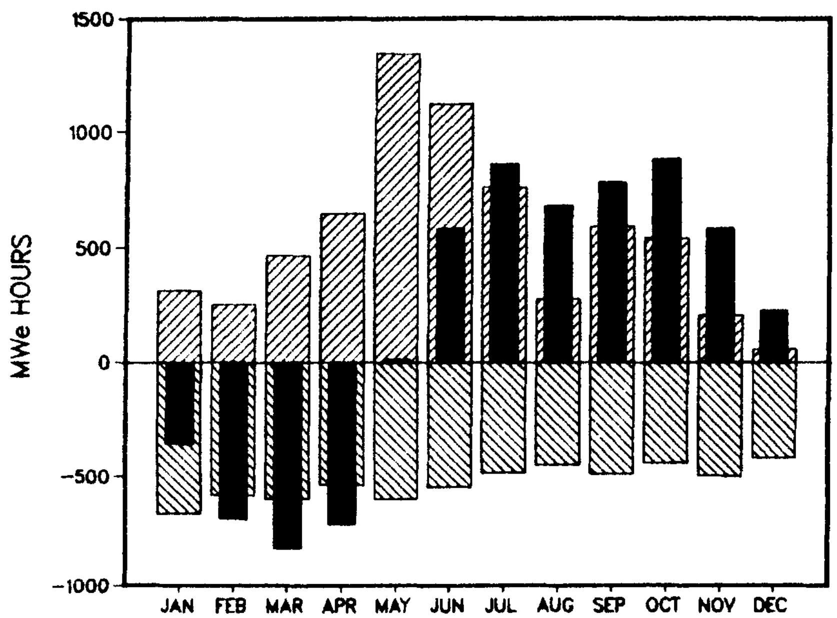

Figure ES-4 - Shaded areas above zero are gross output; below zero, 24 hour plant load, both on a monthly basis. Solid bars are 24 hour net, cumulative for the year.

Operations and Maintenance Experiences

Southern California Edison, as principal, operates and maintains Solar One. Costs for operations and maintenance are displayed in Figure ES-5 and maintenance is broken down by major system in Figure ES-6.

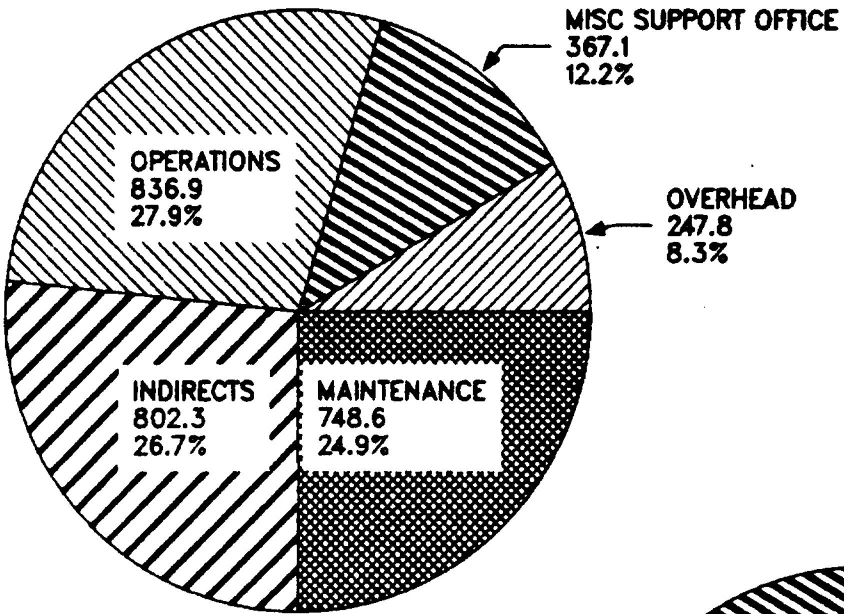

Figure ES-5
O&M Costs $K
and % of Total

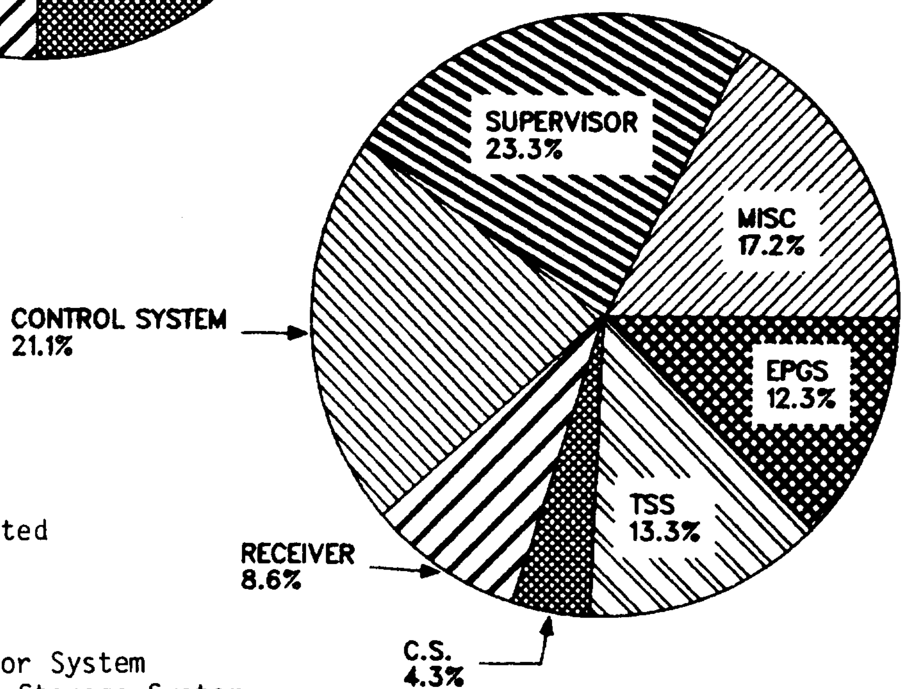

Figure ES-6
Maintenance
Cost Distributed
by System

CS - Collector System
TSS - Thermal Storage System
EPGS - Electrical Power Generation System

Principal operations and maintenance activities are summarized by month on the following table.

The 1983 Monthly Operational Highlights were:

January - Mode 2 operation - charging storage while concurrently generating electricity - was performed for nine consecutive days. Automatic start-up of the receiver tested successfully. Mode 2 to Mode 5 transition accomplished. Alternate heliostat stow configuration adopted.

February - 7.3 MWe net achieved during Mode 6 operations, exceeding the 7.0 design point. Simulated operational control system software test reduced receiver/collector start-up time from 50 minutes to 16 minutes.

March - The highest monthly output was obtained 397.2 MWe-h net while synchronized. A new heliostat stow procedure was adopted. This reduced time from tracking to high wind stow, from 40 minutes to 17 minutes. Mode 5, storage charging, released to SCE for routine use.

April - Net positive output for the month (107.8 MWe-h) was achieved. Operators below 400 watts/square meter in Mode 5 were feasible exceeding design value.

May - A second net positive month. A record 78.5 MWe-h were transmitted during a 11.3 hour synchronization period on May 30. The 7 MWe (net) for four hours storage extraction design point was verified. Total extraction energy was 43.8 MWe-h net. A baseline power production engineering test was begun 5/21.

June - Net positive power production again in June. Three power production tests results are notable 12.3 MWe net peak power in Mode 3, with 104 MWe-h net generated over 15 continuous hours synchronizing an extended duration test with 33 continuous hours synchronized. 729.9 MWe-h net generated over 23 days of operation.

July - A net positive month. Two receiver tube cracks were discovered in panel 18, the plant was shutdown on July 26 as a precaution. Scheduled automation hardware changes were implemented during the outage.

August - On August 23, the plant was restored to operation, the receiver leaks were repaired, and the repair was inspected and certified. Due to the extended outage, the plant consumed more energy than it generated. Mode 2 operation was released to SCE for routine operation.

September - Weather severly impaired operations. 131 hours of weather outage of 360 available hours were recorded. A new plant shut-down procedure with nitrogen gas blanketing of all water steam piping began. Automatic morning and mid-day start-up of the collector field was demonstrated.

October - A new receiver shut-down procedure was initiated to reduce temperature changes during transients. Continued efforts reduced auxiliary energy consumption (parasitic load) to the lowest point since plant start-up (April, 1982).

November - Testing continued to minimize plant load during non operating hours. A reduction to 300 KWe from 500 KWe was observed. Turbine generator automation of pressure control from receiver to turbine and back was demonstrated. Mode 6 was released to SCE for unrestricted operation.

December - A two week outage was scheduled to remove receiver tube specimens for metallurgical analysis and repair additional edge tube cracks. Receiver absorptivity measures indicated a 2 percent reduction annually. Tracking of the moon's image was performed to evaluate the heliostat field.

The 1983 Monthly Maintenance Highlights were:

January - Oil leaks noted in all thermal storage charging train condensers and subcoolers noted. The average number of heliostats out of service was 65 or 3.6 percent.

February - 14 mirror modules had additional vent tubes installed to evaluate this method for eventual use should mirror corrosion be reduced. A complete plant safety inspection was performed with no major deficiencies identified. 1803 heliostats were available on one day, a record.

March - A modification to the turbine admission stop valve was identified. This change would convert the valve to a control valve preventing overspeed when rolling the turbine off storage supplied steam.

April - 1809 heliostats operating, was a new record. Meteorology equipment had yearly maintenance. The turbine gland seal exhauster pump was cleaned and the system rerouted saving on equipment of $1,000/month in water useage.

May - Concurrent with the power production period, scheduled repair of the thermal storage heat exchangers began. Complete removal of a subcooler tube bundle was begun and repair of heat exchange flange gaskets began.

June - The admission step valve was replaced converting it to a full arc control valve. X-ray measurements of selected heliostat modules were completed to observe the effect of the additional vent tubes. All thermal storage heat exchangers were repaired/modified to reduce leaks. All heliostats were spray rinsed.

July - Scheduled activities to repair/modify equipment was moved up with the forced outage. Modification of the control room computer displays began. Remote station weather proofing also started.

August - Maintenance supported the receiver outage, assisting in receiver inspection and repairs of the leaking tubes.

September - Routing of thermal storage water sample lines to the chemical lab was completed. Charging train #2 condenser was retorqued and all gaskets were sound after the August change out. 15 more mirror modules were fitted with additional vents.

October - A complete receiver inspection employing ultrasonic techniques disclosed a new receiver tube leak and several internal tube cracks. The leak was repaired and a schedule to monitor cracks was established.

November - All receiver flow control (18) and vent valves were checked for leakage. Three of the 18 and 2 of the 3 vent valves were leaking and scheduled for repair.

December - Receiver panel support rollers were found cracked, these were replaced and the balance lubricated.

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10 MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT:

1983 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 1983. It includes summaries of testing and operational experiences. In general format, this report follows that of the CY1982 Operational Report (Reference 1).

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 reciever 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.

Abbreviated System Description

The Pilot Plant is designed to deliver 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:

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

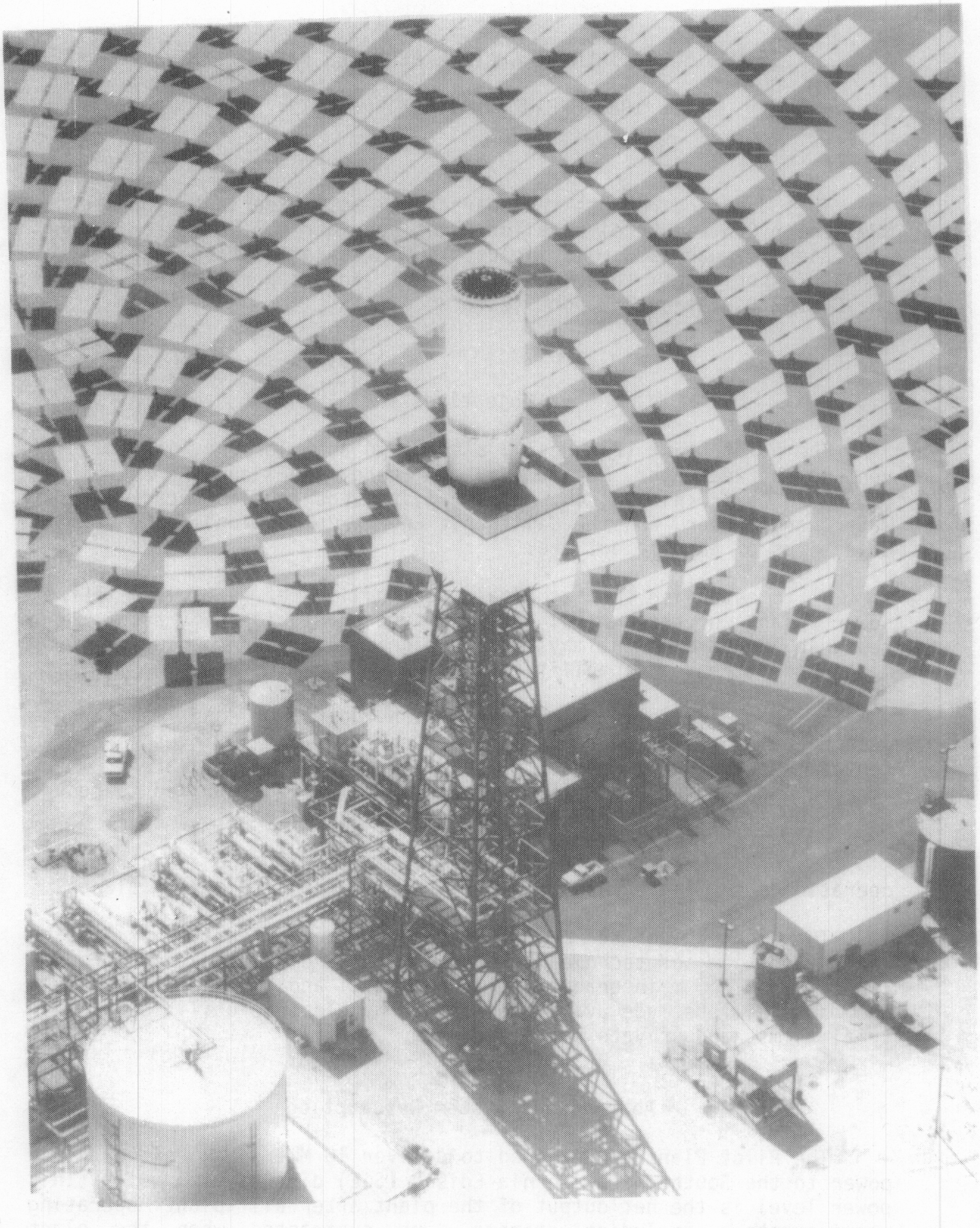

Figure 1. Overhead Shot of Solar One

2. At least 7.8 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. (For a more detailed description, refer to Reference 1).

Solar Facility

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-sand media 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 is that equipment permitting rapid and automatic measurement and characterization of flux delivered by any single heliostat.

Turbine-Generator Facility

The major components of the turbine-generator facility are:

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

(2) Circulating Water System: This system of the EPGS 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 of the EPGS 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 intergration. 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, shut-down, operation, 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, as shown in Figure 2.

Start-up was 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 is designed to demonstrate stable, controlled plant 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, enviornmental 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.

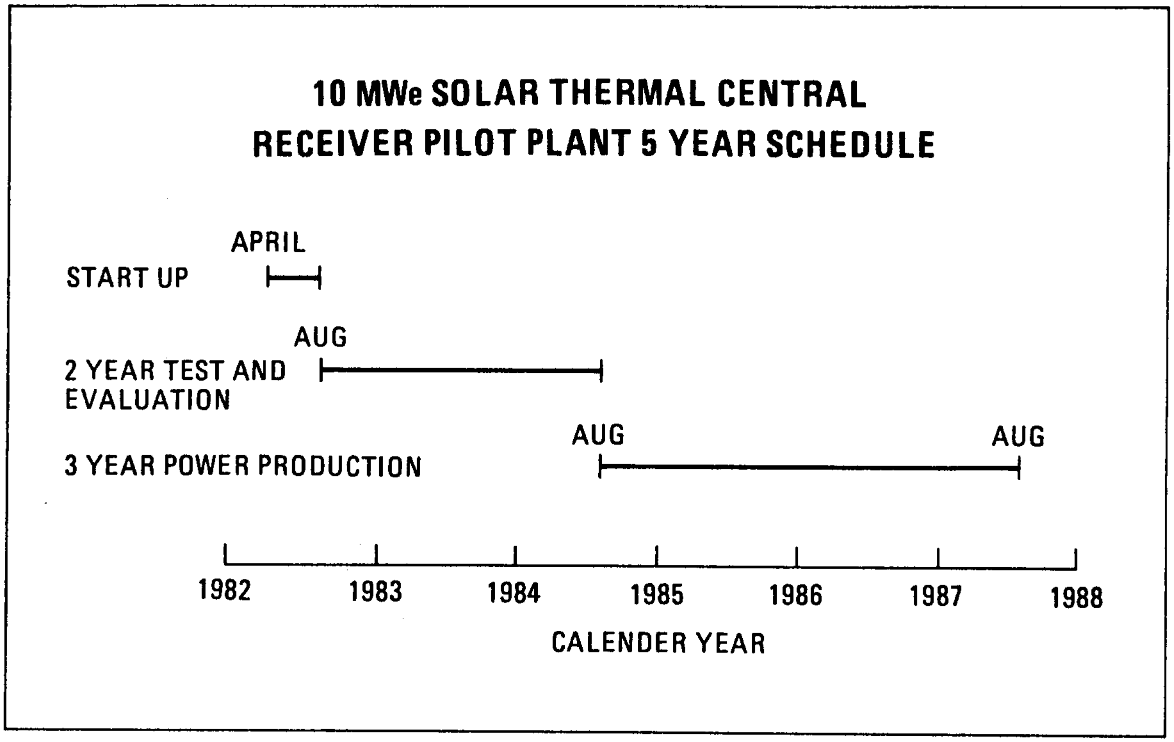

Figure 2. Five Year Schedule

Management of the Experimental Test and Evaluation Phase

Responsibility for the pilot plant start-up operational test activities was delegated to DOE San Francisco Operations Office by the Division of Solar Thermal Energy Systems, DOE/Headquarters. 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. Through out 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 seven active operating modes (see Figure 3) will be tested using one or more of the following control combinations: manual, and 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.

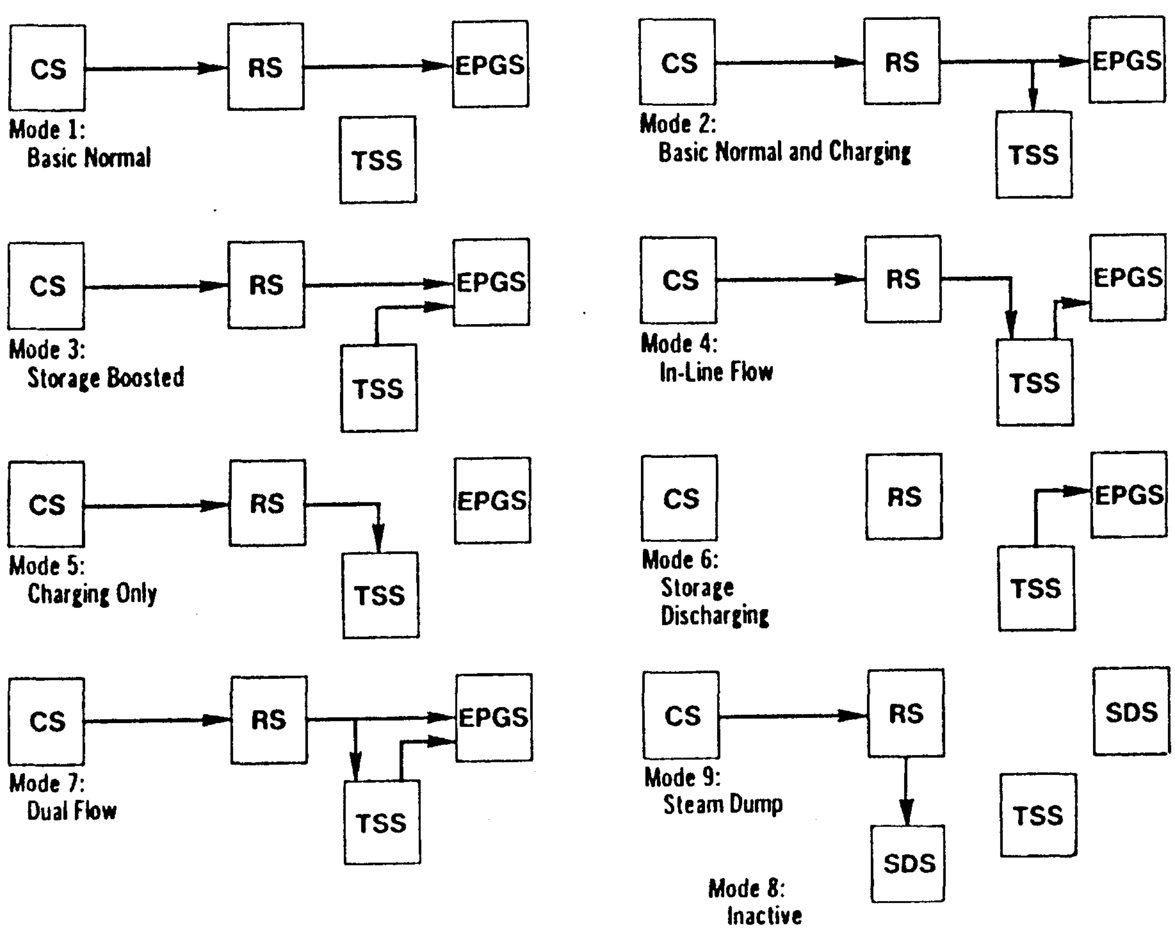

Figure 3. Major Plant Operating Modes

Planned 1983 Test Operations

Figure 4 displays the 1983 Test Schedule. The mode testing refers to intersystem testing in the major operating modes (See Figure 3 for a schematic of the operating modes). All mode tests were initially scheduled for completion by June 1982. However, construction delays and resource depletion precluded this from occurring. The mode performance tests were deferred into the Test and Evaluation phase.

