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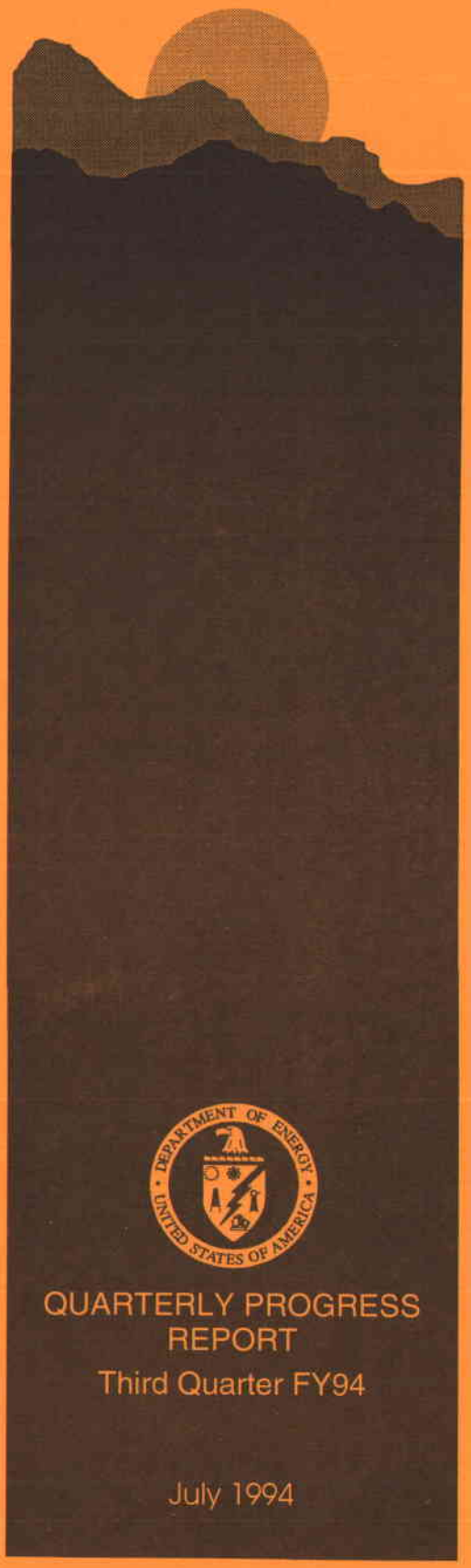


QUARTERLY PROGRESS REPORT

Third Quarter FY94

July 1994

Sandia National Laboratories

Sandia National Laboratories
Albuquerque, New Mexico

NREL

National Renewable Energy Laboratory
Golden, Colorado

SUMMARY OF ACCOMPLISHMENTS: THIRD QUARTER FY94

Significant progress toward program goals and objectives was made during the quarter. Following are selected highlights. Details can be found in the main body of the report.

Solar Two

- Bechtel completed Phase 2, Development of Major Bid Packages, of the Solar Two Project.
- Solar Two is approximately 60% complete and 70% of the equipment awards have been made.
- Contracts have been placed for all major systems: receiver (Rockwell), thermal storage tanks (Pitt-Des Moines), steam generators (ABB Lummus), nitrate-salt pumps (Borg-Warner, Lawrence Pump & Engine).
- Demolition/removal of the Solar One thermal storage system was completed.

Dish/Engine Joint Venture Programs

- SAIC has defined the design specifications for the next generation of their faceted stretched-membrane dish. The dish will have 16 facets; the focal length will be 9 to 10 meters.
- Cummins Power Generation's (CPG's) Clever Fellows Innovation Consortium engine has experienced technical difficulties.
- CPG is providing power to the West Texas Utility Grid with a free-piston Stirling engine.
- CPG completed the preliminary design of their Utility Scale Joint Venture Program concentrator.
- CPG has made significant progress in the fabrication of their hybrid heat pipe and now expects to begin natural gas testing in July and on-sun testing in August 1994.

System Operation and Maintenance (O&M) Cost Reduction

- A new solar pump seal has been developed.
- Optimized maintenance planning and mirror reflectance studies continue.
- Solar Electric Generating Systems O&M planning systems were eviewed by the Solar Two Project.

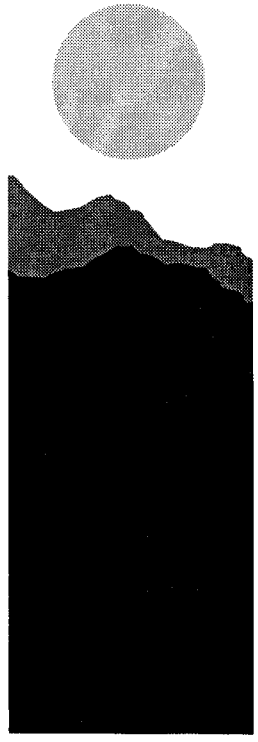
Concentrator Technology

- A request for proposal, *Heliostat Manufacturing for Near-Term Markets,* was released as the first solicitation under the Solar Manufacturing Technology (SolMaT) Inititative.
- A proposed collaborative cost-shared subcontract for *Advanced Reflector Materials Research and Development* with NREL and Industrial Solar Technology (IST) is underway.
- IST initiated a commercial solar heat project using ECP-305+ as the reflective surface for a parabolic trough. If the project proceeds, it will mark the first commercial deployment of ECP-305+.
- NREL and Monsanto Co. research resulted in a new candidate coating for solar reflector materials.
- NREL and vacuum deposition companies interaction has resulted in new candidate solar reflector materials.
- NREL and CPG jointly installed and activated meteorological monitoring equipment and deployed candidate reflector material samples at an outdoor exposure test site.
- A report documenting the status of NREL's outdoor testing activities was completed.

Power Conversion Technology

- Photometers have been integrated into the Solar Two receiver design.
- Nitrate salt component testing continues to support Solar Two with the testing of a ball valve.
- A felt-metal wick has demonstrated excellent performance in a bench-scale reflux receiver.
- CPG and Thermacore have accumulated more than 1500 hours on-sun on a single receiver, and more than 1350 hours on another receiver in a solar simulator.
- Additional pool-boiler on-sun testing has improved hot-restart confidence.
- The STC hybrid pool-boiler receiver demonstrator was successfully tested on-sun at NREL.
- Phase 2 of the Northern Research and Engineering project to solarize and test a Brayton cycle power conversion system was initiated.
- On-sun testing continues on the Detroit Diesel/Stirling Thermal Motors STM4-120-based power conversion system.
- NREL solicited feedback from stakeholders on the potential of the new combined cycle/power tower (CC/PT) concept and discussed how to proceed with development.
- NREL is exploring Design for Manufacturing Assembly (DFMA), a Hughes Electronics manufacturing technology that involves teaming during early stages of new product development cycles.

TABLE OF CONTENTS



INTRODUCTION

A need for new electric generating capacity, a heightened awareness of the environmental impacts associated with energy generation and use, and increased attention to energy efficiency will lead to a greater demand for solar thermal electric (STE) and other alternative energy technologies in the years ahead.

To date, over 350 MW_e of STE systems have been installed in the United States, representing over 90% of the world's installed solar capacity. This power meets the needs of over 350,000 people and annually displaces the energy equivalent of 2.3 million barrels of oil. In addition, key cooperative joint ventures representing 50/50 cost share between the federal government and the private sector have been established for power tower, parabolic dish/engine, and parabolic trough technologies. These joint ventures, valued at more than $150 million, strengthen the partnership among industry, utilities, and users. They are some of the current steps being taken to reduce levelized energy costs from solar thermal electric plants to between 6 and 10 cents per kilowatt-hour, thus leading to direct competition with conventional technologies.

OUR VISION

Our vision for solar thermal electric technology is the large-scale acceptance and installation of U.S.-designed and -manufactured solar thermal electric systems operating worldwide by the year 2000. We expect to realize this vision through a coordinated program of joint venture projects, technology development and validation, and market conditioning.

OUR MISSION

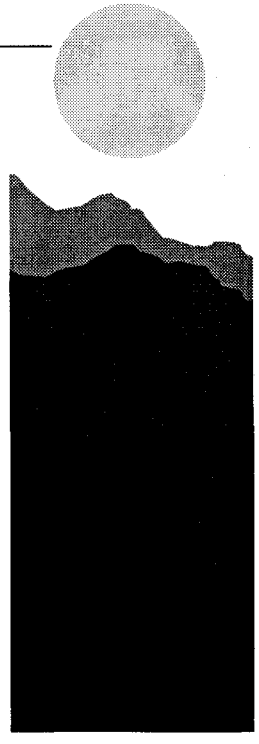
The mission of the Solar Thermal Electric Program is to work with current and potential manufacturers and users of solar thermal electric technology and to conduct research for technology development and validation to

- increase acceptance of this technology as a candidate for cost-competitive modular power generation by utilities, industry, and manufacturer/user groups, both in the United States and abroad,
- develop reliable and efficient solar thermal electric systems for generation of economically competitive power that can contribute significantly to the national energy mix and thereby reduce dependence on imported energy sources, and
- aggressively support the development of the industrial base required for this technology to penetrate the various energy applications and markets, creating new jobs and business opportunities for U.S. industry.

OUR STRATEGY

The Solar Thermal Electric Program strategy is consistent with the objectives set forth by the Office of Solar Energy Conversion in *Solar 2000—A Collaborative Strategy.*[1] The Department of Energy (DOE) and its field laboratories (Sandia National Laboratories and the National Renewable Energy Laboratory) will

- increase, through the following cooperative ventures, industrial participation in both the planning and execution of the following program elements:
  - — The Solar Two molten-salt power tower project led by Southern California Edison will provide the technical base for Solar 100, the first 100-MW power tower module.
  - — The Cummins Engine Company 7-kW_e dish/Stirling system, designed for both remote and grid-connected applications, will be operated at utility and industrial sites.



[1] *SOLAR 2000, A Collaborative Strategy*, Office of Solar Energy Conversion, United States Department of Energy, Washington, DC, February 1992.

— Science Applications International Corporation and Cummins Engine Company contracts awarded under the Utility-Scale Joint-Venture Program for 25-kW_e dish/Stirling, will result in at least 1 MW of dish/engine system capacity installed by utilities.

— The operations and maintenance cost reduction study with the Kramer Junction Company will provide for lower levelized energy costs for power tower and dish/engine solar systems as well as trough plants.

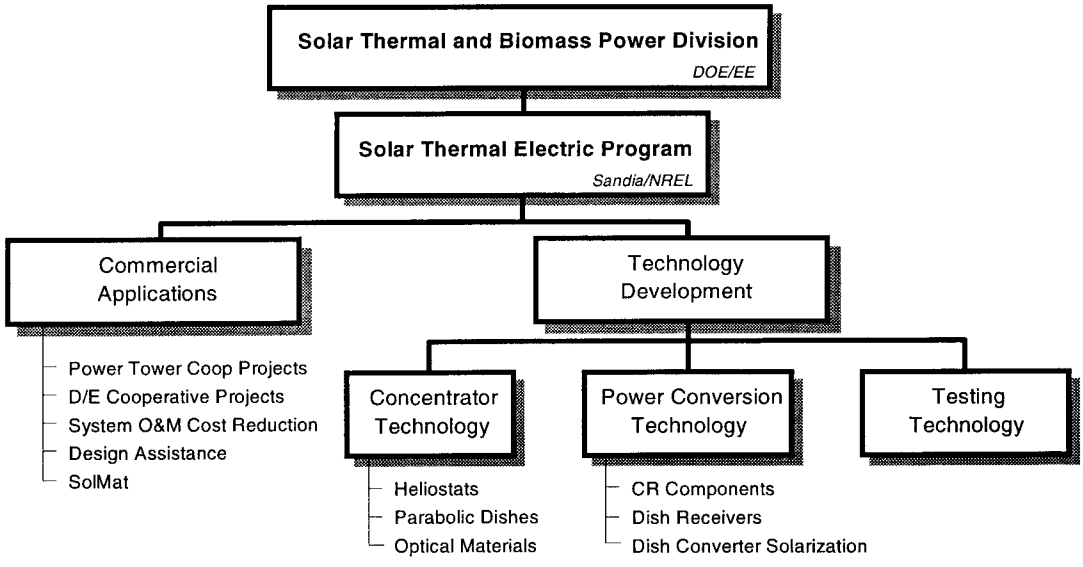
- utilize the analytical and experimental capabilities of the program to support and enlarge the technology's user, supplier, and decision-making constituency
- contribute to the DOE's Office of Energy Efficiency and Renewable Energy's goal of making solar thermal electric technology a viable option for both the domestic and international power-generation markets

The DOE's role in implementing the program strategy centers on the development of improved cost effectiveness and reliability of solar thermal electric components and the development of additional energy markets with high strategic or economic value to U.S. industry. This balanced approach to technology development and validation, coupled with joint-venture projects and market conditioning, will introduce essential technological improvements while allowing industry to acquire the production experience to further lower cost. Implementation of this strategy relies on the following: (1) opportunities for research to identify and prove solar electric generation concepts for trough, power tower, and dish components and processes; (2) technology development to translate research into useful prototypical hardware; and (3) industry interaction through technical assistance and joint-venture projects to validate and commercialize the technology.

This report describes the progress made during the third quarter of FY94 toward acceptance of solar thermal electric technology as a serious candidate for cost-competitive electric power generating options by utilities, industry, and other manufacturer/user groups.

OUR MANAGEMENT STRUCTURE

Specific implementation of the Solar Thermal Electric Technology Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the National Renewable Energy Laboratory in Golden, Colorado. Sandia National Laboratories is the Program's lead laboratory. Together, these two field laboratories are responsible for implementation of the research and development plans that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts placed with private industry, other research organizations, and universities.



I. COMMERCIAL APPLICATIONS

The Solar Thermal Electric Program emphasizes two major categories of modular solar thermal technology: power towers (central receiver systems) and parabolic dish/engine systems. These two types of systems can satisfy utility needs for capacities ranging from a few kilowatts up to 200 MW. The program also supports existing parabolic trough collector systems for the purpose of operation and maintenance (O&M) cost reduction. The 354 MW of installed trough capacity represents $1.2 billion of capital equipment and an invaluable source of information regarding solar electric power plant operating experience. Much of this experience is appropriate for power tower and dish/engine system operations.

The program emphasizes cost-shared activities where there is significant industrial involvement in the planning and execution of the activities. These government/industry partnerships represent teams that are uniquely qualified to rapidly advance each technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of the government laboratories. Presently, five major 50/50 cost-shared cooperative activities are underway within the program with a total value of $100 million. The following organizations are the private sector leaders of these joint activities:

A. **Southern California Edison and a consortium of other utilities and industry (power towers)**

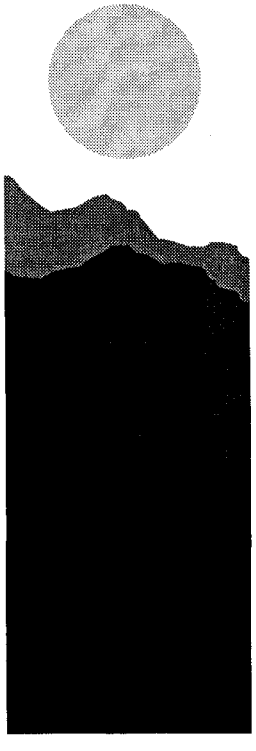
B. **Cummins Power Generation and Science Applications International Corporation (dish/engine systems)**

C. **KJC Operating Company (system operation and maintenance cost reduction)**

A. POWER TOWER COOPERATIVE PROJECTS

The goal of this project is to advance the near-term commercialization of solar power tower electricity generating facilities. The systems for a power tower plant have been proven through testing and analysis. The next step in the commercialization of the technology is to design, construct, and operate a demonstration plant of a size that is large enough to reduce the risks (technological and economic) of building the first commercial plant to acceptable levels.

A consortium of U.S. utility concerns led by Southern California Edison Company (SCE) is conducting a cooperative project with the U.S. Department of Energy (DOE) and industry to convert the 10-MW_e Solar One Central Receiver Pilot Plant to utilize molten-nitrate-salt technology. Successful design, construction, and operation of the converted plant, to be called Solar Two, will reduce the economic risks of building the initial commercial power tower projects and accelerate their commercial acceptance. Joining SCE and the DOE in sponsoring this project are the following organizations: Los Angeles Department of Water and Power, Idaho Power Company, PacifiCorp, Sacramento Municipal Utility District, Arizona Public Service Company, Salt River Project, City of Pasadena, California Energy Commission (CEC), Electric Power Research Institute (EPRI), South Coast Air Quality Management District, Bechtel Corporation, and Rockwell International. Sandia chairs the project's Technical Advisory Committee and supports the DOE in technically monitoring the project. The Solar Two Project will convert the Solar One heat transfer system from water/steam to molten nitrate salt by replacing the water/steam receiver and oil/rock thermal storage systems with a nitrate-salt receiver, thermal storage, and steam generator. The estimated cost of Solar Two, including its 3-year test period, is $48.5 million. The plant is expected to be on line in 1995.



Accomplishments

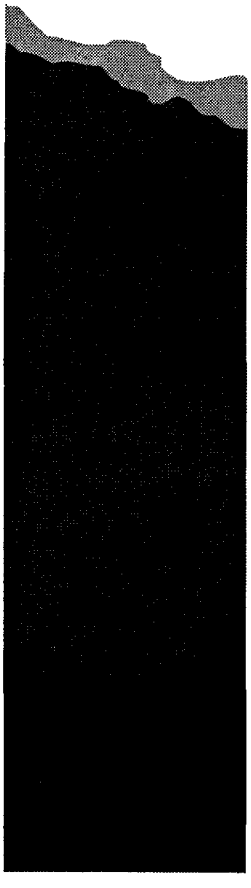
The major accomplishment this quarter is the selection of vendors for all the major subsystems, including the receiver, thermal storage system, steam generator, and salt pumps.

Progress continues on the Solar Two Project

The Project is well into the third of six phases and remains on schedule and within budget. Overall engineering is approximately 60% complete and 70% of the equipment awards have been made, including the receiver (Rockwell), thermal storage tanks (Pitt-Des Moines), and steam generators (ABB Lummus). Phase 3, Detailed Design/Equipment Fabrication, will be completed this October, at which time initial site construction work will begin. Startup and checkout are scheduled to begin in July 1995, followed by start of the test and evaluation phase in January 1996.

At the June 23 Steering Committee meeting in Boise, Idaho, Mark Skowronski, SCE Project Manager, reported that total Project funding remains slightly below required levels since the withdrawal of Pacific Gas and Electric last fall. The Project currently has total funding of $47.136 million, of which $43.936 million is firm. Construction is still projected at $39.5 million and the 3-year operation and maintenance phase is estimated at $9 million. SCE continues to seek additional project participants, with Bureau of Reclamation, Edison Electric Institute, Nevada Power, Science Applications International Corporation (SAIC), and SoCal Gas Co. as possible new participants.

Southern California Edison Company and its contractors completed demolition and removal of the Solar One thermal storage system. More than 98% of the removed materials were recycled. Final environmental surveys have been conducted and SCE considers the task successfully completed.



