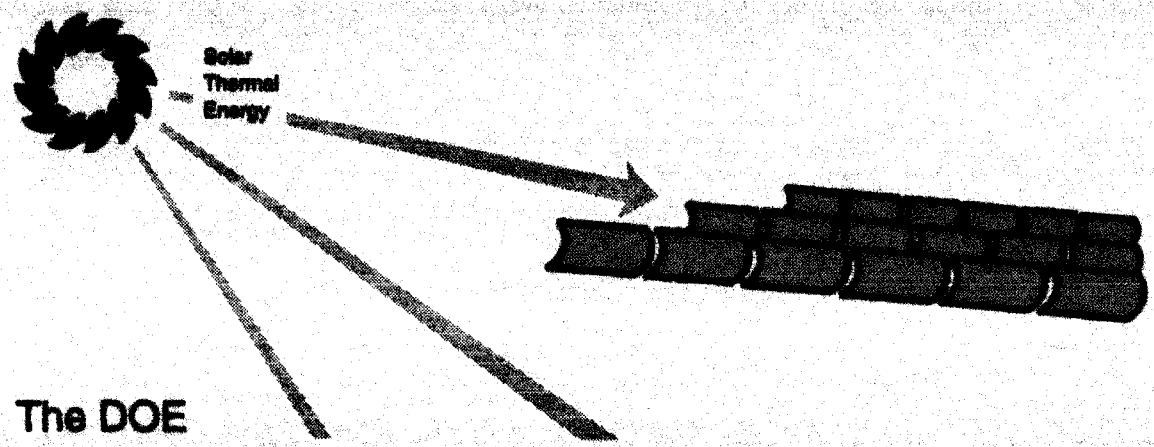
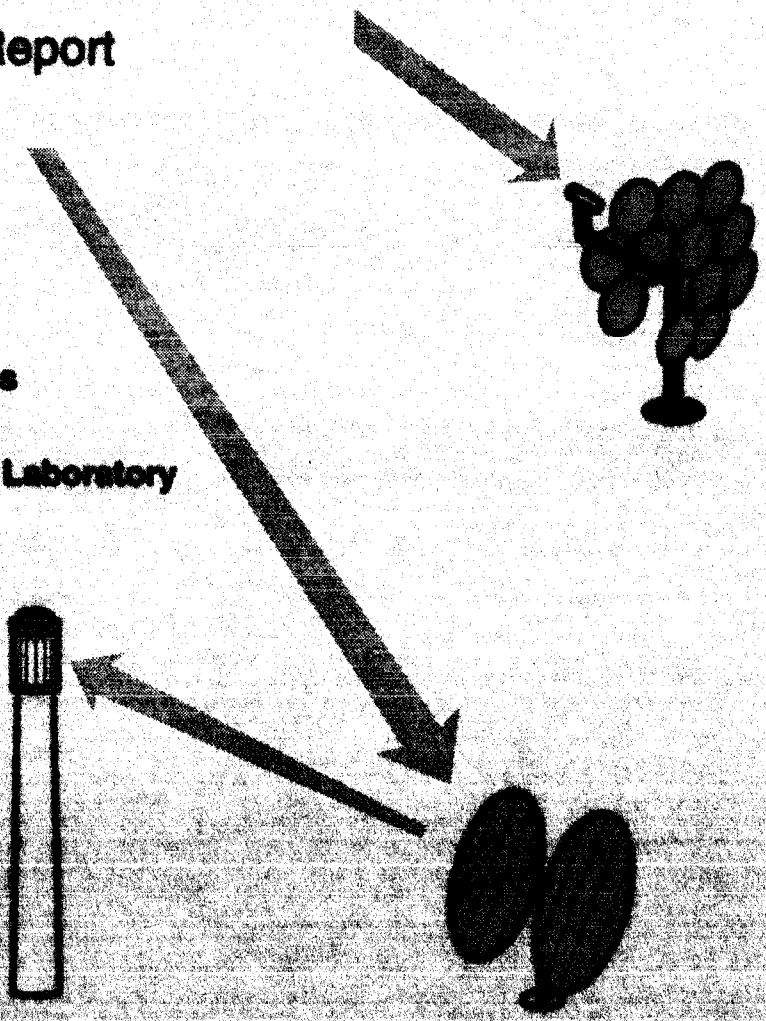


The DOE

Solar Thermal Electric Program

Quarterly Progress Report
Third Quarter FY93



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Solar Thermal Electric Program Summary

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.

To date, over 350 MW_e of STE systems have been installed in the U.S., 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 the power tower, parabolic dish/engine, and parabolic trough technologies. These joint ventures, valued at over $75M, 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

Installation of 900 MWe of U.S.-designed and -manufactured solar thermal electric systems worldwide by the year 2000. We expect to realize this vision through the Office of Solar Energy Conversion's coordinated activities[1] in:

- Systems and Market Development
- Manufacturing
- Research and Development

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, technology development, and validation to

- increase acceptance of this technology as a candidate for cost-competitive power generation by utilities,
- 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,
- aggressively support the development of the industrial base required to penetrate the various energy applications and markets, creating new jobs and business opportunities for U. S. industry.

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

Our Strategy

Our program strategy is consistent with the objectives set forth by the Office of Solar Energy Conversion in ***SOLAR 2000 - A Collaborative Strategy.*** The Department of Energy (DOE) and its field laboratories will seek to

- Increase, through cooperative ventures, industrial participation in both the planning and execution of program elements. Successful projects include the following:
    - 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_e utility-scale power tower module, which is due for installation by the end of the decade.
    - The Cummins Engine Company 7-kW_e dish/Stirling system will be commercially available by 1996 for remote and grid-connected applications.
    - Contracts will be awarded under the Utility-Scale Joint-Venture Program for 25-kW_e dish/engine systems, with the last phase of this program resulting in at least one megawatt of dish/engine system capacity installed by utilities by the late 1990s.
    - The operations and maintenance cost reduction study for parabolic trough plants will be completed by 1995, thereby providing 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 national labs to support and enlarge the program's user, supplier, and decision-making constituency.
- Contribute to the DOE 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 core program: 1) opportunity for high-risk 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 FY93 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.

Program Structure

The Solar Thermal Electric Program is structured to provide a balance of activities that exploit near-term commercialization opportunities, improve readiness to meet long-range performance and cost goals, and maintain a forward-looking research thrust to open new applications. There are three major program elements:

I. COMMERCIAL APPLICATIONS

- A. Central Receiver Cooperative Projects
- B. Dish/Engine Cooperative Projects
- C. System Operation and Maintenance Cost Reduction
- D. Design Assistance

II. TECHNOLOGY DEVELOPMENT

- A. Concentrator Technology
  1. Heliostats
  2. Parabolic Dishes
  3. Optical Materials
- B. Power Conversion Technology
  1. Central Receiver Technology
  2. Dish Receiver Technology
  3. Dish Converter Solarization Technology

III. REIMBURSABLES

Summary of Accomplishments: Third Quarter FY93

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

Solar Two

- The Solar Two Engineering and Construction Management Agreement was signed by Southern California Edison and Bechtel.
- Request for bids to demolish/remove the Solar One thermal storage system were released by Southern California Edison on June 25, 1993.
- Solar One heliostat riveting/venting was completed.

Cummins Joint Venture

- Various updates/improvements were made to Cummins 7kWe system.
- Cummins' Phase 2 design definition was completed.
- Cummins' 7kWe system was recognized by *R&D Magazine* as one of the 100 top R&D achievements in 1993.

System Operation and Maintenance (O&M) Cost Reduction

- An improved reflectance measurement device estimated to reduce Solar Electric Generating Systems (SEGS) survey time by a factor of five was developed.
- An alternative selective surface coating device, expected to cost ~1/4 that of the machine developed for LUZ, was proposed. Coupons coated using the process envisioned for the new machine were found to have similar properties to those produced for LUZ.
- State-of-the-art maintenance planning software was installed by the Kramer Junction Company.

Concentrator Technology

- The dual-module stretched membrane heliostat's tracking was evaluated.
- On-sun testing of SKI's 3-meter diameter dish facets was completed.
- Flux and calorimetry measurements of the faceted stretched membrane dish were completed.
- Collaborative efforts with three industrial partners, Dow Chemical, 3M Company and Martin Marietta, have produced three optical materials for evaluation for solar applications.
- Reduced silvered polymer reflector delamination was demonstrated.

Power Conversion Technology

- Molten-salt loop testing has begun.
- Low corrosion rates were measured in molten-salt/steel corrosion tests.
- Spain/USA joint central receiver test preparations are continuing.
- Testing of the second-generation pool boiler receiver was completed.
- 3800-hour point was reached in the 10000-hour bench scale dish receiver durability test program.
- Hybrid dish receiver fabrication continues on schedule.
- A Statement of Work was negotiated with Northern Research and Engineering to develop a Brayton cycle power conversion system.
- On-sun testing was initiated on the Detroit Diesel/Stirling Thermal Motors STM4-120-based power conversion system.

Solar Thermal Electric Program
Quarterly Progress

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 megawatts. The program also supports existing parabolic trough collector systems for the purpose of operation and maintenance (O&M) cost reduction. The 354 megawatts 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, three major 50/50 cost-shared cooperative activities are underway within the program with a total value of $75M. 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 (dish/engine systems)

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

A. Central Receiver Cooperative Projects

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

A consortium of United States utility concerns led by Southern California Edison Company (SCE) has begun a cooperative project with the U. S. Department of Energy (DOE) and industry to convert the 10 MWe Solar One Central Receiver Pilot Plant to utilize molten-nitrate-salt technology. Successful operation of the converted plant, to be called Solar Two, will reduce the economic risks in building the initial commercial central receiver power projects and accelerate its 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, Pacific Gas and Electric Company, Sacramento Municipal Utility District, Arizona Public Service Company, Salt River Project, City of Pasadena, California Energy Commission, Electric Power Research Institute, South Coast Air Quality Management District, and Bechtel Corporation. Sandia National Laboratories is providing technical support to 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 a 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

Solar Two E&CM agreement.

The three key agreements necessary to begin the Solar Two Project have been signed. The three key agreements are the Participants Agreement (signed December 9, 1992), the Cooperative Agreement (signed April 6, 1993), and the **Engineering and Construction Management (E&CM) Agreement with Bechtel, which was signed this past quarter on June 29**. Little technical progress has been made on the Solar Two Project in the last two months of this quarter because of the delay in finalizing the Bechtel agreement.

There are numerous other Solar Two agreements with other participants and contributors that are currently being finalized. **Two important agreements that were finalized this past quarter are the Electric Power Research Institute (EPRI) Funding agreement** (signed June 25, 1993), which allows Utility Tailored Collaboration funding to be received by the Project, and **the Amendment to the EPRI Funding Agreement** (signed July 2, 1993) that makes EPRI a Participant on the Solar Two Project.

Two other important agreements that have not been finalized are the Pacific Gas and Electric Company (PG&E) Agreement and the California Energy Commission (CEC) Contract. The participation and funding from PG&E are questionable at this time because of the reorganization and restructuring at PG&E. It appears at this time that if they do participate, PG&E may only sign on as a Contributor ($100 K). No problems are expected with the CEC contract.

At this time the Solar Two Project Participants are funded at a level of $17.5 M (this assumes PG&E participation), although Southern California Edison (SCE) has agreed to backstop the Project. SCE is still pursuing funding from the Bureau of Reclamation, Nevada Power, and Rockwell.

Prior to Bechtel stopping work in early May because of the expiration of the interim funding, Bechtel had drafted the Design Basis Document, Operation and Maintenance Document, and a Receiver Specification. All of these documents have been reviewed by the Technical Advisory Committee (TAC) and comments and recommendations have been given to the SCE Project Manager. Now that Bechtel is back at work, they have begun work on the plant design and all the major documents. The current Solar Two schedule calls for Phase One to be completed Oct. 15, 1993. At that time, engineering design will be completed and an engineering cost estimate will be finalized. Phase Two, major procurements, will last 7 months, and Phase Three, construction, will last 16 months, being completed in August 1995. Phase Four, Startup and Checkout, will last six months and Phase Five, Power Production, will begin in the Spring of 1996.

Solar Two TAC meetings.

A Solar Two Technical Advisory Committee (TAC) meeting was held on April 14-15, 1993, in Los Angeles, California. The meeting consisted of a tour of the Energy Technology and Engineering Center and a day of meetings to discuss the reviews of the Solar Two documents. Thirty-three people attended the meeting, including representatives from all Participants, Contributors, the DOE, and Sandia. The meeting was useful in reviewing the documents and plant design and transferring technology to the Participants.

Solar One thermal storage system.

The DOE and Southern California Edison have reached agreement and are proceeding with demolition and removal of the Solar One thermal storage system. SCE will act as Project Manager for the thermal storage removal. SCE intends to contract with a single firm that will handle the entire demolition, material removal, and site restoration effort. Bids are due on July 30, 1993, and SCE plans to award the contract in mid-August.

Solar One heliostat riveting.

The riveting and venting of the Solar One heliostat field facets, to prevent further lost of facets, was completed this past quarter. Sandia is pursuing three other activities related to the heliostats at Solar Two: the development of a new stimulator, the completion of the survey of the heliostat field at Solar Two, and the installation of a Lugo-type heliostat with flat glass facets at the National Solar Thermal Test Facility (NSTTF) for testing. The new stimulator was ordered this past quarter and will be available in August to use in the survey of the field. In May, a meeting was held with Carrisa Solar at their Lugo site to inspect the trackers and discuss the use of "Lugo"

heliostats at Solar Two. It appears that a heliostat made up of a Lugo type tracker ($95m^2$) and flat glass from the Carriza Plains facility could work at Solar Two. In order to test this design, an existing "Lugo" type tracker along with Carrizo Solar-supplied glass will be installed and tested at the NSTTF. The "Lugo" heliostat will be operational in October 1993 for evaluation.