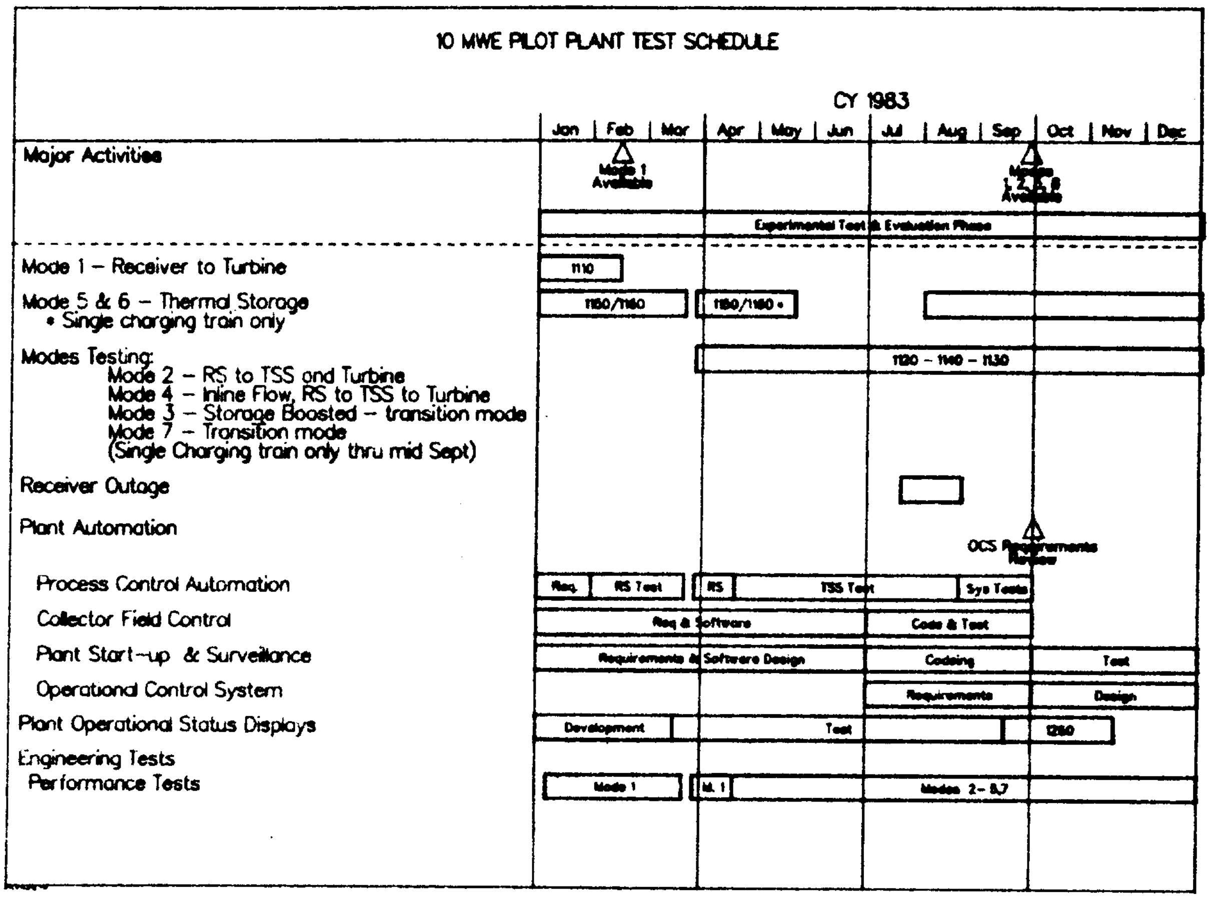

Figure 4. 1983 Test Schedule

All 1100 series tests involve evaluation of the plant systems interacting together; the thrid digit of the test number refers to the particular mode; 1130, for example, is an integrated systems evaluation of mode 3. The 1200 series tests are primarily concerned with plant automation activities and transition testing from mode to mode.

Figure 5 is a schematic depicting the principal thermal circulation paths of the pilot plant.

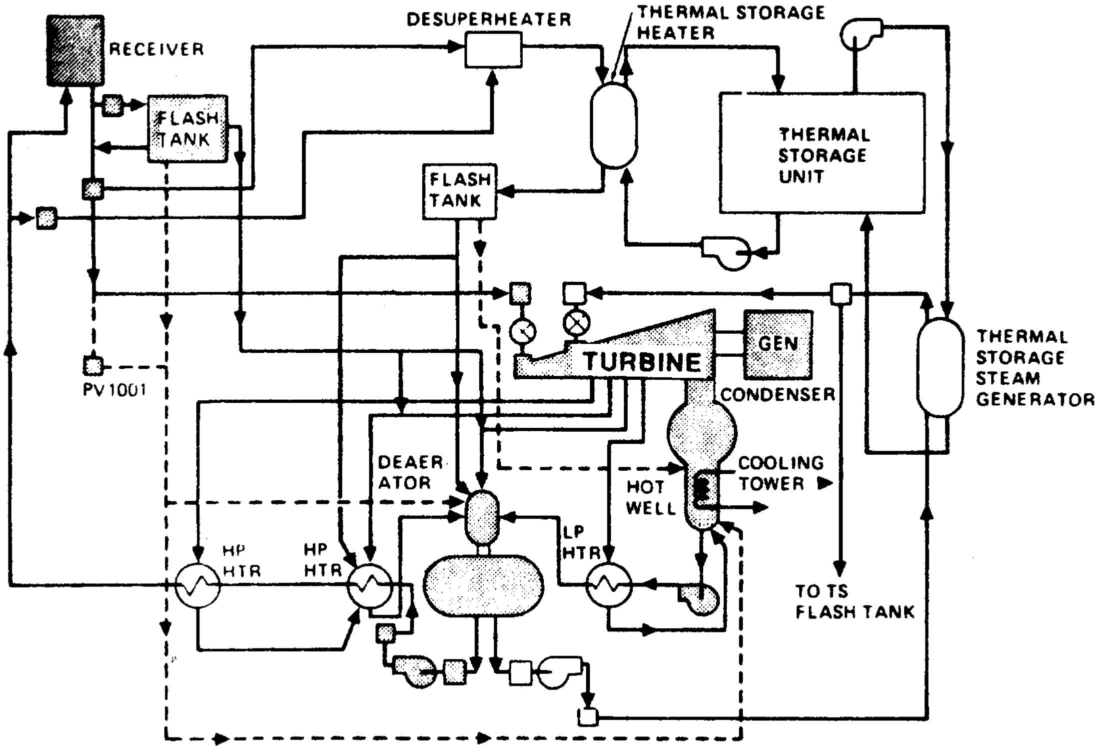

Figure 5. System Schematic of Major Thermal Flow Paths

Shaded areas of this figure show those components which were completely operational at the beginning of 1983. Those components which were evaluated during 1983 are primarily associated with the thermal storage system. Figure 5 is simplified deleting details such as the two separate 50 percent capacity storage-charging oil heaters and two 50 percent capacity steam generation trains. The dashed lines are simplified flow paths which are used during start up and shut down of the steam systems.

In effect, the plant has three major thermal systems: steam supply directly to the turbine (Mode 1), receiver steam to the thermal storage charging system with thermal energy transfered to the thermal storage media (oil-rock-sand) via heat transfer oil (Mode 5), and steam generation from the thermal storage unit by transfering heat from the storage media, with the oil heat transport fluid, to the thermal storage steam generators (Mode 6). Other modes are a combination of these flow paths.

Early in CY1983 the full performance characteristics of the turbine direct operation (Mode 1) were completed. All storage system controls and systems, the unshaded areas of Figure 5, were operationally evaluated and the plant level automation activities were begun. Some of these are detailed in the following.

Plant automation was added to the test program and is an enhancement of the basic control scheme established in CY1982. During CY1983, the following automation steps were scheduled;

Process Control Automation - optimum control of separate plant system through the separate subsystem process controllers (SDPC).

Collector Field Control - essentially an internally programmed sequence to add or delete heliostats with simple operator entered commands and provide a power ramp for receiver start-up.

Plant Start-up Surveillance - semi automatic start-up of the plant systems with operator intervation at programmed hold points. Improved techniques for monitoring critical performance parameters which would screen alarms, etc., providing only the important data for operator actions.

Operational Control System - a plant level control system with the above steps incorporated. The goals were to achieve fully automatic start-up of the solar systems, maintenance of the plant operation during the day, and automatic transition to various operator specified operating modes.

Plant Operational Status Displays - this enhancement was directed toward providing selected data from all the systems to two separate high resolution CRT displays. Plant level, supervisory displays were accomplished with this addition.

Engineering performance testing was planned to evaluate plant performance on a continuing basis. These tests were scheduled at various times of the year to ascertain if mode performance was charging as operating time increased.

A Summary of 1983 Results of Test and Operational Activities

During calendar year 1983, the objectives for the 10 MWe Solar Central Receiver Pilot Plant Evaluation and Test Phase included completion of intersystem mode testing, initiation of plant level automation, and continued power production.

All of the major modes of operation were functionally demonstrated during CY1983. By the end of the year, Modes 1, 5, 6, and 8 were released to SCE for routine operations. Automation activities included integration of the separate system controllers under the control of a main operational control system computer. Many power design points were achieved during 1983, however, the requirement to deliver 10 MWe net for 4 hours on Winter Solstice was not realized.

Receiver tubine leaks were encountered and repaired. The cause of the leaks is unknown and investigation continues. Programs were initiated to reduce the parasitic power requirements during non-operating periods and improve component performance during operation. Although the plant began to "break even" on electrical generation, CY1983 was only a start toward energy production goals.

Throughout CY1983, 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 cost of the plant operations were within budget.

Test Productivity

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 scheduled outage, time during which scheduled work was performed and forced outage, time periods when test or power production activities were planned but malfunctions prevented operation; and finally, weather outage time, daylight hours during which weather precluded operation. (If weather and plant outages occurred, they are logged separately). The 1983 experience at Solar One is shown on Figure 6. Below the trend line are productive activity hours (power production and testing).

Also shown on Figure 6 are hours during which the insolation was above 450 watts per square meter (reference 2) the anticipated operating threshold for the plant. Generally plant utilized the available insolation time effectively.

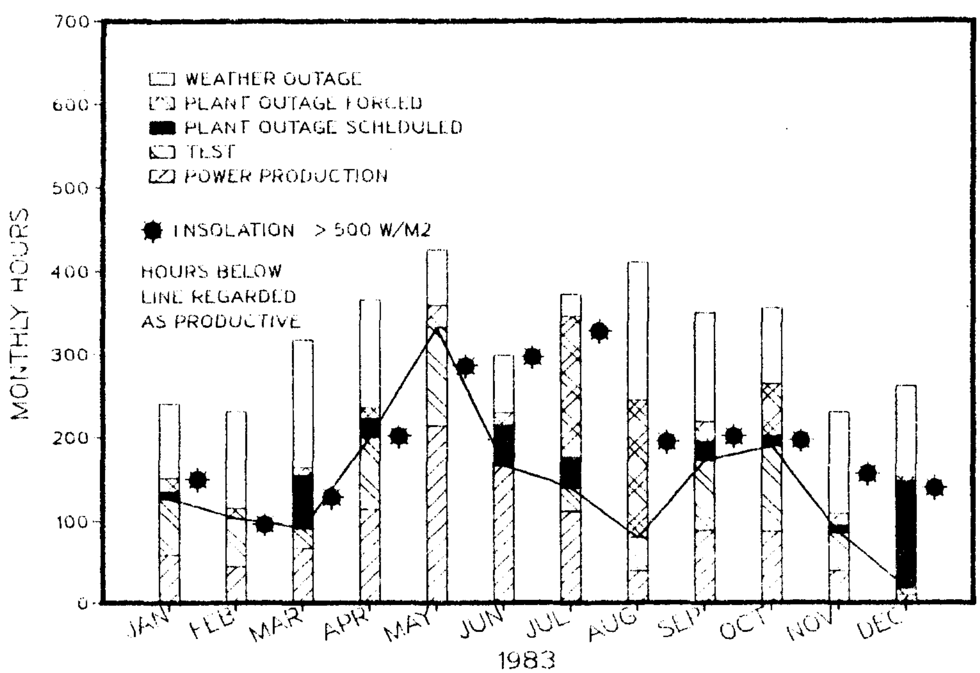

Figure 6 - Distribution of Activities

Principal Technical Objectives:

The status of principal technical objectives is summarized in Table 1. In general, the objectives have been met; the most notable exception being the realization of the energy design points.

Table 1

STATUS OF THE VERIFICATION OF PRINCIPAL TECHNICAL OBJECTIVES AT 1983 YEAR-END.

10.0 MWe net from receiver supplied steam.	10.4 MWe
7.0 MWe from storage system for four hours •	7.1 MWe net for four hours, (7.3 peak).
Plant operable at 2 MWe •	Operable to 1.0 MWe
95 per cent heliostat availability •	Better than 97 per cent
Operation at insolation above 690 watts/sq. meter •	Operates above 300 watts/sq. meter
Plant transitions among all modes •	Complete
Automatic control of separate systems	Demonstrated 1983
Automatic control of the integrated plant	Scheduled 1984
Evaluation of all modes:	
Modes 1, 2, 5, 6	Complete
Modes 3, 4, 7	Scheduled 1984
10MWe for 4 hours Winter Solstice •	Not achieved

• Design requirement.

Table 2

SIGNIFICANT 1983 MILESTONES

Continuous synchronization to the grid for 33 hours	June, 1983
Peak power output of 12.1 MWe net, Mode 3	June, 1983
Total storage capacity of 41.3 MWe–h net	June, 1983
Peak single day energy of 104 MWe–h net, using stored plus incident solar energy	June,1983
Peak single day energy of 78.5 MWe–h net while synchronixed, incident solar energy only	May, 1983
Peak single day energy of 62 MWe–h net , 24 h basis	May, 1983

The plant's design point of 10MWe at 2 p.m. on Winter Solstice, is arrived at using the assumptions shown in Figure 7. During the operation of the plant a number of factors became apparent which reduced the expections for energy production.

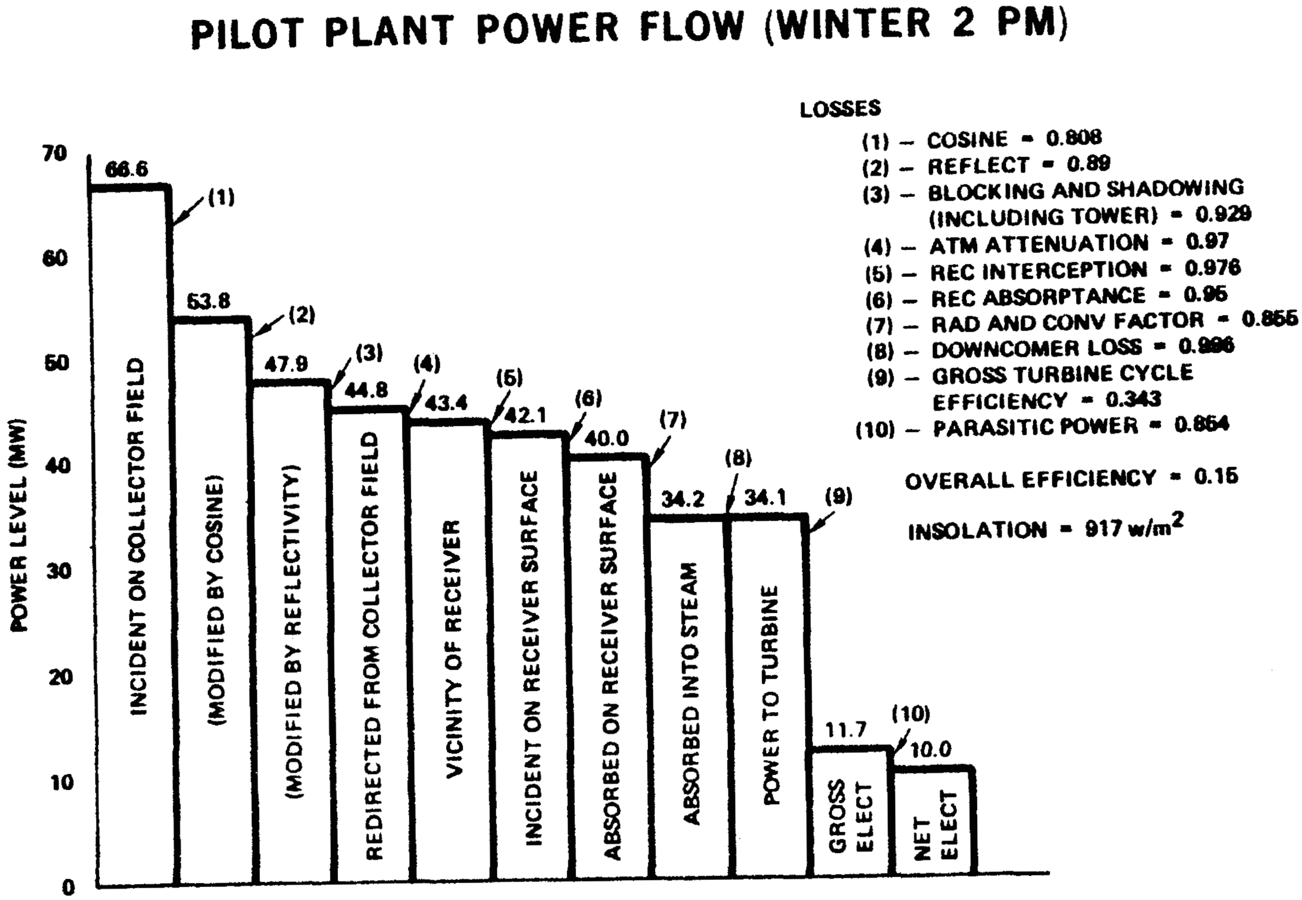

Figure 7. 10 MWe Solar Thermal Central Receiver Pilot Plant Design Point Power Flow Diagram, Winter 2 p.m. (Reference 1).

Major differences observed in operations were:

1. Heliostat reflectivity - an assumed 0.89 value. Actually, the field average is 90.6 when clean and an average cleanliness is 95%; hence, for 1983 a "working" reflectivity value of 0.86 is more appropriate (0.906 x 0.95).

2. Heliostat availability - 1818 were assumed to be available. The 1983 experience is about 1760 are available, or 0.97.

3. Receiver absorptivity - assumed to be 0.95. The experience is a 2 percent degradation per year (ref. 3). By mid year 1983, the absorptivity was about 0.91.

On a power design point, therefore, the peak expected would be reduced by (.89 - .86) + (1.00 - 0.97) + (0.95 - 0.91) 0.1 or 10 percentage points. This calculation assumes the input insolation was as defined at the design point which it wasn't most of the time. Figure 8 displays the monthly insolation during CY1982 and CY1983 against baseline year 1976.

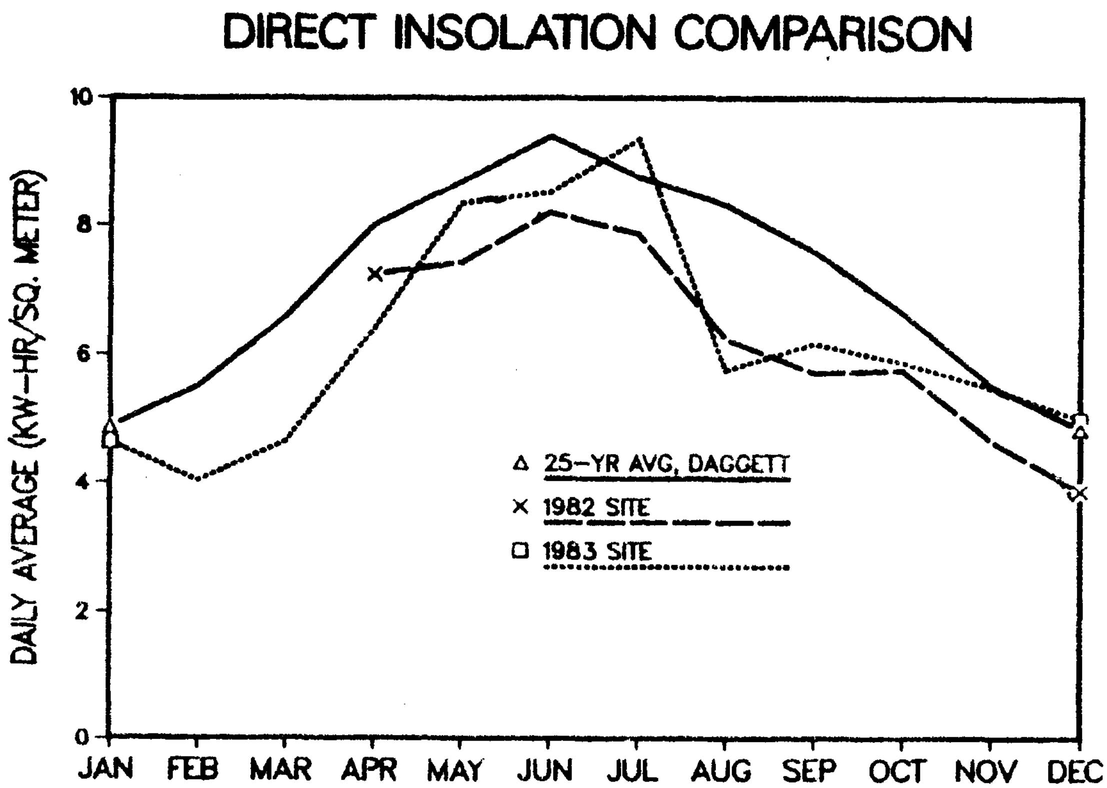

Figure 8. Daily Average Direct Normal Insolation Comparison

Monthly absolute peak and average peak direct normal insolation were significantly lower in 1983 compared to 1976 as Figure 9 shows.