Technical Advisory Committee continues to support the Solar Two Project

The Solar Two Technical Advisory Committee (TAC), chaired by Sandia, continues to support the Solar Two Project at the request of the Project Manager. A quarterly meeting of the Solar Two TAC was held in San Francisco, California, on June 8, 1994; information on the Project status, schedule, and engineering were presented. The evaluation of eliminating the heliostat additions and the Test and Evaluation plan were also discussed in detail. Twenty-five people attended the meeting, including representatives from most Participants, Contributors, the Engineering and Construction Manager, the DOE, Sandia, and other consultants.

The key issue at this meeting was the results of the cost/benefit evaluation, requested by the Steering Committee, of the planned heliostat field modifications and additions. The results of the evaluation, conducted and presented by Jim Chavez (Sandia) and Doug Morris (EPRI) indicate that eliminating these changes would only buy two to three extra months of plant operation. Moreover, the evaluation concluded that the Solar Two Project goals and objectives can only be met if the field modifications and additions are implemented as originally planned. After a lively discussion on the topic, the TAC voted unanimously to recommend to the Steering Committee that the Project keep the field modifications and heliostat additions. The Steering Committee agreed with the TAC's recommendation at their June 23 meeting.

Three TAC subcommittee meetings were held this past quarter at the request of the Solar Two Project Manager. Subcommittee meetings were held to discuss the plans for test and evaluation of the plant, to review the Piping and Instrumentation Diagrams (P&IDs), and to review the specifications for the master control system.

Bechtel Corporation hosted a meeting May 9 and 10 to continue planning the test and evaluation phase of the Solar Two project. The meeting was attended by project personnel from EPRI, Sandia, and Bechtel, including the manager of Bechtel's plant startup organization. Over the past year, Sandia has worked closely with Bechtel to develop a draft test and evaluation plan. One of the primary elements of the draft plan is an identification of the total plant instrumentation and data acquisition requirements. Meeting participants addressed the next element of the plan by developing a preliminary list of the specific tests and evaluations that will be performed at Solar Two. This effort builds on recent discussions of the overall goals and objectives of Solar Two and translates them into specific tests. One of the outcomes of the meeting was a list and description of each test in an agreed-upon format. This preliminary list will be presented to the Solar Two TAC for their review, comments, and additions.

The TAC subcommittee meeting to review the P&IDs was held on May 9-11, 1994 at Bechtel's offices in San Francisco. The purpose of this meeting was to "walk-through," with Bechtel, the P&IDs for the electric power generation system, the steam generator system, the thermal storage system, and the receiver

system. Representatives from Sandia, SCE, PacifiCorp, Salt River Project, and an outside consultant participated in the review. A number of issues that ensure the safe and efficient operation of the Solar Two Project were uncovered in the review.

The third TAC subcommittee meeting was the review of the specification for the master control system. The Solar Two Project Manager wanted the specifications reviewed by the TAC prior to sending them out for bid. Representatives from Bechtel, SCE, Sacramento Municipal Utility District, Arizona Public Service Company, and Sandia attended the review meeting. The entire master control process and plans for procurement were discussed. During the meeting, Bechtel received a number of worthwhile comments that will improve the chance of high quality, complete proposals for the master control system.

Sandia will continue to assist the Solar Two Project Team with technical reviews of all specifications and designs, input on nitrate-salt instrumentation and components, and technical information on current test results at Sandia. Seven additional TAC subcommittee meetings are scheduled through the end of Phase 3.

Project to study SEGS 1 energy flows is canceled

The study to evaluate the energy flows at the Solar Electric Generating Systems (SEGS) 1 solar power plant has been canceled because a confidentiality agreement could not be reached between the Sandia contractor, Hank Price and Associates of Denver, Colorado, and the Dagget Leasing Corp., operators of SEGS 1.

Collector field maintenance and heliostat assessment

Sandia continues to support the maintenance and assessment of the collector field at Solar Two and to evaluate "new" heliostats for Solar Two. This is discussed in the Concentrator Technology/Heliostat section (Section II.A.1).

Sandia supports DOE/GFO in evaluating the *Solar Two Challenge* proposals

The DOE and Project Participants initiated the *Solar Two Challenge*, an intercollegiate competition in which teams will design, construct, and operate small-scale, working, solar thermal central receiver models. Teams will set up and operate their models December 2-4, 1994, at the Solar Two site. Prize money is $25,000 for first place and $10,000 and $5,000 for second and third places, respectively. Nine design proposals were received by the June 24 due date. A proposal review team comprised of Solar Two Participants, plus Sandia and the National Renewable Energy Laboratory (NREL), reviewed the proposals. The review team met at SCE on July 12, 1994, to compile final proposal scores and develop for each proposer a concise list of comments concerning adherence to the contest guidelines. Judging by the proposals, the school teams are putting an impressive effort into designing their models and have come up with a good variety of approaches and design optimizations.

Study of tax equity issues continues

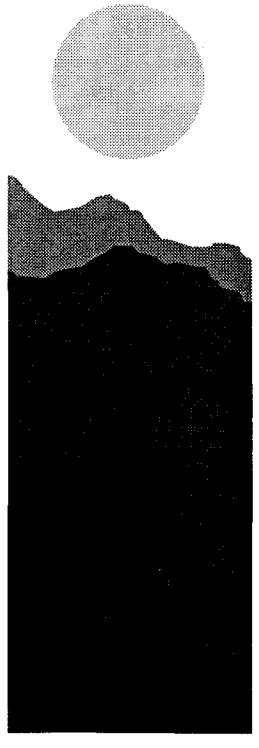
National Power Company has run their modified cash flow model for a number of solar thermal plants under a variety of taxation scenarios. This analysis supports a Sandia-sponsored study of tax equity issues associated with investor-owned solar thermal power projects. The study is being conducted jointly with the California Energy Commission and coordinated with other efforts at the CEC and NREL.

This quarter National Power ran fossil power plant cases; compared the taxes paid by the fossil plants to comparable solar thermal trough and central receiver plants; and completed the study by designing a "tax equalization" case under which the solar and fossil plants pay equal taxes.

A report has been drafted and is being reviewed by Sandia.

Planned Activities for Next Quarter

- Continue to support SCE's efforts to complete the Solar Two consortium of utilities, industry, and regulatory agencies.
- Continue to support the DOE in the technical monitoring of this Project.
- Complete Phase 3, Detailed Design/ Equipment Fabrication.
- Initiate Phase 4, Plant Construction.
- Attend the next full TAC meeting, scheduled for August 30, 1994. Attend the next Steering Committee meeting, scheduled for September 14, 1994.
- Attend a meeting of the Test and Evaluation and Performance Subcommittees that will be held July 28, 1994.
- Complete review of the Tax Study Report.



Major Milestones

Milestone	Planned	Actual
Complete Phase 1, Systems Engineering, of the Solar Two Project.	Oct 93	Oct 93
Complete removal of the Solar One Thermal Storage System.	Jan 94	Mar 94
Complete Phase 2, Development of Major Bid Packages, of the Solar Two Project.	Apr 94	Mar 94

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	540	0	0	540
Contracts	0	0	7260	7260
Total	540	0	7260	7800

B. DISH/ENGINE COOPERATIVE PROJECTS

The objective of the dish/engine cooperative projects is to commercialize dish/engine solar thermal electric systems. The approach is to form joint ventures with industry, utilities, and other users.

The Dish/Stirling Joint Venture Program (DSJVP) with Cummins Power Generation, Inc. (CPG), underway since 1991, will develop a 7.5-kW dish/Stirling system primarily for remote application. Two new Utility Scale Joint Venture Program (USJVP) contracts with Science Applications International Corp. (SAIC) and CPG will develop 25-kW dish/Stirling systems for utility application. These are discussed separately below.

DSJVP Accomplishments

The primary objective of the Dish/Stirling Joint Venture Program is the commercialization of the CPG 7.5-kW_e dish/Stirling System for remote power applications by the mid-1990s. The DSJVP is a 5-year, $17-million effort. The Cummins-led industrial consortium and the U.S. Department of Energy are each cost-sharing approximately 50% of the total program costs. During the final phase of this program, production-level dish/Stirling systems will be field tested at the following host test sites: AT&T, Georgia Power Company, Arizona Public Service, and Nevada Power Company.

CPG solid-state conditioning and control system operational

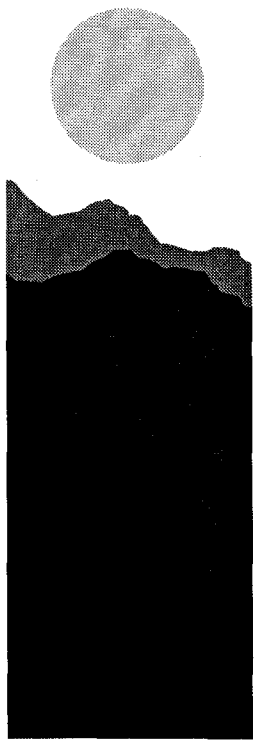
A new solid-state electric-power conditioning system was used to condition power from the Sunpower free-piston Stirling engine/linear alternator operating on-sun and supply power to the utility grid. To our knowledge, **this is the first time that solar generated electric power from a free-piston Stirling engine has been supplied to a utility grid.** The solid state conditioning and control (SSC&C) system was developed by CPG for the CPG 7.5-kW_e dish/Stirling system. During testing, the CPG SSC&C system supplied 6 kW_e to the Texas Utility grid while operating on sun, and 9.75-kW_e while operating off of one leg of the utility grid and providing power to another leg. Total harmonic distortion was approximately 2-3% and efficiency was over 90%. The efficiency design goal of 95% appears to be achievable following some minor modifications. The CPG SSC&C will permit operation of the free-piston Stirling engine at any frequency, can be used to produce clean 3-phase AC power, and accommodates relatively inexpensive AC motors (compared to the DC motors currently used in the water pump system). CPG has continued to durability test the SSC&C throughout the quarter using grid power input. Fabrication of additional units has been initiated.

CPG single-board computer controller operational

The CPG single-board computer became operational early in the quarter on the newly installed "southwest" dish at the CPG Abilene, Texas, test site. The new computer controller features a real-time embedded executive programmed in C++ to provide engine and receiver control, concentrator control, system protection, and data acquisition oversight. The new controller is mounted in a cabinet on the dish platform, and replaces as many as four computers used in the past. The dish tracking algorithms are based on the ones used in the Sandia-developed *Solartrak Solar Array Tracking Controller*. These algorithms enable the dish to determine misalignment parameters after one day of on-sun tracking. This feature also minimizes the precision and cost of foundations and installation.

CFIC free-piston Stirling engine development experiences technical difficulties

Cummins Power Generation Inc. has experienced problems in achieving adequate performance and continuous operation of the Clever Fellows Innovation Consortium (CFIC) free-piston Stirling engine. The maximum continuous output from the CFIC engine/alternator to date has been about 5-kW_e at approximately 21% thermal efficiency. Total engine run time has been about 60 hours. A flow distribution problem near the hot end of the regenerator has been identified as an issue. Sandia is bringing its thermodynamic, heat transfer, and fluid flow capabilities to bear on this problem. Modifications required to improve performance to over 7-kW_e and 30+% efficiency will probably not be implemented until Phase 3. Thermal expansion mismatch problems in the regenerator have also been problematic and have limited the number of operational hours. While CPG expects to resolve these problems relatively soon, the scheduled October 1994 Phase 2 completion is in jeopardy.

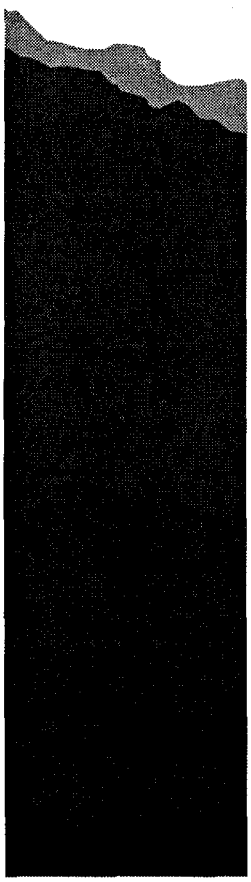


Manufacture of five CPG PCUs continues

Despite problems in achieving continuous and efficient performance of the CFIC free-piston Stirling engine/linear alternator, Cummins Power Generation Inc. is continuing to expedite the manufacture of five new power conversion units (PCUs) to assure that hardware is available when the engine/alternator problems have been resolved. CPG's current schedule calls for four system deliveries in September and October of this year. As of the end of the quarter, parts manufacture of the five engines was 90% complete. (Some of the parts may need replacement pending resolution of performance and durability issues). Assembly of the critical heater head/heat pipe was completed and assembly of all five alternators was about 50% complete. CPG expects to run the first of the five new engines by August.

CPG/Thermacore durability heat-pipe solar receivers keep going and going

Cummins Power Generation Inc. and Thermacore have continued to durability-test heat-pipe solar receivers, on-sun and in Thermacore's new test facility in Lancaster, Pennsylvania. **At the end of the quarter, approximately 1500 hours had been accumulated on-sun and at temperature on the "northwest" CPG-460 in Abilene, Texas.** All three dishes in Abilene are being operated sunrise to sunset seven days per week. In addition, round-the-clock testing of a full-scale durability heat-pipe solar receivers was continued during the quarter. The facility, which uses quartz lamps, is capable of delivering over 30 kW_t through a receiver. The durability test plan calls for four hours at temperature, turning off power until the sodium in the receiver freezes, and then turning the power back on. Thermacore is able to accumulate approximately 110 hours at temperature per week in the facility. Following some difficulties with the quartz-lamp array, Thermacore was finally able to achieve reliable operation. **By the end of the quarter, over 1300 hours at temperature had been accumulated on the quartz-lamp durability receiver.** The Thermacore durability heat-pipe solar receiver on the CPG-460 solar concentrator at the California State Polytechnic University (Cal Poly) test site has accumulated over 900 on-sun hours at operating temperature and is being operated sunrise to sunset six days per week.



Nickel wick mechanical properties under evaluation at Sandia

In support of the DSJVP, an effort is underway to determine the strength requirements of a Thermacore-type thick nickel wick Our present focus is on determining the wick's creep and fatigue behavior. The creep behavior will be incorporated into a model that will be used with the fatigue data to predict wick failure. High-temperature creep testing of nickel-wick samples has just begun at Ad Tech (Beaver Creek, Ohio). At Sandia, fatigue-testing hardware has been assembled and test protocols and software are being developed. A second wick sample is being prepared from new Thermacore Inc. wick samples made from a new powder.

CPG/Thermacore heat-pipe receiver progresses

Cummins Power Generation Inc. has made significant progress in the fabrication of their hybrid heat pipe during the quarter. A major bottleneck has been machining of the outer heat pipe cylindrical wall but that has now been completed. A mandrel for the gas-fired wick was completed; however, the mandrel did not release properly after the sintering process. A modified mandrel has been built and the gas-fired wick will be resintered in early July. With the exception of resintering the gas-fired wick, most of the subassemblies have been completed for the heat pipe and are waiting final assembly. CPG now expects to begin natural gas testing in July and on-sun testing in August.

Sandia/NREL provide optical materials technical support to DSJVP

Sandia and the National Renewable Energy Laboratory (NREL) continued to provide optical materials support for the DSJVP. Sandia is working with CPG on the implementation of thin-glass mirrors for the CPG facets. NREL is providing weatherometer testing, reflectivity and SHOT measurements, and design assistance for the internal CPG efforts to develop high-performance plastic films. **NREL also provided CPG with significant quantities of 3M ECP-305+ film for field evaluation.** During the quarter, Sandia's order with Naugatuck Glass Company for 60-inch diameter thin-glass (1-mm thick) mirrors arrived at CPG broken into little pieces.

DSJVP Planned Activities for Next Quarter

- CFIC and CPG will build the first of the five new engine/alternators.
- CPG and Sandia will perform limits tests on a test bed concentrator of a Thermacore heat-pipe receiver.
- Sandia will flux map two CPG-460 solar concentrators in Abilene, Texas.
- Thermacore will initiate testing of a hybrid heat-pipe solar receiver.
- CPG plans to deliver systems to Cal Poly and Georgia Power.

SAIC USJVP Accomplishments

The objective of the Utility-Scale Joint-Venture Project is to develop 25-kW_e dish/Stirling systems for use in utility markets. The Energy Projects Division of Science Applications International Corporation's in Golden, Colorado, leads a team comprising Stirling Thermal Motors of Ann Arbor, Michigan, and Detroit Diesel of Detroit, Michigan, and several utility partners. SAIC is the systems integrator and will also develop the solar concentrator, the second-generation faceted stretched-membrane dish. STM will provide their kinematic Stirling engine, and Detroit Diesel is responsible for engine testing and mass-production engine design considerations. The $17.6-million contract is a 50/50, 3-year, cost-shared activity between the design team and the DOE (Sandia) for Phases 1 and 2 of the project, Proof of Concept and Pre-Production Prototype Development. If the first two phases of the project are successful, then SAIC and Sandia will enter into negotiations for Phase 3, the deployment at utility sites of 1-MW of dish/Stirling systems.

Dish concentrator design completed

The next-generation of the faceted stretched-membrane dish design has been completed and all major components are being fabricated or procured. The dish will have 16 facets and an increase in the focal length from 9 to 9.95 meters. The gear drive for the dish will be a Carrisa Plains Flenders drive. The control system for the dish in Phase 1 will be a programmable logic controller to allow for ease of changing algorithms and control strategies. Standardization of the design of many structural elements is intended to result in a simplified concentrator design with reduced fabrication costs.

The only concentrator-related fabrication problem is the delayed delivery of the glass for the optical surface of the concentrator. Because of additional time allotted in the schedule, this is not expected to impact the installation of the dish at the test site in late October.

Phase-1 solar PCS completed

Of the initial five engines to be tested in Phase 1 of the project, two engines have been completed and most of the parts for the remaining three have been fabricated and/or procured. The plan is to test the Phase 1 solar power conversion system (PCS) in a gas-fired mode at STM and to perform endurance and forced testing on the remaining four engines in STM's test facility. Five more engines will be fabricated and tested later in Phase 1.

The solar engine includes a direct insolation receiver, a new hydraulics block, a redesigned front oil sump and cooler, and the oil-lubrication system design has been improved to operate over a wider range of elevation angles. The following are some of the areas that have been addressed in improving the PCS design:

- Operating Experience at Sandia has resulted in a simplified cooling system and support structure; control system upgrades; and revised component packaging to allow for ease of service and maintenance.
- Solar PCS redesigned to replace three copper/brass radiators with two off-the-shelf Harrison brazed aluminum radiators; cooling fan replaced with larger, standard design; coolant pump capacity increased; new helium valve supplier; improved cycle/crankcase pressure relief valve; structural frame simplified for pedestal mount; receiver cavity formed from single, molded component; electrical wiring/harness simplified; control system modified.
- The direct insolation receiver (DIR) has been improved by implementing mass-production-level fabrication techniques. These include precision tube bending, non-destructive testing inspection techniques, improved castings, and vacuum brazing of the final assembly. A fabrication of the bent tubing has been located and their product evaluated and incorporated in the design.