Sandia/Rockwell receiver discussions.

Engineers from Rockwell requested a meeting with Sandia in early June to discuss receiver materials issues. Rockwell has been working on a receiver design in anticipation of the Solar Two receiver specification. Rockwell discussed their concerns with using 316 Stainless Steel for the receiver tubes--and their interest in other materials. Unfortunately, there is little thermal-mechanical fatigue and salt corrosion data on other materials. Rockwell may be interested in having Sandia conduct some salt corrosion materials tests.

This past quarter, Sandia has begun a study to evaluate the effect of different operational strategies on the Solar Two plant parasitics. The study is evaluating whether the salt risers and downcomers should be drained or bumped, or if alternate heat tracing techniques should be investigated. Sandia is also studying the parasitics of the SEGS 1 plants to determine if there are lessons that can benefit Solar Two and molten salt plants.

Planned Activities for Next Quarter

- The next Steering Committee meeting is scheduled for July 23, 1993, in Albuquerque, New Mexico. The next TAC meeting is scheduled for August 11-12, 1993, in Albuquerque, New Mexico.
- Continue technical support of SCE's efforts to define the design of Solar Two that best simulates a commercial plant and addresses the technical issues of central receivers.

Milestones (Planned/Actual)

(Nov 92/ Jun 93) Finalize Solar Two Participants, Engineering and Construction Management, and DOE Cooperation Agreements.

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. In January, the Dish/Stirling Joint Venture Program (DS-JVP) with Cummins Power Generation, which is the archetype of the joint venture team approach, progressed from phase 1 to phase 2 on schedule and on budget. Although much of the effort during the quarter was spent "cleaning-up" phase 1 issues, significant progress has been made toward key phase 2 objectives, primarily in the engine and collector development areas. Request for best and final offers were sent to the responsive proposers for the Utility Scale Joint Venture Program (US-JVP). The amended proposals are currently being evaluated at Sandia. Avenues for proceeding with the US-JVP are being explored.

Accomplishments

Cummins system updated.

Operation of the Cummins Power Generation, Inc. (CPG) dish/Stirling system continued throughout most of the quarter at the CPG facility in Abilene, Texas. The use of a "heavier" space frame constructed from 1 1/4" 18 gage steel tubes vs. 1" 20 gage steel tubes has helped to avoid resonant 60 Hertz vibrations induced by the free-piston Stirling engine. Prior to the change, space frame members had continued to fail in spite of the lower vibration levels resulting from the isolators. The rate of failure incidents recorded in the Standard Engine Reliability Tracking System (SERTS) used by Cummins, dramatically decreased after the vibration isolators were implemented. Most of the incidents were related to over-temperature of the aperture plate thermocouples caused by the vibration of the free-piston Stirling engine. The most severe incident, a leak in the heat-pipe receiver, occurred near the end of the quarter and resulted in a one-month shutdown of the system. **At the end of the quarter, 431 hours**

of operation have been logged on the Abilene system.

New heater head on Lancaster system.

The system installed at the Thermacore test site in conjunction with the Pennsylvania Energy Office was retrofitted with a new electron-beam welded heater head and began operation during the week of June 14. For the "design validation" engines, Sunpower and Cummins are developing an innovative all welded design that appears to also have the advantage of lower stress. **At the end of the quarter, 35 hours were logged on the Lancaster system.**

Phase 2 design definition completed.

Design definition of the "design validation" (DV) engine was completed during the quarter and quotes for the various components have been received. Like the "concept validation" (CV) engine, the DV engine incorporates gas bearings. However, it also uses planar springs (a kind of flexure) to provide piston centering and to minimize hysteresis losses. The drawing package for the DV engine (approximately 120 total drawings) is significantly slimmer than the one for the CV design (approximately 214 total drawings). As mentioned previously, a new type of heater head configuration will be used. In addition, the cooler and alternator configurations are being modified. **The DV engine's nominal rated output is 9 kW_e, although a potential to grow to 13 kW_e is being designed into it. At the same time, the engine/alternator weight will be more than 100 kg less than the CV engine/alternator.** The lower engine/alternator weight will permit the cooling system to be mounted near the engine. In the CV system, the cooling system is mounted on the backside of the concentrator space frame.

The engine/alternator efficiency goal is 33% at 675°C. The use of Inconel 625 for the heater head should enable higher temperatures and efficiencies. Onan Corporation, a wholly owned subsidiary of Cummins Engine Company, is providing alternator design consulting and is assisting in the fabrication of some of the alternator and flexure parts. Much of the DV engine/alternator design was performed during phase 1; however, this still remains as the key critical path activity in phase 2. Most of the parts have been ordered. Engine testing is expected to take place by October.

DSJVP meetings/demonstrations held.

The second phase-2 team meeting of the Dish-Stirling Joint Venture Program (JVP) was held at the Sunpower, Inc. facility in Athens, Ohio on May 19, 1993. The meeting focused on Stirling engine/linear alternator status and on system controls. In addition, an industry team meeting and demonstration was held in Abilene on June 9-10. Representatives from Southern California Edison, the Electric Power Research Institute, West Texas Utilities, Central and South West Corporation, Georgia Power, American Telephone and Telegraph, California State Polytechnic University, the National Renewable Energy Laboratory, the United States Department of Energy, and Sandia National Laboratories were in attendance.

Parallel engine/alternator development.

Because of the importance of the free-piston Stirling engine/linear alternator to the Joint Venture Program, Clever Fellows Innovation Consortium (CFIC) was included as a parallel Stirling engine developer. The CFIC engine technology, which utilizes flexures, virtually eliminates wear and makes possible extremely long-life engines. Cummins is paying 100% of the CFIC engine development cost. CPG plans to select either the Sunpower or CFIC engine for further development in the August 1993 time frame in phase 2 of the JVP. The CFIC engine/alternator incorporates a number of clever innovations, including a relatively low-stress heater-head configuration, strap-type flexures, and a low-cost alternator. The opposed configuration of the CFIC design is also inherently balanced. Design and fabrication of the CFIC engine/alternator is now approximately five months behind schedule. Most of the delays have been caused by vendor errors in critical parts. In addition, an error was made in a linear-alternator design calculation. The linear alternator was able to produce only 4 kW_e. Because of the attractiveness of the CFIC alternator design from a manufacturability perspective, CPG and CFIC have decided to demonstrate the engine/alternator at a reduced power output. **CFIC expects to initiate engine testing by August.**

CPG controls development approach.

CPG has relieved Cummins Electronics (CEL) of controls development responsibility and has acquired personnel and consultants with the required controls background. The analog load interface, remote village electrification system developed by CEL was not cost effective and will be replaced by a digital-control load interface system. CPG is also consulting with Onan who is developing a digital control system for recreational vehicle power systems. The ADA programming language used by CEL (it was

originally dictated by NASA during the Advanced Stirling Converter System (ASCS) program) will be replaced by C++. The concentrator controls are already programmed in C++. CPG expects to finally integrate the concentrator and engine controls by September. Development of digital interface remote village electrification and utility grid tie system controls is in progress. CPG also wants to look at implementing lower-cost AC motors for the water pump application. CPG still intends to use CEL in a consulting role and in the next phase to assist with controls and sensor qualifications and design.

Internal power modulation device.

Sunpower demonstrated a new internal power modulation device on a CV engine/alternator that allows nearly constant voltage and constant frequency output with changes in load. **This approach should be much cheaper and more reliable than either the auto-transformer or pulse-width-modulation digital control methods previously considered.** Details of the internal power modulation design have not been completed. However, the DV design has space to accommodate an internal power modulation device.

Heat-pipe receiver development.

During the quarter, Thermacore worked with Sandia on the investigation of the source of the hot spots that were observed on the Durability heat-pipe receiver after approximately 450 hours of testing. The receiver completed over 500 hours of on-sun testing in May 1992 and was subsequently sent to Sandia for limits testing. The receiver was then returned to Thermacore, where on-sun testing continued for a total test time of approximately 600 hours before it was removed and dissected. Other than a number of very fine cracks in the wick, no change in wick morphology was detected. Pull tests indicated no loss of wick adhesion with the absorber wall, and permeability tests, at Thermacore and Sandia, indicated no change in wick permeability over the 600 hours of on-sun testing. Mercury porosimeter analysis also indicated no change in pore size distribution. To minimize wick requirements, Thermacore has incorporated "refluxing" into the next durability heat pipe receiver design. This next generation receiver, which is being supported by NREL, also incorporates an artery free design to reduce fabrication cost and complexity. As of July 1, 1993 the durability receiver had accumulated over 150 hours on-sun in Abilene, Texas. As a result of the "warm spots" observed during testing, Thermacore will use both arteries and reflux in receivers delivered in phase 2. Sandia simulations of the Thermacore design with the WICKSOLV computer model indicates marginal design margin (factor of safety of 1) with either refluxing or arteries alone and an adequate margin with both approaches (factor of safety of 2). Sandia is working with CPG and Thermacore on resolving this issue. Collaboration and technology transfer of the WICKSOLV model, wick properties measurement techniques, electron microscopy, and development of alternative wick designs are areas in which the Sandia receiver team is helping the JVP on this issue.

SNL/NREL coordinate concentrator support.

Sandia and NREL coordinated optical materials support for the JVP. Sandia provided sample thin-glass mirrors for the CPG facets and is working with U.S. glass companies to provide a low-cost, yet flexible-enough mirror option for the CPG design. The glass mirrors have the advantages of high reflectivity (> 90%) and long-term durability compared to the polymer film mirrors. NREL is providing weatherometer testing, reflectivity and SHOT measurements, and design assistance for the internal CPG efforts to develop a high performance plastic film. NREL is also working to deploy program-supported, silver film options, as they become available, on CPG facets. **This coordinated, multiple parallel path approach is seen as essential for addressing the critical optical materials issue, and is a good example of the "joint venture" approach to technology development used in this program.**

R&D 100 Award announced.

The technical significance of the **CPG 7.5-kW$_e$ system was recognized by *R&D Magazine***, with the recent notification of an R&D 100 Award. This international competition, which is in its 31st year, recognizes innovators and organizations for outstanding practical technical developments and identifies significant technological advances.

Two teams selected for USJVP negotiations.

Four responses to the request for proposal (RFP) for the Utility-Scale Joint Venture Program (US-JVP) were received on October 23, 1992. The RFP solicits industry for proposals to enter into a joint venture with Sandia with the objective of developing and commercializing distributed, point-focus, solar thermal systems that can be used by utilities. The companies that submitted technically responsive proposals were solicited for best and final offers after discussions with Sandia. Scores for the technical

proposals were essentially equal. Based on the best and final cost proposals, Cummins Power Generation, Inc. and Science Applications International Corporation (SAIC) were selected for negotiations. Depending on the availability of resources, negotiations with the third bidder may be initiated later.

Planned Activities for Next Quarter

- The concentrator and engine controls for the CPG 7.5-kW_e system will be integrated.
- The CPG system in Abilene will be retrofitted with a new receiver.
- CFIC will initiate engine/alternator testing.
- A JVP team meeting emphasizing receiver issues will be held in Lancaster, Pennsylvania.
- US-JVP contracts will be negotiated with CPG and SAIC.

Milestones (Planned/Actual)

(May 1993/) Demonstrate village electrification application. Delayed until FY94.

(May 1993/) Deliver prototype water pumping system to Cal Poly. Delayed until FY94.

C. Operations 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 electricity costs. Reductions in O&M costs would enhance the marketability of solar thermal technologies currently being developed by the DOE. An example of a DOE technology that would benefit is the Solar Two demonstration project and commercial central receivers power plants. Central receiver power 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 central receiver power plants. This guarantees that this initiative will benefit current solar thermal technology (SEGS troughs) as well as future technology (central receivers). The project is being performed on a 50/50 cost-share basis between owners of the SEGS plants (primarily US 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 Operating Company (KJC) in July 1992. The work to be performed during the 3-year project was described in the Third Quarterly, FY92. The progress made during the present quarter is described in the following paragraphs.

Accomplishments

Improved reflectance measuring device.

Frequent reflectivity measurements in a large solar thermal plant, or concentrating photovoltaic (PV) plant, are needed to define mirror cleaning strategies. The current measurement instrumentation consists of a portable specular reflectometer (Device & Services [D&S] Model 15R). While this instrument is generally accurate and has been adequate for small solar research facilities in the past, the instrument is proving to be too cumbersome to be practical for measuring the reflectance of large solar fields, characteristic of the five plants at the Kramer Junction solar power park. Over the past year, Sandia has been working with TMA Technologies to develop a more practical and user-friendly reflectometer. **This new device, called the Microscan Scatterometer, is portable and light (< 2 lb.), has data logging capability, is PC compatible, and**

works on a different principle than the old D&S device. Rather than measuring the specular component of the reflected light, the Microscan measures the scattered component.

During the quarter, the new instrument was tested over a 2-day period at Kramer Junction. The test indicated that the Microscan is accurate and that it significantly reduces the time needed to perform reflectance measurements and to process the collected data. **Sandia estimates that the Microscan will reduce the time needed to perform and analyze reflectance measurements by a factor of five.** Kramer Junction personnel were impressed with the Microscan and plan to purchase them as soon as proprietary issues are resolved with TMA Technologies.

Cermet selective surface.