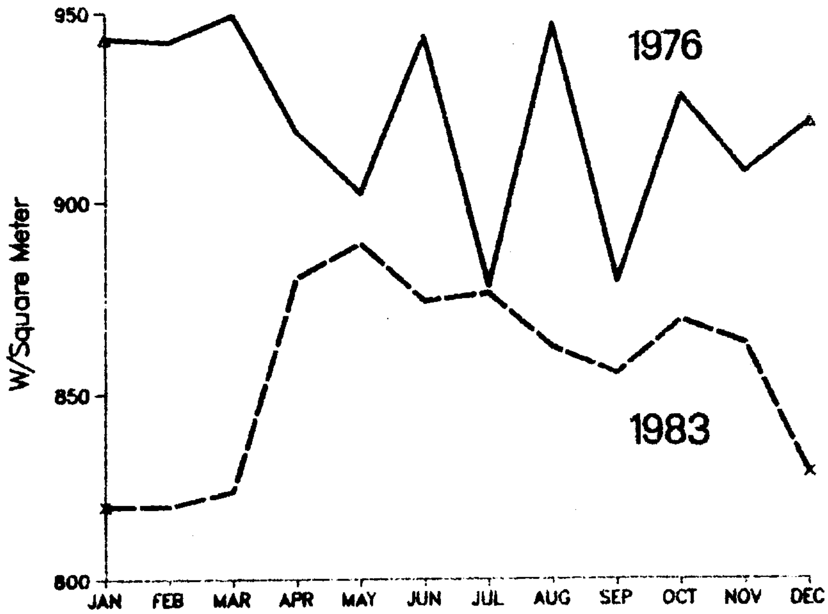

Figure 9a. Monthly Average Peak Insolation

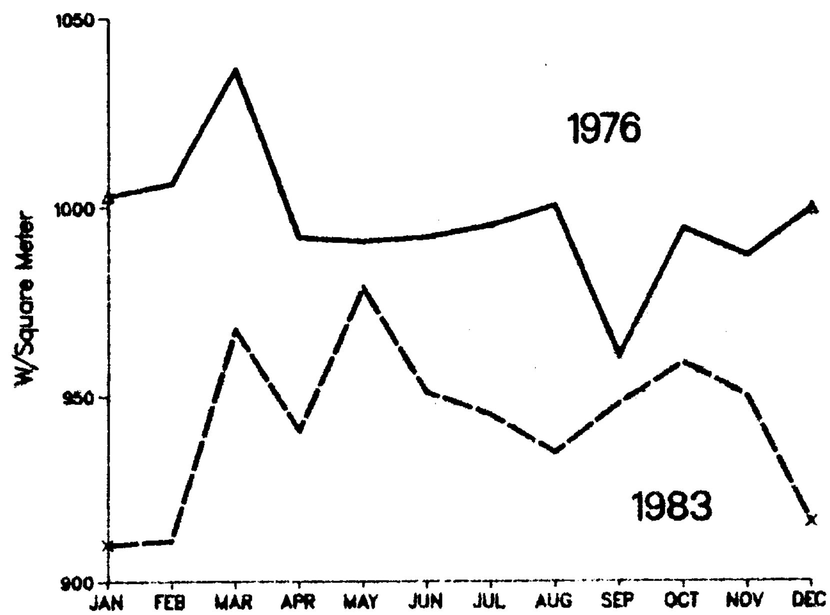

Figure 9b. Monthly Peak Insolation

The purpose of the three preceding figures is to indicate three important facts (1) the direct normal insolation was significantly lower during 1982 and 1983 compared to the baseline year 1976, by any measure; (2) attainment of design values of 950 watts/m2 summer and 970 watts/m2 winter insolation as average peak values in either 1976 and 1983 did not occur. Absolute peak values for the design values were not achieved during the summer and winter periods in 1983. The consequences of the above are that at lower than design insolation, inefficiencies cascade through the plant and compound. Thus, if the input power to the turbine is 20 percent lower than anticipated, a drop in energy production of 30 percent can be projected due to lower thermal to electrical net conversion efficiency.

Power Production and Mode Testing:

Table 3 displays time spent in various plant operating modes, categorized by month. Major contributions to Mode 1 were weekend power production and power production engineering tests performed during May and June. Other principal modes were storage charging Mode 5 and storage extraction Mode 6. Storage charging time is greater than extraction time because the majority of charging time is necessary to store energy for later use as sealing steam. This energy is consumed during off-hours and plant start-up and shut-down transitions which are not part of the principal seven operating modes. A distribution of the mode operating time is displayed in Figure 10.

TABLE 3

1983 PLANT TIME IN VARIOUS PRODUCTIVE MODES

MONTH	Mode 1	Mode 2	Mode 3	Mode 4
January	35.27	5.30	.60	.00
February	24.97	11.80	.00	.00
March	35.23	15.53	.00	.00
April	55.14	31.25	1.60	1.10
May	140.00	24.22	.80	3.95
June	130.32	.00	10.81	4.60
July	84.01	.00	.00	.00
August	36.11	2.60	.00	.00
September	42.55	16.36	.00	.00
October	51.70	1.35	11.31	7.06
November	28.81	.00	1.00	3.76
December	4.47	.00	.60	1.25
TOTALS	668.58	108.41	26.72	21.72

MONTH	Mode 5	Mode 6	Mode 7	Modes 1-7
January	23.02	.15	5.80	70.14
February	20.82	2.852	.00	60.442
March	2.35	2.80	.00	55.91
April	23.16	5.80	9.01	127.06
May	44.25	27.83	.25	241.30
June	20.82	19.80	.00	186.35
July	12.01	.65	.00	96.67
August	11.31	.00	.00	50.02
September	25.43	8.20	.00	92.54
October	30.35	12.95	.00	114.72
November	49.18	.20	2.80	85.75
December	18.62	.45	1.80	27.19
TOTALS	281.32	81.682	19.66	1208.10

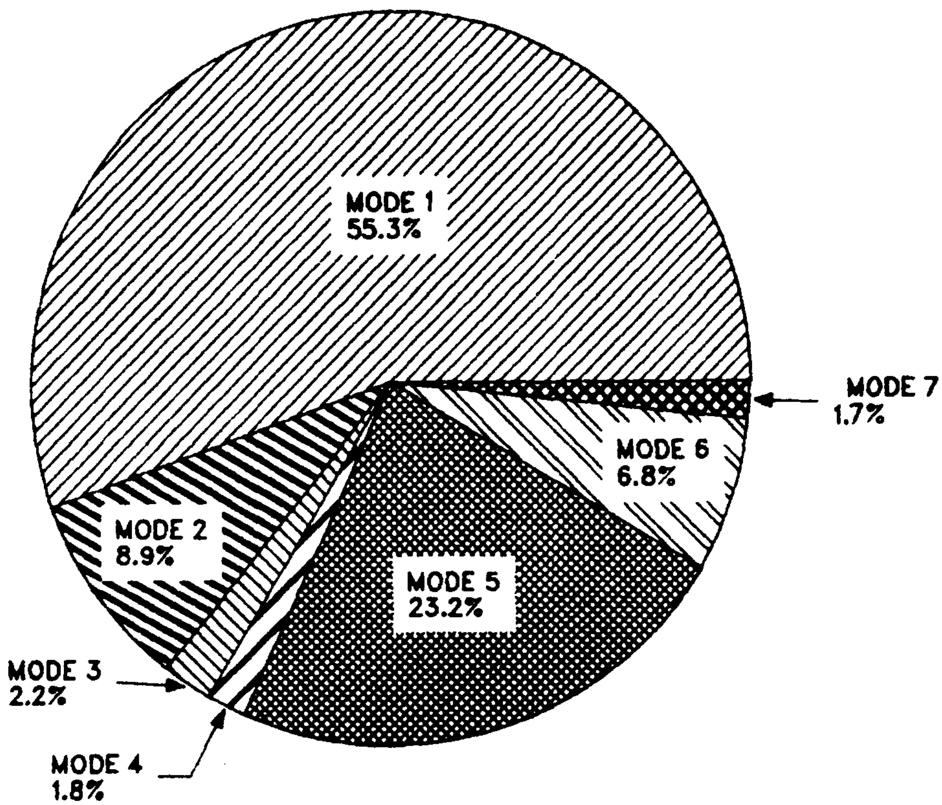

Figure 10 Distribution of Mode Operating Time During 1983

Storage extraction testing completed the major mode operations during 1983. As a result of the mode testing, plant operational procedures were established for all modes and Modes 1, 4, 5 and 8 were released to SCE for routine operation.

To gauge use of the solar resource turbine synchronizing time, synchronization time plus test time are plotted in Figure 11 as a fraction of the time insolation was above 500 watts per square meter. Favorable trends were observed in both time until June. In June, testing was curtailed to allow the power production engineering test. From July through most of August the receiver leak problems curtailed most plant operations. This was also the case during November and December.

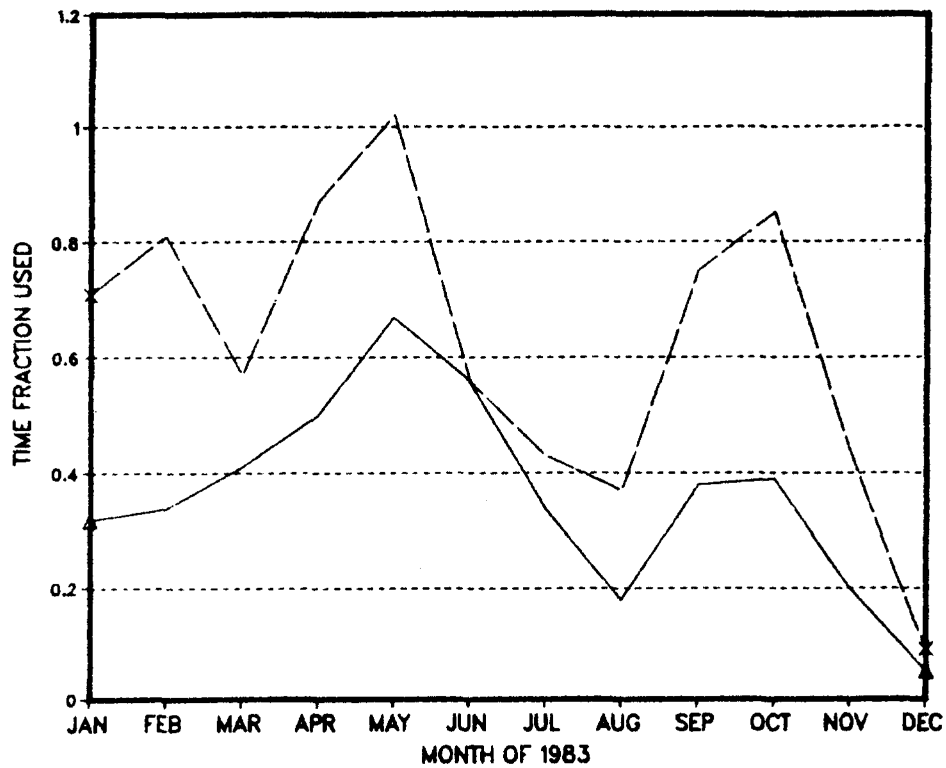

Figure 11. Synchronization time (solid line) and synchronization plus test time as a fraction of time the insolation was above 500 watts per sq. meter during 1983. The sum of test and synchronization time are regarded as productive time during the test and evaluation period.

Electricity Production

Figure 12 shows the historical cumulative energy production net while synchronized at the pilot plant during 1983. Through mid July, the monthly rate of energy production continued to increase. Following July, a decrease in the rate of production was occasional by equipment failures and poor weather.

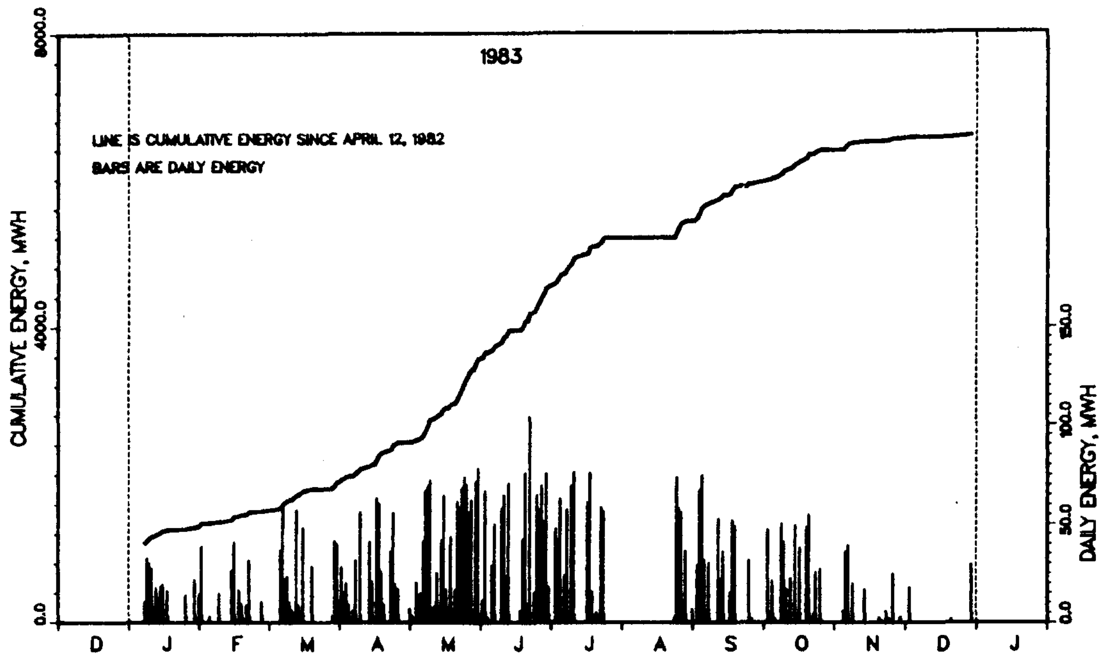

Figure 12. Net Energy Production While Synchronized

Figure 13 Displays in twenty-four hour net electricity production by month at the pilot plant. Through out the test program, the prime motivation was to generate test data, however, it is clear that the plant is capable of producing net energy on a twenty-four hour basis.

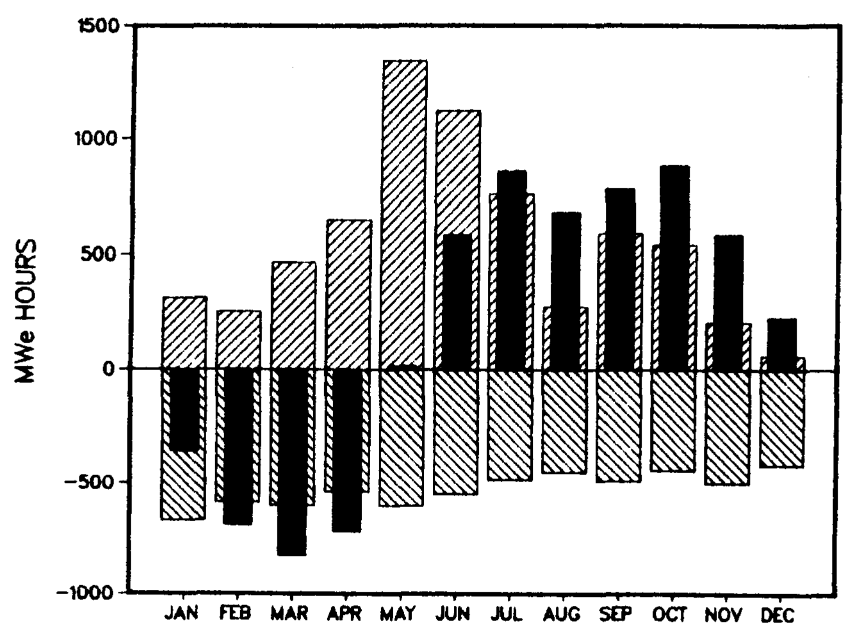

Figure 13. Energy Production. Hatched bars above zero are monthly gross, below plant load, solid bars are 24 cumulative net.

During 1983 a favorable trend in plant load has been observed both when synchronized and off-line. Figure 10 shows the trend.

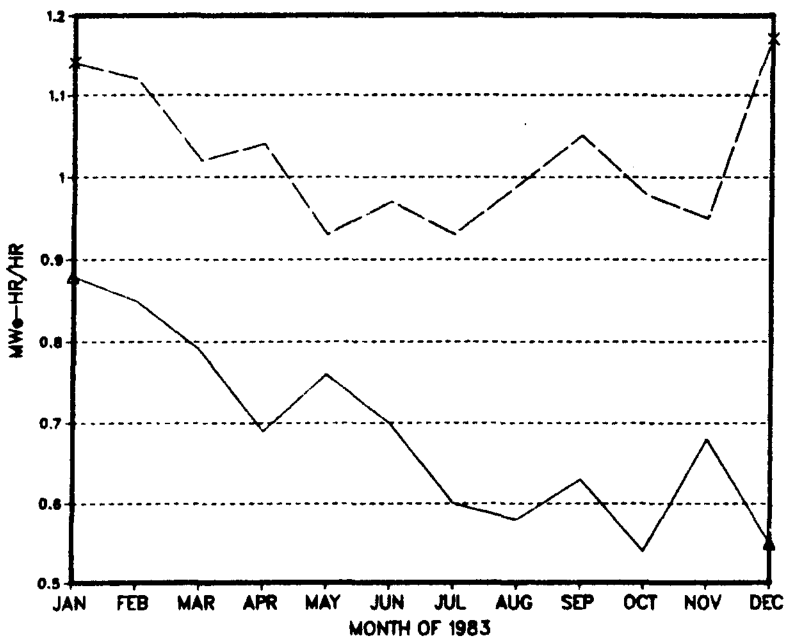

Figure 14. Monthly Average Plant Load Dashed line indicates average plant load while synchronized and solid line shows offline load. November is anomalous for offline load due to a large amount of time spent testing major systems without the generator synchronized. December synchronized load is artificially high because of Mode 4 testing.

The continued decrease in load while synchronized and offline is attributed to the reduction in electrical power consumption by the electric boiler during operation by shutting it down sooner and the availability of thermal storage supplied sealing steam during offline hours. (The electrical boiler was necessary during start-up to maintain the deareator level and blanket the steam lines during shut-down. Both of these requirements were satisfied by altering the thermal storage steam supply system in 1983). An operational change was also made in 1983 where by the heliostat field was stowed as much as possible during non-operation hours. Prior to this, the field was tracked as much as possible to accumulate operational hours to disclose any failures in the system. In addition, nitrogen blanketing of the plant piping systems and condenser system reduced parasitic load and sealing steam requirements. The last saved energy two ways; vacuum pumps were not operated during off hours and lower seal steam requirements reduced the solar energy required to charge storage allowing more generated energy.

Automation Activities During 1983

Solar One is unique in the electric utility industry because it is automatically controlled by a Master Control System consisting of an Operational Control System computer which supervises two Heliostat Array Control computers four subsystem process controllers (SDPC) and two thousand microprocessors. Information is supplied to operators on color-graphic video monitors. Figure 15 displays an overview of the control system architecture.

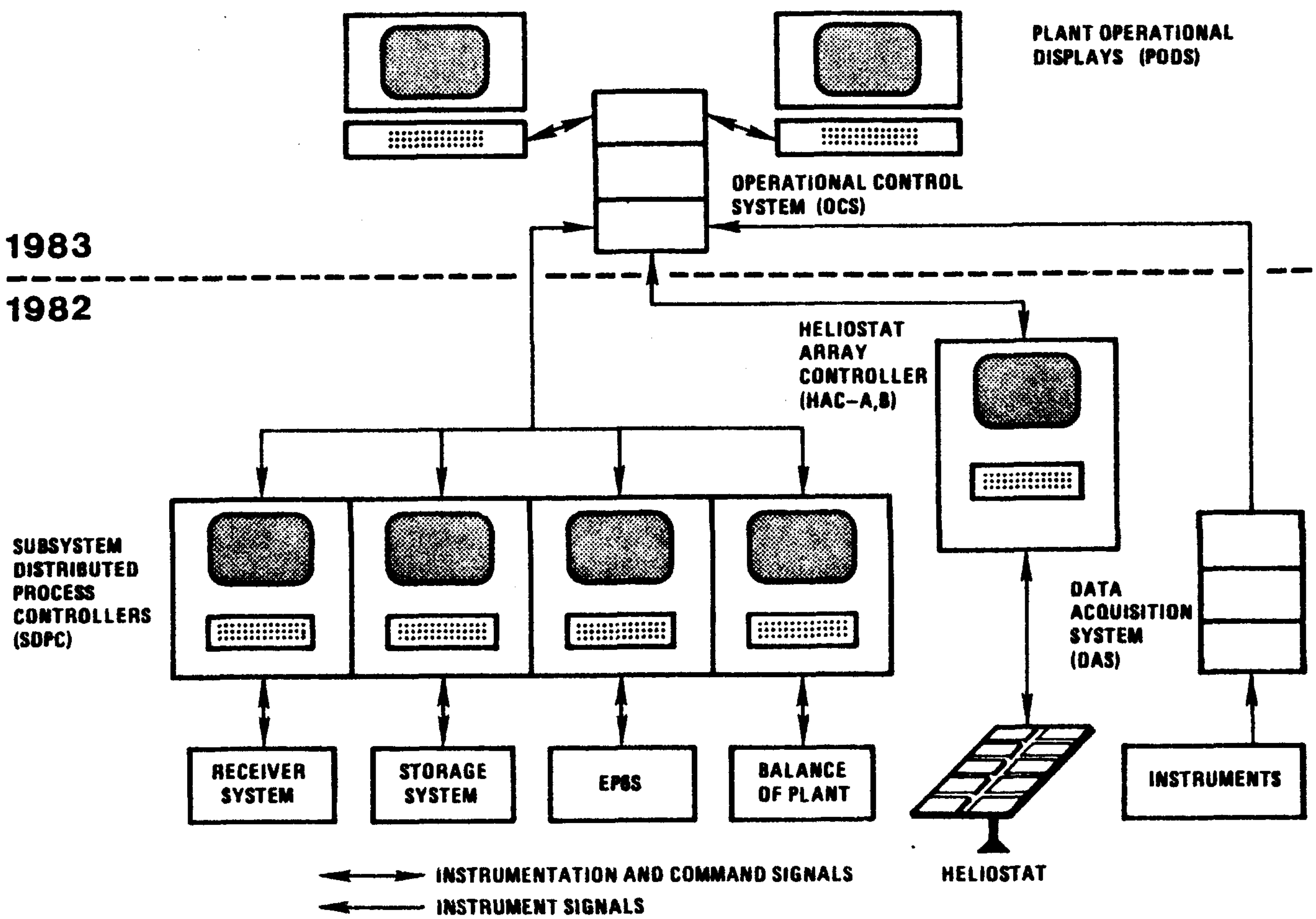

Figure 15. Overview of the Master Control Architecture

Initial emphasis was placed upon automation within the SDPC, signals from these and the heliostat controllers, were integrated into the Operating Control System computer and plant level data could then be displayed by the plant operational displays.

Schematically, the automation sequence of a receiver start-up to attainment of Mode 9 is shown in Figure 16.