Systems test site selected

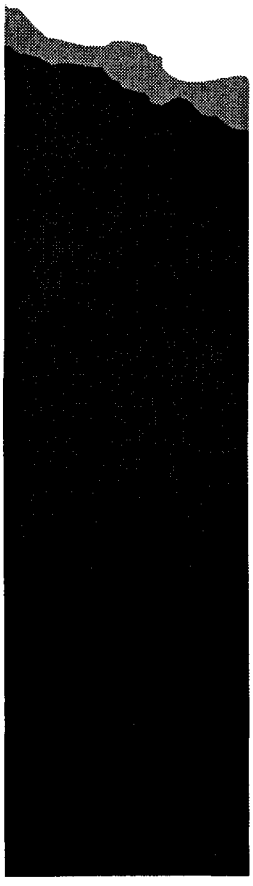
The test site for the Phase 1 system has been selected at the Jefferson One Research Center, located approximately 10 miles north of SAIC's Golden, Colorado, office. The site layout has been defined and building permits are in process.

SAIC USJVP Planned Activities for Next Quarter

- Complete acquisition of all dish hardware and start assembly.
- Complete a failure modes and effects analysis.
- Test the solar PCS in the gas-fired configuration.
- Develop a system field test plan.
- Proceed with hybrid and alternate receiver designs.

CPG USJVP Accomplishments

The baseline design for the USJVP concentrator was selected during this quarter. Cummins Power Generation Inc. will be developing a totally new design with a parabolic mirror and employing an azimuth/elevation drive system. The parabolic mirror will be constructed from glass/metal gore sections that will be placed on a space frame. To address the manufacturing issues associated with making the glass/metal panels (or gores), CPG is negotiating with Solar Kinetics, Inc. (SKI), which developed metal gore sections under contract to Sandia in the late 1980s.



Preliminary design work on the concentrator is well under way. Detailed stress analyses of candidate space frame geometries have been performed, and a baseline geometry has been selected. In addition, a baseline geometry for the mirror panels has been selected that has a low specific weight and should be cost effective.

Design work on the CFIC 30-kW_e Stirling engine has not yet begun because of difficulties that have arisen with the 7.5-kW_e CFIC engine that is under test in the DSJVP. It is anticipated that design work on the engine will commence very early in the next quarter.

Preliminary design work on the control system is underway. The design to be used in the USJVP will draw extensively from the DSJVP control system. The major difference that is anticipated between the two control systems is the the USJVP will employ distributed controls.

CPG USJVP Planned Activities for Next Quarter

- Continue design of the baseline solar concentrator.
- Begin design of the 30-kW_e CFIC Stirling engine. (This has been delayed until nominal operation of the 7.5-kW_e CFIC engine is achieved in the DSJVP.)
- Continue design of the 90-kW_{th} Thermacore heat pipe receiver.
- Continue design of the 30-kW_e NREC Brayton engine.
- Continue design of the 100-kW_{th} DLR volumetric receiver.
- Begin design of the Stirling engine cooling system.
- Begin design of the solid-state control and conditioning system.

Major Milestones

Milestone	Planned	Actual
Award USJVP contracts to SAIC and CPG.	Dec 93	Jan 93
Install a CPG "C" dish/Stirling system at Cal Poly.	Dec 93	Dec 93 (dish only)
Award a USJVP contract to HEA, subject to contract negotiations. *(Negotiations underway; award delay until fall is likely).*	May 94	
Operate a CPG "D" dish/Stirling system in Abilene, Texas. *("D" systems have been delayed ~2 mo.)*	Jun 94	
Install a CPG "D" dish/Stirling system at Georgia Power.	Jul 94	
Install a CPG "D" dish/Stirling system at Cal Poly.	Aug 94	
Conduct Phase 2 review of the DSJVP. *(Now planned for Sept.)*	Aug 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	900	50	0	950
Contracts	4950	0	500	5450
Total	5850	50	500	6400

C. SYSTEM OPERATION AND MAINTENANCE COST REDUCTION

The nine Solar Electric Generating System (SEGS) power plants located in Southern California are the only utility-scale solar power plants currently operating in the world, with an existing capacity of 354 MW. The costs associated with operating and maintaining (O&M) solar thermal plants have a significant influence on the economic viability of the technology. For example, O&M costs account for greater than 20% of the SEGS electricity costs. Reductions in O&M costs would enhance the marketability of solar thermal technologies currently being developed by the Department of Energy (DOE). An example of a DOE technology that would benefit is the Solar Two demonstration project and commercial power tower plants. Power tower plants have many of the same subsystems contained within a SEGS plant, and the O&M of these subsystems would be similar.

The goal of this project is to reduce O&M costs associated with utility-scale solar thermal power plants. This is being accomplished by characterizing O&M costs incurred at the SEGS plants during more than 40 plant-years of operation. Research and development is then performed to reduce the cost of the most important categories. The assessment of the important categories at SEGS plants indicated that roughly ***two-thirds were applicable to O&M at power tower plants****. This guarantees that this initiative will benefit current solar thermal technology (SEGS troughs) as well as future technology (power towers). The project is being performed on a 50/50 cost share basis between owners of the SEGS plants (primarily U.S. utilities and major investment firms) and Sandia. A significant portion of Sandia's cost share is being contributed through in-kind technical support. The contract was established with Kramer Junction Company Operating Company (KJC) in July 1992. The work to be performed during the 3-year project was described in the Third Quarterly Report FY92. The progress made during the present quarter is described in the following paragraphs.*

Accomplishments

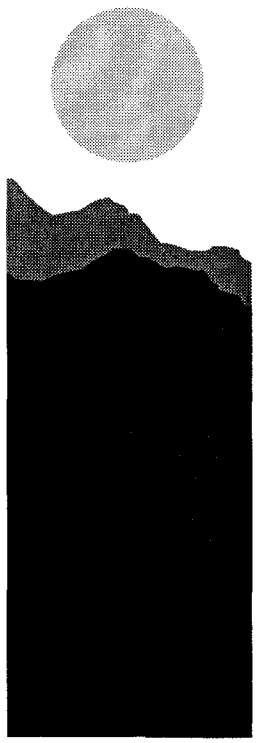
New solar pump seal developed

The pumps that circulate the oil-based heat transfer fluid (HTF) to the solar field have experienced many seal failures at SEGS III through V over the past several years and have been a significant contributor to maintenance costs. In an attempt to remedy the problem, a new type HTF seal was installed on a SEGS V pump in 1993. The seal is a double-bellows Borg-Warner mechanical seal, offering expectations of better sealing and increased durability. For the 12 months prior to the new installation, the seal on this pump failed 42 times at a materials and labor cost of about $250,000. When accounting for the loss of electricity production, the cost is even higher. In addition to the installation of the new seal, a heat exchanger was added to the pump coolant loop to maintain the seal at a lower operating temperature and the pump suction pressure was raised to increase the net positive suction head to the pump. Finally, the pressure was re-balanced between this pump and another operating in parallel. As a result of all these changes, pump cavitation was virtually eliminated and the seal has performed without failure for almost one year. This new seal is now being implemented on another pump at SEGS III.

Optimized maintenance planning continues

With the advent of the personal computer age, U.S. utilities are beginning to rely upon a multitude of newly developed software products to streamline their maintenance planning activities. These software products bring together such activities as the master equipment list, equipment reliability histories, work order system (both corrective and preventative), purchase orders, stock issue requests, manpower planning and scheduling, inventory accounting, warehouse management, and all tracking for accounting purposes.

During the present quarter, state-of-the-art maintenance planning software (MPAC, by System Works) became fully operational at the Kramer Junction, California, power park and will be utilized for all future routine O&M operations and yearly plant overhauls. Incorporation of this planning tool into the KJC organization is one of the largest and most monetarily intensive tasks within this O&M Cost Reduction Program. The steps taken to fully implement this new way of doing business has been described extensively in previous quarterly reports. It is expected that maintenance costs will be reduced by approximately 20% over the next few years after the plant staff becomes completely familiar with it and optimizes its use.



Improving solar field reflectance

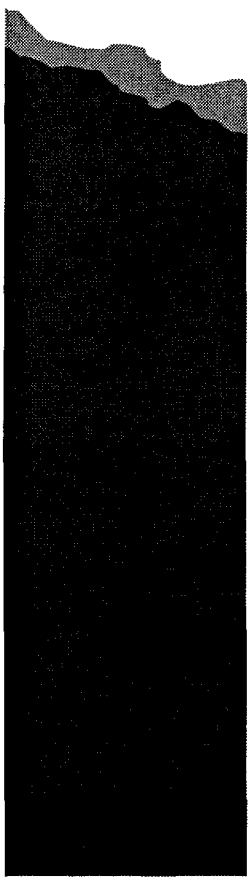
A program of increased reflectivity measurements on solar field mirrors has been

put in place following satisfactory test experience with the new Microscan reflectometer developed by Sandia (reflectometer was first described in Third Quarter FY93 report). This data will allow a more extensive and accurate evaluation of mirror-washing effectiveness. Initial data indicates that previous reflectance measurements at Kramer Junction, with the old Devices and Services reflectometer, were too optimistic; actual field reflectance was probably lower than originally estimated.

Near the cooling towers at several plants, mirrors are especially dirty because of condensation of minerals that are present in the tower plume (called "drift"). It was found that one cooling tower had a sizable open air path that increased the drift above the design rate. To quantify this problem, pieces of mirror (approximately 100 samples) have been attached to mirrors around the cooling tower and a reflectivity degradation test is being performed. About one half of these mirrors are being tested with a commercial anti-soiling product known as Invisible Shield. In addition, a cooling tower expert is providing recommendations on solution of the cooling tower problem.

SEGS O&M planning systems reviewed by Solar Two Project

Because of the many similarities among the systems and between the operation and maintenance capabilities of parabolic trough and power tower plants, the O&M Cost Reduction Project provides consultation to the Solar Two Project on a regular basis. During June, a meeting was held at Kramer Junction to review the O&M planning systems recently developed as part of the O&M project. The purpose of the meeting was to help define O&M planning needs for Solar Two and to get comments on the new software from the solar thermal community.



KJC and Sandia organized the meeting and invited Solar Two personnel from Bechtel, Electric Power Research Institute, and Sandia. The group was exposed to recent advancements in O&M planning software including MPAC, FRACAS, and Computerized Operator Logs (OPLOG). MPAC is the software KJC uses to plan maintenance in the balance of plant (see discussion in previous section). FRACAS is used by maintenance personnel for solar field activities. The OPLOG software is used by operations to track power production, production losses, as well as other performance and reliability information. On-line demonstrations were given.

Bechtel and the Electric Power Research Institute were impressed with the capabilities of the planning software and found it to be much improved over that used at Solar One. The information received at the meeting will help Bechtel formulate the request for quotation for the O&M subcontract at Solar Two.

Planned Activities for Next Quarter

- Complete documentation for the interim report.
- Hold a mid-term project review meeting at Kramer Junction.
- Establish a subcontract to upgrade solar field maintenance planning system.
- Commence a study of fugitive emissions from heat transfer oil.
- Continue to provide lessons learned to Solar Two Project.

Major Milestones

Milestone	Planned	Actual
Document FY93 O&M Cost Reduction Activities.	Oct 93	Dec 93
Implement O&M evaluation and analysis software on site network.	Apr 94	Jun 94
Complete the final report describing progress made in FY94.	Sep 94	
Complete documentation of historical frequencies and causes of equipment outages at Kramer Junction.	Oct 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	88	30	0	118
Contracts	782	0	100	882
Total	870	30	100	1000

D. DESIGN ASSISTANCE

The objective of this subtask is to accelerate the use of solar thermal systems through cooperative efforts with private industry by assisting and educating potential users, and by supporting industry and users in the selection, design, characterization, and demonstration of promising solar thermal systems. These efforts include direct technical assistance to users; testing, evaluation, and technology development; and education and outreach.

The Solar Thermal Design Assistance Center (STDAC) activities reported here are supported by (1) the Solar Thermal Electric Program, (2) the Solar Industrial Program, or (3) both programs. They are reported together for completeness and in recognition of the fact that boundaries are often not distinct within each activity.

Accomplishments

Assistance given to SEGS operators

An aerial flyover of the Solar Energy Generating Systems (SEGS) fields, during operation, is being organized to assess the tracking quality of the parabolic collectors. By observing the illuminated receiver of the collector, from the appropriate flying altitude, a qualitative measure of collector alignment can be measured. Providing collector misalignment information to the SEGS operators will aid them in identifying collectors that need alignment, potentially improving plant performance. A commercial vendor as been selected for a video shoot using a helicopter, a gyrostabilized camera mount, and broadcast quality video equipment. Current efforts are directed toward addressing the environment, safety, and health (ES&H) requirements related to aviation safety.

Additional work is underway to identify the chemical composition of the residue formed on the interior of the glass envelope on some heat collector elements (HCEs) at the SEGS plants. This particulate residue reduces the solar transmittance of the envelope and thus, the thermal performance of the HCEs. The affected HCEs exhibit a bright glow ("fluoresce") during on-sun tracking. The chemical composition of the residue is important to determine what solvents (if any) can be used to "clean" the interior of the tube without significantly degrading the absorber and to mitigate the ES&H concerns.

Wind response analyzed

Program engineers have been assisting Industrial Solar Technology (IST) regarding the wind damage to the solar trough hot water system in Tehachapi, California. At IST's request, Sandia engineers conducted a finite element analysis of the trough system in order to recommend structural improvements to the design that would prevent future damage. A working model was developed, and last quarter we gave some preliminary results to IST that indicated that the welds used to connect some external support bars to the module frame were deforming during wind events and causing damage to the trough structure. IST is discussing some additional controlled destructive module tests to verify these conclusions. This information is needed to help IST decide whether to use a different system to connect the supports to the module frame. The test will be conducted next quarter or early next year.

New data indicates solar systems are more expensive in federal facilities

As a result of in-house efforts to install solar systems on Sandia facilities, significant new information has emerged that indicates that solar systems may be much more expensive when installed in federal facilities. The new information was discovered during a bid review for a solar swimming pool heating system at Sandia's Coronado Club. In the private sector, these solar systems effectively compete with natural gas and have paybacks of less than 10 years. However, when this system was bid for the Sandia application, significant additional costs were added to meet federal regulations. These additional costs more than doubled the cost of the project and extended the payback to greater than 20 years, more than twice the maximum allowed for solar projects in federal facilities such as Sandia's.

The additional costs arise from federal regulations such as the Davis-Bacon act that requires that all federally-funded projects over $2K must use laborers paid at stipulated prevailing wages (also known as "union wages"). Other additional costs are for mandatory ES&H inspections and oversight inspections. To assess whether these mandatory cost additions may be typical in federal facilities, the STDAC contacted the U.S. Army Corps of Engineer's Civil Engineering Research Lab (COE/CERL). The COE/CERL monitors costs for construction projects for most military and many civilian

federal facilities. They confirmed that a variety of mandatory construction requirements that are prevalent throughout the federal sector substantially increase the cost of solar projects in a federal installation.

The federal sector is a large potential market for solar systems such as dish/Stirling, and these cost additions could impact future sales. As a result, Sandia will team with NREL and FEMP to more carefully document the extent of the mandatory cost additions within the federal sector and to identify ways to reduce or eliminate them. This new effort is expected to begin in earnest in the next fiscal year.

State cooperative activities

STDAC engineers are assisting several states. In the state of California, Sandia engineers are assisting the California Energy Commission (CEC) in developing Request for Proposals (RFPs) for third-party financed solar systems in prisons. Sandia engineers will help assess the loads at various prisons; this information will be included in the RFPs. A second effort is underway to monitor the performance of an evacuated tube, solar industrial process heat (IPH) system at Galt, a California Department of Corrections training facility. The monitoring system is installed; performance data are being collected and will be reported for the next year. Preliminary reports indicate that the system is operating normally and is displacing about 40% of the hot water load. However, based on the data collected to date, the projected simple payback for the system may be longer than the life of the system. Additional analysis will be conducted to verify these conclusions.

Solar program engineers are assisting the New Mexico Energy, Minerals, and Natural Resources Department (EMNRD) and the New Mexico Solar Energy Industries Association (NMSEIA) in four refurbishment projects. The first project consists of providing technical assistance and test equipment for the refurbishment of two flat plate solar systems at the Northern New Mexico Community College. This system appears to be a candidate for cost effective refurbishment. However, the on-site maintenance staff are not enthusiastic about the project. The EMNRD is considering canceling the project and using the refurbishment resources on other projects. A decision will be made next quarter. The second involves technical assistance to refurbish a 2000-m^2 system at the State Prison in Las Lunas, New Mexico. Program engineers have suggested field piping changes, which were accepted and are being implemented. Additionally, program engineers suggested control system modifications to improve system performance. Quotes for implementing the control system upgrades are being evaluated. A third project involves two solar IPH systems at the Eastern New Mexico University. This quarter, program engineers discussed the possibility of obtaining used collectors for the refurbishment. These used collectors will allow the refurbishment costs to stay within the allocated budget. The fourth project involves several systems at the New Mexico Institute of Mining and Technology. Program engineers visited the site and are discussing refurbishment plans with the EMNRD.

Military installation activities

This quarter, Sandia engineers visited MacDill Air Force Base (AFB) near Tampa, Florida, to help base officials to identify and analyze solar thermal applications. The base has $300,000 available for solar thermal projects that meet the Department of Defense's (DOD's) Energy Conservation Investment Program acceptance criteria. The Florida Solar Energy Center (FSEC) is providing technical assistance to this project. The goal of the analysis is to determine if solar thermal applications meet the base acceptance criteria of a 10-year payback. One significant solar heat project was identified. However, two cost estimates from local solar contractors were too high to meet the base's economic criteria. Sandia engineers will assist FSEC in analyzing the estimates to try to identify ways to reduce the price.

Sandia engineers are assisting in an effort to refurbish an energy monitoring system for one of the solar trough systems located at Luke AFB. The refurbishment of this trough system is cost effective. This quarter, most of the support/consulting related to the installation of a monitoring system. The energy monitoring system will allow base personnel to quantify energy and cost savings derived from the parabolic trough solar systems. Warrantee repairs of new monitoring equipment have delayed the completion of this project; completion is anticipated this fiscal year.

The STDAC is working with Department of Public Works officials at Fort Irwin, California, to assess the feasibility of reapplying existing non-operational solar systems. Sandia engineers are helping base officials to identify applications to redeploy collectors

from non-operating systems. This quarter, Sandia helped to identify several potential redeployment applications and has finished preliminary performance and economic analysis on them. The analysis indicates that redeployment may not meet the base's economic criteria. Program engineers are continuing to investigate the details of the cost analysis.

The STDAC is continuing to work with the U.S. Corps of Engineers (COE), Mobile District to help review and refine the basic methodology that the Corps uses to assess the applicability of solar systems within the DOD's facilities and installations. This project is strategically important to the Department of Energy (DOE) solar program because this COE methodology is used by most U.S. military installations throughout the world to decide whether solar technology is applicable. Improvements to these tools may result in a number of new solar applications within the DOD in the near future. A Work for Others agreement is currently being agreed upon by both parties. Work on this program will begin next quarter and continue into FY95.