The demise of LUZ has removed the source for commercial-grade cermet selective surfaces for solar field receiver tubes. In addition, the performance of a central receiver could be significantly improved if a selective surface could be used. For example, if cermet was used instead of Pyromark paint, radiation losses at a central receiver would be reduced by a factor of five. Kramer Junction Company Operating Company (KJC) and Sandia are working with Vapor Technology of Boulder, Colorado, to develop a lower cost method for applying cermet coatings. This company was chosen because key individuals now working there developed the cermet machine for LUZ. The machine built for LUZ cost $3.5 M. The cost estimate for a new machine proposed by Vapor Technology is $750 K. In the new machine, a batch rather than continuous process method is proposed. This lowers costs because the number of vacuum chambers is reduced along with several other simplifications in the design.

Last quarter, KJC and Vapor Technology coated initial sample coupons. The optical properties of the coupons were measured by Sandia and found to similar to that achieved by LUZ in Israel. During the present quarter, a new series of samples were produced comprising 18 coupons and 4 shortened tubes. In this series, the coatings were produced to full specification with respect to the number, thickness, and constituents of the coating layers. The samples will be forwarded to Sandia for testing next quarter.

Software data collection network.

The five SEGS plants at the Kramer Junction site comprise a solar power park. Power parks (multiple plants at the same site) are the expected method of deploying large scale solar power plants during the 21st century. One of the advantages of a power park is that the services of the maintenance crew can be shared by several plants. This increases the efficiency of the maintenance organization and reduces the cost of maintenance per plant.

In order for this improved efficiency to be fully realized, site maintenance planners must have rapid access to maintenance data bases at each of the power plants and a method of quickly ordering the required work and replacement parts. This is being accomplished at the Kramer Junction site through installation of an integrated data collection network. Each plant will have a PC workstation that is connected to the network server located in the site administration building.

Last quarter the network was installed. During the present quarter, software to enter daily operator logs on the network was developed. This will improve access to data for O&M planning, to upgrade accuracy and completeness of logs, and will reduce the time involved in generating and utilizing the logged information. The initial software is currently in alpha testing at SEGS V, VI, and VII. Testing is presently stand-alone, with network installation scheduled for early August. At that stage, the software will be utilized on a routine basis, though subject to monitoring and improvement.

Maintenance planning methodology.

With the advent of the PC 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. KJC Operating Company currently lacks such a maintenance planning system and it is believed that implementation of one would significantly reduce maintenance costs at the site.

Last quarter, an evaluation of available software products was completed and the MPAC software (The System Works Inc., Marietta Georgia) was

selected. **During the present quarter, the MPAC software was installed on the site data network described in the preceding topic.** The remaining work to be accomplished, before fully activating the system on December 1, 1993, is to tailor the software and associated data bases to meet the needs of the Kramer Junction power park. This work is ongoing and involves selection of an off-site contractor to support the effort. This contractor will be selected by the end of July 1993.

Analytical model for HCE efficiency.

Last quarter it was reported that a report and conference paper were completed that described the testing, during CY 1992, of the LS2 trough and associated heat collection elements (HCE). In parallel with testing of the trough, an analytical model was developed by Sandia and Sloan Engineering that characterizes thermal losses from the HCE given a variety of degraded conditions (e.g. vacuum lost, glass broken, etc.).

During the present quarter, the model predictions were compared with experimental data. In general, model predictions were good except for an apparent bias in the model that tends to under-predict heat loss at higher operating temperatures. Next quarter, we will investigate the source of this bias.

This model will be used by Kramer Junction to determine optimum replacement intervals for HCEs given a variety of degraded conditions. In addition, the model is generic enough to allow its use in studying other parabolic troughs. For example, Sandia's Design Assistance Center (DAC) is currently testing a trough built by Industrial Solar Technology (see this topic elsewhere in this report). The analytical model will be adopted to characterize heat losses from IST troughs.

Rotating joints preferred over flex hoses.

Flexible hoses have historically been used as the means to connect heat collection elements in adjacent troughs. Reliability problems have driven Kramer Junction to search for a better alternative. Over the past year, more than 16 flexible hoses have been replaced with rotating joints manufactured by Barco Inc. Barco has installed rotating joints in several applications within the petroleum industry. **Results to date indicate that the rotating joint will be the preferred option;** they are more reliable, they cost less, and the pressure drop in a flow loop, at typical flows, is 40% of the pressure drop in a loop with flex hoses. The reduction in pressure drop will reduce parasitic power consumption and improve power production. These findings have been forwarded to the Sandia's Design Assistance Center. The DAC is working with several companies who use parabolic trough technology.

Planned Activities for Next Quarter

- Complete status report that describes progress made on all project tasks.
- Provide practical solar plant experience to Bechtel to help them with Solar Two Project.
- Continue progress on all tasks described above.

Milestones (Planned/Actual)

(Jun 93/Jun 93) Data acquisition system to facilitate SEGS maintenance planning will be implemented.

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 are categorized into three activities: 1) Direct technical assistance, 2) Testing, evaluation, and technology development, and 3) Education and outreach.

The Solar Thermal Design Assistance Center activities reported here are supported by (1) the Solar Thermal Electric Program, (2) the Solar Thermal 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.

The Solar Thermal Design Assistance Center (STDAC) is providing technical assistance to the solar industry. One of the most important of these projects involves the **SEGS operators.** The assistance, which is being provided to the Daggett Leasing Corporation (DLC) and the Kramer Junction Company (KJC), consists of three major items. The first item involves the eruption of Mt. Pinatubo, whose emissions have caused a significant reduction in the direct normal radiation and, therefore, a reduction in the SEGS plant revenue. The SEGS owners, DLC and KJC, asked for Sandia's assistance in explaining the problem.

Sandia completed an analysis and the findings indicate that emissions from the volcano reduced direct normal radiation by around 20%. This information has been an important part of the evidence that DLC has presented to Federal Energy Regulatory Commission (FERC) in support of their request for a waiver to burn additional natural gas.

The second part of the effort relates to the Landers earthquake last year. **The SEGS 1 and 2 facilities sustained significant damage from the earthquake and Sandia is currently performing a finite element analysis of this problem to help recommend some corrective measures.** Sandia engineers have developed a working computer model and have begun to perform some analysis. Work on this problem will continue through this FY.

Much of the earthquake damage involved loss of reflective surface, but the original equipment manufacturer will not provide replacements and SEGS is looking for help from domestic sources. Industrial Solar Technology (IST) was contacted for help in constructing aluminum plates laminated with reflective film. Sandia and Industrial Solar Technology have agreed to a joint venture to develop the replacement mirrors. IST has completed the development of a prototype facet. One of these facets was delivered to Sandia and SEGS for testing. Among the tests that are being considered include an optical characterization, and environmental testing in a non-destructive test chamber.

Wind response analyzed.

In a related problem, Sandia has been assisting **Industrial Solar Technology (IST)** regarding the performance of the solar trough hot water system in Tehachapi, California. In late 1991, high winds have begun to create problems with the system. **At IST's request, Sandia engineers have been conducting a finite element analysis of the trough system in order to recommend structural improvements to the design that would prevent future damage. Analysis is underway using the** Algor finite element model. A working model was developed this quarter and some suggested improvements are expected next quarter. Work on this project will continue through this FY.

State cooperative activities.

Sandia engineers are involved in several **California Energy Commission (CEC)** activities. The first involves the **solar project at the prison in San Luis Obispo.** Program engineers are planning to monitor the solar system that will be installed. BESICO and the California Department of Corrections (CDC) have stated that they will meet during the summer to sign the contract to install the system. **A second effort is to assist CEC and CDC officials in developing RFPs for third-party financed solar systems in other prisons**. Russ Hewett at NREL has taken the lead to insure that these RFPs are released in a timely fashion, perhaps in the next quarter. A third project, which was initiated this quarter, involves a **demonstration of a solar absorption air conditioning system in a commercial building in Sacramento.** This project is being led by the CEC, but is a collaboration between the Sandia, NREL, Bergquam Solar, Sunsteam, and the Sacramento Municipal Utility District. The project involves the installation of several thousand square feet of Sunsteam solar concentrators on a building owned by Bergquam Solar. This building is currently cooled by a flat-plate solar absorption system that was built and operated by Bergquam. A major objective of this project is to compare the performance of the absorption system using a flat-plate and concentrator systems. Work on the project has begun and will continue through the next FY. The major role of the DOE solar program is to provide cost sharing and

technical consulting regarding the design, installation, and monitoring of the system.

In state related activities, STDAC engineers are assisting several states. One of these involves the **State of New Mexico Energy and Minerals Department** in two refurbishment projects. The first of these projects involves a solar system at the Northern New Mexico Community College. **A cost-shared project to refurbish this solar water/space heating system is underway and includes the Department of Energy, the State of New Mexico, and the New Mexico Solar Energy Industries Association.** Sandia engineers have also supplied some of the instrumentation for monitoring the system's performance.

A second New Mexico effort involves technical assistance to refurbish a 20,000 square foot system at the State Prison in Las Lunas, New Mexico. This flat-plate system is designed to heat water and spaces, but has not been operational for several years. Program engineers have provided the state with a refurbishment plan. Consulting on the effort will continue through this FY.

Sandia is also assisting New Mexico in studying the technical and economic feasibility of repowering some existing electric power plants in New Mexico with solar energy systems. The State has asked for an analysis of two 45-MW plants near Albuquerque. Work on the project has begun and the preliminary results suggest that the most cost-effective method to repower existing plants with solar energy is by applying central receiver technology. A more detailed economic analysis has been completed, and the results suggest that repowering of power plants in New Mexico with solar power may not be cost effective in the current economic environment. The study suggests that a good way to improve the cost effectiveness of solar repowering in New Mexico is to reduce the tax burden on solar systems so that it is about equal to fossil plants. These changes in the tax code will help make solar repowering a more attractive option in the state.

The State of Hawaii Energy Office, in cooperation with several Hawaiian electric utilities, has requested technical support from Sandia in designing, developing and installing a solar monitoring system on the islands as part of their demand side management programs. They have also asked for consulting on the development of their demand side management system. There have been a number of technical interactions so far and Sandia engineers are expected to be involved through this FY. Sandia will also work with the Solar Energy Industries Association to provide the training and technology transfer assistance to the utility engineers who will implement the monitoring program.

Military installation activities.

Sandia engineers are directing the evaluation of potential solar systems at several military installations. **Energy officials from Ft. Huachuca funded the STDAC to provide engineering assistance in analyzing several potential applications for solar thermal technology on the fort.** The analysis is complete, and Ft. Huachuca officials have used the information to prepare proposals that were submitted to the Department of Defense for funding the projects. Four reports were completed, each covering a specific solar application including water heating and air conditioning. Decisions about funding these projects are expected next quarter.

STDAC engineers are working with officials of Luke AFB near Phoenix, Arizona, to refurbish a 1100 sq m solar thermal trough system that was designed to heat water for three airman dormitories. This solar system, which consists of three collector fields, was refurbished this quarter. Currently, however, the system appears to be oversized for the existing load, and some of the potential solar energy is not captured. Luke officials have asked for additional help from the Sandia to assist in documenting the potential solar energy that is not collected and in identifying additional loads for the system. STDAC engineers have designed several possible methods to meet this request. Additional consulting is expected during the last quarter of this year.

Mexican renewables.

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. **The majority of the solar thermal effort involves the development of a 30kW solar thermal electric project in Puerto Lobos, a remote village in the State of Sonora.** The Mexican government has contracted to Industrial Solar Technology to supply the solar system for this project. A used organic Rankine cycle (ORC) engine coupled with 1000 sq m of IST troughs will be used for this demonstration project. The Mexicans have asked for

Sandia consulting regarding the design review and monitoring of the system.

During the third quarter, STDAC engineers consulted extensively with the Mexican engineers about the design of the concrete footings for the trough field. Late in the quarter, a Sandia engineer visited Puerto Lobos to supervise the pouring of the footings. STDAC engineers have also consulted about the ORC engine, which is being refurbished by the manufacturer. Several suggestions were forwarded to the engine manufacturer about methods to help prevent corrosion in the salt air at Puerto Lobos.

The STDAC team is also in the process of developing a working relationship with the University of Sonora. The university is involved in the monitoring program for the Puerto Lobos project, and they have asked for Sandia's technical assistance in understanding the technology and in collecting and analyzing the performance data. The university is also interested in establishing a solar test facility and asked for Sandia's advice about how to build and operate one. Sandia is in the process of writing a formal memorandum of understanding (MOU) that would document the relationship with the university.

Summary of NSTTF activities.

Testing is continuing on the Energy Concepts Full-Isaac solar ice maker. The testing has followed a plan that was jointly developed by DOE and Energy Concepts. The results of the tests are being used by Energy Concepts to improve the design of the system.

Testing of a solar concentrating oven developed by Burns Milwaukee has been completed. The purpose of the tests was to quantify the oven's performance for use in the company's commercialization activities. Currently a final report is in preparation.

Testing has begun on IST's trough collectors. Two troughs have been tested on the rotating platform at the National Solar Thermal Test Facility (NSTTF). Both troughs consist of standard structural elements. However, one of the troughs uses ECP305 reflective film and the other use aluminized SA85 film. Two receiver tubes were tested on each trough. One tube is made of Pyrex and the other will use Solgel AR coated glass.

Testing is scheduled to begin on the Sunsteam trough. The Sunsteam trough will be used in the solar absorption air conditioning project in Sacramento and these tests will provide baseline performance information to be used in sizing the solar field. Testing is expected to begin next quarter.