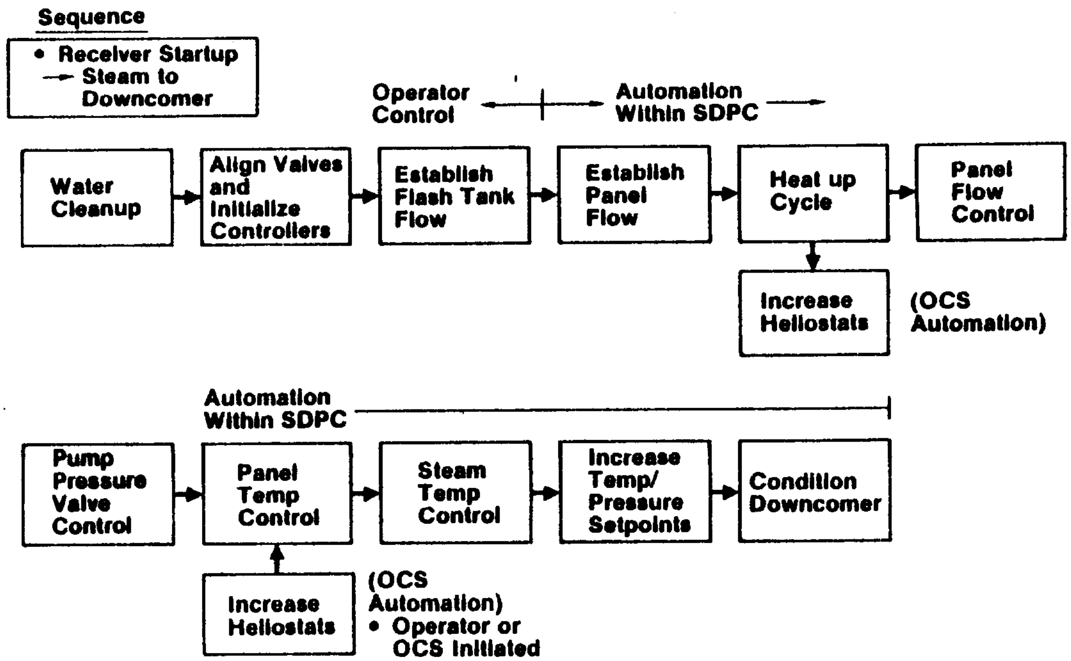

Figure 16. Receiver Start-up Sequence

Mode 9 is not a productive operating mode, but it is important because the receiver system is started every day.

Achievement of this level of automation required hardware equipment changes and major control software modifications. By the end of 1983, most hardware changes had been accomplished, and the programmed start-up/shut-down transitions were demonstrated for Modes 1, 5 and 6. It is difficult to quantitavely demonstrate the effect of plant automation, but the following favorable trends can be inferred as a result of such work.

* Net electrical energy generated, increased dramatically when compared to 1982. This production was aided by faster start-ups and longer plant operation due to automation.

* Parasitic load both off and on line was systematically reduced.

* Operator work load was decreased as evidenced by fewer operators and less overtime when compared to 1982.

* Software modifications to the control system were easily made. Ramp rate changes, control logic changes, and set point changes were accomplished quickly, in hours, when needed. For example, when receiver leaks occurred, operating temperatures, trip sequences, and shut down threshold were all changed from the control room with minimum hard wiring alterations.

At the end of 1984, a scenario for plant automatic operation on clear days had been developed. The plan was to incorporate manual initialization of systems prior to start-up and then provide maximum automation capabilities during start-up of the major systems. This scenario was the basis for planning 1984 automation testing. Figure 16 shows the anticipated clear day automation functions.

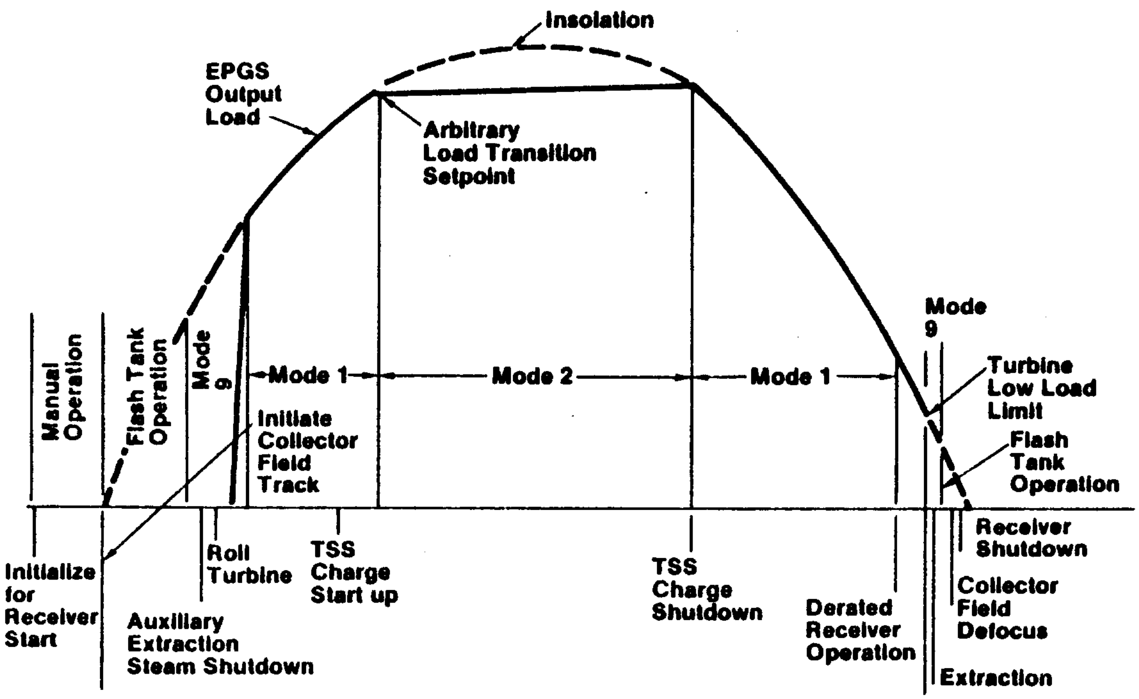

Figure 17. Scenario for Plant Sequencing and Control on Clear Days. The days activities proceed left to right following the insolation profile. Once the plant has been initialized, operations are automatically sequenced with built in "holds" between major points. At these hold point operators decide if the sequence should be continued. For example, at the end of Mode 9, the operator can decide to proceed to Mode 1 or change storage Mode 5. Also, if insolation is insufficient, the operator can decide to continue in Mode 1 instead of transitioning into Mode 2.

Operations and Maintenance

Southern California Edison, as principal, operates and maintains Solar One. The SCE personnel distribution is shown in Figure 18. Plant operations are 24 hours per day, 7 days per week. Maintenance is performed on a single shift basis 5 days per week with scheduled overtime. Contract maintenance is employed to cover computer-related maintenance, and special non routine maintenance services. The SCE personnel distribution is shown in Figure 18. O&M costs for 1983 are summarized in Table 4. Graphically these data are displayed in Figure 19(a), with a maintenance breakdown by major system shown in Figure 19(b). A month-by-month breakdown of maintenance costs are supplied in Appendix A.

In addition to SCE maintenance, Sandia maintained a budget for plant upgrades and spares, to support testing and evaluation activities. Implementation of these improvements is through a Field Change Request (FCR). For completeness, the FCR expenditures on major upgrades are listed in Table 5. Each has been broken down by system. The major items were:

Receiver System - Insolation repair and modification to allow easy access for panel tube inspections. Flow control valve modification to improve sensitivity at low flow.

Heliostat System - Installation of additional vents in 8,000 minor modules to mitigate corrosion.

Beam Characterization System - Improvement to quantative measurement capabilities.

Meterological System - Spares and repair of equipment (the metro system is not formerly covered under SCE maintenance agreements).

Thermal Storage System - Improvements for controllability and ease of maintenance.

Control System - Improvements necessary to carry out plant automation.

It is not anticipated that FCR expenditures will continue beyond the Test and Evaluation Phase (August 1985). These costs are provided here for completeness.

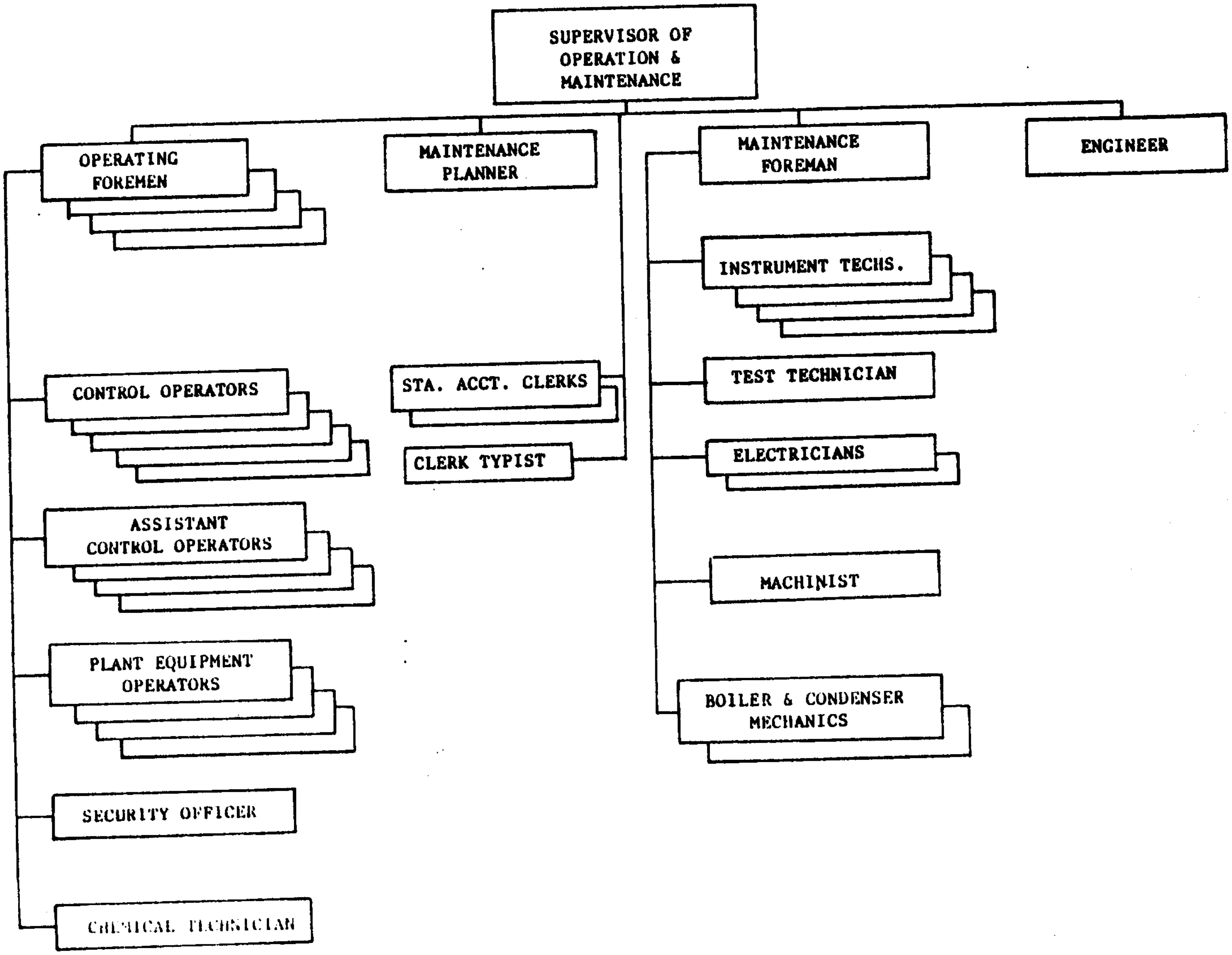

Figure 18. 10MWe Solar Thermal Central Receiver Pilot Plant Operations and Maintenance Staff (mid-year 1983).

Operations personnel follow the "Operating Foreman" line and the staffing provides for 7-day per week/24-hour per day plant monitoring. Others work day shift five days per week.

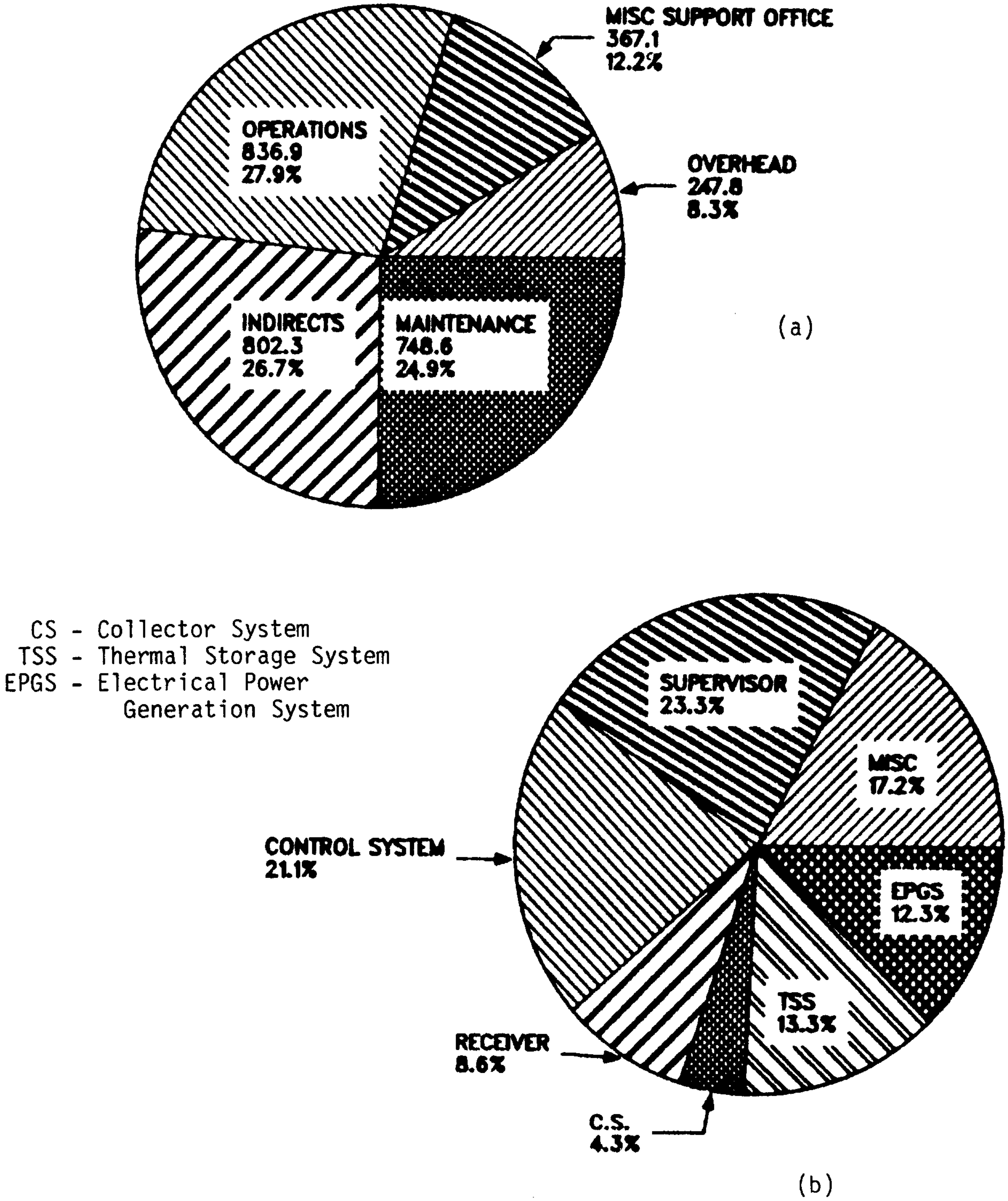

Figure 19. (a) Distribution of O&M Expenses, (b) Maintenance expenses distributed among major systems (NOTE: test and evaluation expenses associated with modifications and upgrades are not included here).

Table 4

January - December 1983

O&M COST SUMMARY
(in thousands)

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	224.8	1.4	1.0	15.6	242.8
OPERATIONS	694.1	133.8	0.0	9.0	836.9
MISC. NONPRODUCTIVE COST	65.5	3.4	33.7	21.7	124.3
MAINTENANCE					
Supervision/Indirect	134.9	28.9	6.2	4.1	174.1
Control System	84.7	39.7	33.2	.1	157.7
Receiver System	45.4	5.7	12.6	.5	64.2
Thermal Storage System	27.4	8.6	53.2	10.4	99.6
Collector System	27.5	4.0	0.6	0.0	32.1
EPGS System	50.5	23.6	16.2	1.9	92.2
Miscellaneous	51.8	13.5	42.0	21.4	128.7
Total Maintenance	422.2	124.0	164.0	38.4	748.6
SUBTOTAL	1406.6	262.6	198.7	84.7	1952.6
Division O.H.					247.8
TOTAL DIRECT					2200.4
Workmen's Comp.					12.0
Payroll Tax					95.0
Pension & Benefits					284.2
Admin. & General					411.1
TOTAL INDIRECT					802.3
GRAND TOTAL					3002.7

TABLE 5

PLANT UPGRADES AND SPARES SUPPLIED UNDER TEST AND EVALUATION PHASE FIELD CHANGE REQUEST (FCR) BUDGET.

FCR	DESCRIPTION		UPGRADE	SPARE
RECEIVER SYSTEM:				
026	PV1001 HEAT TRACING		2.995	
033	PV1001 INSULATION MOD		1,700	
047	RERANGE 4 FLOWMETERS		1,860	
061	HARD WIRE RS TRIP SIGNAL		300	
083	MODIFY 2 RECEIVER FM		2,011	
097	PV 1005 VALVE TRIM	SCE	2,500	
100	RECEIVER LAGGING REPAIR		3,990	
101	FLOWMETER			4,600
119	REMOVEABLE INSULATION PADS		2,000	
129	TOWER WINCH		3,000	
SUBTOTAL			20,356	4,600
HELIOSTAT SYSTEM				
120	MIRROR MODULE VENTS			
	INSTALLATION		140,000	
	MATERIAL		25,000	
SUBTOTAL			165,000	
BEAM CHARACTERIZATON SYSTEM				
020	SUNSHAPE CAMERA		20,000	
	CONTROL INTEGRATION		145,000	
	ENGINEERING, MATERIAL		60,000	
031	ENHANCEMENTS		20,000	
043	POWER MEASUREMENT CAPABILITY		19,000	
SUBTOTAL			264,000	
METRO SYSTEM				
052	REPAIR WIND VANES + HAIL CUBES		1,500	
079	A/D CONVERTERS			19,000
SUBTOTAL			1,500	19,000

FCR	DESCRIPTION	UPGRADE	SPARE
THERMAL STORAGE SYSTEM			
107	OIL DRIP PANS	400	
112	FLOWMETERS		8,400
028	PV-3110,11 TRIM CHANGE	7,125	
032	INSULATION MODIFICATIONS	5,284	
041	MANUAL ISOLATION VALVES	2,300	
042	DESUPERHEATER VALVE MOD	1,793	
049	OXYGEN ANALYZER MOD	130	
054	PUMP STRAINER	805	
055	FM ROTORS		480
056	BOILER LEVEL SENSORS	65	
SUBTOTAL		17,902	8,880
CONTROL SYSTEM			
AUTOMATION			
040	OCS MEMORY EXPANSION	5,300	
057	MVCU HARDWARE FOR RS	18,590	
058	I/O HARDWARE FOR TSS+RS	15,835	
059	ILS HARDWARE	9,690	
SUBTOTAL		49,415	
BALANCE OF PLANT			
048	TV-2402 REPLACEMENT TRIM	17,000	
061	WAREHOUSE FIRE PROT. SYS	225	
SUBTOTAL		17,225	
ELECTRIC POWER GENERATING SYSTEM			
050	TURBINE NON-RETURN VALVE MOD	1,500	
SUBTOTAL		1,500	
TOTAL		536,900	32,480

GRAND TOTAL $569,380.00

Table 6a
1983 Monthly Operational Highlights

January - Mode 2 operation - charging storage while concurrently generating electricity - was performed for nine consecutive days. Automatic start-up of the receiver tested successfully. Mode 2 to Mode 5 transition accomplished. Alternate heliostat stow configuration adopted.

February - 7.3 MWe net achieved during Mode 6 operations, exceeding the 7.0 design point. Simulated operational control system software test reduced receiver/collector start-up time from 50 minutes to 16 minutes.

March - The highest monthly output was obtained 397.2 MWe-h net while synchronized. A new heliostat stow procedure was adopted. This reduced time from tracking to high wind stow, from 40 minutes to 17 minutes. Mode 5, storage charging, released to SCE for routine use.

April - Net positive output for the month (107.8 MWe-h) was achieved. Operations below 400 watts/square meter in Mode 5 were found to be feasible, below the minimum design threshold.

May - A second net positive month. A record 78.5 MWe-h were transmitted during a 11.3 hour synchronization period on May 30. The 7 MWe (net) for four hours storage extraction design point was verified. Total extraction energy was 43.8 MWe-h net. A baseline power production engineering test was begun 5/21.

June - Net positive power production again. Three power production tests results are notable 12.3 MWe net peak power in Mode 3, with 104 MWe-h net generated over 15 continuous hours, an extended duration test with 33 continuous hours synchronized. 729.9 MWe-h net generated over 23 days of operation.

July - A net positive month. Two receiver tube cracks were discovered in panel 18, the plant was shutdown on July 26 as a precaution. Scheduled automation hardware changes were implemented during the outage.

August - On August 23, the plant was restored to operation, the receiver leaks were repaired, and the repair was inspected and certified. Due to the extended outage, the plant consumed more energy than it generated. Mode 2 operation was released to SCE for routine operation.

September - Weather severly impaired operations. 131 hours of weather outage of 360 available hours were recorded. A new plant shut-down procedure with nitrogen gas blanketing of all water steam piping began. Automatic morning and mid-day start-up of the collector field was demonstrated.

October - A new receiver shut-down procedure was initiated to reduce temperature changes during transients. Continued efforts reduced monthly auxiliary energy consumption (parasitic load) to the lowest point since plant start-up (April, 1982).

November - Testing continued to minimize plant load during non operating hours. A reduction to 300 KWe from 500 KWe was observed. Turbine generator automation of pressure control from receiver to turbine and back was demonstrated. Mode 6 was released to SCE for unrestricted operation.

December - A two week outage was scheduled to remove receiver tube specimens for metallurgical analysis and repair additional edge tube cracks. Receiver absorptivity measures indicated a 2 percent reduction annually. Tracking of the moon's image was performed to evaluate the heliostat field mirror facet alignment.