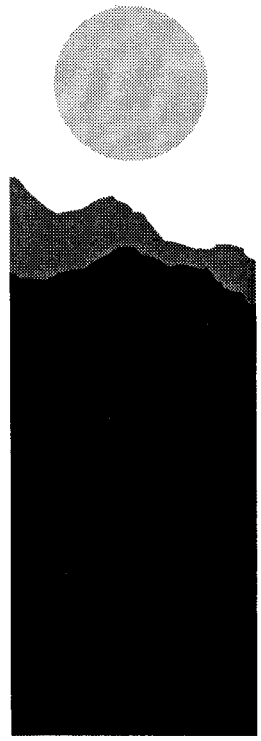
International renewables support

Technical support for international solar energy projects has continued this quarter. Sandia's Photovoltaic and Solar Thermal Design Assistance Centers are cooperating to help the Mexican government apply renewable technologies in Mexico. During this quarter, there were three significant activities: (1) planning for participation in the 1994 Mexican National Solar Energy (ANES) Conference; (2) technical assistance to the University of Sonora; and (3) technical assistance to the Sonoran state government.

The organizers of the ANES conference invited Sandia's participation in this year's meeting, which will occur on October 3-8 in Hermosillo, Sonora. Sandia expects to present a workshop on productive end use technologies, many of which involve solar thermal technologies. This forum is expected to draw Mexican state government decision makers from throughout the country. Additionally, Sandia will provide a Spanish language exhibit of solar technologies. The Mexican meeting hosts will probably use the solar oven and ice maker, which have been loaned to the University of Sonora, to produce cookies and ice for use in the conference. The use of these technologies will be exhibited during the conference. The efforts in this quarter and the next will focus on organizing and coordinating tasks aimed at making United States participation in the conference productive and successful.

As part of the effort to create a climate favorable for the growth of the solar market in Mexico, Sandia is helping to develop the solar engineering resources of Mexican universities such as the University of Sonora. These universities will provide the technical expertise to Mexican government agencies and non-government organizations in implementing solar thermal technology. In May, Sandia and the University of Sonora (UNISON) signed a Memorandum of Agreement to facilitate the exchange of technical information between the two organizations and to pursue joint technology implementation projects. To this end, Sandia loaned UNISON an American made solar oven and in early July will loan them an American made solar thermal ice maker. In the next quarter, Sandia will work with the Energy Group at UNISON to involve technical staff and students at the university in the testing and evaluation of these two products. At a later date, UNISON may be involved in fielding a prototype dish/Stirling system.

For the last two years, Sandia has been providing technical support for the design and installation of a 30-kW solar thermal Organic Rankine Cycle electric generating system at Puerto Lobos, Mexico, a remote fishing village on the Sonoran coast. However, the Mexican general contractor for the project has encountered a number of significant delays and cost overruns. Because this type of technology is not supported within the DOE solar thermal electric program, STDAC project support funds were limited. Early this fiscal year, the STDAC budget for the project was exceeded. As a result, the DOE and Sandia decided to withdraw support for the project; in May, DOE and Sandia officials met with Sonoran government sponsors for the project to discuss the rationale for the decision and to identify other more appropriate collaborative activities. In response, the Secretary for Infrastructure, Urban, and Ecology requested that Sandia provide assistance to him in establishing a methodology to identify and select appropriate solar technology for the state. Additionally, Sandia agreed to train the UNISON Energy Group on monitoring fielded solar thermal projects. Because UNISON will provide technical support to the Secretary's staff on future fielded projects, they believed that this monitoring expertise was essential to support projects such as a



dish/Stirling system. To date, it appears that the withdrawal of the DOE's support for the Puerto Lobos projects has not impacted the cordial and productive working relationship with Sonora. During the next quarter, Sandia will work with the Secretary and his staff to develop the set of criteria requested and to provide the technical training.

Testing evaluation activities

The Solar Thermal Design Assistance Center has completed testing the thermal performance characteristics of a heat exchanger product manufactured by a small Albuquerque company. The testing was done to assist a local solar manufacturer. This company lacked the measurement expertise to thermally characterize the thermal performance of the heat exchanger and approached Sandia's Technology Transfer Center for assistance. In turn, the Tech Transfer Center funded the STDAC to complete the tests.

The heat exchanger consists of three copper tubes fabricated into a double wall, counterflow configuration. The exchanger is designed to heat the water in a hot-water heating tank by flowing a solar heated propylene glycol/water mixture from a roof-mounted collector system through the system. The thermal performance characteristics of the heat exchanger are critical to size and implement the solar systems supplied to the company's residential customers. A thermal model was developed using TRNSYS to assess the performance in an actual application. The model is used to help optimize the solar system design.

Planned Activities for Next Quarter

Current plans are to continue to provide direct technical support to those organizations with which we are currently working. Accelerated efforts are planned to identify other opportunities to provide this service and other technology transfer and outreach activities.

STDAC Contacts

CENTRAL RECEIVERS

Bortz, John	SAIC
Buck, Reiner	Consultant
Dominques, Eric	Nevada Power Co.
Hammond, Roger	Platte Generating Station
Kirchner, Kelly	TMA
Kowinski, Mark	Consultant
Migliori, Albert	LANL

CONCENTRATORS

Boyack, Brent	LANL
Cable, Bob	KJC
Dagan, Dr. Eldad	Israeli visitor
Dr. Lodi	Texas Tech
Gibson, Bob	Tech Ventura Corp
Goldberg, Jeff	Suntek
Luton, Wayne	DLC
Mroz, Ted	NASA LeRC
O'Hare, Ed	Texas Tech U
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Simpson, Marty	SNL/2345
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Dahe, Arne	Consultant
Geiger, Robert	Modular Power Sys.
Johansson, Stefan	STM
Louis, Warren	SNL/PV
Marko, Armin	Consultant
Silver, Dan	Int Inst of Energy Conservation

GENERAL INFORMATION

Albers, Ronnie	Consultant
Alexacen, Jim	Consultant
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Baus, Charles, E.	DOD
Bausch, Bob	USGSA
Beaubien, Mark C.	Yankee Enviromental Systems, Inc.
Bell, Daglin	Consultant
Blair, Larry S.	ATR
Bony, Paul S.	Plumas - Sierra Rural Electric Cooperative
Borton, David N.	Sustainable Energy Systems
Bourque, M. Phyllis	PNM
Cannon, James	NMDOE&E
Carrozza, Allen Robert	Scholfield Solar
Cooper, Robert R., P.E.	USAF
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Danonshire, Scott	SNL/2345
De Franco, Nelson	The World Bank
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Desai, Shivu	The Gas Company

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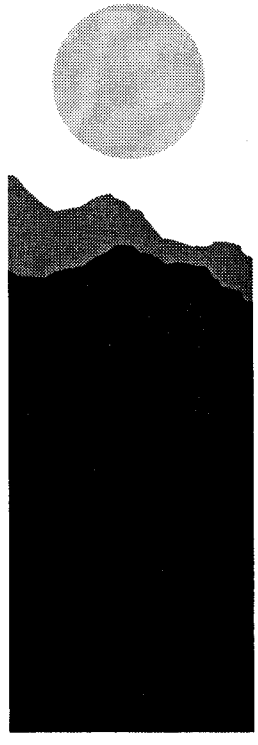
Emerson, Mark	Consultant
Epperley, Kenneth D.	Directorate of Public Works
Ericksen, Fredik	Consultant
Flowers, Larry	NREL
Ford, Charity	Consultant
Ford, Kim	SNL/TT
German, John	Consultant
Gestelli, Richard	SNL
Ghoren, Amy	Energy User News
Gorham, Robert S. Jr.,	Consultant
Gupta, Bim	NREL
Haeri, Ahmed	Bresler & Reiner, Inc.
Harnell, Skip	DOE/AL
Hill, Tony	SNL/2345
Hjilseth, Jane	Consultant
Hollick, John C., P.E.	Conserval Systems, Inc.
Hovkoaghalen, Tor	Consultant
Hundby, Kristin	Consultant
Irenar-Peterson, Suzanne	Consultant
Jadrijevic, Vladimir T.	The World Bank
James, Lee	Consultant
Jelaginski, Robin	Fletcher State
Jones, Myron	EPRI
Jones, James	Consultant
Jurman, Kenneth S.	Institutional Conservation Program
Klemworth, Frank	Reynolds Engineering
Knight, Byron F.	Harris Corporation
Landrey, Marc	NREL
Letendra, Steve	NY State Energy Office
Lockwood, Anita	NMEMD
Manicki, Ken	NM Manufacturing Extension Program
Mastroianni, Marty	EPRI
Mathis, Dianne	UCOS
Merrett, Ron	Consultant
Miller, Kirk	Consultant
Monson, Richard	RePsych Technologies
Montoya, Pat	State Issues Director
Mooney, David G.	NREL
Moore, Mary	Consultant
Mos, Ed	Consultant
Moulton, Michael W.	ATR
Murphy, Kevin	TT
Nelson, Harold W.	Seed International, Inc.
Nesmith, Tom, P.E.	PNM
Nimitz, Jon	ETEC
Nioiner, Torrain	Consultant
Noble, John M., P.E.	PNM
Nunley, John F., III	State of Wyoming
O'Brian, Phil	Consultant
O'Canna, Migra	7145
O'Cheskey, Fred L.	Southwest Public Affairs, Inc.
Onursal, Bekir	The World Bank
Orozco, Ron	NRECA
Paparoni, Hilda Maria	UN/DP
Pastori, Joe	Pastori & Assoc.
Pittie, Ravi	Pittie Solar Corp. PVT. LTD.
Pittie, Shrikant	Pittie Solar Corp. PVT. LTD.
Plympton, Patricia C.	USEPA
Radford, George O.	Radco Products, Inc.
Ralph, Claire	Consultant
Riser, Steve	Solar Letter
Sanders, Grant	SNL/2345
Sanders, Judy	SC
Saunders, Robin	The City of Santa Clara, California
Schenkel, U.	TAMPOPRINT GmBH
Segal, Barry Jay	Segal's Solar Systems
Sheffield, Mike	Texhoma Communications
Shugar, Daniel S., P.E.	APS, Inc.
Smith, Pete	NRECA
Sorenson, Kurt	SNL/2343
Stallings, Ellen	LANL
Steward, Greg	Global Solar Services
Stimac, James	LANL
Swenson, R.B.	Enigma Logic
Swift, Gregory	LANL
Taylor, Roger W.	NREL
Terrence, Lee	Consultant
Thomas, Edwin	TOPOG-E
Thompson, John	Environmental Enterprise Institute
Tlaiye, Laura	The World Bank
Tsuo, Simon	NREL
Ulrich, Jim	Consultant
Van Buren, Taylor	LANL
Vandegorgh, Nich	LANL
Warawa, K.C.	K.C. Associates
White, Andrew	LANL
Whitlow, Jeff	SNL/6641
Williams, Michael	LANL
Williamson, Richard	DOE
Wirdzek, Phil	USEPA
Wood, Byard D.	ASU, CESR
Worl, Laura	Consultant
Zuñiga, Ricardo Xavier	State Co-Director
Zygmunt , Stanley Jr.	LANL
Zyvoloski, George	LANL



INDUSTRIAL PROCESS HEAT

Benett, Mark	Consultant
Betten, Guy	RETI
Bielick, Tim	SNL/2345
Daunt, Dave	Wescam Marketing
Ducey, Rock	Army CERL
Dunken, Cameron	Energy Effic & RF Clearinghouse
Fox, Lucien	Ogden Power
Franey, Harvey	CDC
Gee, Randy	IST
Giffor, John	Poctor & Gamble
Glissman, Lt. Mark	USAF
Hamasaki, Les	Sun Utility
Harkness, Tim	Consultant
Harrison, John	FSEC
Jaromin, Dennis	U.S. General Service Administration
Johnson, Brian	NMEMD
Johnson, Leland	SNL/7145
Kulkarni, Promod	CEC
Lane, Richard	Packerland Solar Systems
Leonard, Bob	Passive & Active Solar
Markham, Chuck	AAA Solar
Mills, Evan	LBNL
Moore, Mack	SEIA
Quinones, Rene	Dept. of Public Works, Fort Irwin, CA
Reeves, Lewis	ENMU
Ringle, Greg	Gould Inc.
Roltz, Ross	Foltz Engineering
Schenkopf, Ken	SEIA
Schmitt, Jeff	AAA Solar
Schoen, Neil	Consultant
Spalding, Bill	AET Rep
Starling, Bob	COE/Huntsville
Stein, Bill	Ft. Huachuca
Taswell, Ann	Sarasota Florida
Thomas, Susie	VA Energy Office
Utley, Mel	Central NM Correctional Institute
Velter, Paul	State of California
Wildin, Bud	UNM

INSOLATION

Dolmier, Steve	N. Power Systems
Perez, Richard	State U of NY
Renae, Dave	NREL
Stoefel, Tom	NREL

MODELING

Burns, Tom	Burns Milwaukee

ABSORPTION COOLING

Byam, John	Morgantown Energy Technology Center
Chabot, Ernie	DOE/HQ
Clark, Nolan	U.S.D.A.
Ericson, Don	Energy Concepts
Gotzi, Phil	Zamack
Nimmo, Bruce	FSEC
Nixon, Jack	Yuma Proving Ground
Taylor, Mark	Socorro

SOLAR EDUCATION

Miller, Jennifer	Science Service
Olaxac, Jim	Showboard Inc.
Ordego, Sheila	Santa Fe Community College
Ross, Jeff	RETI

SOLAR THERMAL SYSTEMS

Allegro, Joe	Inner Solar Roof Systems, Inc.
Bataglia, Tony	COF
Bell, Craig	ENMU
Holsher, Jim	Meridian Corp.
McDonald, Monica	Consultant

SOLAR THERMAL TESTING

Bahm, Ray	Ray Bahm & Assoc.
Franklin, Tanya	Wescam Marketing
Haeger, Matthis	Consultant
Hammerbacher, Milferd	TI
Henza, Charles	DOE/OFTA
Jacob, John	Consultant
Jacobs, Jeff	Consultant
Keshishian, Vahe	Rockeydyne
Maiden, Miles	American Sun Co.
Malone, Robert	LANL
Matthews, Steve	Consultant
Michael, Dan	Neptune & Co.
Reisle, Camron	Consultant
Rosenthal, Andrew	NMSU
Rosocha, Louis	LANL
Scoulou, Gene	Consultant
Stone, Ken	McDonald Douglas
Streit, Gerald	LANL
Tuck, Lesley	Consultant
Turner, Dave	Consultant
Whetstone, Don	EISI

UTILITIES

Grasse, Wilfried	SolarPaces Secy.
Haque, Nabilah	EPA
Haarklou, Olav	Utility Free
Johnston, Glen	Energy Research Centre

Jones, Perry	WIPP Site - NM
Kearney, Dave	Kearney & Assoc
Lasich, John	Solar Research Corporation Pty Ltd
Montoya, Ben	PNM

INTERNATIONAL

Barr, Summer	LANL
Barrett, Chris	LANL
Berger, Michael	LANL
Berr, Michael	Energy Technology Programs
Bitner, Lisa	Meridian Corp.
Booth, Steven	LANL
Branski, Joel	Inter-American Development Bank
Brown, Donald	LANL
Cabanillas, Rafael	U of Sonora
Christiansen, Amy	DOE
Cottinggame, William	LANL
Davies, Mac Cosgrove	World Bank
Duchane, Dave	LANL
Foster, Robert	NMSU
Galindo, Ing. Victor Tamayo	ENTEC
Gallegos, Richard	Consultant
Glasser, Robert	CNSS
Glassley, Bill	LLNL
Loose, Verne	LANL
Machina, Eduardo	ENTEC (Mexico)
Meyers, C. Wes	LANL
Muhn, Rob	Meridian
Ochoa, Ing. Lopez	Sonora State Gov.
Peterson, Elias-Axel	Consultant
Rosenbert, Nina	LANL
Rovero, Chris	Meridian
Sanchez, Manuel	U of Sonora
Schaefer, John	Schaefer & Assoc
Stack, Desmond	LANL
Trocki, Linda	LANL
Villaescuza, Victor	CIDESON
Wais, M.A.C.	Al-Effendi Est, for Industry, Trade, and Cont.
Weinrach, Jeffrey	LANL

Major Milestones

Milestone	Planned	Actual
Participate in Soltech '94.	Feb 94	Feb 94
Document FY93 STDAC activities (SAND94-0257).	Mar 94	Mar 94

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	582	35	0	617
Contracts	153	0	100	253
Total	735	35	100	870

E. SOLAR MANUFACTURING INITIATIVE

The objective of the Solar Manufacturing Initiative is to develop manufacturing technology and processes that will permit cost-effective deployments of solar thermal systems in low-volume, early commercial applications; to reduce uncertainty in the cost and reliability of key solar components in order to improve financing of early commercial systems and reduce the risk of performance warranties; to promote the development of system-level business plans and industrial partnerships linking manufacturing scenarios to commercial sales prospects; and to establish the manufacturing basis for achieving the substantial cost reductions possible through higher volume production.

The Solar Thermal Manufacturing Technology (SolMaT) initiative is aimed at reducing the cost of solar thermal technologies in an environment of uncertain future sales and modest initial production volumes. In this way, SolMaT will fill a critical need for allowing solar thermal manufacturers to produce cost-effective products even before market demand will support high volume production.

Accomplishments

Heliostat manufacturing procurement

A Request for Proposal, Heliostat Manufacturing for Near-Term Markets, was distributed on April 22, 1994, to approximately 40 interested parties. This solicitation is the first thrust under the SolMaT (Solar Manufacturing Technology) initiative. Work to be performed under this solicitation is to develop heliostat production scenarios, heliostat costs, and market strategies consistent with near-term markets. Based on queries from potential bidders, it appears that there is serious interest from several significant potential industrial partners. Proposals are due to the National Renewable Energy Laboratory (NREL) by July 22.

Design for manufacturing assembly

Design for manufacturing assembly (DFMA) is a second thrust under the SolMaT initiative. DFMA is a manufacturing technology developed by Hughes Electronics that basically involves teaming during the early stages of a new product development cycle. Hughes has found that if the teaming involves the right group of people and is properly facilitated, significant reductions—on the order of 30%—in the cost of a manufactured component or system will result

Major Milestones

Milestone	Planned	Actual
Award contract on heliostat solicitation.	Aug 94	
Award contract on manufacturing improvement studies.	Sep 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	100	180	0	280
Contracts	0	1720	0	1720
Total	100	1900	0	2000

II. TECHNOLOGY DEVELOPMENT

Technology Development projects support the Commercialization projects by developing, in collaboration with the private sector and the international community, solar thermal plant components and subsystems that meet the cost, performance, and reliability standards needed by industry.

A. CONCENTRATOR TECHNOLOGY

The objective of Concentrator Technology Development activities is to bring heliostat and parabolic dish concentrator designs to commercial readiness for use in solar thermal electric systems. The heliostat designs will be used in central receiver systems and parabolic dish designs in dish/Stirling applications. Because of their importance in developing high-performance and cost-efficient concentrator designs, optical materials development is also an important part of concentrator development.