Sandia has continued a 50/50 cost-shared contract with IST to develop an advanced receiver. The effort involves three efforts: 1) Develop a commercial Solgel AR coating process for trough receiver envelopes; 2) Develop a black nickel process to replace black chrome; and 3) Develop a commercial evacuated receiver. The need for the work was identified through work conducted by Tom Williams at NREL.

The AR coating work has been completed and represents a significant technology transfer success. This Solgel process was developed at Sandia and was documented in the public literature. IST, working with program engineers at Sandia through this cost-shared contractual effort, have fully commercialized the Solgel process; it is currently integrated into IST's trough manufacturing/assembly process. More information about this technology transfer success is forthcoming.

Sandia and NREL have begun a collaborative project to develop a technique that would allow a solar thermal system's performance to be mathematically characterized without the need for cutting pipes to install intrusive data monitoring sensors. The data for the mathematical characterization will use a clamp-on BTU meter that uses ultrasonic detectors and surface mounted thermocouples to estimate the energy collected by a solar system. The characterization technique, which is currently under development, will use these data to determine a mathematical relationship between the system's performance as a function of ambient conditions (temperature and solar radiation). The result will be a single regression equation that can be used to estimate system performance for any given set of ambient conditions. Thus, using this equation, the performance of a solar system can be estimated for any past, present, or future time using only a record of ambient conditions and without the need for a monitoring system. The development effort will address two concerns: 1) The level of accuracy of the mathematical equation in estimating system performance, 2) The amount of data that must be collected by the clamp on meter to accurately reflect typical operational characteristics. A portable data acquisition system, that integrates the clamp-on BTU meter, has been developed and is ready for use in this

research effort. The development effort will be completed in the next FY.

Planned Activities for Next Quarter

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

Milestones (Planned/Actual)

There are no delays in the major milestone schedule, and no changes planned for the future.

STDAC Contacts:

Central Receivers

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Cannon, Jim	New Mexico State

Concentrators

Carlton, Jim	SRI
Cartwright, Peter	Cartwright Consulting, Inc.
Evans, Donald	OTEC
Glick, Ira	Consultant
Hogan, John	Institute of Advanced Manufacturing Sciences
Maiden, Miles	American Sun Co.
Mancini, Frank	Arizona Energy Office
Parks, Roger	Boeing
Spacer, John	Spacer, Inc.

Dish/Engine

Barton, Dave	Consultant
Bertolotta, Charlie	Rockwell International
Blumenthal, Phil	NASA Lewis
Burns, Richard	Rockwell International
Godett, Ted	Stirling Thermal Motors
Goodman, Joel	Consultant
Larson, Nona	Boeing
Luchow, David	Consultant
Rillich, Mark	Boeing
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Stine, Bill	California PolyTech
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General Information

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Papier, Isaac	Consultant
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Puriponga, Naboone	U. S. Gov't OPM
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Risser, Vern	Daystar
Rodchester, Julie	SNL/TT
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Fisher, Kathy	Visions West
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Franey, Harry	California Department of Corrections
Gee, Randy	Industrial Solar
Gerics, Lou	Innovative Design
Kelly, Quinten	World Water, Inc.
Kelly, Ingrid	State of New Mexico
Kulkarni, Promad	California Energy Commission
Lane, Richard	Pacherland Solar
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O'Neill, Walter	Photocom
Olson, Scott	New Mexico Energy Research Institute
Thomas, Susie	Virginia Energy
Truskey, Ted	NMSEA
Truskey, Ted	BDM
Volek, Tom	NMSEIA
Waldsmith, Gary	McClellan AFB
Wringley, Greg	Gould

Insolation

Augstyn, Jim	Augstyn Co.
Cohen, G.	KJC Operating Company
Micholski, Joe	SUNY
Perez, Richard	SUNY/ASRC
Vignola, Frank	University of Oregon

Solar Absorption Cooling

Bergquam, Jim	Consultant
Bronstein, Alan	Consultant
LaPorta, Carlo	UST
Marquise, Brian	Consultant
Merrigan	Florida Solar Energy Center

Solar Detox

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Ham, Dave	Envirochem, Inc.
Jones, Judy	Researcher
Curry, Randy	Tetra Corporation
Turner, Tom	Republic Geothermal, Inc.

Solar Education

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Solar Instrumentation

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Solar Thermal Systems

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Anders, Ian	Pacific Corp.
Bensinger, Charles	Consultant
Brooks, Bill	North Carolina Solar Center
Bullard, Mark	Solar Total Energy
Burns, Tom	Burns-Milwaukee
Carrozza, Allen R.	Scholfield Solar
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Davenport, Roger	SAIC/Golden
Deutch, Sidney	Consultant
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Falcone, Pat	SNL/CA
Fugate, Robert	Phillips Lab
Ginsberg, Mark	DOE/HQ
Grandienetti, John	Grand Solar
Gregory, Diana	Florida Dept. of Community Affairs
Harvey, Tom	Visions West
Heath, Don	Visions West
Hughes, Ken	Sierra Club
Jones, Wayne	Innovative Design
Kane, Herb	National Park Service Advisor

Kearney, David	Kearney & Associates
Koffman, Roy	Florida State Energy Center
Kreider, Jan F.	Centre d'Energetique, France
Louison, Luis Donderis	Universidad Tecnologica de Panama
Robart, Ernie	Visions West
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Solar Thermal Testing

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Jennings, John	Consultant
Johansson, Stefan	Stirling Thermal Motors
Joshi, Dr.	Vegas Analytical Laboratory
Levin, B. Martin	JPL
Martin, Larry	Mauna Loa Macadamia Nut Factory
Miles, Roy	Pacific Missile Range
Peterson, Earl	Consultant
Sadowski, Thomas	Rockwell International

Utilities

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Hiland, Mark	Public Service Company of New Mexico
Katter, Irving	Southern California Edison
Knight, Bryon	Harris Co.
Lutton, Wayne	SEGS
Machuca, E.	CIEDAC Mexico
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Sanchez, Marcelino	CIEMET
Skowronski, Mark	Southern California Edison
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Wichert, Bob	Sacramento Municipal Utilities District
Wills, Eric	Daggett Leasing
Wilson, Keith	JPL
Wyman, John	

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. Accomplishing this will require systems engineering. Subsystems and components will be designed, built, and tested to validate the performance and reliability assumptions made within the systems analyses.

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, cost-efficient, long-lived concentrator designs, optical materials are an important part of concentrator development.

1. Heliostats

Accomplishments

Dual-module stretched membrane heliostat.

We completed testing of SAIC's Dual-Module Stretched Membrane Heliostat. Two issues addressed were (1) Power consumption during tracking and focusing was measured as 60 to 67.5 watts with 10 to 15% due to focus control, and (2) Tracking accuracy was re-measured as 1-3 mr with the azimuth drive loaded to eliminate backlash. However, the tracking system was found to accumulate errors—a problem that will have to be addressed.

Planned Activities for Next Quarter

- Complete a report on the performance of the Dual-Module Stretched Membrane Heliostat.

Milestones (Planned/Actual)

None

2. Parabolic Dishes

Accomplishments

On-sun testing of SKI's facets.

On-sun testing of facets made for the Faceted Stretched-Membrane Dish by Solar Kinetics Inc. of Dallas, Texas, was completed. Sandia's tracking fixture and Beam Characterization System were used to evaluate the performance of four facets at the three focal-length-to-diameter ratios that are representative of the dish, f/D = 3.04, 2.90, and 2.70. **In general, the test results were positive, although there was some drift of the focal length because of vacuum variations,** and the performance varied over a fairly wide range. Some of the key results are listed below.

- The average total power in a 0.203 m-diameter circle was 6.10, 6.12, and 5.98 kW for f/Ds of 3.04, 2.9, and 2.7, respectively. These numbers suggest that **the facets perform slightly better at the two longer focal lengths.**
- The four facets demonstrated different performances at different focal lengths, as shown in the table below. The results indicate that the facets all improve as the focal length is reduced. This suggests that the facets have been over-formed. It also suggests that it may be appropriate to screen the facets before they are installed on a dish and place them at the focal length that demonstrates their best performance.

Percentage of Power in a 0.203m diameter circle			
Facet	**f/D=3.04**	**f/D=2.90**	**f/D=2.70**
1	61.4	74.7	91.4
2	90.5	97.6	98.6
3	85.1	92.0	97.6
4	89.6	96.5	98.7

- Facets were normally tested at the Δp recommended by SKI. We performed a test to evaluate the performance of the facets as a function of Δp and found that SKI's set points were less than the positions of each facet's *best* performance by about 0.1 psi.
- Solar Kinetics' facet control system cycles on the pressure difference. We measured the performance of two facets over one of these cycles and found that the percentage of power in the 0.203 m-diameter circle varied by about 5% over a cycle.

We have completed testing of the individual facets and the information has been provided to Solar Kinetics.

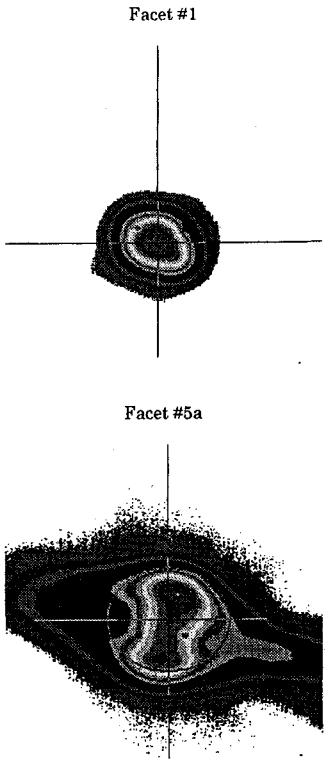

Figure 1. Typical Facet Contour Plot.

Faceted Stretched-Membrane Dish.

Testing of the Faceted Stretched-Membrane Dish (FSMD) with 12 of SAIC's facets installed was initiated in April. The planned tests include measurements of the flux-density distributions produced by the dish and calorimetery of the dish. Measurements with the Beam Characterization System were completed in June.

However, a problem with the operational procedures resulted in the data that were collected not being correct. These measurements, along with the calorimetery, will be repeated during next quarter.

Two facet flux distributions from the dish are shown in the figure. One is from the facet number 1 position, which is almost on the axis of the dish; the other is from the facet 5a position, which is located at one of the off-axis positions. The off-axis aberration of the image from the 5a facet is manifest in the enlarged elliptic shape of the image. **Initial measurements indicate that the dish is producing about 60 kW_t within an aperture of 0.508 meters.**

In response to a request from Science Applications International Corporation (SAIC), we will re-configure the facet alignment for the FSMD for a longer focal length and re-test the dish. This will result in a delay for the testing of the dish with SKI's facets.

Single-element dish follow-on.

Working with the DOE, Sandia has reached a decision on how to proceed with the Single-Element Dish project. Because of the perceived technical risks associated with the dish design and in order to involve an engineering house with commercialization expertise, we have decided to perform a review/redesign of SKI's 10.4-m diameter dish. This review will involve a detailed evaluation of the dish design and, if necessary, a redesign of specific components for cost, ease of manufacture, and performance. This activity will take place through a new procurement that will be started during the next quarter.

2-f measurement of TBC facets.

Using the newly-developed 2f technique, we measured two Test-Bed Concentrator (TBC) facets before and after new glass sheets were bonded to their surfaces. For the first facet, the slope error increased from 0.619 to 0.909 mr and for the second it increased from 0.629 to 0.787 mr. Development of a color 2f system will continue during the next quarter.

Planned Activities for Next Quarter

- Heat treat the SKI facets for the FSMD.
- Complete calorimetery and flux mapping of the FSM Dish with SAIC's facets.
- Complete flux mapping of the FSM Dish with SAIC's facets.
- Realign SAIC facets on the FSM Dish for a longer focal length and perform flux mapping and calorimetery.
- Complete on-sun testing of two round-robin facets.

Milestones (Planned/Actual)

(Nov 1992/Nov 1992) Conduct final design review for the Single-Element Stretched-Membrane Dish design.

(Jan 1993/Jan 1993) Complete installation of the Faceted Stretched-Membrane Dish at the NSTTF.

(Mar 1993/) Place contract to fabricate a Single-Element Stretched-Membrane Dish. Replaced with decision to investigate redesign for manufacturing.

(May 1993/) Complete testing of FSM Dish with SAIC's, elastically-formed facets. Underway.

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3. Optical materials

Accomplishments

Corning Incorporated discussions held.

Corning Inc., a Fortune 500 company well known for its expertise in using science and technology to meet precise technical requirements and answer unique needs, has expressed renewed interest in solar thermal electric applications.

Corning was involved in a joint project with NREL in the early 1980's to develop a solar alumina-borosilicate thin (1 mm thick) sheet glass suitable for solar mirror applications. This product (Corning Code 7809) was a technical success, but Corning elected not to go into production based upon market analysis results at that time.

Recently, preliminary discussions were held at NREL with Corning's manager of new product development regarding STE market potential and technical barriers. Task staff were then invited to visit Corning to present an overview on the basics of STE technologies emphasizing problem areas, barriers and opportunities. **A presentation titled "Reflector Materials for Solar Concentrator Applications" was given to roughly 25 Corning personnel on March 30, 1993. Interest was high on the part of Corning's staff and the talk was well received.** Corning is presently evaluating product ideas and follow-up discussions are anticipated.

Alternate reflector materials.

Progress has been made in collaborative efforts with industrial partners to develop alternate reflector materials. A collaborative, cost-shared R&D effort to develop an innovative alternate reflector material for solar applications has been initiated with the Dow Chemical Company of Midland, Michigan. **Dow's concept uses alternating coextruded layers of low-cost commercially available transparent thermoplastics to produce all-polymeric reflector materials.** Because this concept is an all-polymeric design, degradation of optical performance caused by corrosion of metallic reflecting layers is not of concern. Another attractive feature of this approach is that **such reflector materials can be directly thermoformed into usable structures,** thereby reducing costs associated with support elements. Efficient broad band solar reflectors are envisioned that are fabricated from a high-speed, low-cost technique that has been commercially demonstrated.