Table 6b
1983 Monthly Maintenance Highlights

January - Oil leaks noted in all thermal storage charging train condensers and subcoolers. The average number of heliostats out of service was 65 or 3.6 percent.

February - 14 mirror modules had additional vent tubes installed to evaluate this method for eventual use should mirror corrosion be reduced. A complete plant safety inspection was performed with no major deficiencies identified. 1803 heliostats were available on one day, a record.

March - A modification to the turbine admission stop valve was identified. This change would convert the valve to a control valve preventing overspeed when rolling the turbine off storage supplied steam.

April - 1809 heliostats operating, a new record. Meteorology equipment had yearly maintenance. The turbine gland seal exhauster pump was cleaned and the system rerouted saving on equipment of $1,000/month in water useage.

May - Concurrent with the power production period, scheduled repair of the thermal storage heat exchangers began. Complete removal of a subcooler tube bundle was begun and repair of heat exchange flange gaskets began.

June - The admission step valve was replaced converting it to a full arc control valve. X-ray measurements of selected heliostat modules were completed to observe the effect of the additional vent tubes. All thermal storage heat exchangers were repaired/modified to reduce leaks. All heliostats were spray rinsed.

July - All maintenance activities for repair and modification of equipment were rescheduled to occur simutaneously with the receiver tube leak repair outage.

August - Maintenance supported the receiver outage, assisting in receiver inspection and repairs of the leaking tubes, modification of the control room computor displays and remote station weather proofing.

September - Routing of thermal storage water sample lines to the chemical lab was completed. Charging train #2 condenser was retorqued and all gaskets were sound after the August change out. 15 more mirror modules were fitted with additional vents.

October - A complete receiver inspection employing ultrasonic techniques disclosed a new receiver tube leak and several internal tube cracks. The leak was repaired and a schedule to monitor cracks was established.

November - All receiver flow control (18) and vent valves were checked for leakage. Three of the 18 and 2 of the 3 vent valves were leaking and scheduled for repair.

December - Receiver panel support rollers were found cracked, these were repaired. Many annual checks of values, flowmeters and instruments were performed during a scheduled outage.

Special Topic I - ENERGY PRODUCTION ENGINEERING TEST

The "Baseline" Power Production Engineering Test, initiated on May 21, 1983, was completed on June 12, 1983. During this period, Solar One operated in Mode 1 only (Receiver Steam/Turbine). The Thermal Storage Unit (TSU) was fully charged prior to testing and thermal storage system generated steam was the main source of sealing and auxiliary steam. It was anticipated that the TSU stored heat energy would be sufficient to meet the auxiliary steam demand throughout the Power Production Test. However, the TSU was depleted before the end of the test and consequently one day was dedicated for TSU recharging.

The following chart summarizes the statistical data collected during the test:

Duration	23 days	(5/21 through 6/12)
Period Hours	552	
Usable Energy - NIP Time (Hours)	235.5	
Total On-Line Hours	152.15	
Total Net MWH	729.9	(1,117 MW Gross)
Weather Outage Hours	35	
Equipment Outage Hours	44.5	

Based on the above data the capacity factor for this period

$$\frac{\text{MWH Net}}{\text{(Period Hrs.) (Peak Power *)}}$$ was <u>0.13.</u> The capacity

factor based on insolation values greater than 450 watt/m^2

$$\frac{\text{MWH Net}}{\text{(Usable Energy) (Peak Power *)}}$$ was <u>0.31.</u> The load factor

$$\frac{\text{Average Power}}{\text{Peak Power}} = \frac{\text{MWH Net/Oper. Hrs.}}{\text{10 MW}}$$ for the period was 0.46.

* MW Rated Peak Power.

A record daily energy production of 78.4 MWe-h net was achieved on 05/30/83, while operating at rated pressure (1450 psi) and reduced temperature (850 degrees F). Another record achieved on the same date (05/30/83) was the highest online time (11 hours and 22 minutes), since startup.

The conditions under which Solar One operated during the Engineering Test period were less than favorable. The heliostat mirrors were only 88% clean, as compared to 98% when freshly washed, and the insolation values were below normal. Numerous valve positioner failures due to oil/desiccant contamination of the instrument air system, and numerous receiver leaks -- angle valves/filters/vent valves/flowmeters -- resulted in startup failures and short term outages. High winds and overcast skies accounted for 35 hours of weather outages.

During this period, operators stressed reduction of auxiliary power consumption to include:

a. Selective shut down of cooling tower fans during low load operation.

b. Shut down of cooling tower fans during inactive periods allowing for natural draft cooling.

c. Shut down of non essential air conditioners.

d. Reduce lighting around station.

e. Operation of only one circulating water pump during shut down periods (evenings-nights).

Despite uncontrollable obstructions, valuable data was collected and observations were made during the Preoperational Power Production Test that provided an insight for future power production and the potential capabilities of Solar One.

Special Topic II - RECEIVER TUBE STEAM LEAKS

In July/August 1983, two receiver tube leaks were observed. For safety reasons, personnel are not allowed inside the core area with flux incident on the receiver; in this case a source of water leakage was being sought and found beneath manifold insulation at the top of panels #18 and #11. (See Figure 20 for panel numbering scheme and Figure 21 for tube numbering scheme.) Removal of the manifold insulation disclosed two primary types of leaks, I and II. Type I was associated with a weld between 10 tube subpanels of the receiver panel. This failure is always associated with wrap around interstice weld at the top of the subpanel assemblies (See Figure 22). Type II failures occur at panel edge tubes, in the first tube bend. Located at the outside of the tube bend, this circumferential crack is interesting because the failure is from the inside to the outside. In contrast, the interstice failure follows the weld heat affected zone and propagated from the tube O.D. to I.D.

Several theories have been advanced as to the cause of the tube cracks, and an extensive investigation was initiated. The following will describe the operational steps taken to support separate analysis steps, concurrent activities necessary to bring Solar One back into operation, and operational and field modifications taken to mitigate further damage to the receiver.

Assessment of the Receiver Condition

After leak discovery the plant was shutdown and a complete receiver inspection performed. This was accomplished by installing the "skyclimber", a moveable platform which can be installed on the receiver exterior from which these panels can be examined. The lagging and insulation were removed from the panel tops and over a 3-day period the entire receiver was inspected. This inspection was completed again in December, 1983. Results from both inspections are presented in Tables 7 and 8.

In addition to conventional dye penetration techniques, ultrasonic inspection was performed to try to detect internal cracking associated with the Type II cracks.

The immediate task in August was to repair the three cracks and to provide representative metallurgical samples of the failure for subsequent analysis. To repair a pressure vessel, the State of California requires that a repair technique be certified and the welder be certified in the repair. The repair technique had been developed by the panel manufacture Rocketdyne Division - Rockwell International. Welder qualification began and a welder was qualified and certified within two weeks. Prior to repair, metallurgists and welding engineers from Sandia and the Solar Facilities Design Integrator supervised sample removal. From panel 11 (tube 70) the entire bent tube section was removed; from panel 18 the weld region between tubes 30 and 31 was removed and the similar crack between tubes 40 and 41 was ground out and weld filled. A new elbow section was installed in panel 11 (tube 70) and repair was made on tubes 30 and 31.

Operational Effects:

Suspected causes of failure included higher operating temperatures of edge tubes. To mitigate this possibility, maximum steam temperature was lowered from 960 degrees F to 850 degrees F (In 1984 this was lowered further to 775 degrees F.) Also, the shut down control procedure was changed to close the panel water inlet valves shortly after defocussing the collector field. This precaution was taken to preclude liquid water from striking hot tubing at the top of the panels.

Since receiver inspection was becoming necessary and routine, the outlet header insulation pads were removed and removeable insulation installed.

With these procedures complete, the plant was restored to operation on August 24, 1983.

Subsequent modifications to the panels included removal of panel support horses (5 of 7) and splitting of several interstice welds to minimize further Type I failures, See Figure 23. This failure was assumed to be caused by mechanical constraint of the upper end of the panels during thermal cycling. Stress analysis was unable to confirm that high loads were present because the geometry of the panel outlet to header connections is very complex, See Figure 24. The presence of high stresses was surmised, based upon metallurgical examination of the weld region which exhibited the characteristics of a low cycle fatigue failure. See Reference 5 for a complete description.

Table 7

Summary of Receiver Tube Leaks and Cracks
Type I
Dye Penetration Detection

Detection	Location Panel	Tube	Type	Disposition
11-01	4	30	Weld Defect	Ground Out
11-01	5	20/21	Weld Defect	Ground Out
11-01	6	41	Crack in Weld	Crack Ground Out
11-01	7	30	Crack in Weld	Crack Ground Out
11-01	8	41	Crack in Weld	Crack Ground Out, Weld Fill
01-26	8	50/51	Crack in Weld	Crack Ground Out
01-26	9	30/31	Crack in Weld	Crack Ground Out
11-01	9	41	Crack in Weld	Crack Ground Out, Weld Fill
11-01	10	41	Surface Irregularity	Polish
11-01	10	50/51	Crack	Ground Out
10-28	12	30/31	Weld Defect	Ground Out
10-26 *	12	41		Repair
11-01	12	41	Surface Irregularity	Polish
11-16	13	11	Weld Defect	Ground Out
08-02	13	30	Crack	Ground Out
10-26	13	40/41	Crack	Ground Out, Weld Fill
01-26	13	50/51	Weld Defect	Ground Out
08-18	14	10/11	Weld Defect	Ground Out
08-18	14	60/61	Weld Defect	Ground Out
08-16	17	10/11	Weld Defect	Ground Out
08-16	17	20/21	Weld Defect	Ground Out
11-01	17	30/31	Weld Defect	Ground Out
07-15	18	20		
07-26 *	18	30/31	Leak Type I	Window Repair Metallurgical Sample
07-26	18	41	Crack	Weld Fill
08-18	19	60/61	Weld Defect	Grind Out
01-26	20	30/31	Crack	Grind Out

Interstice Weld Failures, Type I
tubes (grouped by symmetrical arrangement)

10/11-1	60/61-0
20/21-2	50/51-2
30/31-6	40/41-6

Table 8

Summary of Receiver Tube Leaks and Cracks
Type II
Ultrasonic Detection

Detection	Location Panel	Tube	Disposition
-----	4	1	Repaired, Metallurgical Sample
-----	6	1	Repaired, Metallurgical Sample
02-05	9	70	Monitor
02-05	10	70	Monitor
08-02 *	11	70	Leak, Reapir, Metallurgical Sample
02-05	11	70	Monitor
02-05	12	70	Monitor
11-16 *	15	1	Leak, Repair, Metallurgical Sample
11-16	16	1	Repair, Metallurgical Sample
-----	16	2	Metallurgical Sample for Reference
11-16	16	3	Metallurgical Sample for Reference
11-16	17	1	Monitor
10-26	18	1	Monitor

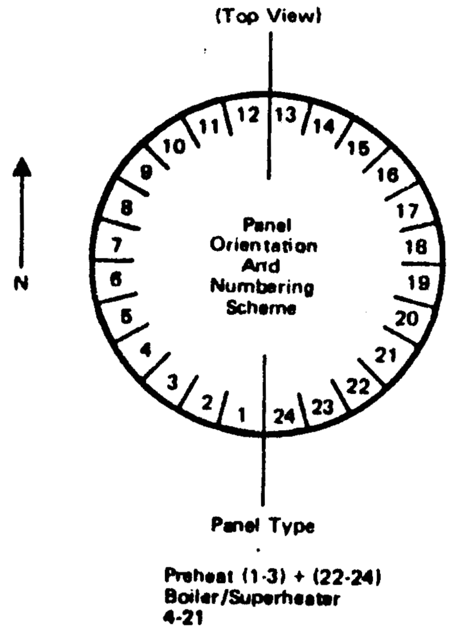

Figure 20 - Receiver panel numbering scheme

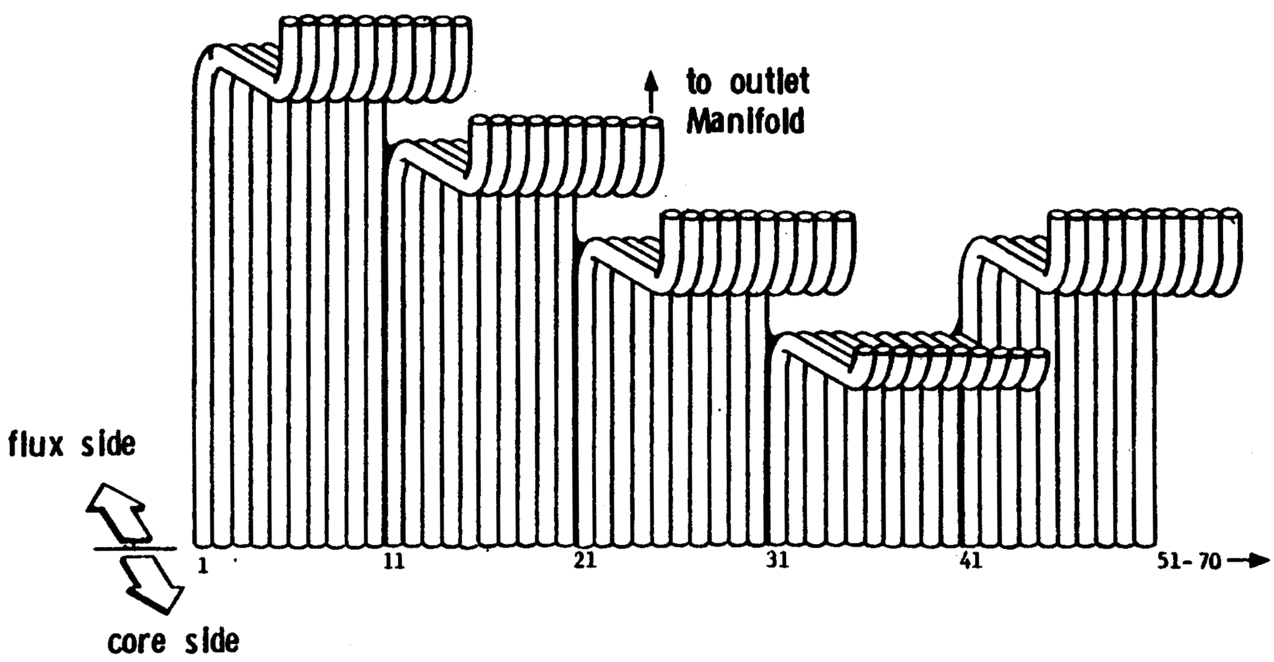

Figure 21 - Panel tube numbering scheme;
1-10, 11-20, etc. are subpanels.

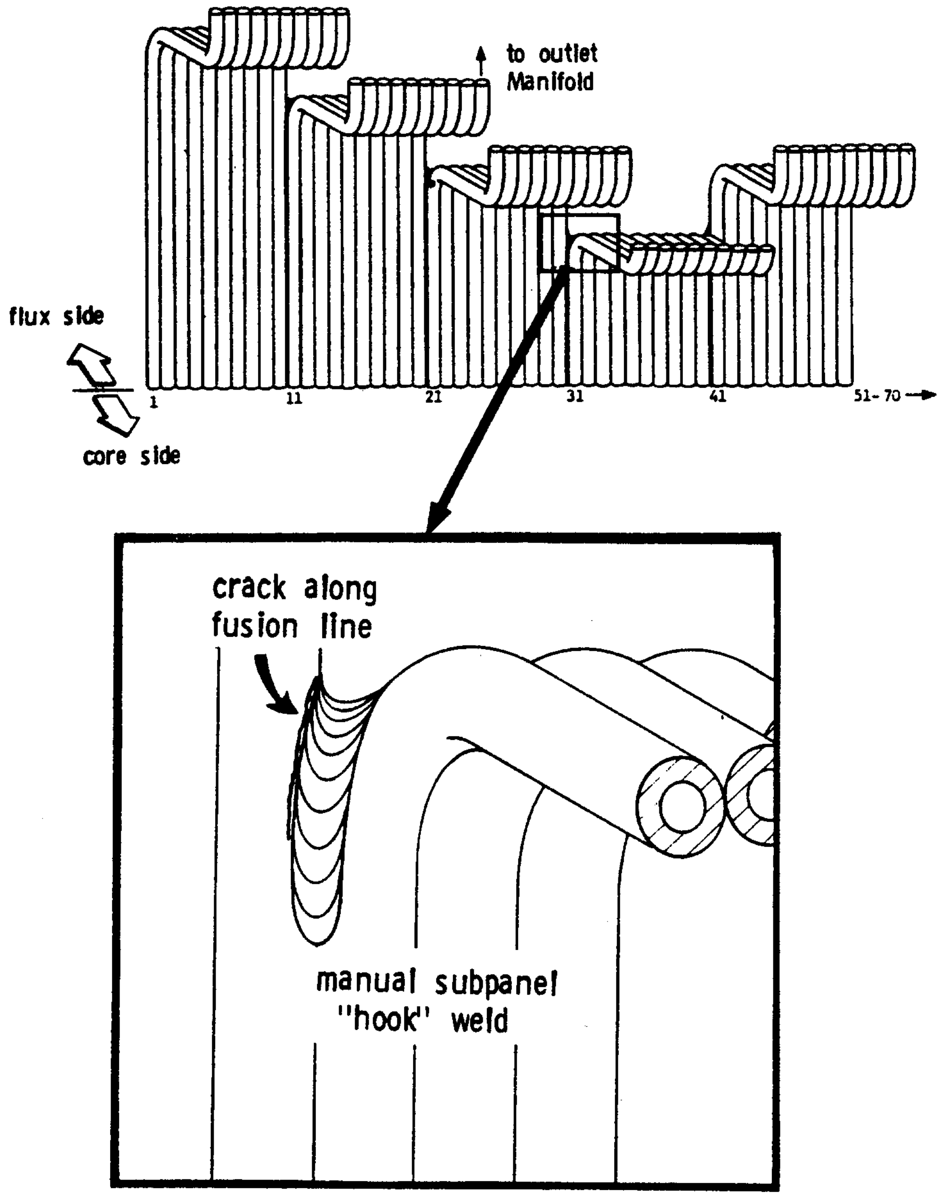

Figure 22a
General configuration of subpanel interstice weld failure - Type I

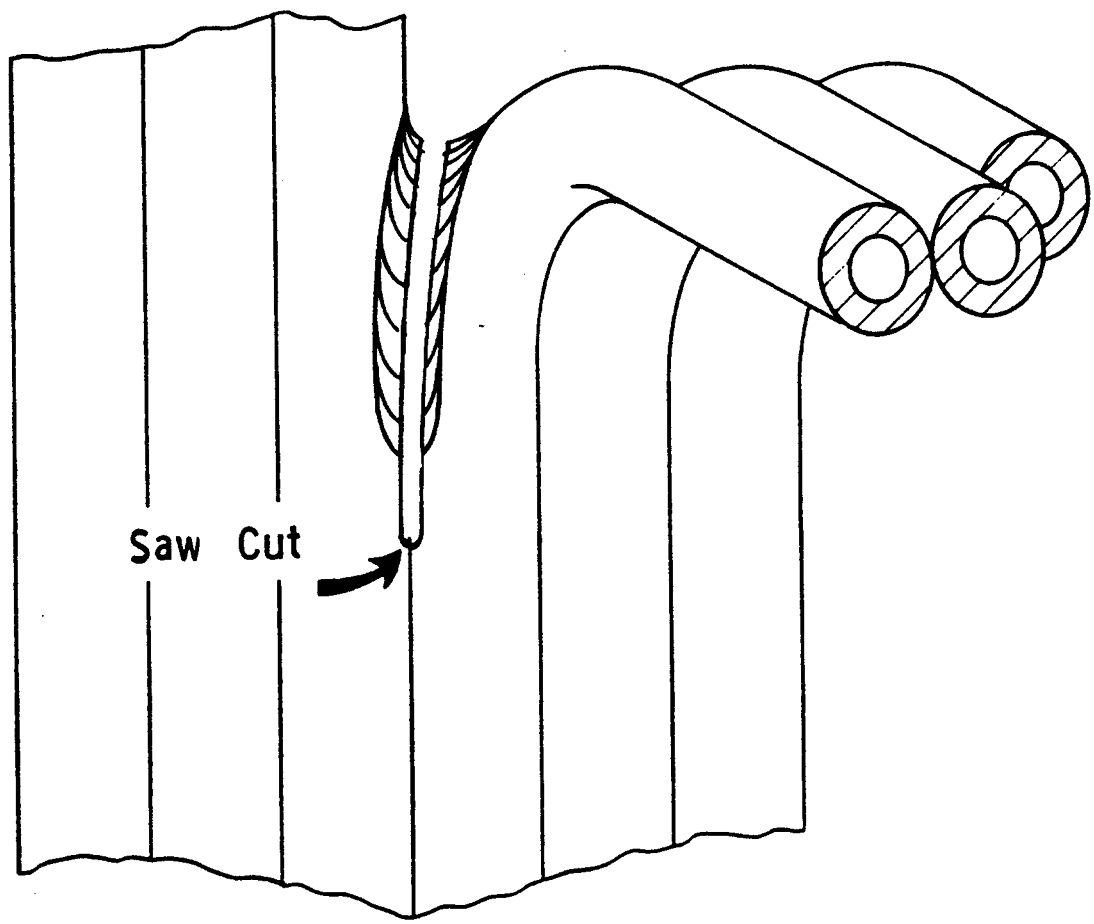

Figure 22b- Schematic Modification of Interstice Weld Area

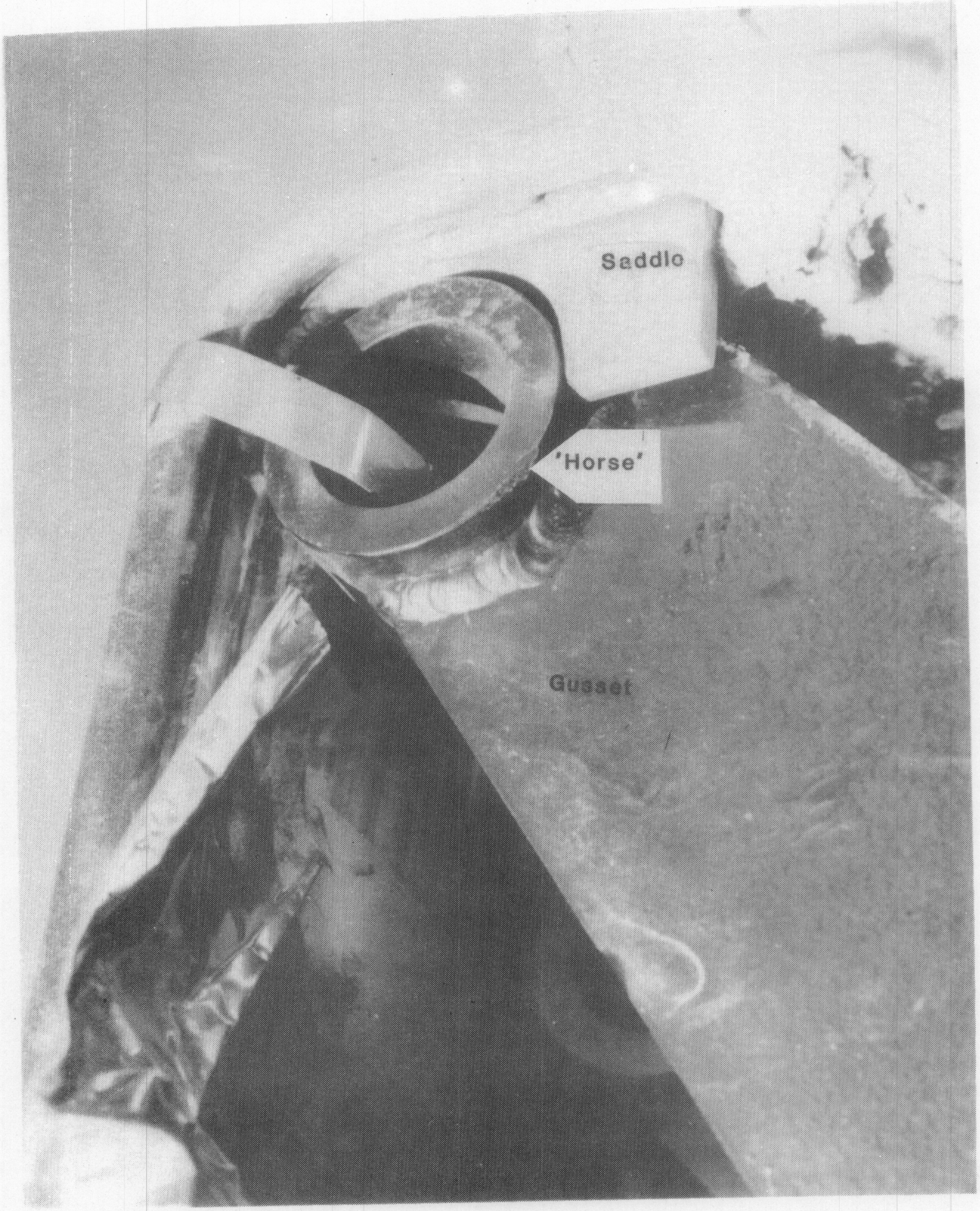

Figure 23. Subpanel Top Support Detail

Each 10 tube subpanel was supported by separate "horse" and "saddles" (4). Modification included removal of all gusset's and horses except those of the edge subpanels.