1. HELIOSTATS

Accomplishments

Heliostat development activities are primarily associated with support of the Solar Two Project.

Beam quality of LUGO and Solar One heliostats measured

A report describing beam quality measurements of the 95-m^2 LUGO Heliostat with horizontal mirror modules and the Solar One heliostat with replacement flat glass has been prepared and will be released next quarter. The results indicate that more than 85% of the energy reflected from the LUGO heliostat fell within the projected area of the Rockwell receiver. The performance of the Solar One heliostat with two flat glass facets was reduced from a 99% to a 96% intercept.

Temperature-curvature effects measured for flat-glass facets

Flat glass mirror modules from Carissa Plains will be used to construct the 95-m^2 LUGO heliostats and also will be modified as replacements for missing or damaged facets on Solar One heliostats. The following results of tests in an environmental chamber have been documented in a memo report:

- The modules were found to become globally convex at temperatures between -7°C and 7°C, and remain concave above this temperature range.
- The individual facets change shape only slightly as a function of temperature, implying that most of the overall shape change occurs at the junctures between facets.
- Facets at the ends of the modules tended to be slightly convex at all temperatures.
- Interior facets were slightly concave at all temperatures.

These results indicate that low-temperature defocusing of the flat-glass modules, while present, is likely not to be an issue for the LUGO heliostats or replacement facets at Solar Two.

Simplified beam characterization system recommended for Solar Two

The beam characterization system (BCS) at Solar One was developed with many capabilities and a high level of automation, which matched the research orientation of the Solar One project. Some of the capabilities of the BCS were rarely used, and problems prevented the originally intended level of automation from being fully implemented. The operation of Solar Two requires a simpler, PC-based BCS, which is Sandia's recommendation. The Solar Two BCS system will be used mainly for determining the heliostat tracking errors by measuring the location of the beam centroid.

A site visit indicated that the existing lenses, cabling, camera controllers, and targets could be reused. New equipment required for the BCS upgrade includes the following: a new PC, Beamcode™ software, monitors, and four new solid-state cameras. Sandia is working with Bechtel to order these components and prepare them for installation in the system.

Initial results on heliostat canting study

The Solar One heliostat facets were optically aligned (canted) to a nominal distance of 400 meters when originally installed. Because the Solar Two receiver is much smaller than the Solar One receiver, spillage will be reduced at Solar Two by re-canting the inner 17 rows of the field to a shorter aim point. A unique, on-axis canting method developed at the Weizmann Institute in Israel is currently being tested; Sandia has recommended that this procedure be used at Solar Two. Computer modeling of the field performance shows that on-axis canting methods will give the best insolation-weighted, annual plant efficiency. This method may be applicable to the LUGO heliostats and flat glass, replacement mirror modules as well. Further work is needed to adapt the canting procedures and equipment to optimize its use by subcontractors working at the Solar Two site.

Solar One heliostat pedestal tilt study started

Heliostat pedestal tilt causes tracking errors that vary with sun position. Concern about the possible detrimental effects of the June 1992 Landers earthquake on Solar One heliostats led to a small, preliminary study to measure the tilt of heliostats throughout the field. An experimental apparatus to measure the tilt of the Solar One heliostats was developed using an inclinometer. Three days were spent at Solar One troubleshooting the system and measuring the tilt of about 15 Solar One heliostats. Preliminary results indicate that measured pedestal tilts were within acceptable limits. The data reduction will be completed next quarter and a report issued.

Additional changes made to the Solar Two stimulators

Advanced Thermal Systems has received a contract to upgrade the Solar Two heliostat stimulators: to remove unnecessary commands, to add a halt command and a trim function that will reduce the time required to determine the bias offsets for a heliostat that has lost this information, and to add four diagnostic tests to verify the timer, initialize the HC, and allow for beam pointing and corridor walk.

Heliostat field survey results further analyzed

The field refurbishment planned for Solar Two requires the development of the procedures a subcontractor will follow when installing the new 95-m^2 heliostats and replacing missing/damaged facets on the Solar One heliostats. The development of these procedures has begun cooperatively with Bechtel and has been aided by information from the heliostat field survey. The field survey will also be used by Bechtel to prepare instructions, which detail what repairs must be made on each heliostat, for the subcontractors. Specific elements of these procedures are provided to Bechtel as they are developed at Sandia.

Advanced heliostat activity combined with advanced dish procurement

The advanced heliostat and dish concept development activities were merged into a single concentrator procurement activity. This will result is a slight delay in the August deadline for placement of a contract. Also, this procurement will be reported with the dish concentrator development activities.

Planned Activities for Next Quarter

- Develop a canting method for use on flat-glass modules for both the LUGO trackers and the Solar One heliostats.
- Finalize recommendations for repair of the Solar One heliostat field and assist Bechtel with solicitation of subcontractors to perform the work.
- Oversee and assist with upgrading of the BCS camera hardware at Solar One.
- Complete the pedestal tilt study.

Major Milestones

Milestone	Planned	Actual
Complete report on the dual-module, stretched-membrane heliostat.	Dec 93	Dec 93
Complete evaluation of facet replacement for Solar Two using flat Carrizo Solar glass. (Final report in progress.)	Jan 94	Mar 94
Complete evaluation of a LUGO heliostat with flat Carrizo Solar glass. (Final report in progress.)	Mar 94	Mar 94

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	234	0	0	234
Contracts	250	0	0	250
Total	484	0	0	484

2. PARABOLIC DISHES

Accomplishments

Dish development activities were greatly reduced this quarter because it was necessary to reassign concentrator resources to higher-priority heliostat activities in support of the Solar Two project.

Faceted stretched-membrane dish evaluated at longer focal length

The facets on the faceted stretched-membrane dish were realigned to an increased focal length of 9.95 meters to accommodate the design revision incorporated by Science Applications International Corporation (SAIC) into their concentrator for use in the Utility Scale Joint Venture Program (USJVP). The concentrator was tested with the flux mapper and calorimeter at the new focal length. The power on the target normalized to 1000 W/m^2 and for a 0.508-m (20-in.) diameter aperture was 68.0 kW with a peak flux of 3578 kW/m^2.

The improvement in the intercept curve for the increased focal length is shown in Figure 1 below. The solid lines in the figure are the intercepted power as it varies with receiver aperture diameter for the 9.90- and 9.95-meter dish focal lengths. The points shown in the figure are the data measured with the calorimeter.

On-sun testing of the SAIC facets was completed and the facets have been removed from the dish structure.

SKI's plastically-formed facets installed on the faceted dish

Solar Kinetics Inc.'s (SKI's) plastically-formed facets are installed on the faceted dish. Sandia is currently installing the focus-control wiring and vacuum piping. The solar concentrator will be tested during the next quarter.

Request for quotation released to SKI for development of a dish system

This project, which is referred to as the Single-Element Stretched-Membrane Dish Commercial Development Project, is proposed for SKI and their identified partner to develop a commercial product

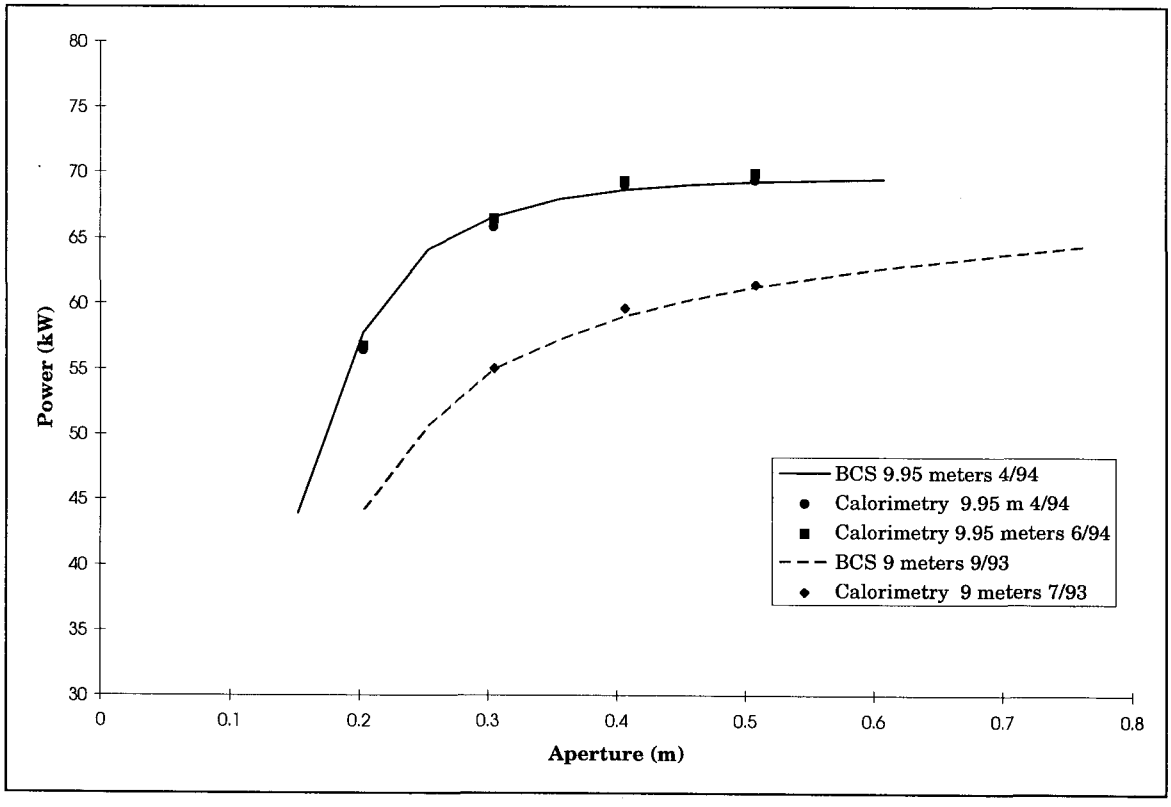


Figure 1. Intercept curves for the faceted dish.

that incorporates the stretched-membrane dish. The project shall include a review of the single-element dish design, identification of a commercial product, and a preliminary market analysis for the identified product. As with other commercial development programs currently being pursued by the Department of Energy, future product development activities will require substantial cost share by the industry participants.

The proposal is due on July 29, 1994. The proposal review should be completed next quarter and a potential contract would be placed during the first quarter of FY95.

Advanced concentrator initiative started

The Advanced Solar Concentrator Development Project is to provide multiple, small contract awards for proof-of-concept activities such as the following: new/innovative ideas that address the fabrication of heliostats or dishes; the adaptation of existing fabrication techniques or components to solar applications. Any approach must have the demonstrable potential to substantially improve the optical performance of the solar concentrator or reduce its costs relative to existing designs.

Planned Activities for Next Quarter

- Complete installation of the plastically-formed SKI facets on the faceted dish and perform calorimetry and flux mapping.
- Evaluate SKI's proposal for commercial system development.
- Complete statement of work for advanced solar concentrator concepts.
- Resume development of the 2f color system.

Major Milestones

Milestone	Planned	Actual
Complete testing of the faceted stretched-membrane dish with plastically-formed facets. *(Delayed due to Solar Two heliostat testing.)*	Mar 94	
Place a contract to further evaluate and analyze the single-element, stretched-membrane dish. *(In progress.)*	Apr 94	
Release advanced concentrator procurement.	Aug 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	324	0	0	324
Contracts	180	0	0	180
Total	504	0	0	504

3. OPTICAL MATERIALS

Accomplishments

Advanced solar reflector concept

A proposed collaborative, cost-shared subcontract for *Advanced Reflector Materials Research and Development* by Industrial Solar Technology (IST) is underway. The proposal for *Development of a Teflon™-Based Reflective Film for Solar Concentrators* by Industrial Solar Technology (IST) was received in response to a competitive request for proposals (RFPs) intended to capture new concepts and opportunities, and to fill in gaps in the technology that are believed to be critical to the success of commercial solar reflector products. On the basis of technical merit and cost, this proposal had earlier been reviewed and recommended for funding by a Source Evaluation Panel at the National Renewable Energy Laboratory (NREL). The proposed work builds upon progress demonstrated during a previous collaborative, cost-shared subcontract between IST and NREL. Under the proposed project, IST will investigate a promising approach to improving the specular reflectance of silvered Teflon™ mirrors by using sol-gel leveling layers deposited prior to metallization of the film. Sol-gel is readily silvered, has excellent flexibility for the thin layers of interest, and could provide improved corrosion resistance by providing an additional barrier layer between the polymer film and the silver layer. IST will also explore an innovative cleaning process, namely, a jet-spray technique that has been demonstrated to be very effective in removing particulates for specialized cleaning tasks within the aerospace and defense industries. Development of a mirror that is easy to clean in service and that has high optical performance is important because the success of solar thermal concentrator systems is strongly related to these properties of potential solar reflector materials.

New solar reflector materials

Discussions with several commercial vacuum deposition system vendors have identified several interesting reflector material constructions and these vendors have agreed to fabricate such samples for evaluation by NREL. One of the most promising ways to reduce the cost of solar mirrors is to metallize an appropriate and inexpensive substrate material such as a polyester film, and then overcoat the reflector with a dense, durable, protective top layer. Some reflectors having this generic construction have demonstrated promising results in accelerated durability tests at NREL, indicating that they may be capable of achieving the cost and performance goals of the program. Two processes that can potentially create such coatings have been offered by industrial contacts, namely, plasma-enhanced chemical vapor deposition and ion-assisted deposition. Both of these processes are claimed to be scalable for commercial production applications. Prepared samples will be optically characterized and subjected to durability testing at NREL. Development of a mirror having low cost and high durability is important because the success of solar thermal concentrator systems is strongly related to the optical durability and economic viability of the reflector materials.

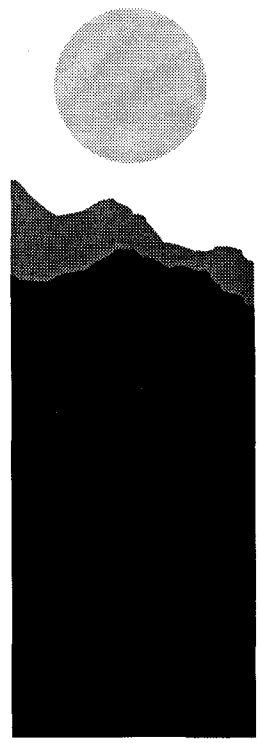
Commercial solar heat project initiated using ECP-305+

IST has begun a commercial solar heat project using ECP-305+ as the reflective surface for a parabolic trough. The project will deploy approximately 700 m^2 of troughs to provide hot water for a Colorado prison. The project represents the first commercial deployment of ECP-305+, a highly durable solar reflector material recently developed collaboratively by NREL and the 3M Company.

Outdoor testing activities documentation

A June 1994 milestone to "document the status of NREL's outdoor testing activities" was completed. Significant efforts include the following:

- Four outdoor test sites are presently in operation at which reflector material performance data and meteorological data are collected in a routine manner.
- A fifth site is expected to be activated in August 1994. (The May 1994 milestone titled "Initiation of Outdoor Materials Testing at Fifth Site" was delayed.) The intended site is the Solar Two plant at Barstow, California. The effort has been delayed by Southern California Edison's involvement and responsibilities associated with the Solar Two Project. Progress toward activation has been made. Candidate reflector materials have been prepared and optically characterized. Meteorological monitoring equipment has been procured and has been received. Exposure racks have been ordered and are being shipped to Barstow for installation.



- At least one additional site is being considered, namely, a coastal/marine environment to emulate a remote island location for remote power markets.
- The International Energy Association Solar PACES program has expressed an interest in becoming involved with NREL's outdoor test program.
- A database program is being developed under a subcontracted activity to organize, analyze, archive and perform quality control tests on the meteorological data.

The overall objective of this activity is to provide data on reflector material durability and life as a function of outdoor exposure. All advanced solar thermal concentrator designs require reflector materials that are low cost, light weight, durable, and efficient. Consequently, outdoor testing of candidate reflector materials is important because it will demonstrate to potential investors, utilities, and manufacturers the optical durability of candidate reflector materials in outdoor environments representative of prospective sites for solar system installation.

Planned Activities for Next Quarter

- Negotiations will continue with a second industrial partner who has proposed cost-shared development of an advanced solar reflector.
- A fifth outdoor test site will be activated at Barstow, California.
- Collaborative efforts with industrial partners to develop advanced alternate reflector materials will continue.
- Fabrication and characterization of promising candidate reflector materials will be carried out in parallel at NREL.

Industrial Contacts

CONTACT	ORG.	COMMENTS
J. Allen	Rainbow Farms	Thermal polymers
P. Bhat	MRG, Inc.	Deposition systems
B. Benson	3M	Alternate reflectors
D. Dahlen	3M	Alternate reflectors
R. Davenport	SAIC	Thin glass mirrors
R. Gee	IST	Alternate reflectors
A. Gill	ESD	Mirror technologies
M. Jacobson	Optical Data Assoc.	Reflector materials
A. Madan	MVSystems	Deposition systems
M. Maiden	American SunCo	ECP-305+
K. May	IST	Selective absorbers
J. Pernicka	Pernicka Corp.	Deposition systems
P. Reader	Ion Tech	Deposition systems
J. Scheirs	ExcelPlas	Polymer mirrors
N. Schoen	Task & Rosilands	ECP-305+
W. Schrenk	Dow Chemical	Alternate reflectors
N. Small	Dielectric Coatings	Front surface mirror
T. Strainic	RCE	Reflector materials

Major Milestones

Milestone	Planned	Actual
Issue Request for Proposal (RFP) for additional alternative reflector R&D.	Feb 94	Nov 93
Activate fourth outdoor test site (Abilene, Texas).	Mar 94	Mar 94
Activate fifth outdoor test site (Barstow, California).	Aug 94 (rescheduled)	
Document status of outdoor testing activities.	Jun 94	Jun 94
Document alternative reflector materials R&D progress.	Aug 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	0	890	0	890
Contracts	0	500	0	500
Total	0	1390	0	1390

B. POWER CONVERSION

Power conversion development efforts synchronize R&D activities with the needs of users, expanding the availability of resource data and improving system performance. Power conversion systems for both dish/engine systems and power tower systems are tested at Sandia's National Solar Thermal Test Facility (NSTTF). Power tower receiver development is focusing on advanced salt-in-tube receivers, molten-salt film receivers, and volumetric air receivers. Dish receiver development, particularly of the reflux type, is critical to the long-life reliable operation of parabolic dish/Stirling engine systems. The heart of a solar thermal dish/engine system is the subsystem that converts thermal energy into electricity: the engine generator. While the program does not directly support development of these converter subsystems, it provides testing and solarization support to industry.

1. CENTRAL RECEIVER TECHNOLOGY

The primary objective of the Central Receiver Technology program is to advance the development and commercialization of central receiver technologies. This work will mitigate risk of central receiver systems, support industry and utility concerns by conducting research on new concepts, and perform testing and analysis of components and procedures. The following are key tasks within this activity: (1) molten-salt component tests, (2) molten-salt stability and corrosion tests, (3) development of instrumentation to measure flux and temperature on central receivers, (4) volumetric receiver development, and (5) system studies of power tower systems.