In another collaborative effort, the 3M Company has produced samples of their commercial ECP-305 solar reflector material having thin, corrosion resistant copper protective back coatings of various thicknesses. **Recent experimental enhancements of ECP-305 by NREL have demonstrated substantial improvements in optical durability during accelerated exposure.** The 3M materials have been subjected to similar accelerated testing in NREL's solar simulator chamber, and preliminary results are available. After roughly 300 hours, the sample without any protective backing started to exhibit optical degradation. After over 700 hours, all samples having protective coatings maintain good optical performance. Unlike similar NREL-prepared constructions, the sample having 100 Å of copper

experienced a small initial loss in reflectance that has subsequently leveled off.

An innovative reflector material sample has been received from **Martin Marietta Laboratories** (MML) and optically characterized. **This mirror is a "stainless" aluminum alloy. MML has obtained excellent corrosion performance with this type of material.** Visually the sample is very specular. However, the solar weighted hemispherical reflectance is only 70%. MML has indicated that similar alloys made with silver could have higher reflectance while retaining good corrosion resistance properties.

Delamination failures.

A simple, inexpensive means of substantially reducing delamination failures of silvered polymer reflectors has recently been demonstrated under a cost shared, subcontracted project between NREL and the 3M Company. Previous work at NREL in collaboration with 3M had developed ECP-305, a commercial product that represents the state of the art in polymer reflective materials. A significant failure experienced by ECP-305 during field service has been delamination of the top polymer film from the silver reflective layer, usually in the presence of moisture. NREL has previously identified several alternative engineering solutions to this problem. The 3M approach can be directly incorporated into their production process without increasing costs and without necessitating any additional treatment of the reflector material. This improvement should significantly allay concerns of solar manufacturers regarding the use of this material in solar concentrator systems.

CPG Reflector Materials.

Task staff visited Cummins Power Generation (CPG) South in Abilene, Texas to discuss their requirements for reflector materials and ways NREL can support their efforts. Test results were presented for more than 30 candidate reflector samples provided by CPG that are being tested at NREL. An additional sample was provided to NREL for optical characterization and exposure testing. The relationship between NREL's overall reflector materials task and CPG's support activities was refined. CPG emphasized that fundamental coating issues, identification of failure modes through analytical characterizations, and anti-soiling/cleaning strategies were of particular importance and interest to them. Expansion of NREL's outdoor testing program to include a site relevant to CPG's dish/Stirling development efforts was also discussed.

Service Life Prediction.

Task staff attended an American Society of Testing and Measurements (ASTM) subcommittee (G3.08) meeting on Service Life Prediction. The scope of this subcommittee is to develop standards for use in predicting the real-world service life of materials, components and systems. The identification of important weathering variables and failure modes, and the design of appropriate testing protocols, are of particular significance. The main intent of this meeting was the deliberation and identification of relevant task groups. This activity is directly applicable to task efforts to allow the lifetime of reflector materials used in solar concentrators for STE applications to be predicted based on accelerated laboratory test results.

Planned Activities for Next Quarter

- A meeting will be held at NREL in August, 1993 to provide an update on advanced reflector material development. Results of recently completed collaborative efforts by a number of NREL subcontractors will be presented. Planned activities by other newly initiated subcontractors will also be described. Program directions will be reviewed and a forum will be provided to allow discussion of commercialization issues.

- 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

- Meteorological monitoring equipment will be installed at the three operational outdoor exposure test sites.

Milestones (Planned/Actual)

(Apr 93/Apr 93) Document status of outdoor testing activities.

Industrial Contacts

CONTACT	ORGANIZATION	COMMENTS
J. Affinito	PNL	Alternate reflectors
W. Baouchi	Donnelly Films	Glass mirrors
K. Beninga	SAIC	Alternate reflectors
B. Butler	SAIC	Alternate reflectors
S. Cox	Courtaulds Films	Metallized polymers
R. Davenport	SAIC	Alternate reflectors
G. Davis	Martin Marietta	Alternate reflectors
M. DeVries	Donnelly Corp.	Glass mirrors
M. Featherby	SAIC	Alternate reflectors
T. Gardner	Corning	Thin glass mirrors
R. Gee	IST	Alternate reflectors
L. Gehrigs	Innovative Designs	Polymer reflectors
L. Ioffe	Scientech	Reflectance samples
M. Langlois	Catalina Coatings	Alternate reflectors
R. Lewis	Dow Chemical	Alternate reflectors
M. McGlaun	Cummins Power Gen.	Alternate reflectors
P. Nava	Flagsol	Glass mirrors
J. Ross	Armstrong	Hardcoats
R. Scully	Scully Assoc.	Alternate reflectors
D. Shaw	Catalina Coatings	Alternate reflectors
W. Schrenk	Dow Chemical	Alternate reflectors
P. Soliday	Cummins Power Gen.	Alternate reflectors
P. Svoboda	Flagsol	Glass mirrors

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. 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 this activity 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 performing testing and analysis of components and procedures. The key tasks within the Central Receiver Technology Program are 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. All but (4) directly support the Solar Two project.

Accomplishments

Molten salt loop testing.

Testing of a components in the molten-salt loop was initiated this quarter. The purpose of the molten-salt experiments is to verify the use, operation, and reliability of components, instrumentation, and procedures proposed for implementation in the Solar Two project. Many of the components have been proven in a molten-salt environment but additional information is required. Other components have not been tested sufficiently in molten salt. The results from these experiments will aid in the design of the molten-salt systems and reduce uncertainties of the performance of untested components and operating procedures.

Modification to the existing PRE molten-salt loop was completed this quarter, and testing begun with check valves, flanges, flow meters, and pressure transducers. The components have experienced several flow cycles and there have been no failures or leaking from the components to date. The loop includes an area to implement coupons for thermally and flow enhanced erosion/corrosion experiments. In addition, two wing panels from the Category B receiver have been installed to test cold receiver startup procedures and conduct freeze/thaw experiments to assess damage that might occur to the panels and to test procedures to thaw the panels safely. A new high-temperature fiberglass insulation was installed along with a lower temperature pre-formed fiberglass insulation on straight runs of piping to test their applicability to molten-salt systems. The panel tests will begin next quarter.

Molten Salt Corrosion Tests.

The static experiment on the corrosion of steel in molten nitrate salt was completed. The experiment successfully demonstrated the effect of salt composition on the corrosion of stainless and carbon steels at temperatures of the hot and cold loops, respectively, of a molten-salt solar power plant. **Data were obtained for exposure times up to 7000 h, corresponding to approximately three years of power-plant operation.** Overall, the test indicated that solar salt impurity levels in the range obtainable commercially probably will not be important for determining corrosion rates, with a few minor exceptions.

Metal weight loss rates for carbon steel at 316 °C were low in all the salt mixtures, ranging between 1- 4 μm/yr. Also, for this steel, corrosion rates were insensitive to salt impurities. For 316 and 304 SS, metal loss rates ranged between 6 - 9, and 6 - 12

μm/yr, respectively, corresponding to rather low rates of corrosion. 316 SS was insensitive to chloride; however the 304 SS samples did experience faster corrosion for salt mixtures containing elevated levels of chloride. In general, the oxide layers that formed on all three steels experienced substantial spallation when the coupons were removed from the pots and brought to room temperature. This spallation signaled the need for thermal cycling experiments because once the protective oxide layer is lost, corrosion can begin anew at an accelerated rate.

The goal of Phase 2 of the molten-salt corrosion investigation is to determine if the temperature cycles characteristic of the operation of a solar power plant cause oxide spallation and accelerated corrosion. This quarter, construction began on the apparatus for this test. We expect to begin the experiment by the end of August 1993. The test will indicate if thermal cycling accelerates corrosion. If so, consideration of corrosion rates may gain importance in the final design of Solar Two.

Flux and temperature measurement.

Experiments have begun to test instrumentation to measure flux and temperature on central receivers. The objectives of these tests are to evaluate concepts to measure flux and temperature on an external cylindrical receiver. Three concepts to measure flux (fixed Lambertian target with video cameras for high precision flux measurements, relative flux measurement with photometers for flow control, and real-time measure of flux on the receiver surface with video cameras) and two concepts to measure temperature (low and high resolution infrared (IR) camera measurements) are being tested.

Further tests were conducted with 30 heliostats to evaluate the fixed target concept for high precision measurement of the flux on the receiver. The fixed Lambertian target system is a concept to map the flux on the receiver surface using a video camera and a highly reflective, diffuse target mounted at the top of a cylindrical receiver. The flux patterns on the receiver could be mapped out by sequentially moving the aim points of the entire heliostat field upward in set increments and recording the images on white target with the video camera. The images could then be pieced together to form a composite image of the flux map. The total power on the receiver can be measured this way. **The tests this quarter used large, plasma-sprayed, white panels and 30 heliostats to map out the flux distribution.** The images of the heliostats were captured with the video system (using Beamcode) as the aim point was moved over the target. A section of each image was cropped and stored to form a composite image. Analyses of the composite image indicated the total power, peak power, and beam size were within 2% of mean values of the individual images that made up the composite.

Characterization of Pyromark properties will begin next quarter. This is an important step in determining the feasibility and accuracy of some of the concepts to measure flux and temperature.

"Residual Issues" study.

The "residual issues" study to evaluate design, cost, and warranty issues associated with molten-salt thermal storage and steam generator designs was finalized this past quarter. This study was conducted by Bechtel to obtain information on the design and cost of the thermal storage and steam generator systems for commercial size molten-salt central receiver plants. In this study, Bechtel contracted with Chicago Bridge & Iron, Pitt-Des Moines, and Technigaz on the thermal storage system and with Foster Wheeler, ABB Lummus Heat Transfer, Struthers Wells, and SAIC/B&W on the steam generator. The contractors provided information on the design, cost, performance, and potential problems with their designs.

The study report, which **concluded that a steam generator for a 100 MW_e plant could be successfully fabricated and installed for approximately $8 million, and that a hot salt tank for a 100 MW_e central receiver plant could be fabricated and installed for approximately $5 million,** is currently going through the review and approval process at Sandia.

Parasitic losses.

Preliminary analysis of the proposed design for Solar Two indicates that parasitic consumption could be high if improvements to the balance of plant equipment are not made (old Solar One equipment) and/or if the use of heat trace is used extensively during operation of Solar Two. Consequently, during the quarter Sandia investigated promising methods for reducing thermal and electrical parasitics at Solar Two. This preliminary analysis was documented in letter to the Solar Two Technical Advisory Committee (TAC), entitled "Parasitic Reduction at Solar Two," G. Kolb, May 18, 1993.

A major conclusion of the analysis is that off-line parasitics can be significantly reduced through the

use of lightweight piping insulation in conjunction with draining salt piping during the overnight shutdown period. The greatest reduction will be realized if a thermal rather than electrical method of pipe preheat is used during startup the next morning. Methods for thermal conditioning included use of pressurized hot air and a low-melting-point "startup salt." Assuming a favorable review of these methods by the TAC in August 1993, we will decide what additional analysis and experiments are needed to continue development of these new ideas. Current thoughts are that the startup-salt method holds the most promise.

Electrical parasitics in the balance of plant will be analyzed through careful review of the design of the Solar One balance of plant and by studying parasitic consumption at the neighboring SEGS 1 plant. Because SEGS 1 is similar in size to Solar Two, we want to identify the design features that SEGS 1 used to reduce parasitics. Studying SEGS 1 will also help us develop a parasitic consumption goal for Solar Two.

Air and advanced salt receivers.

Alternative central receiver concepts are also being evaluated, including the **volumetric air receiver** and the **molten-salt internal film receiver** concepts. In these areas Sandia has had built a 200 kW_t volumetric receiver to be tested in Spain, and we are working with the Spanish on the testing of their 500-kW_t internal film receiver.

The Bechtel-designed and -built wire mesh volumetric air receiver absorber was shipped to the Plataforma Solar de Almeria this past quarter. The absorber, which is a layered nichrome knit wire mesh volumetric receiver, with a total of fifteen screens made up of 41 layers of nichrome (80-20 nickel chrome resistance wire) knit wire mesh, was installed on the 250 kW_t volumetric receiver test bed in June. The absorber is being tested as a cooperative program between the Spanish, US DOE, and Bechtel. The testing is expected to be completed in September.

In support of the volumetric air receiver development Sandia has contracted with **New Mexico State University (NMSU) to test the absorber design and materials that are used in the Bechtel absorber.** This past quarter NMSU has been conducting performance testing of the absorber on their solar furnace. The absorber has been tested up to temperatures of 450°C with performance factors (efficiencies) of approximately 80%. However, because of artifacts of the test set up we can expect performance factors of 6-10% higher in a larger absorber. NMSU is also developing a model to evaluate the results of these tests and the tests in Spain. Early versions of the model are predicting 5 to 12% higher performance factors. The model is being validated with the results of the furnace testing. NMSU will complete the performance testing early next quarter; however, the model development will continue.