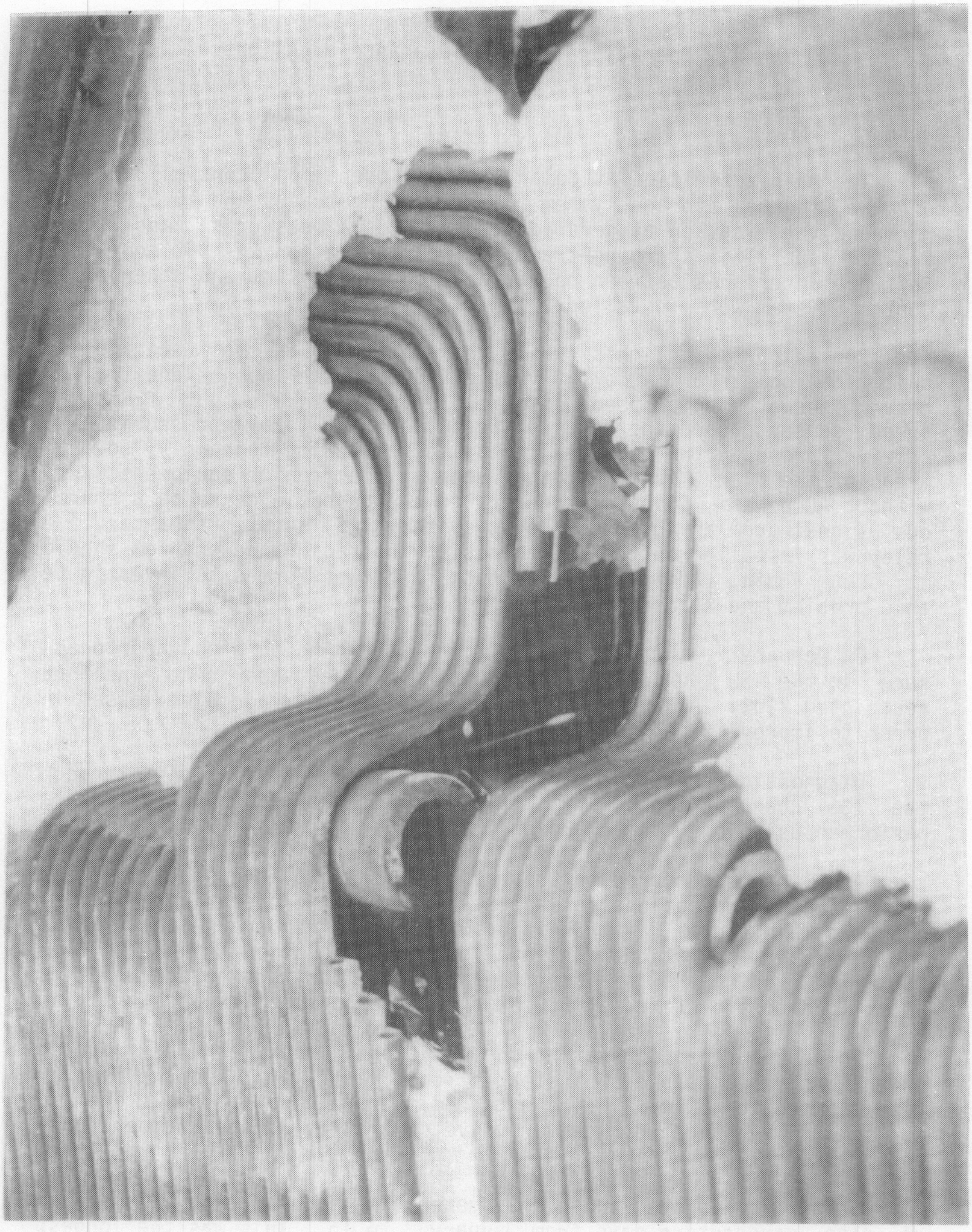

Figure 24. Panel Top Configuration

Panel top section view: Two adjacent panels are shown. Three end bend tube sections have been removed from the end subpanel. Steam flow is from the bottom to the top, 0.5" O.D. tube terminates at a panel header hidden from view.

Monthly Operational and Maintenance Highlights

January

The main activities at Solar One were open loop control testing of the thermal storage system (TSS) charging trains and turbine performance verification at derated temperatures, pressures, and steam flows. The TSS charging train control automation was 90% complete. Software interfaces between operational control system and other plant control system were installed.

Operational Highlights--While charging the thermal storage unit (TSU) on January 4, a 480 volt circuit breaker opened and the receiver feedwater pump speed sensor failed. The zero output from the speed sensor caused the receiver feedwater pump to overpressurize the receiver and open the receiver safety valves. Simultaneously, several areas of the plant, including the receiver electronics equipment, were without AC power. Investigation traced the probable cause to a spurious signal from an interlock logic system (ILS) input/output card. A relay was installed on the ILS to assist in tracing the problem should it occur again. Additionally, a task force was formed to investigate this problem and recommend further action.

On January 7, the TSU tripped during charging on high vapor pressure in the TSU tank. The problem was a plugged vapor vent line that restricted flow. A valve was removed to decrease minor pipe losses in order to improve flow.

Diagnostic tests to remedy minor oil flow oscillations through the TSS charging trains at low flows were performed. The tests were performed using only one charging train.

A milestone occurred on January 14, when Solar One smoothly went from turbine operations on main steam to turbine operation on admission and main steam This transition was impressive because the turbine and charging operations continued despite insolation transients from 800 w/m^2. During the low insolation periods, the turbine operated under load control fixed at 5.0 MW on admission steam.

Solar One began generating one additional hour per day during power production periods, instead of coming off-line when the insolation dropped to 450 w/m^2. The extended operation was possible due to smooth turbine and receiver valve control at derated temperatures and pressures.

Solar One operated in Mode 2, generating and charging TSS on each of nine consecutive days from January 7 to 15. This was the longest production run to date.

On January 25, a simulated operation control system software program automatically brought the heliostat field from standby to tracking the receiver until steam was in the downcomer and all receiver boiler panels were in temperature control. The program went very smoothly and lasted 50 minutes.

On January 30, operators took 70 minutes to make the transition from initial tracking of the receiver to sychronization of the generator. On January 31, the time was 93 minutes. Those start-up times were faster than past efforts because of electrical heat tracing installed on the main steam dump valve, to eliminate the time required for preheating the valve using receiver steam.

A new heliostat stow position was initiated to mitigate mirror corrosion due to water seeping into the honeycomb mirror support. All heliostat mirrors were stowed in a vertical east-west plane, except during periods when high winds were expected; face down stow was used in such circumstances.

A total of 13,500 gallons of caloria were added to the thermal storage unit (TSU) to raise the caloria level above the upper header. The new oil was required to account for minor oil leaks and spills, decomposition of caloria to hydrogen, condensible and noncondensible carbon chains, and removal of residual water vapor from rock and gravel in the TSU.

The collector field began using the "summer" strategy when moving from the stow position to standby points near the receiver. This change was made to minimize the number of singularities that occur in the south quadrants during the movement of the collector field. A singularity occurred when a heliostat reached one limit of azimuth movement and had to rotate toward the other limit to continue tracking the sun.

A small portion of the canvas winterizing blanket caught fire when wind blew it into contact with a hot uninsulated steam drain line. The fire was immediately extinguished. The canvas tarp had been draped around the auxiliary bay to minimize freeze damage to piping and associated instrumentation during freezing weather.

Maintenance Highlights--The pipe tap on the bottom of the TSS extraction boilers for the boiler level transmitter was blocked with scale on several occasions. Larger taps and drain valves were installed for blowdown capability.

The condensers and subcoolers on both TSS charging trains began leaking small amounts of oil, less than 1 gph, past shellside tubesheets. The flange bolt torques were scheduled to be checked ultrasonically during the next outage.

On January 18, the flow indicator on a preheater panel shorted the 24 volt power supply to all receiver panel flowmeters. The defective flowmeter was bypassed since that meter was not required for plant operations.

All one inch treaded inspection plugs on top of the receiver boiler panels were seal welded to prevent recurring steam leaks.

The decision was made to send the TSS steam flowmeters back to the manufacturer for modifications to improve accuracy and to mitigate water intrusion into the electronic components.

The average number of heliostats out of service was 65 out of 1818, or 3.6%. The primary causes for heliostat failures were shorted mechanical relays, shorted solid state relays, and off-frequency communication crystals in the individual heliostat controllers (HC). Less frequent problems included loose motor connections, reduction gear-shaft separation in the motor reduction gear housing during high winds, and position encoder problems. SCE electricians began installing fuses on each motor circuit in each HC to protect sensitive microprocessor and rectifier relay shorts.

February

During February a new milestone was achieved when the turbine generator reached 7.3 MWe (net) on thermal storage admission steam. This production exceeded the 7.0 MWe (net) design point.

A simulated Operational Control System (OCS) program was tested; this program reduced from 50 minutes to 16 minutes the time required to bring the collector and receiver into operation (all panels in temperature control). 16 minutes is about the minimum period during which the operators can reliably monitor the start-up process.

The turbine/generator performance testing continued at derated steam conditions.

Operational Highlights--A continuing high cation conductivity in the condensate and feedwater was due to service water deposits in the gland seal exhaust condenser system. The gland seal exhauster drains were diverted to waste. The drains will be rerouted to the main condenser as soon as contaminated equipment and piping are chemically cleaned.

As a test, the trim in receiver panel #8 flow control valve was replaced by one of "more desirable" flow control characteristics at small valve opening, to eliminate oscillations at low flow.

On Friday, February 25th, a milestone was achieved when the turbine generator reached a net load of 7.3 MWe for approximately 20 minutes while operating on admission steam, - steam generated with the thermal storage subsystem. Steam flow conditions were 540 degrees F, 349.4 psia, and 105,000 lbs/hr. This milestone verifies the design point for maximum load on admission steam of 7.0 MWe (net) at 525 degrees F, 385 psia, and 110,000 lbs/hr.

Maintenance Highlights--As an experiment, in fourteen of the mirror modules that presently contain water, a second vent was installed opposite the existing vents to aid in water removal.

On February 9th, the circuit breaker on the cooling tower 4KV supply failed to open. Investigation of the incident found that a spurious discrete logic signal from the interlock logic system (ILS) caused the breaker to open. Much later the problem was found to be due to the attempted programming of an ILS unit while operating.

On February 21st, while charging the thermal storage unit, the oil leak on charging train #2 condenser increased from 1 gph to 5 gpm. The train was taken out of service and scheduled for repair during a plant outage.

Two defective heat flux sensors were removed from panel #11 and sent to the manufacturer for repairs. They were replaced by new ones.

Due to excessive steam leakage at the intermediate turbine steam seal packing, the General Electric turbine/generator was to be synchronized manually when starting on admission steam and required an excessive amount of steam. The planned interim repair involved using an internal bypass in the admission stop valve as a throttling valve to provide turbine/generator speed control.

Plant waste water line failures continued despite the installation of several expansion loops.

Receiver feed pump recirculation valve control logic was revised to expedite transitions to speed, pressure, and valve control. Receiver feed pump being in pressure control during initial fill resulted in several unit trips. Under the new program, the receiver feed pump was to be under speed control with the recirculation valve in automatic until flow is established.

Heliostat Array Controller (HAC) and heliostat field loss of communication problems were experienced intermittently. Electrical noise interference, a possible cause, has been minimized by the installation of capacitors at selected heliostat motors.

A safety inspection and fire protection review was made by representatives from Sandia, SCE, and Stearns-Roger. The inspection lasted two days and no serious violations were uncovered. A check list of safety items was to be compiled for near term correction and reference during routine safety inspections.

On February 28th, 1803 of 1818 or 99.2% of the heliostats were available for service.

March

March was a highly active period for Solar One. Despite the adverse weather conditions, which accounted for about 153 hours of outage, power generation attained 397.2 MWe-h, the highest monthly value since operations began. Part of the work performed during a scheduled five day maintenance outage brought the plant automation near completion.

Operational Highlights--A new high wind stow procedure was developed to reduce the time required to move the heliostats from tracking to the stow position. This procedure would be in effect when wind speed was at 40 mph and records showed that there were three or more occurrences of winds in excess of 35 mph within the previous ten minutes. The new procedure ensured that 99.5% of the heliostats would be in stow position within 17 minutes.

Solar One was released to SCE personnel for unassisted weekend thermal storage system (TSS) charging operations, Mode 5. Previously, the plant was limited to Mode 1 receiver/turbine direct on weekends. Weekend charging operations would help ensure availability of steam for auxiliary usage, thus minimizing the operation of the electric auxiliary boiler, a high power consumption component.

Receiver flux transducer sensitivity tests were conducted to detect any deviations from the original calibration. Test results indicated changes in transducer sensitivities which were generally less than the originally calibrated ones. In addition, there were indications that high environment temperatures rather than flux accounted for the changes.

A turbine trip was experienced due to a malfunction of the Beckman subsystem controllers. An operator entered valve position command was not transferred correctly and the thermal storage system (TSS) steam flow control valve stepped from 10% to 90% open, causing diversion of all receiver steam from the turbine to the TSS charging train. Investigation found defective PROMs (Programmable Read Only Memories) in the operator station processor (OSP) to be the cause of the anomalies. The PROMs were replaced.

The condensate high cation conductivity problem that had been experienced, was effectively resolved with the chemical cleaning of the gland steam condenser system performed during the plant outage. The system's drains were routed back to the main condenser with no effect on the hotwell water quality.

Maintenance Highlights--Four incidents of plant waste water line failures were experienced during March. The failures were attributed to thermal expansion of the pipe material (PVC). Due to the high frequency of the incidents, replacement of the waste water line was planned.

The thermal storage extraction system oil flowmeters were replaced with new ones of higher sensitivity to ensure accurate measurements at low load operations. Extraction system feedwater flowmeters were cleaned, inspected, and calibrated. Charging train #2 steam flowmeter was removed and shipped to the manufacturer for repairs of damages caused by moisture intrusion into the meter's electronic components.

Failures of the thermal storage system flash tank steam side rupture disk were experienced twice during March. Investigation determined that the disk did not meet design requirements.

Solar One was shut-down on March 20th for a five day maintenance outage. The following are the major work accomplishments during the outage.

- Control room Beckman consoles were relocated to accommodate the operational control system (OCS) computer hardware.

- The heliostat array controller (HAC) computers were replaced to facilitate the installation of additional memory. The additional memory will aid in resolving HAC/BCS communication problem.

- Manual steam isolation valves were installed at the thermal storage system extraction exchanger trains. Previously, the plant had to be shut down in order to do maintenance work on either of the two trains.

- The thermal storage desuperheater attemperator valve was replaced. The valve body and internals were damaged due to erosion.

- Two thermal storage charging train #1 boiler water level indicator valves were replaced with full flow valves to ensure accurate level indication.

- Eleven valves on the west air compressor were rebuilt or replaced. Erosion had caused extensive valve leakage.

- Minor repairs were made on various other valves (i.e., feedwater, steam, oil, etc.) to minimize heat losses.

April

Operationally, April was the first anniversary of Solar One. The turbine/generator was synchronized to SCE System for the first time on April 12, 1982.

April, also, was the first month since operations began that Solar One generated a net positive 24 hour output (transmitted 107.8 MWe-h). Energy production while connected to the SCE System was 528 MWe-h net.

Operational Highlights--On two occasions during April, there were 1805 of 1818 heliostats available for service. The significantly improved collector system reliability was the result of software revisions, replacement of defective motor/gear drives, installation of heliostat controller proctective fuses, and routine servicing of limit switches.

To reduce auxiliary power consumption and because of the demonstrated high reliability of the collector system, the collector field is now being operated only to support energy production, testing and rain washing rather than on a continuous basis.

During Mode 5, TSS Charging Operation, it was noted that Solar One could operate for prolonged intervals with insolation values below 400 watts/m^2. This indicates that the plant can operate in Mode 5 at below the minimum design criterion of 450 watts/m^2.

Receiver trips on false indications of low superheat temperature were sporadically experienced. Investigation revealed that the trips occurred during the activation of the receiver moisture separators. A new operating procedure was instituted to enable moisture separators to be activated as soon as the receiver panels controlled by any two Multivariable Control Units (MVCU's) go into temperature control. The moisture separators disable after the last pair of receiver panels goes off temperature control. Previously, the moisture separators would activate at the operators discretion through the operation of an enable/disable switch. The automated procedure solved the problem.

Receiver flowmeters from panels 7, 18, 20 and 21 were replaced with meters having greater sensitivity at low flows to ensure accurate flow measurements during early morning start-ups. This was done after satisfactory results with a revised valve trim in panel #8 (see February).

In the continuing effort to automate plant functions, tests were performed to refine the cooling tower fan start-up sequence, whereby all three fans are started sequentially and transferred from the low speed to the high speed setting through a single keystroke. Following the completion of the tests, the system was released to operations for service.

Maintenance Highlights--A faulty receiver (panel #5) flowmeter caused a plant shutdown on April 27th. The flowmeter electronics were damaged due to water intrusion, resulting in erroneous readings which prevented the panel from going into flow and temperature control. The necessary repairs on seals were made and the meter was reinstalled. Similar problems were also experienced with several other flowmeters and corrected.

New valve trim was installed in the receiver bypass valve (PV-2002). Inspection of the valve after the trim installation revealed damage in valve body allowing leakage. Temporary repairs were made to permit continued operations. Final repairs were scheduled.

Small caloria oil leaks were experienced in charging train #1 condenser and the extraction train #1 superheater. The leaks were temporarily repaired by tightening the flange bolts. Final repairs will be made during the next maintenance outage scheduled for early June.

The bearings of the anemometers and wind direction sensors on all Special Heliostat Instrumentation and Meteorological Measurements System (SHIMMS) stations and towers were replaced according to the manufacturer's recommendation.

Two more incidents of plant waste water line failures were experienced in April.

Failure of the Thermal Storage System flash tank steam side rupture disk was experienced again. Investigation determined that the rupture disk currently in use did not meet the design specifications. A rupture disk of different material, which meets the design requirements, was ordered.

The Gland Seal Steam Condenser was chemically cleaned to remove service water deposits from the system's pipe walls. The chemical cleaning (at an estimated cost of $250) effectively removed all deposits and allowed recovery of 4.5 gpm or 2,430 gallons per day of condensate as well as the condensed steam leak-off. Assuming daily operation and a nine-hour day, for a period of one month, this savings amounts to 72,900 gallons. The cost saved from the above activity, including water and pumping costs, was about $1,063 per month or $12,756 per year.

May

May for the second consecutive month since plant start-up Solar One had a net positive output (transmitted 734.1 MWe-h). The net energy production while connected to the grid was 1138.8 MWe-h.

Two new records were achieved on May 30th when Solar One's net positive output while connected to the grid was 78.5 MWe-h with total on-line time of 11 hours and 22 minutes.

A new milestone was set on May 18th with the design point verification of 28 MWe-h capacity of the Thermal Storage System.

Operational Highlights--A 28 MWe-h Thermal Storage System (TSS) capacity test was conducted on May 18, for design point verification. The design power level of 7 MW for four hours was met and power production on admission steam continued at derated temperature and pressure for a total gross generation of 50 MWe-h (43.8 MWe-h net). The turbine/generator was on-line for 8 hours and 5 minutes.

A new turbine low load shutdown procedure was developed during the first week of May and was verified operationally and released to SCE for service. The turbine/generator protective device operates when the load reaches 1.0 MW during start-up and removes the unit from service if the load drops to 0.5 MW. This unit shut-down logic is designed to prevent the turbine/generator motoring which had previously been experienced during severe changes in available insolation.