Accomplishments

The major accomplishments this past quarter are: the continued testing of the molten-salt component test loop and the receiver panels, infrared tests of the receiver temperature measurement system, and the continuation of the molten-salt corrosion thermal cycling tests.

Material corrosion testing in molten salts

Thermal cycling corrosion tests involving stainless steels have been run for 4500 hours and more than 500 cycles. Thermal cycling did not significantly increase the corrosion rates of 316SS or 304SS compared to isothermal corrosion rates, although the intrinsic corrosion rate of 316SS is less than 304SS. Isothermal corrosion tests of chromium-molybdenum steels have reached 4500 hours (of 7000 anticipated) and demonstrated that 2-1/4Cr-1Mo is not acceptable for the steam generator evaporator. At 450°C, 9Cr-1Mo has demonstrated good corrosion resistance, which is further improved by minor silicon additions. Sandia has designed fixtures to allow corrosion coupons to be placed at strategic Solar Two plant locations and removed for evaluation during major maintenance shutdowns.

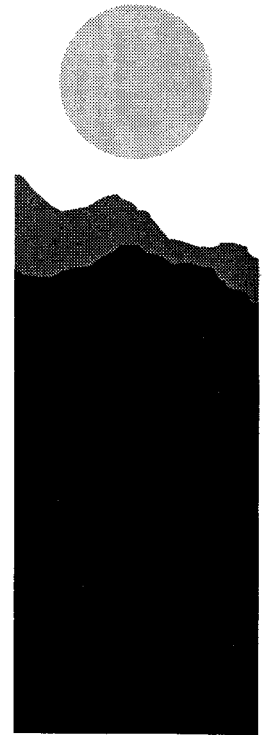
Photometers integrated into Solar Two receiver design

Last quarter, photometers were tested at Sandia as an instrument to measure relative flux on a black receiver panel. Measurement of changes in flux on the receiver is important for feed-forward control of molten-salt flow rate. Other instrumentation previously used (imbedded flux gages) cannot withstand the harsh, high flux environment and maintain reliability. The impetus for this investigation was to determine if there are more reliable, lower cost alternatives to flux gages that are easier to maintain. Photometers should cost less to maintain and should be more reliable.

As a result of the positive results from our experiments, Rockwell International, the receiver vendor for the Solar Two project, has decided to incorporate photometers in the receiver design. Sandia has consulted extensively with personnel Rockwell and Bechtel, the architect and engineer for the Solar Two project, to transfer our experience to them.

Ball valve undergoing testing in molten-salt loop

At the request of members of the Technical Advisory Committee (TAC) and Bechtel National Inc., Sandia is testing a ball valve, manufactured by Mogus, in a salt loop. Ball valves have not previously been tested in molten-salt environments. The valve will undergoing pressure cyclic testing to test its suitability as a drain valve and to measure its leak rate. Ball valves have an advantage over globe valves in that they have a lower pressure drop across them and smaller valves could be used for given line size.

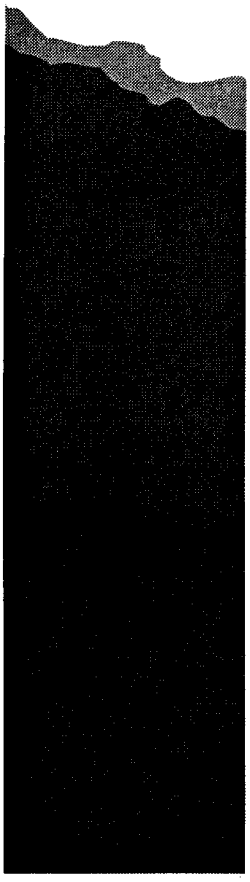


Flanges hold up well to thermal shocks

Several flanges have undergone thermal shock at Sandia in an experiment to determine their ability to handle severe thermal transients characteristic of cold startup of a molten-salt plant. During a cold start, the components and piping may be near ambient while the salt is at the inlet receiver temperature (287°C). Cold starting the piping and associated components has several advantages in a molten-salt central receiver plant, including reduced parasitic power consumption, increased operating flexibility, and greater availability. During cold start, a component can change temperature rapidly and develop severe internal stresses. These stresses can lead to a breach in the flange seal. Results have shown that even after 150 extreme thermal shocks, none of the flanges has failed catastrophically. Only a few show signs of minor leaks (a few drops per hour). We have shared these results with the Solar Two TAC.

Simple element freeze/thaw tests continue

In molten-salt systems, components and piping can be damaged if the nitrate salt freezes and then is thawed out. Unlike water, nitrate salt expands upon thawing. Depending on the conditions, there can be either no damage or complete yielding of the material. Experiments have been underway to quantify damage inflicted to samples of receiver tubes under various freezing/thawing sequences. These experiments will help to understand the freezing phenomena and correlate the damage seen in the panel freeze/thaw tests to the phenomena experienced in these tests.



Assembly of the CIEMAT molten-salt internal film receiver

The internal film receiver is an adaptation of the direct absorption receiver concept, except to prevent fluid loss to the atmosphere, the fluid (molten salt) flows on the inside of the panel. Sandia is working with the Spanish to complete the fabrication and testing of a 500-kW_t molten-salt internal film receiver test, to be called the **R**eceptor **A**vanzado de **S**ales or salt advanced receiver (RAS). This past quarter, the personnel at the Plataforma have been conducting a number of water flow tests on the panel. During the water flow tests, a number of heat trace failures were experienced. After the water flow testing was completed, nitrate salt was melted in the system. However, no salt flow testing has been conducted because the air cooler plenum is too cold to flow salt. The Plataforma personnel are currently working to add additional heat trace and insulation to the air cooler plenum so that salt flow can initiated. Testing of the RAS will most likely begin in early September.

Combined cycle/power tower

NREL staff developed a new power tower concept in FY93 that interfaces a nitrate-salt power tower with a conventional gas-fired combined cycle plant. The concept provides several technical benefits relative to a solar-only power tower plant and offers an alternate commercialization path with some attractive features. A key feature of combined cycle/power tower (CC/PT) is that, beyond required demonstration of nitrate-salt power tower technology at Solar Two, no other technology development is needed. While waiting for most of 1994 for a patent application, NREL staff performed numerous systems analyses to quantify the technical and economic benefits and formulated concepts for commercialization. During this quarter, NREL staff met with several stakeholders to solicit feedback on the potential of the concept and to discuss how to proceed with development. Meetings with Electric Power Research Institute, Sacramento Municipal Utility District, California Energy Commission, Rockwell, Southern California Edison Company, Bechtel, Arizona Public Service Company, the Department of Energy (DOE) Golden Colordo Field Office, the DOE Headquarters, and Sandia were generally very positive. NREL staff are now working towards a collaboration between the national laboratories and industry to further promote CC/PT.

Planned Activities for Next Quarter

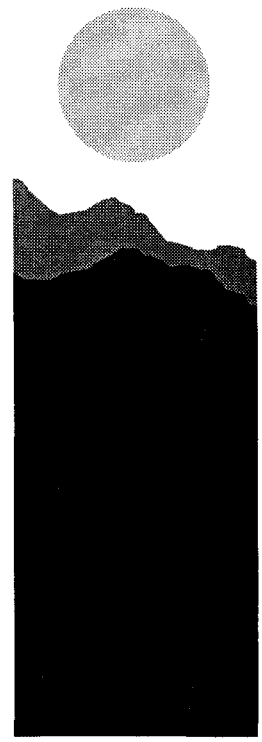
- Continue to evaluate and document the results of the thermal cycle and isothermal corrosion tests.
- Evaluate the need for and plan (if necessary) for future molten-salt tests of a Solar Two receiver panel.
- Initiate salt flow testing of the RAS (internal film receiver) at the Plataforma Solar de Almeria.
- Continue the simple element freeze/thaw testing.
- Complete the ball valve tests and report results to Bechtel.

Major Milestones

Milestone	Planned	Actual
Complete testing of the Bechtel volumetric air receiver at the Plataforma Solar (FY93 carryover milestone).	Jun 93	Oct 93
Publish a report on the testing of the Bechtel volumetric air receiver.	Nov 93	Nov 93
Complete the planned thermal cycling corrosion testing of Stainless Steels and 4000-hr static molten-salt corrosion tests of Cr-Mo materials.	Mar 94	Mar 94
Complete planned tests of the molten-salt components and of the receiver panel on the molten-salt loop. *(Testing continues.)*	Apr 94	
Initiate testing of 500-kW_t RAS molten-salt internal film receiver at the Platforma Solar de Almeria. *(Delayed until Sept.)*	Apr 94	
Complete the planned testing of photometers for measuring global flux on receivers.	Sep 94	Apr 94

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	540	0	0	540
Contracts	489	0	0	489
Total	1029	0	0	1029



2. DISH RECEIVER TECHNOLOGY—

Reflux receivers have the potential of improving the life and performance of dish-Stirling power generation systems. The reflux receiver provides a thermal "transformer" between the dish and engine, providing isothermal, uniform flux to the heater heads. This results in a higher average engine temperature, lower stresses, and fewer constraints on dish design. In addition, the two-phase heat transfer allows a smaller, cheaper, and more efficient receiver. The short-term objectives of the receiver development effort are the demonstration of reflux receiver technology on-sun at scales appropriate for current dish-Stirling projects and to directly compare the performance of a reflux receiver with a directly illuminated heater head through application to the Stirling Thermal Motors (STM) power conversion system (PCS) package. In the longer term, the program will pursue high performance, low cost concepts, develop design tools, develop hybrid receiver technology, and transfer the resulting technology to industry for commercialization.

Accomplishments

Two promising advanced wick structures are under development and test for application to future heat pipe receivers, particularly in support of the joint venture programs. A felt-metal wick option has shown promising initial results. The next-generation Thermacore 75-kW_t heat pipe final fabrication has begun after Thermacore demonstrated significantly improved wick properties. Several full-scale heat pipe receivers have accumulated more than 1000 hours of operation each. Post-test analysis of the bench-scale durability pool boiler is continuing. Sandia is assisting Science Applications International Corporation (SAIC) in the design of a pool boiler for application to the joint venture program.

Bench-scale tests of metal felt wick materials

Felt metals are now being explored as a potential wick structure for a solar receiver. Felt metals are typically made with fine fibers (≈10μm or less) that are loosely laid down to form a mat with a high porosity. Felt metals are commonly used in filtration applications. In an unsintered state, felt metals are extremely pliable so they can easily conform to the shape of a receiver dome.

A bench-scale, heat-pipe receiver was constructed to measure the performance of felt-metal wicks in a liquid metal heat pipe. This test heat pipe is basically a rectangular duct with two sides curving inward (see Figure 2). Along one of the curved surfaces, two strips of a fine stainless steel felt were sintered in place to form a wick. Along the other curved surface, two layers of coarser felt were attached. The felt metal shrinks during the sintering process, so by attaching the material along the convex inner surface of the heat pipe, the felt draws down on the surface while sintering and forms a better bond. After sintering and a slight amount of mechanical compacting, the fine felt had a final thickness of 5.7±0.5 mm, which corresponds to a 99.3% porosity. The coarse wick was given a final thickness of 5.5±0.5 mm, which translates to a porosity of 98.6%. The felts selected were supplied by Porous Metal Products; one will later be incorporated in a full-scale receiver.

The heat pipe was vacuum-baked to remove water and other contaminants in the stainless steel wick and heat-pipe body, and filled with approximately 460 grams of sodium. The heat pipe was then tested on Sandia's bench-scale receiver test apparatus. An array of 12 quartz halogen bulbs delivers power to the heat pipe. Sodium in the wick beneath the heated section evaporates and removes energy from the surface. Sodium vapor then travels to the cylindrical condenser section where energy is removed from the pipe by a water-cooled gas-gap calorimeter. A duct system in the condenser ensures that the liquid falls back to the pool at the bottom of the heat pipe and not directly onto the wick.

High-flux tests have been performed on the fine wick. The lamp array was placed at the center of the 56-cm long curved section, so sodium must flow roughly 30 cm to cool the heat-pipe surface at the top of the lamp array. In this initial test, the lamps delivered an estimated 4200 watts of power to a 33-mm x 203-mm section of the heat pipe. The average flux on the surface is therefore on the order of 620 W/m^2. The heat pipe performed flawlessly during this test. At an operating vapor temperature of 750°C, the heat pipe showed no signs of overheating. Operating conditions that were simulated in this test exceeded the conditions that will be encountered in a full-scale receiver. In the first part of the fourth quarter of FY94, tests will be performed on the coarse wick and additional tests will be conducted to determine the operating limits of the fine wick.

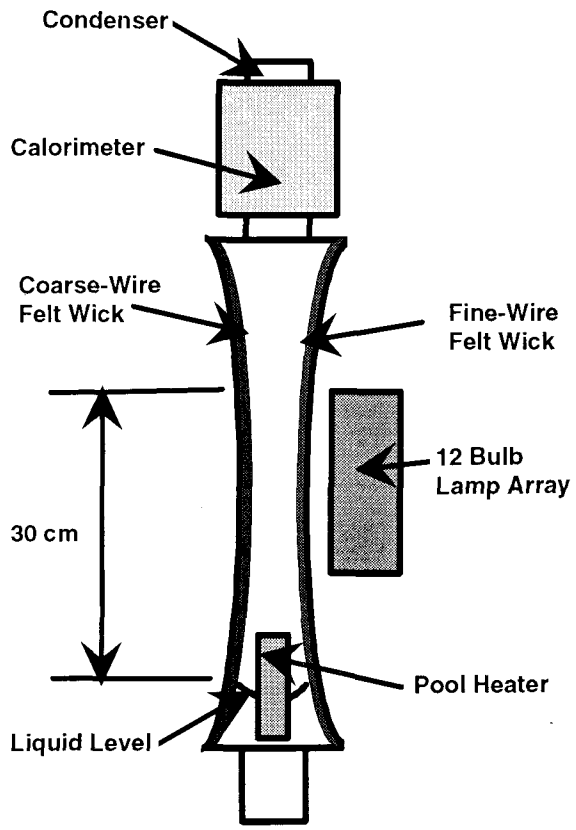


Figure 2. Bench-scale heat-pipe receiver that was constructed to test felt metal wicks. One surface of the test pipe was covered with a fine-wire felt metal wick, and the other surface was made with a coarse-wire felt metal.

Full-scale receiver with a felt metal wick

Porous Metal Products (PMP) in Jacksboro, Texas, is under contract to deliver a wick-covered receiver dome that uses a felt metal material. The first felt-covered receiver dome was delivered in May. The 41-cm diameter hemispherical dome is made of Haynes 230 that is covered with 2 layers of a fine stainless steel felt. Measurements that were made at Sandia on the receiver dome showed that the wick was less than 1-mm thick at the top and about 2.5-mm thick near the edge. A series of tests performed at Sandia indicated that much of the compaction in the wick near the dome's top could have been caused by an overly high sintering temperature. Subsequent tests by PMP have indicated that the thickness can be improved by sintering at a lower temperature.

A second dome was delivered to Sandia in July, incorporating the process changes necessary for a more uniform felt thickness. However, the wick was damaged by rough handling during shipment. A replacement dome will be delivered early in the fourth quarter.

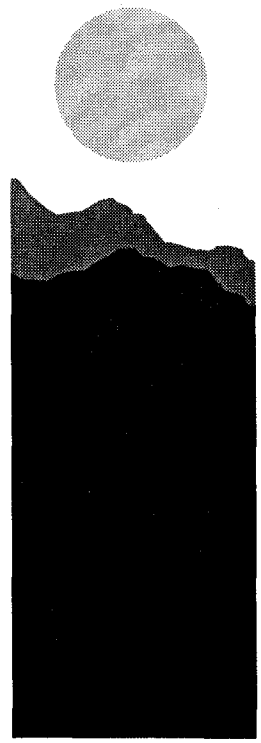
Friction Coating Inc. brazed powder wick

Friction Coating Inc. of Michigan has continued to develop a method of applying their brazed-powder-metal wick structure to the concave surface of a dome. Initial tests on wick samples have indicated good wicking properties with a high wick strength. However, application to a dome has been more difficult than anticipated. Friction Coating delivered a full-size dome to Sandia this quarter. The center one-third of the dome appeared to have a uniform thick coating. However, the remainder of the dome exhibited small "mud cracks" throughout. Friction Coating will continue to develop their process to provide a uniform coating on the entire dome.

CPG/Thermacore full-scale receivers accumulate hours

On-sun operation of the Cummins Power Generation Inc. (CPG)/Thermacore artery-free receiver continued on a regular basis throughout the quarter. **Cummins has accumulated over 1500 hours of operation on-sun with this receiver**. The receiver continues to operated without difficulties or maintenance. Operation will continue based upon dish availability. Thermacore developed an artery-free receiver design for application to the Dish/Stirling Joint Venture Program (DSJVP) project. This has the potential of reducing the receiver manufacturing costs significantly.

A second durability heat pipe has accumulated more than 1350 hours of operation on a solar simulator lamp array at Thermacore. This is the same receiver that was previously limit-tested at Sandia. After initial difficulty with the lamp array, Thermacore is accumulating hours with few bulb failures. The receiver is cycled to a frozen state every four hours. The receiver is also tested at varying solar elevation angles. No degradation in performance has been noted throughout the test. Eventually, the receiver will be limit-tested at Sandia again.



CPG 75-kW$_t$ heat-pipe receiver

Cummins Power Generation Inc. is developing a 75-kW$_t$ heat-pipe receiver under

contract with Sandia. The receiver may be applied to the STM engine package after direct-illumination testing is completed. The receiver is based upon existing wick technology used on the 36-kW_t receiver. All of the receiver parts are available awaiting final assembly. Final assembly has been awaiting demonstrated improvements in the wick permeability. The limited permeability has been blamed on differential thermal expansion between the absorber and the sintering mandrel, and has been seen on the 36-kW_t receiver as well.

Thermacore modified their sintering mandrels and changed their "green" powder metal. These changes resulted in a wick structure with properties suitable for completion of the 75-kW_t receiver. A sample dome has been sent to Sandia for structural analysis. The second 75-kW_t receiver will be fabricated during the next quarter.

Nickel wick mechanical properties

An effort is underway to determine the strength requirements of a Thermacore-type thick nickel wick. This is in support of (1) Sandia's collaboration with Thermacore to develop a 75-kW_t heat-pipe receiver and (2) the DSJVP.

Our present focus is on determining the wick's creep and fatigue behavior. The creep behavior will incorporated into a model that will be used with the fatigue data to predict wick failure. In the present period, high-temperature creep testing of nickel-wick samples has just begun at Ad Tech (Beaver Creek, Ohio). At Sandia, fatigue-testing hardware has been assembled and test protocols and software are being developed. A second wick sample is being prepared from the new Thermacore Inc. wick sample.

Hybrid receiver development

Stirling Technology Company (STC) completed a rebuild of their burner assembly subsequent to a problem experienced in January 1994. The new burner assembly was modified to minimize the possibility of burner flashback, the main problem experienced in January. Modifications included stiffer mounting flanges for the burner element, improved forming of the burner element, and additional instrumentation/software to help identify the problem more quickly. The reassembled system was checked out in both simulated-solar operation and gas operation during a visit by the National Renewable Energy Laboratory (NREL) staff on May 26 and found to operate satisfactorily. During the visit, NREL and STC staff finalized the test plan for on-sun testing at the NREL High Flux Solar Furnace (HFSF), which was subsequently completed in late June.