The other alternative receiver being evaluated is the molten-salt internal film receiver (IFR). The IFR is an adaptation of the direct absorption receiver concept, except that the fluid (molten salt) flows on the inside of the panel. In 1989, the Spanish had fabricated (with design recommendations by Sandia) all the components for a 500 kW_t molten-salt IFR test, to be called the Receptor Avanzado de Sales or salt advanced receiver (RAS). The components were never assembled and installed because of budget cut-backs. The Spanish have asked Sandia to work cooperatively with them on the installation, setup, and testing of RAS. This past quarter, Marcellino Sanchez, from CIEMAT, visited Sandia to work with our engineers on the molten-salt equipment. Later, Earl Rush visited the Plataforma Solar de Almeria to work with the Spanish on the installation of their molten-salt system for the RAS. Installation of the RAS will not be completed until late September. **Testing of the RAS will most likely begin in October.**

Planned Activities for Next Quarter

- Document the Phase I static corrosion tests.
- Begin the Phase II thermal cycling corrosion tests.
- Continue to investigate the reduction of parasitic energy consumption for Solar Two.
- Publish the "Residual Issues" Study.
- Complete the performance testing of the volumetric receiver absorber at NMSU.
- Initiate testing of the Sandia/Bechtel absorber at the Plataforma Solar.
- Continue working with the Spanish on the installation of the RAS.

Milestones (Planned/Actual)

(Deferred until Sep 93) Complete testing of wire mesh materials at New Mexico State University.

(Sep 93/Apr 93) Publish the Second Generation Report.

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 STM 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

Hybrid receiver development.

Stirling Technology Company (STC) has completed fabrication and helium leak testing of their pool boiler. Fabrication work on the burner and hybrid heat exchangers is progressing on schedule. NREL has loaned STC a power supply for their radiant-lamp tests. **STC expects to start testing on schedule in August.** A meeting is planned for August 30 at STC to observe operation of the pool boiler and to discuss results to date for the STC test program. This meeting will be attended by NREL, Sandia, and STC staff.

Second-generation pool-boiler receiver.

Testing of the second-generation pool boiler receiver has been successfully completed. This completion meets an April 1993 milestone. This receiver boiled NaK-78 in an envelope made from Haynes alloy 230, with a Friction Coatings Corporation heated-surface modification to promote stable boiling. The NaK is liquid at room temperature, eliminating the need for electric pre-heaters. The Friction Coatings boiling surface was selected based on positive bench-scale results last summer. The absorber surface area and the gap between it and the rear dome are larger than in the first pool-boiler receiver, providing greater margins of safety against film boiling and flooding. The receiver, designed at Sandia, was fabricated and inspected by a commercial firm using potential limited-production techniques.

Operation of the receiver was characterized at temperatures up to 750°C and throughput powers up to 61.5 kW_t. The receiver was first tested without any noncondensible gas addition: excellent boiling stability was observed at all times, but hot restart behavior was only fair (although much better than in the bench tests). With the addition of about 1/3 torr of xenon, stability remained excellent and the hot-restart problem was completely eliminated. Unstable hot restarts at high dish elevation angles, observed in the original pool boiler, did not occur in the present tests. Next, the low-temperature restart that led to a leak in the first-generation receiver was repeatedly executed without any problem. Finally, preliminary results from the calorimeter indicate a thermal loss of about 6.5 kW_t at 750°C, which should improve with time as the solar absorptivity of Haynes Alloy 230 increases. On-sun testing was limited to these proof-of-concept tests because of the large manpower expenditure for continuous operation.

10000-hr Pool Boiler Durability Test.

The first 3800 hours of operation of the durability bench-scale pool-boiler receiver have been completed. The test is running routinely around the clock. The durability pool-boiler test will demonstrate the long-term boiling stability on the friction coatings boiling stabilization surface as used on the second-generation pool-boiler on-sun receiver test. In addition, it will demonstrate the long term alkali metal compatibility of Haynes 230 alloy, which is currently used on both pool-boiler and heat-pipe receivers. The test is scheduled to operate around the clock for 10,000 hours, and will be complete in the spring of 1994. The device cycles briefly to ambient temperature every eight hours to simulate the diurnal cycle. No changes in the boiling or startup behavior have been observed. Completion of the testing is expected in March '94.

Several test-equipment-related problems occurred this quarter, causing limited down time. After the initial set of lamps lasted 1400 hours, subsequent sets ran 70 to 300 hours before failure. Discussions with the lamp assembly and bulb vendors led to conflicting solutions. After several futile attempts at repair, a reduction of cooling air flow increased bulb life to 1000 hours. Evidently, the quartz envelop was over-cooled, causing deposition of tungsten on the envelope. Actual down time was limited because operation continued at reduced power until the bulb was replaced. A phone line outage also caused a one-week shutdown. Without phone lines, the on-call engineer cannot be warned of a problem, so operation of the test is not safe. The phone switch will be replaced soon, eliminating such outages in the future.

The initial test results of the durability bench test will be reported at the IECEC conference in August in Atlanta.

Friction Coatings wick.

A heat pipe has been constructed at Sandia to evaluate a new porous metal wick structure developed by Friction Coatings in Sterling Heights, Michigan. The new wick structure is applied to the substrate material through a process known as "decalcomania." **With this process, it is possible to attach a porous metal structure to a dome shaped surface without the use of special molds, potentially reducing the cost over the Thermacore process.** Deformations that are encountered in using a sintered screen wick structure are also eliminated. It is expected that the capillary pumping performance of the Friction Coatings wick will be comparable to the Thermacore wick. However, the presence of braze material in the wick is expected to make the wick more robust while improving manufacturability.

The wick is formed out of stainless steel powders and it is applied directly to the solar receiver dome through a process known as decalcomania. This wick structure was recently tested in an 1800 Watt bench-scale heat pipe. **The wick performed well in the sodium heat pipe tests. It lifted liquid sodium over 10 cm to cool a surface that was subjected to an average flux of 60 W/cm^2. Rapid restarts at full power did not pose any problems.**

The wick structure that was tested in the bench-scale system would require an extensive artery system to function properly in a full-scale solar receiver. Friction Coatings is currently preparing samples of an improved wick structure that reduces the complexity of the artery structure. Samples of the improved wick structure will be delivered to Sandia in July for testing. Friction Coatings is also investigating methods to form the wick decal into a dome-shape to cover the receiver's evaporator surface. Bench-scale tests on the improved Friction Coatings' wick are scheduled for September.

Because of the exceptional performance and the robustness of the technology, **application of the Friction Coatings wick structure to the Cummins/Thermacore receiver has been proposed.** Sandia is in the process of placing a contract with Friction Coatings to develop the techniques needed to apply the wick to a hemispherical dome. If successful, we anticipate delivering a suitable dome to Thermacore late next quarter.

Reticulated vitreous carbon wick.

A contract was placed with ERG, Materials and Aerospace in Oakland, California to develop a wick structure using their Reticulated Vitreous Carbon (RVC) materials. The structure of RVC is ideal for wicks and, during one phase of its formation, RVC is pliable so it can easily be formed into curved shapes. RVC can be attached to substrates (such as solar-receiver domes) by electroless nickel plating. The electroless nickel plating should also protect the RVC from sodium.

ERG has prepared four samples of nickel-coated RVC that will to be delivered to Sandia in July. Tests will be performed by Sandia to determine the flow characteristics of the RVC wick. A section of the wick will be installed in an upcoming bench-scale test to determine the compatibility of the material with sodium.

Wick model.

Sandia's wick model for heat-pipe receivers has been modified to model the current receiver technologies. The pool depth, previously limited to one node, has been expanded to allow an input depth in inches. This is important for the Thermacore receivers, which typically have a large excess pool. Refluxing of the returning condensate to the wick structure has also been added. The liquid is injected into the wick at a pressure exactly equivalent to the gravity head. This assumes that enough liquid is injected to form a free surface of liquid at this point. This model was applied to the Thermacore durability and 75kW$_t$ designs and compared to the test data. These significant model enhancements will be reported at

the IECEC conference in Atlanta in August Next quarter the changes will be documented and the user interface will be improved. In addition, **Sandia has begun a collaborative effort with Thermacore** to include their porous structure boiling model in the Sandia program. This should allow more accurate modeling of this type of heat pipe.

CPG heat-pipe analysis.

Sandia has performed a metallurgical analysis of the wick structure from the Cummins/Thermacore 600-hour durability heat pipe. Several cracks were noted in the nickel structure. These cracks were likely caused by thermal expansion mismatches and the thermal gradient through the wick thickness. Bonding of the particles was not strong. The particles themselves were hollow, reducing the strength of the structure. A slight discoloration near the surface of the wick was due to very thin concentrations of phosphorous, silicon, and sulfur. These deposits did not likely cause difficulties with the operation of the pipe. Thermacore needs to improve their wick strength while maintaining or improving the permeability of the structure. This feat could be accomplished by the above-mentioned Friction Coatings wick structure.

In addition to the metallurgical analysis, **Sandia assisted Cummins in evaluating the wick properties of the 30kW$_t$ heat pipe.** The permeability was measured at 16 μm^2, which is about half the design value. Thermacore's measurements agree. Previous measurements by Thermacore on samples prepared in a similar manner indicated permeabilities as high as 35 μm^2. This reduced permeability results in a receiver with very little if any operating margin, possibly explaining the degrading performance of the durability pipe. These results also apply to the artery- free heat pipe. Sandia used the modified wick analysis program to model the receiver as built. We determined that using a circumferential artery together with refluxing to the wick surface (as in the artery-free heat pipe) will provide sufficient margin with the current wick structure. Thermacore and Cummins will emphasize pursuing a resolution of the wick permeability issue.

Thermacore 75kW$_t$ heat pipe.

Design changes to the Thermacore 75kW$_t$ heat pipe were agreed upon by Sandia and Thermacore. A contract modification was placed for an additional calorimeter-controlled heat pipe. The gap between the domes was increased from 0.6 inches to more than 3 inches to allow vapor flow to the condensers without a significant pressure drop. In addition, the wick was thinned to 0.2 inches from 0.3 inches to reduce the possibility of boiling in the wick during the critical startup period. The contract modification was delayed in purchasing because of a high workload, but was placed earlier this quarter. The reduced permeability seen on the smaller heat pipes may affect the 75kW$_t$ version. The first receiver will be cut open and analyzed prior to beginning the sintering process on the modified design receiver. The Sandia wick model indicates that the receiver, with 16 μm^2 permeability, would have a similar operating margin as the 600-hour durability heat pipe. The new receiver domes and sintering mandrel are nearly complete. All other parts are ready for final assembly. The receiver should be delivered to Sandia in late August if it is not delayed for wick improvements.

Steam cleaner fabrication.

The latest (permanent) version of **the steam cleaner has been assembled and tested.** This system uses dry steam with a hot nitrogen purge to clean sodium- and NaK-78-contaminated parts generated by our receiver and engine development programs. This method results in **a smaller, less hazardous waste stream** than previous disposal methods. Cleaning the parts also allows re-use and post-test examination. The current steam cleaner is mounted permanently in a wall-less shelter at the NSTTF. The system was demonstrated late in the quarter, cleaning a fill volume from the pool-boiler project. The cleaner will be operated over the next quarter to clean the large backlog of contaminated parts, test vessels, and receivers. The system will be characterized in a series of cleaning tests to accurately determine reaction completion.

Test-Bed Concentrator updates.

Cold water calorimeter was performed on Sandia's TBC-2 during May and June after completion of the second-generation pool boiler testing. Using the same instrumentation as the receiver tests, **TBC-2 calorimeter indicated 67.5kW$_t$ delivered through a 6.8-inch diameter aperture**. Tests are continuing to determine the accuracy of using water-glycol calorimeter in place of water, reducing the waste stream and allowing winter testing without special measures. The TBC-2 will be re-lustered this summer, **improving power delivery to approximately 80kW$_t$**.

Planned Activities for Next Quarter

- 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. On the basis of the test results, Thermacore will conclude the integration of a similar receiver with the Stirling Thermal Motors (STM) heater heads. Sandia will complete the interface design and prepare the heater heads and fixture for attachment to the receiver.
- Testing will continue on the 10,000-hour pool-boiler bench test. If testing continues to progress, we expect to have completed nearly 6000 hours of testing by the end of the quarter. Testing of the Friction Coatings bench-scale heat pipe will be completed.
- Development of advanced wick options will continue. Friction Coatings will begin development of fabrication techniques to attach their wick to a dome suitable for the Thermacore 30kW_t heat pipe. ERG will fabricate and deliver small wick samples for evaluation at Sandia.
- The TBC's will undergo re-lustering to bring their performance back up to specifications. This will allow full-power testing of heat pipe receivers. If integration of a heat pipe with the STM package is successful, the re-lustered dish will give us a good shot at the world solar-to-electric conversion efficiency record this fall.

Milestones (Planned /Actual)

(Apr93/Apr 93) Complete planned on sun testing of 75 kW_t second generation pool boiler.

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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 statement of work has been negotiated with the Northern Research and Engineering Corporation (NREC) to develop a Brayton cycle PCS. 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 NREC PCS if hardware is fabricated. The project has been structured for execution in two phases. Phase 1 is a technical and economic feasibility study to determine the systems' potential for commercialization when mated with a point focus concentrator. A decision point has been built into the project at the end of Phase I. 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 II, if the option is exercised, will include system fabrication, on-sun testing in Germany and the USA, and an evaluation of the system performance. The contract details and cost issues were negotiated with NREC during this quarter. A tentative agreement was reached and the contract is in the final stages of placement.