A larger valve trim was installed in the charging train #1 pressure control valve (PV-3110). This modification improved charging operations, since the time required to charge the Thermal Storage Unit (TSU) with one charging train was reduced to two-thirds of the original time.

Significant progress was made towards process control automation. The following subroutines were verified operational and released to SCE Operations for service:

1. Initialization of receiver for start-up.

2. Transition from receiver flash tank to steam dump.

3. TSS extraction train #2 operation for auxiliary steam generation.

4. TSS charging operation.

5. TSS extraction train #1 shutdown.

6. Automatic downcomer pressurization.

7. Cooling tower fan start-up sequence.

Additional automation procedures were developed and tested but were not released for service.

A "Baseline" Power Production engineering Test began on May 21st. During this period, Mode 1 (Receiver/Turbine Direct) was the primary mode of operation and data were collected to determine the plant's potential capacity factor and to establish a reference standard for: a) Future system performance comparison and b) Future plant betterment evaluations. The Thermal Storage Unit (TSU) was fully charged prior to starting the test and it was anticipated that extraction system generated steam would meet the sealing and auxiliary steam requirements throughout the energy production period. Instrumentation calibration was also previously performed to improve data accuracy.

Maintenance Highlights--A maintenance outage began on May 31st, for Thermal Storage System heat exchanger repairs. The outage work was scheduled to last until late June and did not require complete plant shutdown. Charging train #1 was available for charging operations except for a one week period when flange bolts were retorqued. The major maintenance activities during the TSS outage were:

a. Removal of charging train #2 subcooler tube bundle and shipment to the manufacture for grinding and re-welding of the tubes to obtain an effective tube to tube sheet seal.

b. Splitting of all vessel annuli, i.e., separate heat exchanger oil and water/steam tube sheets by cutting their common cylindrical attachment.

c. Repair of all heat exchanger oil flange leaks.

Three of four second generation heliostats (McDonnell Douglas, Arco, and Boeing) to be tested at the Solar One site were installed at the beginning of the month.

An equal percentage trim was installed in the Thermal Storage Charging System main steam inlet valve (UV-3102) to replace the original linear trim. This modification allowed better charging process control during low steam flows.

Routine inspection and calibration of all Thermal Storage System thermocouples were performed. The inspection did not reveal any problems.

Receiver panel #5 flowmeter (Ramapo 12 gpm) developed seal leaks and was removed and shipped to the manufacturer for repairs. It was replaced with a 20 gpm flowmeter from panel #4 while a new 10 gpm flowmeter was installed in #4 panel. Low capacity flowmeters were installed on selected panels in an effort to improve flow measurement accuracy during early morning start-ups and low flow conditions.

The Thermal Storage Charging System flowmeters, FE-3102 and FE-3205, which had previously been removed and shipped to the manufacturer for repairs were reinstalled and function properly, after minor pressure and temperature compensation adjustments.

June

Solar One had a net positive output of 561.8 MWe-h. The net energy production while connected to the grid was 956.9 MWe-h.

Three power production tests demonstrated once more the design validity and the capabilities of Solar One:

- Peak Power/Energy Test (12.1 MWe net, 104 MWe-h net, 15 consecutive on-line hours).

- Extended Duration Test (33.6 consecutive hours of operation).

- Preoperational Power Production Test (729.9 MWe-h net for 23 days of operation).

<u>Operational Highlights</u>--The General Electric admission steam stop valve internal bypass was replaced with a full arc admission internal bypass valve to allow better turbine speed control during start-ups on admission steam. Previously, throttling of the steam flow when starting from the admission port was achieved by operating the admission steam stop valve main plug. This resulted in poor turbine speed control. The modified valve was tested during start-up at low admission steam pressure and was proven functional. However, adjustment of the turbine speed control and prevention of turbine overspeed remains sensitive.

A new milestone was set during the Peak Power and Energy Test performed at Solar One on Tuesday, June 21, 1983 (summer solstice). The turbine/generator attained a net peak of 12.1 MWe (13.1 MWe gross) and generated 104.3 MWe-h. The unit was on-line for 15 consecutive hours operating in Mode 3, receiver/turbine direct and thermal storage system generated steam. The receiver steam conditions were 900 degrees F, 1400 psi and 105,000 lb/hr and admission steam (from one extraction train only) 541 degrees F, 412 psi and 31,000 lb/hr. There were 1792 recently washed heliostats in service with insolation of 910 watt/m^2. The limited factor on the maximum power generation was the steam capacity of turbine control valves and temperature rise of the generator.

An Extended Duration and Performance Test was conducted on June 27th. Solar One was on-line for 33.6 consecutive hours - the longest on-line time since start-up - and generated 127 MWe-h net (171 MWe-h gross). The Thermal Storage Unit (TSU) was completely charged prior to testing. This test as well as the Peak Power/Energy Test verified once more the design validity of the Solar One Plant.

During an attempt to start-up Solar One, a transformer differential relay operation caused auxiliary power loss. A broken wire to the 13.8 KV breaker current transformer (CT) roto switch on "C" phase of the differential relay was found to have caused the relay operation. Transfer to the emergency 4KV well line took place approximately 10 minutes after identification of the problem.

Panel distortion measurements on selected receiver panels (11, 12, 19, 20 and 21) were taken to establish a reference for further studies. A laser beam was utilized to provide the measurement reference point to the distorted tube panel. Measurements were planned to be repeated in the near future.

X-ray tests on selected heliostat mirrors were performed under the direction of Sandia National Laboratories. This was a part of the mirror corrosion monitoring program to determine the amount of water present in the mirror modules. A survey of total mirror surface corrosion was taken and evaluation is in progress. Conclusions to this date indicate that 50% of the mirrors evidence silver corrosion spots. In addition, the corrosion increased from 0.006% last year to 0.015% of the total plant mirror reflective area.

Preliminary tests on receiver convective heat loss flow patterns and receiver tube overheat detection using an infrared camera were successfully conducted by Sandia engineers.

Maintenance Highlights--The frequently failing section of the plant effluent water line was replaced during June. The new fiberglass line has higher heat resistant properties than the original PVC. Small longitudinal cracks were discovered in parts of the new line's plastic liner during installation; however, according to the manufacturer, these cracks were results of heat stress during fabrication and were not critical since the fibercast fiber was protected by an internal epoxy resin. An attemperation system, which operates to reduce the temperature of the hot blowdown water, was being installed to protect the remaining PVC section of the line from similar past failures.

Numerous valve positioner failures resulted from oil/desiccant contamination of the instrument air system. During a two-day plant outage, the instrument air system was effectively cleaned by blowing down all system headers. The air dryers were repacked with fresh desiccant and all pre-and afterfilters were replaced. The following preventive measures have since been taken to avoid future similar incidents:

a. A differential pressure gage will be installed across each afterfilter to detect pluggage.

b. Preventive maintenance for routine dryer and filter inspection has been instituted.

c. Only one of the two filter trains will be in service at a time, thus providing one primary and one back-up system.

The thermal storage system outage initiated on May 31, was completed in late June. All heat exchanger oil flange leaks were repaired. The charging train #2 subcooler tube bundle was shipped to the manufacturer for grinding, rewelding, and rerolling of the tubes to improve the tube to tube sheet seal. All vessel annuli were split, i.e., the oil and water/steam tube sheets of all heat exchangers were separated by cutting their common attachment to minimize thermal stress. Miscellaneous work at the TSS area accomplished during the outage includes:

a. Replacement of the bonnet gasket of the charging train #1 steam inlet valve (AOV-3206).

b. Replacement of three leaky drain valves.

c. Repair of the seat and plug of the TSS charging train #2 steam header relief valve (PSV-3321).

A heliostat in the south east quadrant (#0730) was discovered to have all azimuth gear motor mounting bolts missing. Investigation indicated that these bolts had never been installed.

All heliostat mirrors (excepting 10 test heliostats) were water spray-rinsed by an SCE insulator wash truck. The average rate of washing was 63 heliostats per hour which includes the time required for refilling and travel to the deminerlized water tank.

The power cable on the receiver tower elevator was replaced according to manufacturer's recommendation. The power cable had become twisted.

The following is a list of receiver repairs accomplished during June:

1. Weld repaired a pinhole leak in receiver panel #5 inlet filter body.

2. Replaced the trim in receiver vent valves (AOV-2902 and AOV-2007).

3. Replaced leaky bonnet gaskets in preheater inlet valve (AOV-2004), panel #15 temperature control valve (TV-2603), preheater angle valve (VFW 200-201) and ring header angle valve (228-203).

4. Replaced flowmeter flange gaskets in panels #7, #15, #16, and #20.

5. Replaced filter gaskets in panels #10 and #19.

6. Replaced/adjusted packing in receiver panels #5, #7, #10, #14, and #19 temperature control valves.

7. The receiver preheat safety valve (PSV-2021) was rebuilt and reinstalled. The valve nozzle was machined to remove erosion effects and the damaged disk was replaced.

8. Replaced plug and seat in receiver flash tank valve (PV-2906).

9. Replaced panel #15 flowmeter with a 30 gpm spare flowmeter.

10. Weld repaired a small body leak on panel #15 temperature control valve.

<u>July</u>

Two tube cracks in reciever panel #18 along with several other equipment failures and scheduled outages -- synchronizing potential transformer failure, HAC Sahdow Memory installation and receiver panel #15 temperature control valve leak resulted in an extended plant outage. However, July was another positive output energy production month of 271.4 MWe-h. The net energy production while connected to the grid was 654.6 MWe-h, which is the third highest monthly production since turbine roll.

Operational Highlights--Following additional modifications the turbine admission stop valve underwent testing again at rated admission steam pressure (300 psi); previous testing at reduced pressure took place during June. Due to the turbine speed sensitivity using manual valve controller adjustment, turbine start-up on admission steam for the present is operated at reduced pressure conditions. Data collected during the test were forwarded to General Electric Company for their evaluation.

The cooling tower fan automation procedure was developed and tested. With this procedure the circulating water temperature will be maintained so that 1) maximum turbine efficiency is obtained, 2) maximum Thermal Storage System (TSS) charging operation (Mode 5) efficiency and auxiliary load reduction is achieved, since experience to date shows that operation of the condenser at higher back pressure does not materially affect plant efficiency during TSS charging operation.

The TSS desuperheater (DS-902) spray water is currently being supplied by the condensate pump. The existing water supply system can become contaminated. The system is being modified so that demineralized water (drawn at the polishing demineralizer outlet) rather than condensate is used as the desuperheater water supply.

A receiver trip was experienced on July 5th due to failure of the local receiver system Uninterruptible Power Supply (UPS). The UPS failure caused a trip of the circuit breaker common to both the receiver main control and back-up power, resulting in receiver valve failure to a safe condition.

Major steps were taken towards plant automation. OCS (Operational Control System), HAC (Heliostat Array Controller) and Beckman computer links have been established and the OCS/HAC testing program began with the automatic start-up of the collector field.

Maintenance Highlights--A number of receiver control problems resulted from water intrusion into the remote station one (receiver electronics room) because of damaged roof seals. Presently, rain water and water resulting from receiver venting during start-ups cascaded onto the remote station one (RS #1) roof. To avoid similar future occurrences, the receiver vent will be relocated and the receiver tower level #15 floor (located immediately above RS #1) will be modified to provide rain water drainage. In addition, the roof seal failure is under investigation and repairs and recoating of the roof will be effected as soom as practicable.

The hot well make-up line (fiberglass) was partially replaced to remove a small crack which contributed to the hot well high dissolved oxygen concentration.

Failure of the generator 13.8 KV line side metering and synchronizing potential transformer, experienced on 07/11/83, precluded energy production for three days. The faulty potential transformer was replaced with a new one manufactured by General Electric allowing the plant to return to normal operation.

The Heliostat Array Controller (HAC) Shadow Memory Controller was installed on July 14th and 15th. The Shadow Memory Controller, installed in both HAC computers (the prime and the back-up) provided separate hardware to simultaneously copy information to both greatly reducing the network communications load.

Three efforts to weld repair a crack in the temperature control valve body of receiver panel #15 were unsuccessful. The valve body was replaced.

Another effluent water line failure was experienced in its original (PVC) portion. The line was repaired promptly. It is expected that similar future failures will be avoided after the installation of the attemperation system which will operate to reduce the temperature of the hot blowdown water in the PVC section of the line.

Miscellaneous receiver repairs performed in July included:

a. Replacement of temperature control valve bonnet gaskets in panels #5, #6, #11, and #19.

b. Repacking of all temperature control valves.

c. Replacement of prefilter flange gaskets in panels #5, #10, and #20.

d. Repair of body leaks in panels #5 and #10 prefilters.

(A summary of the receiver panel #18 tube failures is given elsewhere in this document, see Table of Contents.)

August

Solar One operation was severly impacted during August due to a long weather outage and a plant outage to repair receiver tube leaks. Three receiver boiler panel tube leaks were repaired and the plant returned to service on August 23. The net energy production for the month, while connected to the grid, was 234.7 MW-h; however, on a 24-hour basis the plant consumed more energy than it generated in August. This is the first month since April '83 that this has occurred.

Operational Highlights--All major plant systems were secured on August 3 for an extended outage to implement receiver tube inspection and leak repairs. The receiver tube leak repairs were completed on August 19, and the operational activity was resumed on the same day for condensate and receiver feedwater clean up. Solar One returned to normal operation on August 23, 1983 after the State Inspector had certified the weld repairs.

The meter constant on the backup auxiliary power source, 4KV well water line, was found to be in error during the receiver outage. At this time the plant was transfered from the primary auxiliary power source, 33KV "bug" line, to the backup source to minimize the plant's exposure to area lightning strikes. Correction of station records in August to reflect the correct electrical meter constant in all previous months resulted in a 362 MWe-h reduction in auxiliary power consumption and consequently increased Solar One's net output by the same amount, (corrected values are included in this report.)

The Operational Control System (OPS) check out and acceptance testing was partially completed in mid-August. Following the acceptance testing, control engineers and operators were trained on building graphics using the Plant Operational Display System (PODS). Present plans are for operators to develop their own operational displays as they previously accomplished on the Beckman subsystem controls and for McDonnell Douglas control engineers to continue development of the host computer software.

Maintenance Highlights--The heliostat field was rain-rinsed early August. Reflectivity measurements taken following the rainfall indicated an average of 95% mirror cleanliness (approximately 86% average reflectivity of the collector field).

Tumbleweeds were removed from the 130 acre plant site to reduce the number of rattlesnakes and to provide ready access to heliostat junction box and controller. Selected collector field sections were left undisturbed to aid in the UCLA/LBES (University of California, Los Angeles/Laboratory of Biomedical and Environmental Sciences) studies regarding the reestablishment of desert vegetation under normal plant operation.

An attemperation system was installed on the PVC portion of the plant effluent water line. The attemperator regulator was set at 100 degrees F and will operate to reduce the temperature of the hot blowdown water to prevent PVC line failures due to thermal expansion.

There were 1810 of 1818 heliostats (99.6%) available for service on August 5th. The previous record was 1805 on March 28, 1983.

The 15th level of the receiver tower was modified to help rainwater drain. This modification eliminates water damage to the Remote Station One Receiver Electronics Room. Additionally, the deck coating was removed and replaced with three layers of a new water resistant roof-type coating, and the 3 inch receiver vent was relocated from the east to the west side of the tower to eliminate water from cascading onto the Remote Station One roof during start-up venting of the receiver.

The Thermal Storage System (TSS) water and steam sample lines were routed to the chemical lab. This rerouting ensures better TSS feedwater chemical control and consequently results in the use of higher purity water since instrumentation will soon be provided to continuously monitor parameters such as cation and straight conductivity and pH.

Miscellaneous receiver maintenance work accomplished during this period included:

a. Replacement of bonnet gaskets of the temperature control valves in receiver panels 6, 8, 14, 19, 20 and 21.

b. Packing adjustment of the temperature control valve in receiver panels 6, 8 and 14 and the receiver ring header inlet valve.

<u>September</u>

Operations at Solar One were again this month severely impacted due to 131 hours of weather outage. Accordingly, power production was limited but sufficient to ensure another positive output month--99.8 MWe-h net. The net energy production for the month, while connected to the grid, was 496.4 MWe-h.

<u>Operational Highlights</u>--On September 6, the receiver operation was hindered due to water chemistry analytical instrumentation malfunction. Investigation revealed that the standardizing pH electrode (combination type) had failed resulting in erroneous readings. The faulty electrode was replaced and the water quality control was reestablished. Because the combination electrodes have a very short life span and their accuracy decreases with use, they are not very suitable for continuous pH monitoring. Consequently, the standardizing electrode was replaced by the more common and reliable separate reference and glass electrode set.

Leaks in the turbine-generator bearing cooling water at an estimated rate of 29 gpm resulted in abnormal consumption of the cooling water treatment chemicals. Uranine dye, phosphorescent green color, aided in the leak detection. The leaks were found to occur at the generator air cooler relief valves, which were subsequently repaired and reset to relieve at a 10 percent system overpressure.

Testing of a new overnight plant shutdown scheme, Mode 8, began in September. In Mode 8, all major plant systems are secured and all condensate and feedwater equipment is blanketed with nitrogen, rather than steam, for oxygen protection. Data related to nitrogen consumption, parasitic load reduction, auxiliary steam usage reduction, and water quality during start-ups were collected to determine the feasibility of adopting this procedure as a normal overnight plant shut down.

Automatic collector field start-ups were successfully conducted during early morning and mid-day. The heliostat field received and properly executed commands issued by the Operational Control System (OCS) to track the sun during both clear and partly cloudy conditions.

Fifteen mirror modules, which contained water and displayed high amounts of corrosion, were fitted with one or more test vents and a humidity sensor. Five different venting configurations were used to determine the most effective one in drying out the modules. The selected venting arrangement will be used in the near future for venting all early production mirror modules.

Southern California Edison was authorized to operate the plant in Mode 2, i.e., parallel receiver/turbine and thermal storage charging operation.

Maintenance Highlights--A two-day fire protection equipment inspection was performed. The fire detectors at certain locations were found to be unfit for the application, and it was decided that these detectors had to be replaced with less sensitive ones to avoid unnecessary alarming due to the dusty environment existing in the warehouse and switchgear rooms.

Difficulty in maintaining the turbine on turning gear has recently been experienced. Since disassembling of the turning gear is required, the work will be accomplished during a two-week turbine inspection outage tentatively scheduled for January 1984.

Miscellaneous maintenance work accomplished during September included:

a. Replacement of bonnet gaskets in temperature control valves of receiver panels 15, 16, and 20.

b. Replacement of receiver flowmeters in panels 4 and 19.

c. Replacement of receiver prefilter gaskets in panels 6, 7, 14, 16, and 17.

d. Replacement of the rupture disk in the oil side of charging train #2.

e. Retorquing of the head flange bolts of charging train #2 condenser.

f. Installation and routing of the thermal storage system sample lines to the chemical lab.

g. Installation of a 30 psi air pressure regulator and filter assembly at the local service air outlet, to facilitate the safe unloading of the bulk concentrated sulfuric acid and sodium hydroxide.

h. Replacement of three deteriorated receiver flux sensors in panels 9, 10, and 19.

i. Installation of a turbine type flowmeter at the steam inlet of the thermal storage charging system to improve flow measurement accuracy.

j. Replacement of the failed 5 volt power supply to the operational control system.

October

Power generation in the month of October was consistent with the previous nine month average. The energy transmitted to the SCE electrical grid was 98.2 MWe-h with a record of lowest auxiliary energy consumption since April 1982, of 441.2 MWe-h. The net energy production for the month, while Solar One was connected to the grid, was 453.7 MWe-h.

A new receiver tube leak was discovered and repaired during October. Ultrasonic inspection revealed two additional cracks similar to those previously experienced. Repairs of the tube cracks will take place during a two-week outage scheduled for December.

Operational Highlights--The Beam Characterization System (BCS) was released to SCE for operation. The system evaluates beam pointing accuracy of individual heliostats, and through the automation program, modifies the alignment of up to thirty heliostats per day. Problems still remain with this system's operation with the Heliostat Array Controllers (HAC's) and the investigation of the problem continues.

Heliostat Array Controller (HAC) failovers, prime to backup, have been reduced some by changes in the HAC software. The problem was aggravated by the operation of the HAC/BCS, Beam Characterization System, or HAC/OCS, Operational Control System, computer to computer interfaces.

Review of past receiver operating data found that the receiver metal temperatures change rapidly, as much as 400 degrees F during cloud transients, unit trips, and normal plant shutdowns. A new receiver shutdown procedure has been developed to moderate thermal transients during normal receiver shutdowns.

A failure of the sodium hypochlorite timer/pump controller caused higher than normal concentrations of chlorine (16 ppm) in the circulating water. The abnormal condition was promptly corrected.

The collector field was rain washed on October 1st. Aside from washing the collector field manually using a conventional insulator wash truck, this is the best alternative for maintaining the collector field cleanliness.

The plant was forced to remain shut down on October 21 because of silica contamination in the unit's make-up water due to premature exhaustion of the rental make-up demineralizer. The maximum allowed silica concentration in the make-up water is 20 parts per billion.

A receiver ultrasonic inspection on selected panels followed by a hydrostatic leak test, on October 26, revealed a leak on tube 41 (panel 12) similar to the leak previously experienced on tube 41 (panel 18). The leak was ground and weld repaired two days following its discovery. Ultrasonic inspection on October 27 found an internal 20 mil deep crack on tube 1, panel 18. Visual inspection at the same time revealed an additional crack on tube 41, panel 13. It was decided to postpone the repair of the two new cracks until the two-week plant outage scheduled for December of this year. However, a program was established to monitor the crack growth by ultrasonic inspections at two week intervals. The weld repair on tube 41, panel 12 was approved by a state inspector on October 31.

The thermal storage system automatic shutdown sequence for the charging trains was completed and released to SCE. This sequence also allows for quick steam transition to steam dump or the turbine as soon as the last charging train is taken out of service.

Maintenance Highlights--The inline demineralizer sluice water pump suction and discharge piping was modified to increase the pump's flow capacity. Flow restricting diaphragm valves were replaced with gate valves and the excessive number of pipe fittings was eliminated. Prior to the above modifications each pump delivered approximately 28 gpm compared to its rated capacity of 55 gpm. Pump capacity testing after the modifications indicated that the flow was well above 55 gpm. This increase will definitely improve the inline demineralizer's performance since adequate flow will be available for rinsing and backwash of the resin during the resin's regeneration process.