The main objective of the on-sun testing was to demonstrate that the gas-fired combustor would allow the boiler to deliver constant heat input at constant temperature to a Stirling engine during cloud transients. Specific tests included gas-only testing, solar-only testing, hybrid testing with simulated cloud transients, and hybrid testing with natural clouds. Cloud transients were simulated with the HFSF beam attenuator. This method allowed researchers to test the burner and the control software with a wide range of solar input transients, including step changes up and down, continuous rapid cycling, and a square wave profile. In all cases, the pool and vapor temperatures varied by less than 3°C. A series of natural clouds of widely-varying density and duration gave essentially the same result. The results of this test should significantly improve confidence in the application of dish/Stirling technology for utility applications where dispatchability is a requirement.

Cummins Power Generation Inc. has made significant progress in the fabrication of their hybrid heat pipe during the quarter. A major bottleneck has been machining of the outer heat-pipe cylindrical wall, but that has now been completed. A mandrel for the gas-fired wick was completed; however, the mandrel did not release properly after the sintering process. A modified mandrel has been built and the gas-fired wick will be resintered in early July. With the exception of resintering the gas-fired wick, most of the subassemblies have been completed for the heat pipe and are awaiting final assembly. Cummins now expects to begin natural gas testing in July and on-sun testing in August.

Bench-scale pool-boiler receiver durability test

Metallurgical analysis of the durability bench-scale pool boiler is well underway. There is some evidence of interactions of the boiler construction material (Haynes 230) with the NaK environment. While the precise details of these interactions vary with location in the boiler, the minimal dissolution observed in the worst cases suggests that the alloy is suitable for use in further development studies and for longer periods of operation. Hardness measurements suggest that there are no changes in mechanical properties of the Haynes 230. A preliminary examination of the heated-surface powder-metal coating (Type 304L

stainless steel) revealed no significant changes as a result of 7500 hours of operation. Follow-up direct measurements are planned.

As expected in the last quarter, sufficient information was available by the end of April for completion of a paper on the subject to be presented at the Intersociety Energy Conversion Engineering Conference (IECEC) this August. Metallurgical analysis is continuing and a full report is planned.

Hot-restart testing of the Sandia's second-generation pool-boiler receiver

A series of 155 hot restarts were successfully carried out on Sandia's second-generation pool-boiler receiver with no sign of any problem.

The Science Applications International Corporation Utility-Scale Joint-Venture Project (USJVP) has chosen direct illumination as its primary receiver design. As an alternative, it is considering the Sandia second-generation, pool-boiler receiver. A lingering concern with the pool boiler has been its hot-restart behavior. During hot-restart testing last year, no failures to restart were observed. However, cessation of boiling during cool-down (a hallmark of hot-restart difficulty) did occur. Before xenon was added to the boiler, cessation of boiling during cool-down was regular and persistent; restarts were accompanied by harsh noises and absorber hot spots. After xenon was added, cessation of boiling occurred only twice, early in a series of 34 hot restarts. In both cases, boiling had resumed by the time the shutter opened and the restarts were well-behaved. The lingering concern is that cessation of boiling may occur again, and that if the shutter opens when boiling is not underway, hot spots will recur.

In support of the SAIC USJVP, Sandia has retested its second-generation, pool-boiler receiver. The object of the retest was to increase the size of our sample of hot-restart behavior. We chose to amplify the statistics by executing the restarts under conditions known to aggravate the problem (high sun elevation and a mid-range target restart temperature—650°C). Moreover, we planned to open the shutter immediately if boiling stopped during cool-down.

The tests were conducted on June 14 and 16, 1994. A total of 155 restarts were carried out—37 on the first day and 118 on the second. No cessation of boiling was observed, and every restart was well-behaved. These results indicate that the effect of added xenon requires some short time to maximize; the results substantially reduce our concerns regarding future hot-restart problems.

Absorber buckling analysis for reflux receivers

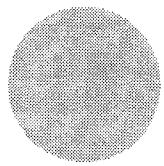
An effort has been started to accurately determine the buckling pressures of real reflux-receiver absorbers. This information is needed to determine how to deal with a leak of high-pressure working gas from a Stirling engine into a receiver. Significant improvements in cost and reliability will accrue if the results indicate that a pressure-relief safety device is not necessary.

In the case of Sandia's second-generation pool-boiler receiver, an appropriate buckling-pressure formula is not available. This initial effort is in support of the SAIC USJVP, which is considering the Sandia second-generation pool-boiler receiver as an alternative to direct illumination, its primary design.

A commercial device (an articulated arm with angle-encoded joints) has been used to accurately measure the surface contour of the second-generation, pool-boiler-receiver absorber. This information is being used as input to a finite-element analysis of the buckling problem. It is expected that first results will be available midway through the next quarter.

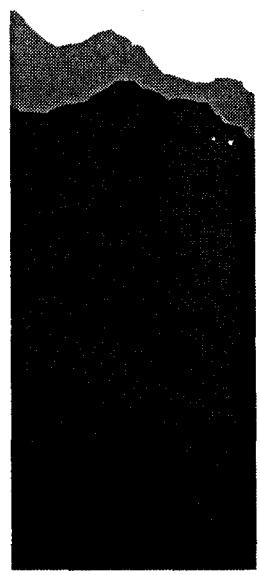
TBC controls and safety upgrades

The control systems for Sandia's Test Bed Concentrators (TBCs) consist of a 1960's vintage satellite-dish controller. These systems can be prone to failure and limit automated operation. An upgrade to modern, flexible, PC-based control systems has been proposed. The specification for the control system upgrade for the TBCs has been finalized and reviewed by purchasing. The request for quotation will be published in the *Commerce Business Daily* early in the next quarter.



TBC-1 lustering program

Sandia's TBC-2 was lustered last summer, improving thermal input to the receiver from 67 kW_t to nearly 80 kW_t. This summer, TBC-1 will be similarly improved. The adhesive has been applied to all of the new mirror surfaces. About one-fourth of the dish's mirrors have been removed and the mounting tabs replaced with a newer design. Complete lustering is expected in the next quarter.



Planned Activities for Next Quarter

- Testing on the bench-scale receiver with a felt metal wick will be continued to determine the operating limits of the wick structure. The measured limit will be compared to models. Once the test plan is completed, the test device will be disassembled and the wick integrity examined. Construction of a full-scale receiver using a felt-metal wick will begin. Plans will be developed for a long-term bench-scale felt-wick heat-pipe receiver.
- The metallurgical examination of the durability bench-scale pool boiler will be completed. Most of the results are expected early in the quarter, and the findings will be presented at the IECEC in August.
- The creep characterization for both the old and new Thermacore thick nickel wicks will be completed. The fatigue testing of the Thermacore thick nickel wick will begin.
- A formal report on the June 1994 hot-restart testing of second-generation, pool-boiler receiver will be completed and distributed to interested parties. In addition, the buckling analysis for the second-generation, pool-boiler receiver in a heater-heat failure mode will be completed.
- Thermacore will complete the fabrication of the modified-design 75-kW_t heat-pipe receiver. The receiver will be processed and tested on Thermacore's bench-lamp array and delivered to Sandia for testing on sun.
- Cummins Power Generation Inc. will continue to test the artery-free heat pipe receiver in Abilene, Texas, as dish availability permits. In addition, operation of complete systems in Abilene and Lancaster, Pennsylvania, will continue to accrue hours on full-scale heat pipe receivers. Thermacore will also continue to accrue hours and cycles on the 36-kW_t heat-pipe receiver in their solar simulator facility.
- Sandia will continue supporting receiver development for the joint venture programs. This includes product improvement for the DSJVP with CPG advanced heat-pipe design for the CPG USJVP, and pool-boiler design support for the SAIC USJVP. STM plans to present a preliminary pool-boiler/engine package design to Sandia this quarter.
- A contract will be awarded for the TBC controls upgrades.

Major Milestones

Milestone	Planned	Actual
Complete 500 hours testing on CPG artery-free heat pipe.	Oct 93	Oct 93
Complete evaluation of relustered TBC-2.	Dec 93	Dec 93
Complete 1000 hrs testing on CPG artery-free heat pipe.	Feb 94	Mar 94
Complete fabrication of Friction Coatings wick on a dome suitable for incorporation in a heat-pipe receiver.	Mar 94	May 94
Complete durability bench scale reflux receiver test.	Apr 94	Jan 94
Begin on-sun testing of STC hybrid pool-boiler receiver.	Apr 94	Jun 94
Complete planned on-sun testing of CPG/Thermacore second-generation 75-kW_t heat-pipe receiver.	May 94	
Begin on-sun testing of CPG/ Thermacore hybrid heat-pipe receiver.	Sep 94	
Complete controls and safety upgrades on Sandia's TBCs.	Sep 94	
Complete on-sun testing of a Sandia-designed heat-pipe receiver.	Sep 94	
Develop statement of work for a second-generation hybrid receiver.	Sep 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	827	175	0	1002
Contracts	862	250	0	1112
Total	1689	425	0	2114

3. DISH CONVERTER SOLARIZATION—

In cooperation with industry, Sandia has been engaged in a program to solarize, test, and evaluate power conversion devices that have the potential to be utilized in commercial solar thermal electric point-focus systems. The goals of the program are to engage in projects that directly support on-going commercialization efforts; to develop solar thermal power conversion systems that are candidates for commercialization; to identify and respond to solar-specific design issues; and to increase the general industry knowledge base on system integration, packaging, and system testing techniques.

Accomplishments

Two projects are currently in progress to develop solarized versions of existing engines. The projects both involve solarization and on-sun testing of engines developed primarily for co-generation applications. The on-sun testing is designed to verify the predicted power conversion system (PCS) performance and determine the suitability of the engines for solar applications.

Brayton cycle power conversion system

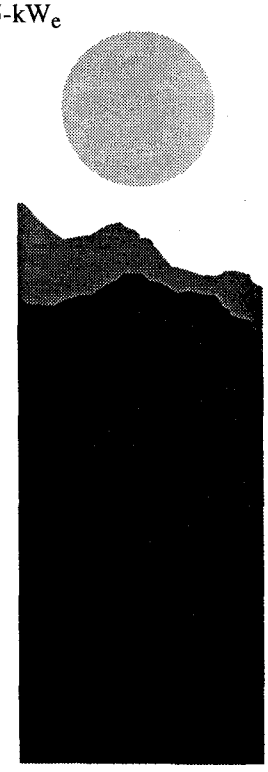
A project is currently underway with Northern Research and Engineering Corporation (NREC) to solarize and test a Brayton cycle PCS. (See Figure 3.) The project builds on the highly successful co-generation (TURBOGEN) system developed by NREC with funding from the Gas Research Institute and Southern California Gas. The German Aerospace Research Establishment (DLR) will supply a volumetric solar receiver for the PCS. The project has been structured for execution in two phases. Phase 1 was a technical and economic feasibility study to determine the system's potential for commercialization when mated with a point focus concentrator. A decision point was built into the project at the end of Phase 1. If the technical characterization or the economic study indicate that the system is not viable for solar use, Sandia has the option to terminate the contract before hardware is fabricated (and most of the project cost is incurred). Phase 2 will include the design, fabrication, and on-sun testing of a 30-kW_e Brayton PCS. The result will be a fully evaluated Brayton system that could potentially be used in the Utility Scale Joint Venture Program (USJVP).

Phase 1 of the NREC project is essentially complete. The draft report on Phase 1 has been written and the final report is expected early next quarter.

Based on the results of the Phase 1 economic analyses and developments in the USJVP, the decision has been made to initiate Phase 2 of the NREC contract. Studies performed by Sandia and industry indicate the cost of a dish/Stirling system at production rates of 10,000 units/year will be in the range of 6 to 9 cent/kWh. The Phase 1 economic analysis obtained cost estimates for dish/Brayton systems at a production level of 10,000 units/year of 6.5 to 8.7 cent/kWh. The value of 6.5 cent/kWh is for a public utility, which does not have to pay corporate taxes, and 8.7 cent/kWh is for a private utility, which does. The values are within the range of cost estimates for dish/Stirling power systems. Thus, it appears that dish/Brayton power systems may be competitive with dish/Stirling systems from the economic perspective. Also, during Phase 1, NREC met with Cummins Power Generation, Inc. (CPG) to discuss the applicability of their 30-kW_e PCS to the CPG USJVP. As a result of this meeting and contingent upon the execution of Phase 2 of Sandia's contract with NREC, CPG has decided to include the NREC engine in their USJVP as a back-up to their baseline Stirling PCS.

Stirling cycle power conversion system

Phase 1 of a cost-shared project with Detroit Diesel Corporation (DDC) and its subcontractor, Stirling Thermal Motors (STM), is complete. This project (see Figure 4) consisted of integrating a 25-kW_e Stirling engine (an upgraded STM4-120) with a direct illumination receiver (DIR), an engine cooling system, an induction generator, and an engine control system into one package. This integrated package is a called a power conversion system.



Prior to delivery to Sandia, the engine was tested with gas-fired heater heads, and then the entire PCS was tested using quartz lamps for the heat input to the receiver. The engine performed quite well during these tests.

Testing of the PCS will be in done three phases. Phase 1 consists of system checkout and debugging. Power and temperature levels started out relatively low (600°C). Two of the specific objectives of this phase are to verify

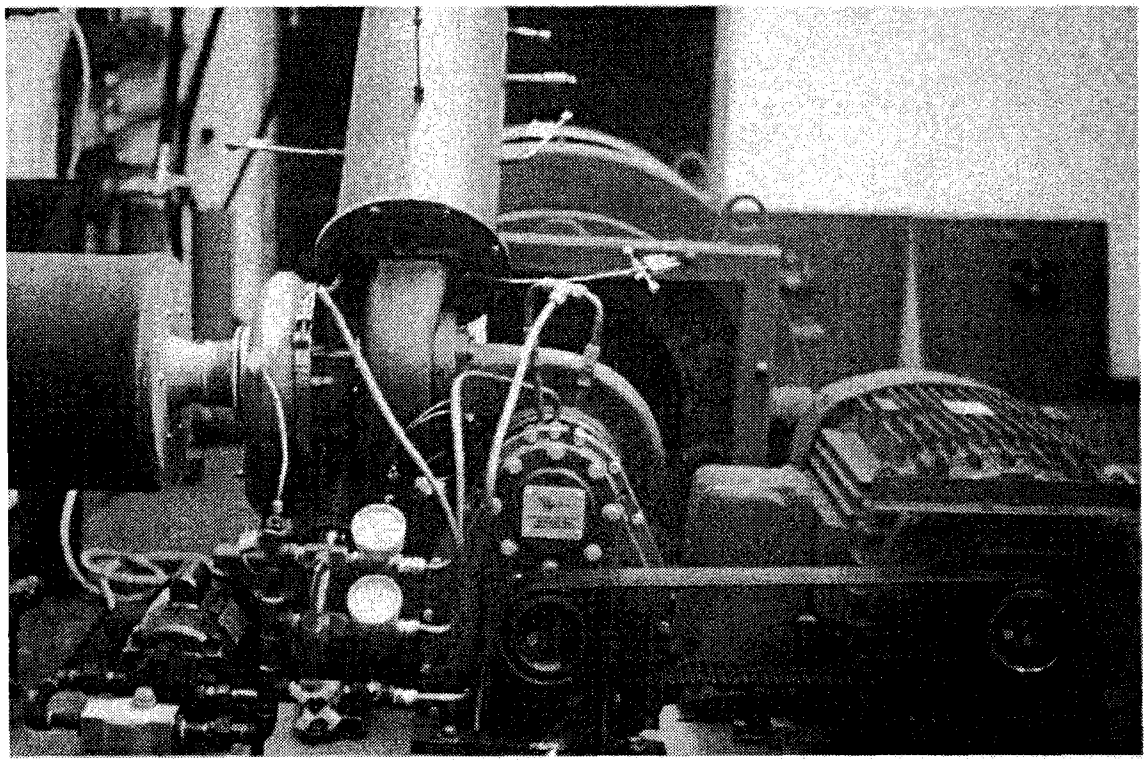


Figure 3: NREC's Brayton engine developed for the Gas Research Institute.

control stability and to verify a reasonable temperature distribution on the DIR. An infrared camera system is used to view the receiver's temperature distribution. For this reason, the 220-mm aperture is removed. This increases thermal losses tremendously, but allows a full view the receiver during these shakedown tests. The infrared system has been a great asset in these tests. After all personnel involved are satisfied with these tests, the 220-mm aperture will be reinstalled and the engine will be operated at full input power. Phase 2 consists of performance mapping the PCS. Power output, PCS, and system efficiencies will be mapped as a function of power input (mirror area) and receiver temperature.

Phase 3 is optional and will be performed only if time and resources permit. The purpose of this phase is to map the PCS at different cycle pressures and to identify anomalies in performance because of less than ideal conditions such as cloud transients and dish tracking errors.

Phase 2 of the project, which consists of performance mapping of the STM engine, was initiated in January. Several difficulties have occurred during this testing: the four heater heads were ruptured when the control system failed during the last quarter and the maximum power level and efficiency achieved by the engine are 16.5 kW_e and 22%, respectively.

During this quarter, the ruptured heater heads were replaced at STM. At the same time, the piston seals were replaced, because faulty seals were thought to be the cause of the low engine power and efficiency. Further on-sun testing at Sandia showed that the new seals did not solve the engine performance problems. Therefore, the engine was sent back to STM for further analysis. STM determined that the cause of the poor performance was rubbing of the engine cross-heads, i.e., the piston rods. This problem is currently being fixed at STM, and it is anticipated that the engine will be returned to Sandia early in the next quarter. Before the engine is returned, additional gas-fired testing will be performed to ensure that the engine performance is near expected values.

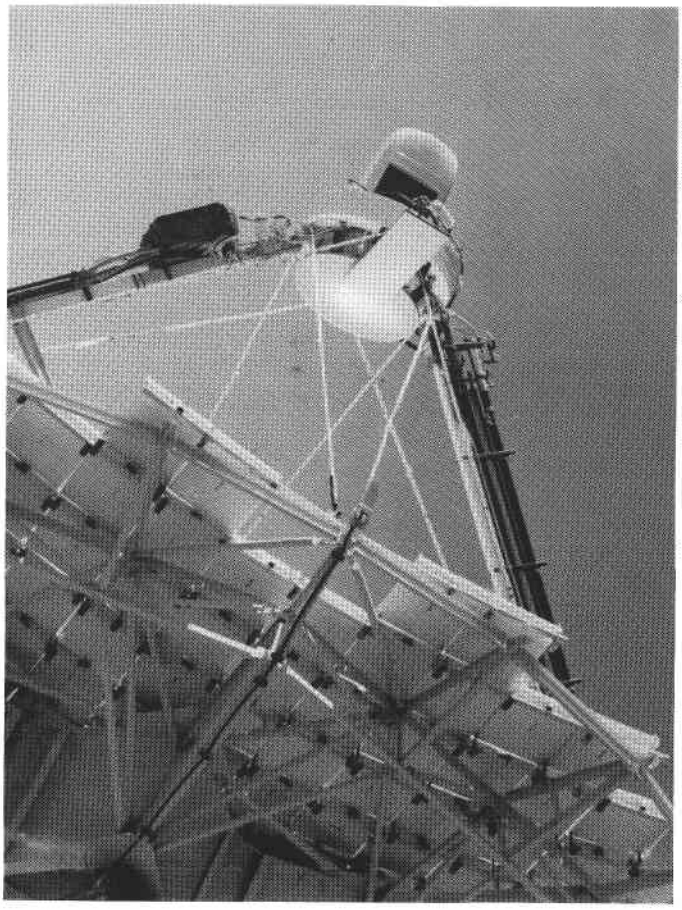


Figure 4: STM/DDC PCS testing at Sandia's NSTTF.