A preliminary economic analysis was performed on a 30 kW_e dish/Brayton solar power generation system. The proposed economic and technical performance of the NREC TURBOGEN system, typical performance characteristics of existing solar concentrators, Sandia estimates of economic parameters and operation and maintenance (O&M) costs, and many rough guesses were used for the analysis. This preliminary analysis

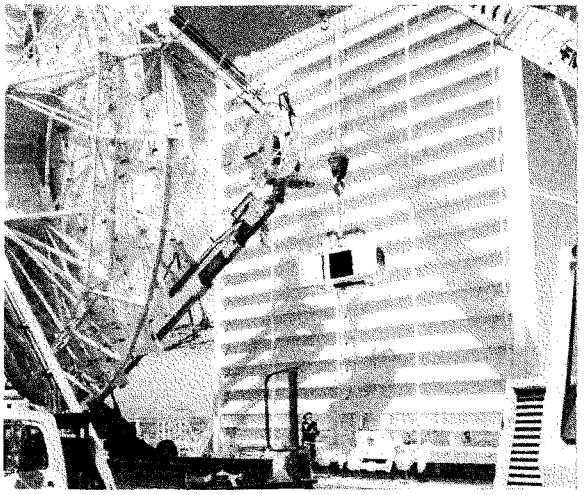


Figure 2. STM/DDC PCS installation on the Test Bed Concentrator at the NSTTF

indicated that the Levelized Cost of Energy (LEC) produced by a dish/Brayton system may be competitive with 25kW$_e$ dish/Stirling systems. The economic model will be polished and refined in Phase I of the project with NREC.

Stirling cycle power conversion systems.

A cost-shared project with Detroit Diesel Corporation (DDC) and its sub-contractor, Stirling Thermal Motors (STM) is nearing completion. The project consisted of developing a 25-kW$_e$ PCS based on the upgraded STM4-120 engine. Most of the design and development work on the project was performed by STM. A directly illuminated solar receiver (DIR), a package support structure, the cooling system, the control system, the engine interface to an induction generator, and the environmental protection packaging were designed and fabricated. The PCS interface to the TBC and to the Sandia data acquisition system was negotiated and documented in an Interface Control Document (ICD) maintained by Sandia. Before delivery to Sandia, the power conversion system was tested extensively using a natural gas-fired system and a quartz lamp array to provide the heat input to the system. The PCS performed very well during these tests.

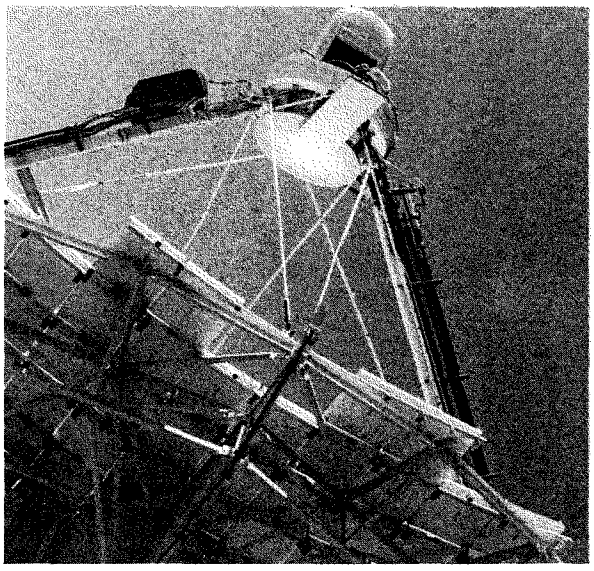


Figure 3. STM/DDC PCS testing at the NSTTF.

The completed PCS was received by Sandia on March 1. The PCS was installed on the TBC and on-sun testing began on April 5. The testing is conducted in three phases. The first phase is a system checkout and shakedown test. The PCS is initially operated at relatively low receiver temperatures and low power levels until the control system stability is verified. The receiver temperatures and power input are gradually increased until the highest safe operating temperature and the rated power input of the TBC is determined. Phase I is conducted with an open receiver aperture to allow viewing of the receiver surface using an infrared camera system. The second phase of the test plan is designed to allow a performance map of the PCS to be generated. The performance of the PCS is measured with a closed aperture, at various power input levels, and at various receiver control temperatures. The empirical model of the results is constructed using a statistical regression technique. The third phase of the plan includes an expansion of the performance map to include engine cycle pressure as a control variable and an investigation of special operating conditions.

The first phase of the testing program was nearing completion in May when a problem was encountered with the PCS. The receiver control temperature had been increased to 650°C; the power input was 8.7 kW$_e$; and the PCS was nearing steady-state operation when the power output level suddenly dropped and the end seal and cross-head temperatures increased. Subsequent efforts to run the engine demonstrated a steadily declining power output. Sandia performed several tests at STM's request in an attempt to diagnose the problem with little success. During motoring of the PCS, an acoustic anomaly was detected in the engine. The rising temperatures, lowered power output, and noisy operation indicated a possible failure in the engine lubrication system. Because this type of failure could be repaired more quickly by STM, the PCS was removed from the

TBC and shipped to Ann Arbor, Michigan for further diagnostics and testing.

STM found a faulty pressure relief valve in the lubrication system that caused helium to be mixed with the oil. The oil/helium foam did not provide proper lubrication to the bearing surfaces, which resulted in increased friction losses, rising component temperatures, and lower power output. The cause of the failure was an inadequate oil filtration system. The oil filter allowed particles up to 20 microns in diameter to circulate in the system. The pressure relief valve manufacturer calls for filtration of particles down to 5 microns for proper valve performance. The improper filtration allowed particles to collect in the valve and interfere with the valve operation.

The engine bearing surfaces were damaged by the lack of lubrication. The engine was replaced by a similar engine that was awaiting testing at STM. The replacement engine was tested in the PCS package for 50 hours of incident-free operation at power levels of greater than 20 kW_e. The PCS was tested for proper operation at tilt levels of up to 80°. These tests were performed using a natural gas-fired heat input system. The DIR was then installed on the PCS and a test was conducted using the quartz lamp array. The PCS was operated for two hours, incident-free, on the quartz lamps. DDC and STM cost-shared the maintenance on the PCS. STM did not charge Sandia for the replacement engine or engine-related costs. Sandia paid for the PCS assembly and testing.

The PCS will be returned to Sandia in early July. The PCS will be reinstalled on the TBC and the Phase I testing will resume by July 15, 1993.

Planned Activities

- The NREC contract will be placed. Phase I of the Brayton PCS project will begin with the development of a detailed economic model of a dish/Brayton system.
- Phase I of the DDC/STM PCS test program will be completed and Phase II will be initiated.
- The PCS will be operated with a closed aperture and the highest thermal input power possible from the TBC.
- The final report from the DDC/STM PCS development, design, fabrication, and bench testing at STM will be completed.
- Support for the ST-DAC will continue and promising power conversion system designs will be evaluated for possible incorporation into the PCS development program.

Milestones (Planned/Actual)

(May 1993/) Complete on-sun tests for the PCS with the directly illuminated receiver. Underway.

III. Reimbursables

Reimbursable activity has been very limited in FY93 and mostly involves planning and preparation for tests scheduled in FY94. The timing of the turndown in this activity is rather fortuitous, however, because facility personnel who have supported reimbursable programs in the past two years are quite busy preparing for Solar-Two-related tests to be conducted next quarter. The objective of the reimbursable programs is to make the unique capabilities of the National Solar Thermal Test Facility (NSTTF) available to users outside of the DOE Solar Thermal Electric program. Organizations such as Northrop, McDonnell Douglas, PDA Engineering, General Dynamics, David Taylor Research Center and Johns Hopkins University Applied Physics Laboratory have used the facility with funding from the Air Force, Navy, Army, and the Defense Nuclear Agency. Commercially-funded organizations have included Science Applications International Inc., Atlantis Energie, Ltd., and Northrop.

All work is performed on a full-cost recovery basis. These funds help offset the operating and maintenance costs of the NSTTF and paid all costs for operation and maintenance of the heliostat field and solar tower in FY91 and FY92.

Accomplishments

User Facility designation sought.

During the last reporting period, we verified that the Central Receiver Test Facility (CRTF) already is classified as a DOE Designated User Facility; however, the designation only applies to the field of heliostats and receiver tower. Our efforts now will focus on changing the name of the Designated User Facility to the National Solar Thermal Test Facility (NSTTF) to encompass the entire facility, including the parabolic dishes, solar furnaces, parabolic troughs, engine test facility, and Solar Thermal Design Assistance Center (STDAC) activities. We will not seek to establish STDAC separately as a DOE Other-User Resource because some STDAC activities are already performed at the NSTTF and the Other User resource description does not seem appropriate for the remaining STDAC activities. In addition, the primary effort to establish new user facilities at Sandia has shifted to our technology transfer organization.

NSTTF staff visited the recently designated Oak Ridge Centers for Manufacturing Technology User Facility for a National Service Providers Workshop. The facility (part of the Y-12 manufacturing center) became a DOE/DP Designated User Facility. Most other Designated User Facilities have been designated by DOE/EM. The information gathered at the workshop was useful in understanding how Y-12 received their designation and how they intend to operate their facility as a Designated User Facility.

Large scale test of volumetric air receiver.

Discussions are continuing to prepare for a Large Scale Test of Atlantis Energie Ltd.'s Volumetric Air Receiver at the NSTTF. The test schedule has slipped due to other priorities and funding constraints at Atlantis. The tests are scheduled for early next calendar year.

Technology Transfer

Publications:

Chavez, J.M., et al., ***The Solar Two Project,*** proceedings of the 5th Sede Boqer Symposium on Solar Electricity Production, February 1993.

Chavez, J.M., G. J. Kolb, et al., ***Second Generation Central Receiver Technologies: A Status Report,*** Verlag C.F. Müller, Karlsruhe, Germany, April 1993.

Moreno, J.B., and T.A. Moss, ***Bench-Scale Screening Tests for a Boiling Sodium-Potassium-Alloy Solar Receiver,*** SAND92-2253,. Sandia National Laboratories, Albuquerque, New Mexico.

Muir, J.F., et al., ***The CAESAR Project: Experimental and Modeling Investigations of Methane Reforming in a Catalytically Enhanced Solar Absorption Receiver on a Parabolic Dish,*** SAND92-2131, Sandia National Laboratories, Albuquerque, New Mexico, July 1993.

Publications in Progress:

Adkins, D.R., ***High-Flux Testing of Heat Pipes for Point-Focus Solar Collector Systems,*** SAND92-2346C, Sandia National Laboratories, Albuquerque, New Mexico.

Adkins, D.R., R.C. Dykhuizen, ***Procedures for Measuring the Properties of Heat-Pipe Wick Materials,*** SAND92-2347C, Sandia National Laboratories, Albuquerque, New Mexico.

Andraka, C.E., et al., ***NaK Pool-Boiler Bench-Scale Receiver Durability Test: Test Design and Initial Results.***

Andraka, C.E., et al., ***Testing of Stirling Engine Solar Reflux Receivers.***

Bean, J.R., and R.B. Diver, ***Performance of the CPG 7.5-kW$_e$ Dish-Stirling System.***

Cameron, C.P., ***A Summary of Recent Activities at the National Solar Thermal Test Facility,*** SAND92-1348A, Sandia National Laboratories, Albuquerque, New Mexico.

Cameron, C.P., ***High Heat Flux Engineering in Solar Energy Applications,*** SAND93-0229C, Sandia National Laboratories, Albuquerque, New Mexico.

Dudley, V., et al., ***Test Results for the LUZ LS-2 Solar Collector,*** draft report, February 1993.

Kelly, B., ***Resolution of Thermal Storage and Steam Generator Issues for Central Receiver Power Plants,*** Bechtel National Inc., SAND Contractor Report.

Moreno, J.B., et al., ***First On-Sun Test of a NaK-78 Pool-Boiler Solar Receiver.***

Moreno , J.B. et al., ***On-Sun Test Results from Second-Generation and Advanced-Concepts Alkali-Metal Pool-Boiler Receivers,*** SAND93-1251, Sandia National Laboratories, Albuquerque, New Mexico.

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

Powell, M.A., and K.S. Rawlinson, ***Performance Mapping of the STM4-120 Kinematic Stirling Engine Using a Statistical Design of Experiments Method.***

Ralph, M., C.E. Cameron, and C. Ghanbari, ***Thermal Effects Testing at the National Solar Thermal Test Facility,*** SAND92-2167C, Sandia National Laboratories, Albuquerque, New Mexico.

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.

Stine, W.B. and M.A. Powell, ***Proposed Guidelines for Reporting Performance of a Solar Dish/Stirling Electric Generation System.***

Strachan, J.W., and R.M. Houser, ***Testing and Evaluation of the Large Area Heliostats for Solar Thermal Applications,*** SAND 92-1381, Sandia National Laboratories, Albuquerque, New Mexico, February 1993.

Meetings and Presentations:

Adkins, D.R., ***Procedures for Measuring the Properties of Heat-Pipe Wick Materials,*** to be presented at the 28th IECEC, August 9, 1993, Atlanta, Georgia.

Andraka, C.E., et al., ***NaK Pool-Boiler Bench-Scale Receiver Durability Test: Test Design and Initial Results,*** to be presented at the 28th Intersociety Energy Conversion Engineering Conference, August 8-13, 1993, Atlanta, Georgia.

Andraka, C.E., et al., ***Testing of Stirling Engine Solar Reflux Receivers,*** to be presented at the 28th Intersociety Energy Conversion Engineering Conference, August 8-13, 1993, Atlanta, Georgia.

Bean, J.R., and R.B. Diver, ***Performance of the CPG 7.5 KW_edish/Stirling System,*** to be presented at the 28th IECEC, Atlanta, Georgia.

Cameron, C.P., ***A Summary of Recent Activities at the National Solar Thermal Test Facility, SAND92-1348A,*** presented at 1993 ASME/ASES/SOLTEC Energy Conference, April 1993.