The oil strainers at the extraction train #2 boiler and superheater inlets were inspected for pluggage. Both strainers were found free of debris, which indicates the absence of oil oxidation.

SCE Division Maintenance personnel developed and qualified a weld procedure for the receiver Incoloy 800 tube repairs. Station welders are currently being trained using the above weld procedure and will be certified to perform such repairs. The in-house capability of receiver tube leak repairs will ensure promptness in repairing future tube failures.

Miscellaneous maintenance work accomplished during October included:

1. Replacement of leaky flowmeter in receiver panel 4.

2. Replacement of charging trains, one and two, steam flowmeters (tag numbers 3205 and 3705).

3. The cross-tie valve between the thermal storage unit's steam and auxiliary steam systems, PV-1005, was removed and sent to the manufacturer for trim modifications. The new trim will allow for more steam flow to the deaerator during start-ups to ensure positive receiver feedwater deaeration.

4. The internals of the check valve at the PV-1005 bypass line were removed to allow for steam flow to the auxiliary steam system in the absence of PV-1005.

5. The thermal storage system flash tank rupture disk was replaced with a disk with higher ductility to avoid premature disk failures that were experienced in the past.

6. The extraction train one steam flowmeter, Tag #3715, was removed from service due to faulty operation. The flowmeter, although properly installed, was found to have its shaft bent opposite to the direction of the flow. A blind flange was installed in its place until flowmeter design changes are complete.

7. A leak at the top vent valve of receiver panel 19 was repaired.

8. Several leaking inspection plugs on receiver panels 18 and 23 were repaired.

9. The fire detector sensors in the warehouse were replaced with less sensitive ones to allow for the dusty environment.

10. The charging train #1 oil side condenser head flange bolts were retorqued to eliminate minor oil leakage.

11. The inline demineralizer acid transfer pump motor failed due to acid attack at its shaft. The motor was removed and the acid is temporarily gravity transferred to the acid day tank pending motor replacement.

November

Inclement weather precluded significant power production. The gross energy production was 203.5 MWe-h while the auxiliary energy consumption was 498.5 MWe-h. The net energy production while Solar One was on line was 166.7 MWe-h. Test activities generally concentrated on thermal storage system automation to include the parallel operation of two charging and two extraction trains.

Operational Highlights--Plant testing continues to minimize plant parasitic power consumption. During inactive periods, the plant's parasitic power consumption is normally 500 KW. The power consumption during the tests was reduced to as low as 300 KW by breaking condenser vacuum allowing shut down of additional auxiliary equipment. This method of inactive operation, however, was accompanied by high condensate and feedwater dissolved oxygen during the following morning's start-up.

The plant trip logic was revised to ensure complete receiver temperature control valve closure on a plant trip or on collector field defocus. It is hoped the positive valve closure will prevent excessive panel stress due to liquid water quenching of these panels consequent to water flow through the temperature control valve when energy is removed from the receiver.

The turbine/generator first phase automation sequence was developed and tested during November. With the automation, the steam pressure control can be transitioned from the receiver to the turbine and back to the receiver through the operation of two enable switches. The automation includes loading and unloading of the turbine/generator based on available insolation.

Mode 6, Thermal Storage System extraction steam to turbine, was released to SCE for unrestricted operation on November 16.

Dye penetrant tests on selected receiver panels performed on November 1st, revealed cracks at the interstitial welds of panel #12 between tubes 30/31 and tubes 40/41. In addition, receiver ultrasonic inspection on November 16 revealed internal cracks at the top bends in tube 1 (panel 18) and tube 70 (panel 11). Both of these types of failures were previously experienced. The repairs of the tube bend cracks were scheduled during the two-week plant outage beginning December 5. The repairs of the interstitial weld cracks performed were scheduled for January 1984.

Maintenance Highlights--All receiver panel temperature control valves, including three receiver vent valves, were tested for leakage. Three of eighteen control valves and two vent valves were determined to be leaking. In addition, the majority of the control valves did not respond to low signal outputs.

A four foot longitudinal crack with a six inch long leak was experienced on the fire main line adjacent to the diesel pump house. The leak was temporarily repaired pending arrival of replacement material.

The plant effluent water line developed a leak at its original PVC section. The leak was promptly repaired.

Miscellaneous maintenance work performed during November included:

1. Repair of a bonnet leak of the receiver panel 24 drain valve.

2. Replacement of the receiver panel 4 flowmeter gasket.

3. Repairs of two inspection plugs on each of the receiver panels 5 and 7.

4. Repairs of flange leaks at the charging train steam inlet control valve.

5. Installation of new trim at the temperature control valve of receiver panel 8. The new trim improved measurement accuracy at low flow conditions.

6. Replacement of the drain valve at the steam supply line to the Thermal Storage System desuperheater (DS 301).

7. Replacement of the auxiliary electric boiler drain valve.

8. Replacement of a leaky gasket at the Thermal Storage System (TSS) charging train #1 steam inlet valve (AOV-3206).

9. A small fire, with no effect on equipment, resulted from oil leakage at the TSS extraction valves 3905, 3906, and 3920. The valve flange bolts were tightened to stop leakage.

December

Power production and plant testing were impacted by inclement weather and a scheduled two week plant outage. The gross energy output was 59.9 MWe-h while the auxiliary power consumption for the month was 416.8 MWe-h. The net energy generation while Solar One was on line reached 48.9 MWe-h.

Operational Highlights--A two week scheduled outage went into effect December 5 to remove samples from and repair the receiver panel edge tube cracks. All receiver tube repairs were completed on schedule and repairs were approved by the State Inspector. Solar One returned to operation on December 17. The interstitial weld cracks were scheduled for repair during January 1984.

Receiver panel absorptivity measurements indicated some degradation of the "pyromark" paint, a high absorptivity coating by approximately 2% per year.

Receiver ultrasonic inspection of all panel edge tubes that had not previously been inspected was completed in the beginning of the outage and no additional tube cracks were found.

Moon tracking, a heliostat computer operation similar to suntracking, was successfully tested on December 19th and 20th. During the tracking operation, which lasted for four hours on the 20th, the receiver assumed a ghost-like silverish glow; however, as expected, no temperature changes on the receiver were experienced. Moon tracking will be used for "no heat" flux measurement experiments, to facilitate flux mapping on the receiver during non normal working hours and to identify heliostats significantly out of alignment.

Several attempts to run the winter solstice test were unsuccessful due to inclement weather. The goal was to operate Solar One at 10 MW net power level at 10:00 a.m. or 2:00 p.m.

Ethylene glycol, antifreeze, was added to the Bearing Cooling Water System to prevent water from freezing during the low temperatures that are frequently experienced in the area. The concentration of the antifreeze used will provide system protection down to 10 degrees Fahrenheit.

Calibration of instrumentation like the receiver thermocouples, the Special Heliostat Instrumentation and Meteorological Measurements System (SHIMMS), as well as the Data Acquisition Remote Multiplexing System (DARMS), took place during the outage.

A General Electric Company factory representative was on site during the outage period for turbine controller modifications. Following the repairs, testing of the turbine roll sequence on admission steam revealed that the high sensitivity problem with the speed controller has been corrected. Data were collected during the test and were sent to G.E. for evaluation.

<u>Maintenance Highlights</u>--The second point feedwater heater was suspected of having tube leaks due to previously experienced high pressure levels in the shell side. The heater was inspected during the December outage and three tube leaks were discovered. The leaks were caused by weld cracks between the tubes and their seal weld to the tube sheet. In the process of repairing these tube leaks, two additional leaks developed. It was decided that the failures were due to a manufacturing defect and no further attempt was made to repair the new leaks. The heater problem will be further investigated during the next two week outage scheduled for January 1984 in the manufacturer representative's presence. At this point, the heater tube pluggage is 5.5%.

The main steam to auxiliary steam desuperheater DS-902 spray water supply line was modified to prevent receiver system contamination in the event of condenser inleakage. Condensate downstream of the inline demineralizer will now be used for steam attemperation. In the original design, the spray water supply was immediately downstream of the condensate pump discharge.

The circulating water winterizing line, i.e., circulating water return which bypasses the cooling tower, was modified to discharge away from the suction of the north circulating water pump to prevent cavitation due to turbulence at the pump inlet.

The cooling tower was shut down for an annual inspection according to the manufacturer's recommendation. The louvers and fill were freed from accumulated scale and the basin was drained and cleaned.

The connecting bolts of twelve receiver panel support rollers were found broken. Inspection of the rollers indicated that this was a result of seizing of the rollers onto their axles. A considerable amount of corrosion was also found on both rollers and studs, which may have caused the seizing. The rollers and studs were repaired or replaced. A regular inspection of the first three levels of rollers began after the incident.

Heliostat 1851 was taken out of service on December 23 due to an unusual failure. The cause was the failure of the limit switch to stop the elevation drive motor.

Miscellaneous maintenance work accomplished during the month of December including work performed during the outage period is as follows:

1. Replacement of the level indicator and a manhole gasket in the electric auxiliary boiler.

2. Replacement of flowmeters in receiver panels 4, 5, and 6 with lower capacity ones to improve measurement accuracy at low flows.

3. Installation of new insulation panels at the top and bottom of the receiver; work performed by the Metalclad Company.

4. Replacement of the west tubrine lube oil pump bearings.

5. Replacement of nine degraded receiver heat flux sensors.

6. Restroking of all receiver temperature control valves.

7. Installation of new trim in receiver vent valves tag numbers 2903 and 2007. During a previous inspection the vent valves were found to be leaking through.

8. Replacement of the check valve at the caustic transfer pump discharge.

9. Replacement of the heat tracing on the caustic transfer line.

10. Replacement of charging train one condensate return valve (PV3110).

11. Replacement of the 2nd point feedwater heater shell side vent valves.

12. Replacement of the flowmeter rotor in the charging train steam inlet. The old rotor was missing from the turbine style steam flowmeter.

13. Replacement of the bonnet gasket in the receiver steam main outlet valve UV2905.

14. Replacement of the elevation motor in heliostat 1122.

15. Reinstallation of the crosstie valve between auxiliary steam and thermal storage steam system (PV1005).

APPENDIX A - MONTHLY O#M

COST SUMMARIES

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF JANUARY 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	21.3	-	.3	1.3	22.2
OPERATIONS	45.5	22.1	-	0.1	67.7
MISC. NONPRODUCTIVE COST	4.7	0.7	2.2	2.7	10.3
MAINTENANCE					
Supervision/Indirect	7.4	5.6	0.3	0.6	13.9
Control System	3.9	2.5	1.8	-	8.2
Receiver System	0.5	-	-	-	0.5
Thermal Storage System	1.0	0.6	0.5	8.6	10.7
Collector System	1.1	-	0.2	-	1.3
EPGS System	2.3	1.7	2.5	1.3	7.8
Miscellaneous	4.4	1.2	6.5	9.2	21.3
Total Maintenance	20.6	11.6	11.8	19.7	63.7
SUB TOTAL	92.1	34.4	13.7	23.8	163.9
Division O.H.					13.9
TOTAL DIRECT					177.8
Workmen's Compensation					.8
Payroll Tax					6.3
Pension & Benefits					17.5
Administrative & General					30.8
GRAND TOTAL					233.2

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF FEBRUARY 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	24.6	0.4	-	3.5	28.5
OPERATIONS	56.5	0.1	-	0.1	56.7
MISC. NONPRODUCTIVE COST	4.6	0.2	2.9	0.6	8.3
MAINTENANCE					
Supervision/Indirect	9.7	2.6	0.5	1.1	13.9
Control System	5.3	9.7	5.0	-	20.0
Receiver System	1.8	-	8.8	0.3	10.9
Thermal Storage System	3.8	0.5	8.5	0.2	13.0
Collector System	3.2	-	-	-	3.2
EPGS System	3.6	5.3	8.3	0.3	17.5
Miscellaneous	2.8	2.1	1.5	0.1	6.5
Total Maintenance	30.2	20.2	32.6	2.0	85.0
SUB TOTAL	115.9	20.9	35.5	6.2	178.5
Division O.H.					20.5
TOTAL DIRECT					199.0
Workmen's Compensation					1.0
Payroll Tax					8.2
Pension & Benefits					22.6
Administrative & General					36.6
GRAND TOTAL					267.4

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF MARCH 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	11.6	-	.1	1.2	12.9
OPERATIONS	55.4	18.6	-	5.5	79.5
MISC. NONPRODUCTIVE COST	4.0	-	3.1	.7	7.8
MAINTENANCE					
Supervision/Indirect	8.3	1.8	1.4	1.4	12.9
Control System	8.0	2.3	2.5	-	12.8
Receiver System	1.2	-	-	-	1.2
Thermal Storage System	1.9	.2	18.7	.2	21.0
Collector System	1.9	-	-	-	1.9
EPGS System	2.9	1.9	-	-	4.8
Miscellaneous	3.7	.6	.8	-	5.1
Total Maintenance	27.9	6.8	23.4	1.6	59.7
SUB TOTAL	98.9	25.4	26.6	9.0	159.9
Division O.H.					20.4
TOTAL DIRECT					180.3
Workmen's Compensation					.9
Payroll Tax					7.7
Pension & Benefits					21.2
Administrative & General					35.6
GRAND TOTAL					245.7

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF APRIL 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	16.8	.3	-	1.3	18.4
OPERATIONS	53.0	11.4	-	1.1	65.5
MISC. NONPRODUCTIVE COST	.9	.1	4.5	3.1	8.6
MAINTENANCE					
Supervision/Indirect	9.1	3.5	1.6	.1	14.3
Control System	8.3	6.7	2.8	-	17.8
Receiver System	2.4	-	-	-	2.4
Thermal Storage System	1.7	2.1	6.8	.1	10.7
Collector System	1.9	.1	.2	-	2.2
EPGS System	5.5	1.7	.2	.3	7.7
Miscellaneous	4.0	1.1	6.1	1.8	13.0
Total Maintenance	32.9	15.2	17.7	2.3	68.1
SUB TOTAL	103.6	27.0	22.2	7.8	160.6
Division O.H.					21.6
TOTAL DIRECT					182.2
Workmen's Compensation					.9
Payroll Tax					6.9
Pension & Benefits					21.2
Administrative & General					33.1
GRAND TOTAL					244.3

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF MAY 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	30.5	-	.1	.3	30.9
OPERATIONS	84.7	2.7	-	1.1	88.5
MISC. NONPRODUCTIVE COST	8.5	-	3.6	1.5	13.6
MAINTENANCE					
Supervision/Indirect	17.1	1.7	1.6	.1	20.5
Control System	10.5	1.9	2.2	-	14.6
Receiver System	3.6	-	2.7	-	6.3
Thermal Storage System	3.4	.2	.1	.2	3.9
Collector System	3.8	-	-	-	3.8
EPGS System	7.4	.1	-	-	7.5
Miscellaneous	3.1	2.0	.2	-	5.3
Total Maintenance	48.9	5.9	6.8	.3	61.9
SUB TOTAL	172.6	8.6	10.5	3.2	194.9
Division O.H.					34.9
TOTAL DIRECT					229.8
Workmen's Compensation					1.5
Payroll Tax					11.8
Pension & Benefits					36.0
Administrative & General					42.9
GRAND TOTAL					322.0

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF JUNE 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	19.7	-	-	1.4	21.1
OPERATIONS	66.0	23.0	-	.4	89.4
MISC. NONPRODUCTIVE COST	6.7	1.4	1.7	1.6	11.4
MAINTENANCE					
Supervision/Indirect	13.8	.9	.3	-	15.0
Control System	8.1	6.5	2.6	-	17.2
Receiver System	5.1	-	-	-	5.1
Thermal Storage System	3.4	.5	.9	.6	5.4
Collector System	4.2	.2	-	-	4.4
EPGS System	5.1	.8	-	-	5.9
Miscellaneous	2.6	.7	.5	.3	4.1
Total Maintenance	42.3	9.6	4.3	.9	57.1
SUB TOTAL	134.7	34.0	6.0	4.3	179.0
Division O.H.					21.6
TOTAL DIRECT					200.6
Workmen's Compensation					1.1
Payroll Tax					8.8
Pension & Benefits					26.9
Administrative & General					38.1
GRAND TOTAL					275.5

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF JULY 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	16.8	.3	.3	.1	17.5
OPERATIONS	52.2	7.7	-	.1	60.0
MISC. NONPRODUCTIVE COST	6.2	.5	1.6	2.6	10.9
MAINTENANCE					
Supervision/Indirect	10.1	1.5	.3	-	11.9
Control System	8.2	1.9	-	.1	10.2
Receiver System	1.8	-	.8	.1	2.7
Thermal Storage System	2.9	.1	.8	-	3.8
Collector System	1.2	-	-	-	1.2
EPGS System	4.8	1.2	-	-	6.0
Miscellaneous	4.5	1.8	1.5	.3	8.1
Total Maintenance	33.5	6.5	3.4	.5	43.9
SUB TOTAL	108.7	15.0	5.3	3.3	132.3
Division O.H.					17.8
TOTAL DIRECT					150.1
Workmen's Compensation					.9
Payroll Tax					7.3
Pension & Benefits					22.2
Administrative & General					28.7
GRAND TOTAL					209.2

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF AUGUST 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	18.6	.1	-	.8	19.5
OPERATIONS	51.4	12.5	-	.4	64.3
MISC. NONPRODUCTIVE COST	5.5	.5	3.9	1.6	11.5
MAINTENANCE					
Supervision/Indirect	9.5	2.7	.1	.2	12.5
Control System	5.8	1.2	7.9	-	14.9
Receiver System	9.5	.1	-	-	9.6
Thermal Storage System	.9	(2.8)	12.5	.2	10.8
Collector System	2.5	1.7	-	-	4.2
EPGS System	2.6	2.6	5.1	-	10.3
Miscellaneous	5.4	2.4	1.7	.7	10.2
Total Maintenance	36.2	7.9	27.3	1.1	72.5
SUB TOTAL	111.7	21.0	31.2	3.9	167.8
Division O.H.					17.9
TOTAL DIRECT					185.7
Workmen's Compensation					.9
Payroll Tax					7.3
Pension & Benefits					22.3
Administrative & General					35.4
GRAND TOTAL					251.6

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF SEPTEMBER 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	20.6	.1	-	.6	21.3
OPERATIONS	52.1	2.5	-	-	54.6
MISC. NONPRODUCTIVE COST	5.5	-	3.0	2.0	10.5
MAINTENANCE					
Supervision/Indirect	8.6	2.1	-	.3	11.0
Control System	4.8	3.0	2.5	-	10.3
Receiver System	4.2	1.9	.3	-	6.4
Thermal Storage System	3.6	4.0	.3	-	7.9
Collector System	3.2	.8	-	-	4.0
EPGS System	3.1	.8	.1	-	4.0
Miscellaneous	5.1	.2	11.0	.4	16.7
Total Maintenance	32.6	12.8	14.2	0.7	60.3
SUB TOTAL	110.8	15.4	17.2	3.3	146.7
Division O.H.					17.6
TOTAL DIRECT					164.3
Workmen's Compensation					.9
Payroll Tax					6.9
Pension & Benefits					21.3
Administrative & General					29.3
GRAND TOTAL					222.7

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF OCTOBER 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	22.8	-	-	3.0	25.8
OPERATIONS	73.8	11.7	-	.1	85.6
MISC. NONPRODUCTIVE COST	9.0	-	1.3	1.8	12.1
MAINTENANCE					
Supervision/Indirect	16.6	1.4	-	.3	18.3
Control System	6.3	1.8	2.3	-	10.4
Receiver System	5.6	-	-	.1	5.7
Thermal Storage System	2.3	.3	.8	.3	3.7
Collector System	3.9	.5	.2	-	4.6
EPGS System	5.1	1.8	-	-	6.9
Miscellaneous	6.9	2.1	9.7	1.1	19.8
Total Maintenance	46.7	7.9	13.0	1.8	69.4
SUB TOTAL	152.3	19.6	14.3	6.7	192.9
Division O.H.					26.2
TOTAL DIRECT					219.1
Workmen's Compensation					1.3
Payroll Tax					10.2
Pension & Benefits					31.2
Administrative & General					41.9
GRAND TOTAL					303.7

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF NOVEMBER 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	8.6	-	.5	1.1	10.2
OPERATIONS	47.6	10.6	-	-	58.2
MISC. NONPRODUCTIVE COST	4.6	-	4.3	1.6	10.5
MAINTENANCE					
Supervision/Indirect	11.5	3.5	.1	.1	15.2
Control System	8.7	.2	3.3	-	12.2
Receiver System	1.6	.1	-	-	1.7
Thermal Storage System	1.2	1.9	-	-	3.1
Collector System	.2	-	-	-	.2
EPGS System	2.4	2.9	-	-	5.3
Miscellaneous	4.3	.8	.9	1.5	7.5
Total Maintenance	29.9	9.4	4.3	1.6	45.2
SUB TOTAL	90.7	20.0	9.1	4.3	124.1
Division O.H.					15.6
TOTAL DIRECT					139.7
Workmen's Compensation					.8
Payroll Tax					6.0
Pension & Benefits					18.4
Administrative & General					26.3
GRAND TOTAL					191.2

SOLAR ONE

MONTHLY O&M COST SUMMARY
($ X 1000)

MONTH OF DECEMBER 1983

	LABOR	MATERIAL	CONTRACT	OTHER	TOTAL
FIELD OFFICE	12.9	.2	.3	1.1	14.5
OPERATIONS	55.9	10.9	-	.1	66.9
MISC. NONPRODUCTIVE COST	5.3	-	1.6	1.9	8.8
MAINTENANCE					
Supervision/Indirect	13.2	1.6	-	(.1)	14.7
Control System	6.8	2.0	.3	-	9.1
Receiver System	8.1	3.6	-	-	11.7
Thermal Storage System	1.3	1.0	3.3	-	5.6
Collector System	.4	.7	-	-	1.1
EPGS System	5.7	2.8	-	-	8.5
Miscellaneous	5.0	(1.5)	1.6	6.0	11.1
Total Maintenance	40.5	10.2	5.2	5.9	61.8
SUB TOTAL	114.6	21.3	7.1	9.0	152.0
Division O.H.					19.8
TOTAL DIRECT					171.8
Workmen's Compensation					1.0
Payroll Tax					7.6
Pension & Benefits					23.4
Administrative & General					32.4
GRAND TOTAL					236.2

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