Planned Activities for Next Quarter

- Continue on-sun testing of the STM4-120 PCS with a DIR.
- Complete documentation of the dish/Brayton economic analysis.
- Continue design of the of the NREC/DLR Brayton system.
- Complete final report on the DDC/STM PCS development, design, fabrication, and bench-testing.

Major Milestones

Milestone	Planned	Actual
Complete check-out of the Stirling PCS based on the STM4-120 with DIR.	Jan 94	Dec 93
Complete on-sun testing of the Stirling PCS based on the STM4-120 with a DIR.	Mar 94	
Complete preliminary design and cost analyses of dish/Brayton power systems.	Mar 94	Mar 94
Integrate the Stirling PCS with an alkali metal solar receiver.	Apr 94	Jun 94
Begin construction of a solarized Brayton PCS.	Apr 94	Jun 94
Complete on-sun testing of the Stirling PCS with an alkali metal receiver.	Aug 94	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	324	0	0	324
Contracts	625	0	0	625
Total	949	0	0	949

Publications

Chavez, J.M., R. Lessley, and J. Leon, 1994, **"Design, Fabrication, and Testing of a 250 KW_t Knit-Wire Mesh Volumetric Air Receiver,"** *Proceedings of the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.*

Cohen, G., and D. Kearney, 1994, **"Improved Parabolic Trough Solar Electric Systems Based on the SEGS Experience,"** *Proceedings of Solar 94, the 1994 Annual Conference of the American Solar Energy Society, June 27-30, 1994, San Jose, California.*

Cohen, G., D. Kearney, and G.J. Kolb, 1994, **"Comparison of SEGS Solar Field Performance from Laboratory and Operating Plant Testing,"** *Proceedings of the International Conference on Comparative Assessments of Solar Power Technologies, February 14-16, 1994, Jerusalem, Israel.*

Dohner, J.L., and J.R. Anderson, June 1994, ***Solar Electric Generating System II Finite Element Analysis,*** SAND93-4053, Sandia National Laboratories, Albuquerque, New Mexico.

Frier, S. and G. Cohen, 1994, **"O&M Planning and Implementation for Solar Thermal Electric Plants,"** *Proceedings of Solar 94, the 1994 Annual Conference of the American Solar Energy Society, June 27-30, 1994, San Jose, California.*

Goods, S.H., R.W. Bradshaw, M.R. Prairie, and J.M. Chavez, 1994, ***Corrosion of Stainless and Carbon Steels in Molten Mixtures of Industrial Nitrates,*** SAND94-8211, Sandia National Laboratories, Livermore, California.

Hellmuth. T.E., J.M. Chavez, L.K. Matthews, and C.A. Hale, 1994, **"Performance of a Wire Mesh Solar Volumetric Air Receiver,"** *Proceedings of the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.*

Kelly, B., (Bechtel National Inc.), August 1993, ***Investigation of Thermal Storage and Steam Generator Issues***, SAND93-7084, Sandia National Laboratories, Albuquerque, New Mexico.

Kennedy, C. and G. Jorgensen, 1993,**"Progress in the Development of Advanced Solar Reflectors,"** *Proceedings of the Seventh International Conference on Vacuum Web Coating on November 10, 1993, in Miami, Florida.*

Kolb, G. J., J.M. Chavez, P.C. Klimas, W. Meinecke, M. Becker, and M. Kiera,. 1994, **"Evaluation of Second Generation Central Receiver Technologies,"** *Proceedings of the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.*

Moreno, J.B., C.E. Andraka, T.A. Moss, P.G. Cordeira, V.E. Dudley, K.S. Rawlinson; 1994, ***On-Sun Test Results from Second-Generation and Advanced-Concepts Alkali-Metal Pool-Boiler Receivers,*** SAND93-1251, Sandia National Laboratories, Albuquerque, New Mexico.

Pacheco, J.E., R.M. Houser, and A. Neumann, 1994,**"Concepts to Measure Flux and Temperature for External Central Receivers,"** SAND-93-2504C, *Proceedings of the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.*

Peterka, J., and R.G. Derickson, October 1993, ***Wind Load Design Methods for Ground Based Heliostats and Parabolic Dish Collectors***, SAND92-7009, Sandia National Laboratories, Albuquerque, New Mexico.

Prairie, M.R., S.R. Dunkin, J.M. Chavez, R.W. Bradshaw, and S.H. Goods, 1994, **"Isothermal Corrosion Testing of Steels in Molten Nitrate Salts,"** SAND 93-2334C, *Proceedings of the 1994*

American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.

Rosenthal, A., (Southwest Technology Development Institute), April 1994, ***Monitoring Solar-Thermal Systems: An Outline of Methods and Procedures***, SAND94-0007, Sandia National Laboratories, Albuquerque, New Mexico.

Wendelin, T., and G. Jorgensen, 1994, **"An Outdoor Exposure Testing Program for Optical Materials Used in Solar Thermal Electric Technologies,"** *Proceedings of the ASME International Solar Energy Conference in San Francisco, California, March 27-31, 1994.*

Publications In Progress

Andraka, C.E., S.H. Goods, R.W. Bradshaw, J.B. Moreno, T.A. Moss, and S.A. Jones, **"NaK Pool-Boiler Bench-Scale Receiver Durability Test: Test Results and Materials Analysis,"** SAND94-1532C, *Proceedings of the 29th Intersociety Energy Conversion Engineering Conference, August 8, 1994, Monteray, California.*

Andraka, C.E., et al, **"Felt-Metal-Wick Heat Pipe Solar Receiver,"** *Proceedings of the American Society of Mechanical Engineers Solar Energy Division Meeting, March 1995, Maui, Hawaii.*

Andraka, C.E., et al, **"Performance And Materials Analysis Of A Bench-Scale Nak Pool Boiler,"** *Proceedings of the American Society of Mechanical Engineers Solar Energy Division Meeting, March 1995, Maui, Hawaii.*

Diver, R.B., S.A. Jones, S. Robb, and A.R. Mahoney, ***The Lustering of TBC-2,*** SAND94-1832, Sandia National Laboratories, Albuquerque, New Mexico.

Dudley, V., et al., ***Test Results for the LUZ LS-2 Solar Collector,*** draft report, January 1994.

Grossman, J.W., **"Development of a 2f Optical Performance Measurement System,"** SAND 93-1533C, *Proceedings of the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.*

Jorgensen et al., **"Polymers for Solar Energy Devices,"** *Functional Polymers for Emerging Technologies,* American Chemical Society.

Kolb, G.J., **"Evaluation of Power Production from the SEGS Plants at Kramer Junction,"** *Proceedings of the American Society of Mechanical Engineers Solar Energy Division Meeting, March 1995, Maui, Hawaii.*

Romero, V.J., CIRCE2/DEKGEN2: **A Software Package for Facilitated Optical Analysis of 3-D Distributed Solar Energy Concentrators - Theory and User Manual,** SAND91-2238, Sandia National Laboratories, Albuquerque, New Mexico, February 1994.

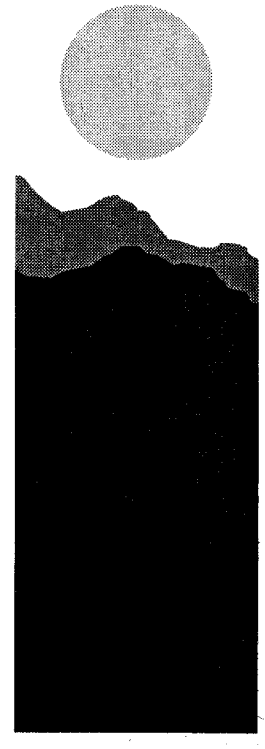
Schissel, P., et al., **"Silvered-PMMA Reflectors,"** *Journal of Solar Energy Materials and Solar Cells* (accepted for publication).

Stine, W.B., and R.B. Diver, ***A Compendium of Solar Dish/Stirling Technology,*** SAND93-7026, Sandia National Laboratories, Albuquerque, New Mexico, January 1994 (in press).

Strachan, J., ***Operational Experience and Evaluation of a Dual-Element, Stretched-Membrane Heliostat.***

Meetings and Presentations

Andraka, C.E., S.H. Goods, R.W. Bradshaw, J.B. Moreno, T.A. Moss, and S.A. Jones, ***NaK Pool-Boiler Bench-Scale Receiver Durability Test: Test Results and Materials Analysis,*** SAND94-1532C, to be presented at the 29th Intersociety Energy Conversion Engineering Conference, August 8, 1994, Monteray, California.



Andraka, C.E., et al, ***Felt-Metal-Wick Heat Pipe Solar Receiver,*** to be presented at the American Society of Mechanical Engineers Solar Energy Division Meeting, March 1995, Maui, Hawaii.

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Frier, S. and G. Cohen, ***O&M Planning and Implementation for Solar Thermal Electric Plants,*** presented at Solar 94, the 1994 Annual Conference of the American Solar Energy Society, June 27-30, 1994, San Jose, California.

Grossman, J.W., ***Development of a 2f Optical Performance Measurement System,*** SAND 93-1533C, Sandia National Laboratories, presented at the 1994 ASME International Solar Conference, San Francisco, California, March 27-30, 1994.

Hellmuth. T.E., J.M. Chavez, L.K. Matthews, and C.A. Hale, ***Performance of a Wire Mesh Solar Volumetric Air Receiver,*** presented at the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.

Jorgensen, G., ***A Strategic Plan for Solar Reflector Material Commercialization,*** presented at a session devoted to "How Companies are Applying their Expertise to Develop Advanced Reflective Films" at the SolTech '94 conference held in Ponte Vedre Beach, Florida, March 1994.

Kennedy, C., and G. Jorgensen, ***Progress in the Development of Advanced Solar Reflectors,*** presented at the Seventh International Conference on Vacuum Web Coating, November 10, 1993, in Miami, Florida.

Kolb, G.J., ***Evaluation of Power Production from the SEGS Plants at Kramer Junction,*** to be presented at the American Society of Mechanical Engineers Solar Energy Division Meeting, March 1995, Maui, Hawaii.

Kolb, G. J., J.M. Chavez, P.C. Klimas, W. Meinecke, M. Becker, and M. Kiera,. ***Evaluation of Second Generation Central Receiver Technologies,*** presented at the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.

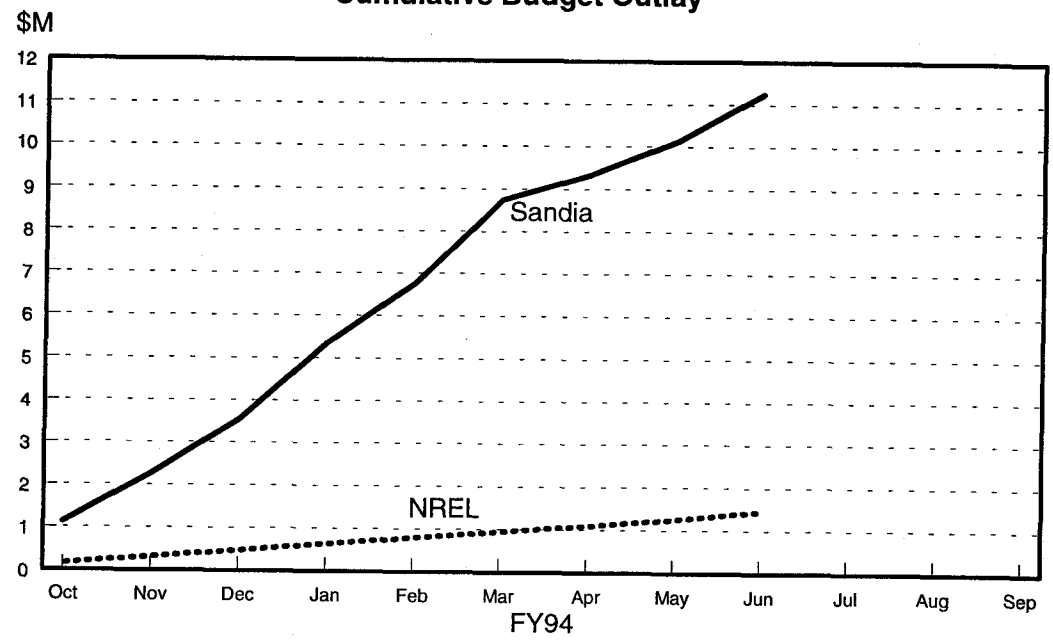
Pacheco, J.E., R.M. Houser, and A. Neumann, ***Concepts to Measure Flux and Temperature for External Central Receivers,*** SAND-93-2504C, presented at the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.

Prairie, M.R., S.R. Dunkin, J.M. Chavez, R.W. Bradshaw, and S.H. Goods, ***Isothermal Corrosion Testing of Steels in Molten Nitrate Salts,*** SAND 93-2334C, presented at the 1994 American Society of Mechanical Engineers International Solar Energy Conference, March 27-30, 1994, San Francisco, California.

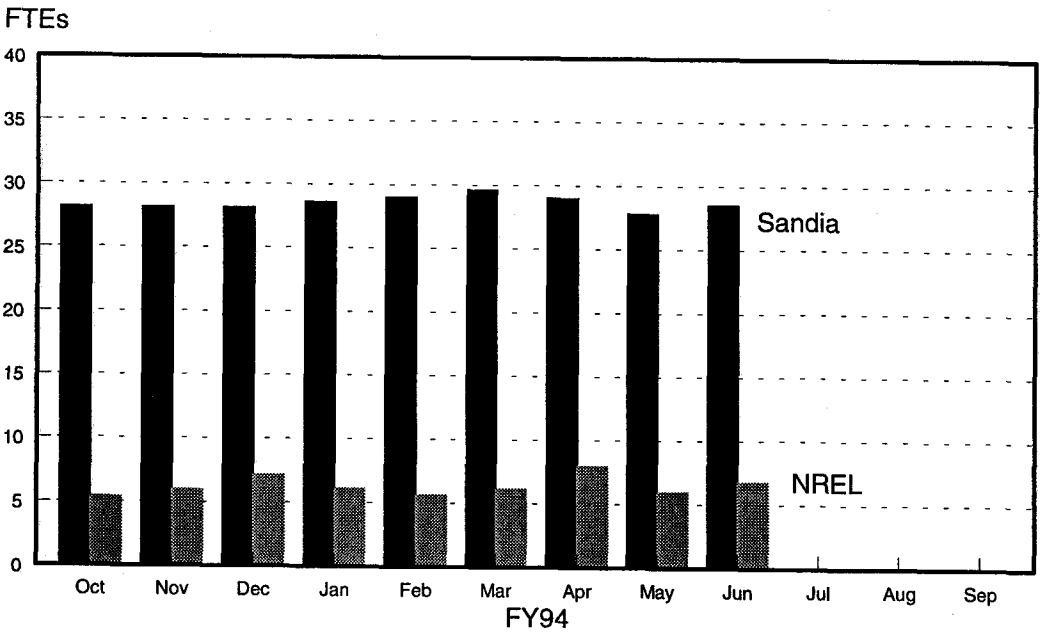
Wendelin, T., and G. Jorgensen, ***An Outdoor Exposure Testing Program for Optical Materials Used in Solar Thermal Electric Technologies,*** presented at the 1994 ASME International Solar Energy Conference, San Francisco, California, March 27-30, 1994.

Williams, T., G. Jorgensen, and T. Wendelin, ***Advanced Reflector Materials for Solar Concentrators***, an extended abstract submitted for presentation at the 7th International Symposium on Solar Thermal Concentrating Technologies, September 26-30, 1994, Moscow, Russia.

Cumulative Budget Outlay



Monthly Manpower Summary



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Contracts over $100k

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($k)	Prior Year Funds ($k)	FY94 Funds ($k)	Total Costs to Date ($k)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IB	DSJVP	Cummins	SNL 69-7763	6968	5045	1000	6045	06/91-09/95	Large	Phase	R. Diver
IB	USJVP	SAIC	SNL AB-8717A	8828	1656	1600	1238	12/93-09/98	Large	Phase	T. Mancini
IB	USJVP	Cummins	SNL AB-8717B	8989	1500	1600	496	01/94-09/98	Large	Phase	D. Gallup
IB	USJVP	Competitive	SNL AI-1530	10900	0	840	0	—	—	—	D. Gallup
IC	O&M cost reduction	KJC	SNL AB-0227	3154	1350	782	1319	07/92-09/95	Large	Phase	G. Kolb
ID	Commercial-ization Support	Meridian	SNL AF-4595	175	175	0	175	06/93-06/95	Large	Final	P. Klimas
II	Solar Test Support	EG&G	SNL AH-5081	990	99	0	96	10/93-10/94	Large	N/A	C. Cameron
II	Electrical Support Service	J&S Electric Co., Inc.	SNL 75-7415	351	351	0	351	02/89-02/94	Serv. Support	N/A	L. Gillette
IIA1	NSTTF Technicians	Ewing	SNL 63-5487	1947	1947	0	1820	04/89-04/94	Serv. Support	N/A	E. Rush
IIB2	Heat-pipe	Cummins	SNL AB-3348A	84	52	32	84	05/93-08/94	Large	Monthly	C. Andraka
IIB3	Dish/Stirling	Cal Poly Pomona	SNL 67-3678	155	146	0	140	11/91-05/94	Univ	Final	P. Klimas
IIB3	STM Engine	DDC	SNL AE-5963	132	132	0	117	03/93-03/94	Large	Final	S. Rawlinson
IIB3	Brayton Engine solarization	NREC	SNL AG-0408	153	153	0	153	08/93-02/94	Large	Phase	D. Gallup

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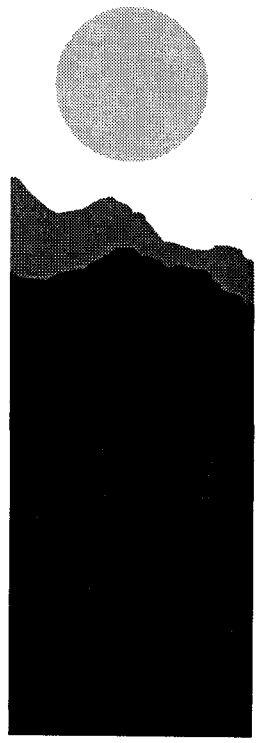

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