Cameron, C.P., ***High Heat Flux Engineering in Solar Energy Applications***, SAND93-0229CC, to be presented at the SPIE 1993 International Symposium on Optical Applied Science and Engineering , July 1993.

Chavez, J.M., et al., ***The Solar Two Project,*** presented at the 5th Sede Boqer Symposium on Solar Electricity Production, February 1993.

Grossman, J.W., scheduled panel session speaker, Solar Concentrator Research and Testing, the ASME International Solar Energy Conference Washington, DC, April 1993.

Jorgensen, G., ***Reflective Coatings for Solar Applications,*** presented at the 36th Technical Conference of the Society of Vacuum Coaters, Dallas, Texas, April 1993.

Kearney, D., ***O&M Cost Reduction for Solar Thermal Electric Plants,*** presented at SOLTECH 93, Washington, DC, April 1993.

Kolb, G.J., ***Thermal Cycling of Thermal Energy Storage Tanks Proposed for the Solar Two Central Receiver Power Plant***, presented at ASME Solar Energy Conference, Washington, DC, April 1993.

Moreno, J.B., et al., ***First On-Sun Test of a NaK-78 Pool Boiler Solar Receiver***, to be presented at the 28th Intersociety Energy Conversion Engineering Conference, August 8-13, 1993, Atlanta, Georgia.

Pacheco, J.E., ***"Flow Stability in Molten-Salt Tube Receivers,"*** *Solar Engineering 1993*, presented at the 1993 ASME International Solar Energy Conference, Washington, DC, April 25-28, 1993, pp. 407-413.

Powell, M.A., ***The Dish/Stirling Solution: Solar-to-Electrical Energy Conversion***, presented at the Public Symposium at Arkansas State University, Jonesboro, Arkansas, April 22, 1993.

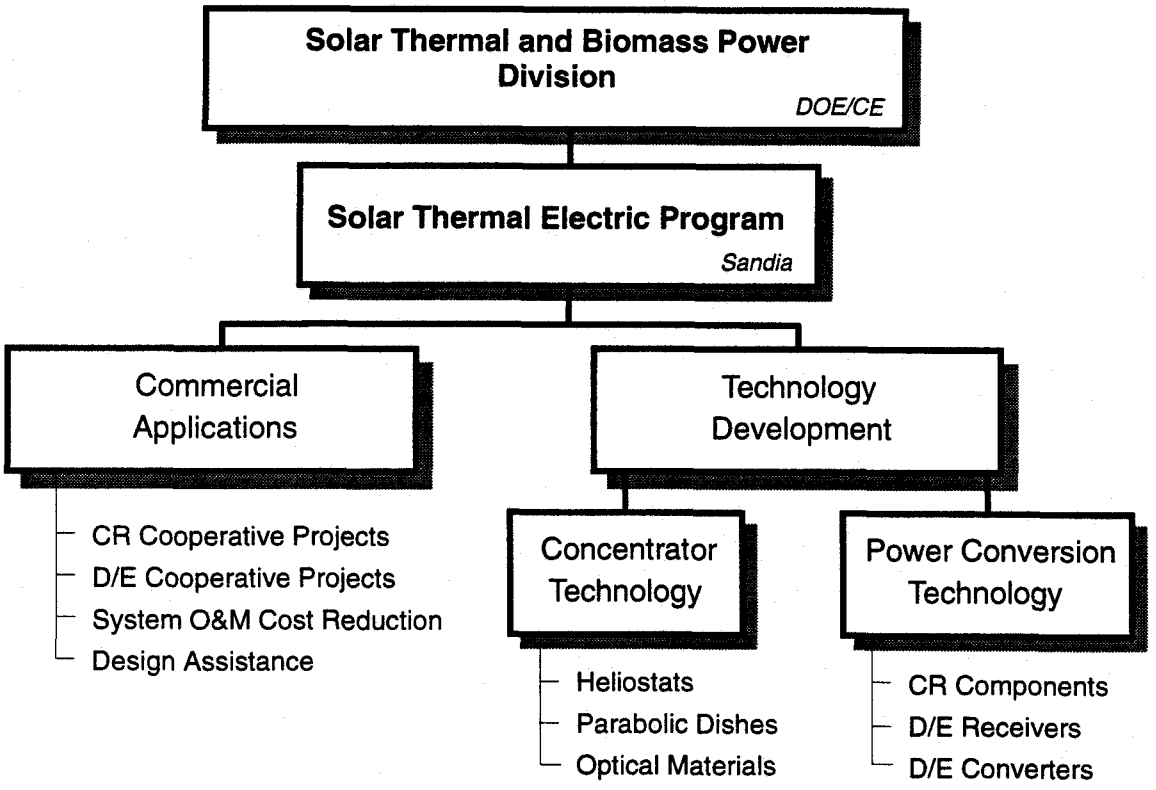
Ralph, M.E., C.P. Cameron, and C.M. Ghanbari, ***Thermal Effects Testing at the National Solar Thermal Test Facility***, presented at the 39th International Instrumentation Symposium, ISA, Albuquerque, New Mexico, May 1993.

Strachan, J., ***Revisiting the BCS: A Measurement System for Evaluating the Optics of Solar Collectors***, presented at the International Instrumentation Symposium, ISA, Albuquerque, New Mexico, May 1993.

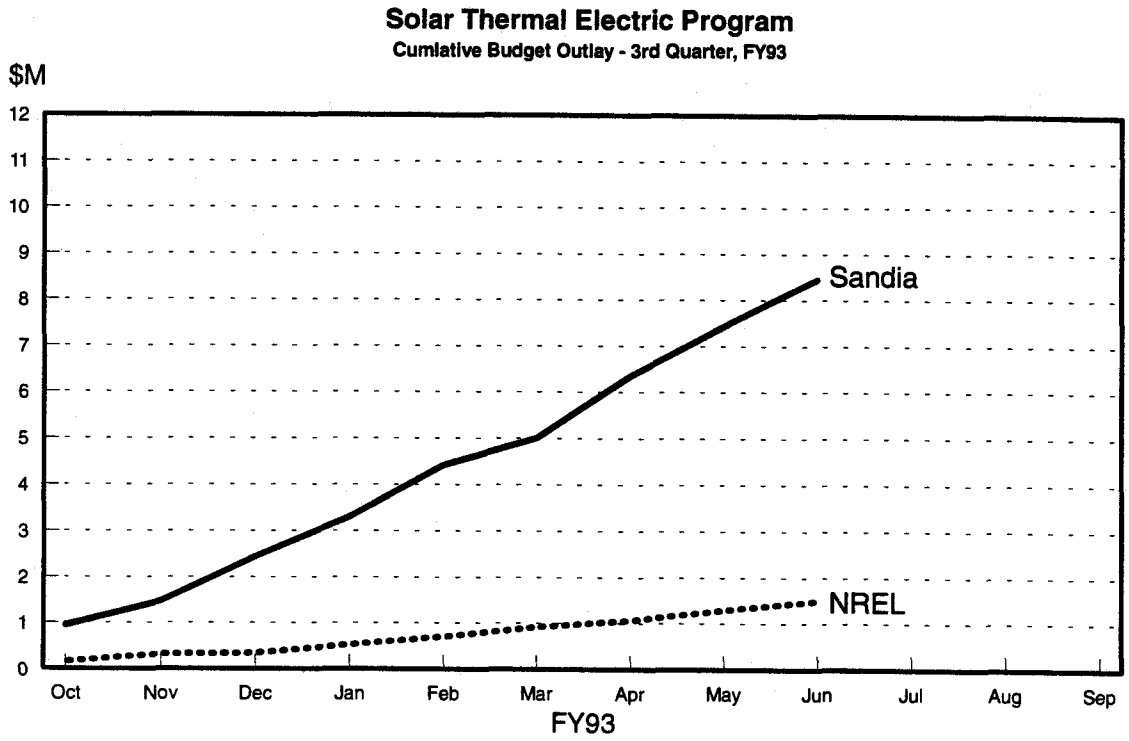
Management Structure Summary

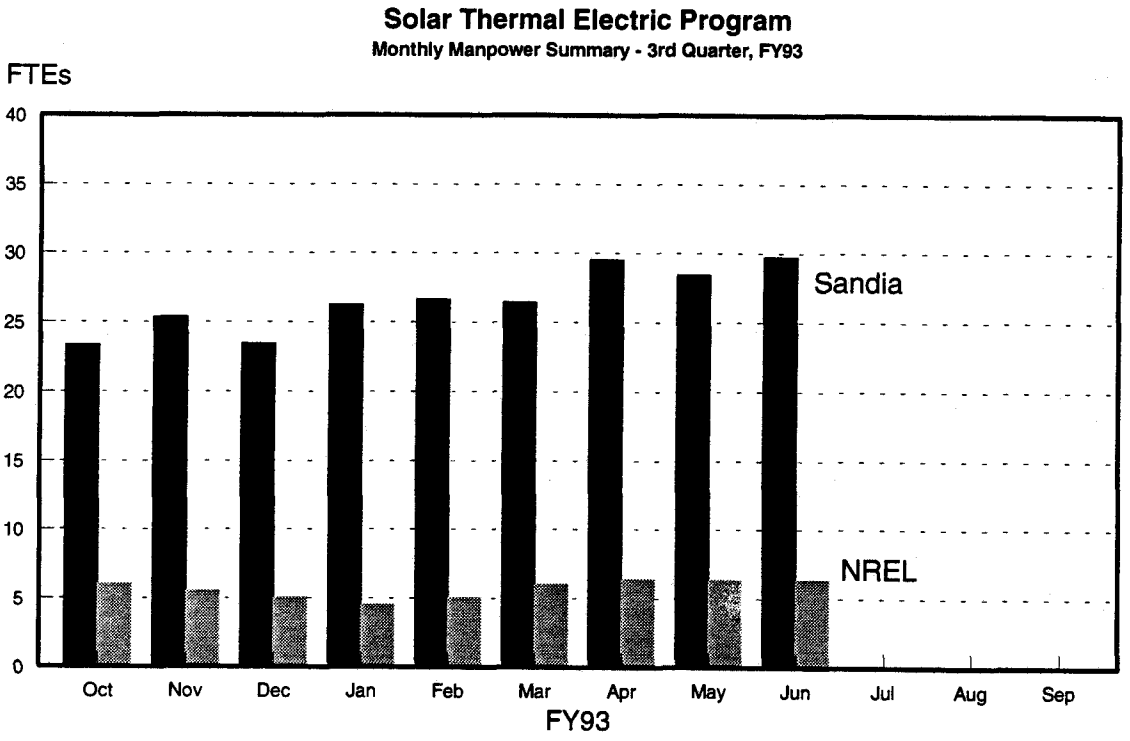
Field Management - Structure and Responsibilities

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.



Budget Summary





Major Milestone Summary

TASK I

	Planned	Actual
The participants Agreement, E&C Agreement, and DOE Cooperation Agreement will be finalized so that the Solar Two project can be officially started.	Nov 1992	Jun 1993
The Fourth Technical Advisory Committee meeting will be held. TAC meetings will be held quarterly thereafter.	Jan 1993	Jan 1993
Authorization to proceed to final design and construction, based on completed plant layout and cost estimate. Delayed to Oct 93.	Apr 1993	
Solar One thermal storage tank removed. Initiated Jul 93.	Jun 1993	
Replacement facets for Solar Two heliostat field selected.	Aug 1993	
Conduct Phase I review of CPG joint venture program.	Nov 1992	Nov 1992
Deliver CPG "prototype" water pumping dish/Stirling system to the California Polytechnic University test site. Delayed to FY94.	Dec 1992	
Demonstrate the remote village electrification application at the CPG Abilene, Texas facility. Postponed to FY94.	Dec 1992	
Complete evaluation of proposals for the utility scale joint venture program.	Jan 1993	Jan 1993
Demonstrate the utility grid-tie application at the CPG Abilene, Texas facility. Postponed to FY94.	May 1993	
Award contract(s) for the utility-scale joint venture program.	Jul 1993	
Sandia will complete documentation of the testing of the SEGS heat collection elements.	Feb 1993	Feb 1993
Survey of advanced selective surface coatings for SEGS plants and central receivers will be completed.	Jan 1993	Jun 1993
Mid-term report that describes advancements in FY93 SEGS tasks 1-7.	Mar 1993	Feb 1993
Data acquisition system to facilitate SEGS maintenance planning will be implemented.	Jun 1993	Jun 1993
Evaluation of cyclic stresses in the power block will be completed.	Jul 1993	
Final report that describes advancements in FY93 SEGS tasks 1-7.	Sep 1993	
Participate in SOLTECH 93 meeting.	Apr 1993	Apr 1993

Major Milestone Summary (cont)

Task II	Planned	Actual
Complete documentation of the test results on the two large-area glass mirror heliostats and the low-cost drive.	Feb 1993	Feb 1993
Completion of testing and documentation on the first prototype of 100-m^2 dual-module stretched-membrane heliostat.	Aug 1993	
Complete installation of the Faceted Stretched-Membrane Dish at the NSTTF.	Nov 1992	Nov 1992
Conduct Final Design Review for the Single-Element Stretched-Membrane Dish design.	Nov 1992	Nov 1992
Place contract to fabricate a Single-Element Stretched-Membrane Dish. Replaced with decision to redesign for manufacturing.	Mar 1993	Jun 1993
Complete testing of FSMD with the elastically-formed SAIC facets. Underway.	May 1993	
Complete testing of FSMD with the plastically-formed SKI facets.	Sep 1993	
Identify procurement process and technical approach for additional alternative reflector.	Nov 1992	Nov 1992
Initiation of outdoor materials test at Arizona Public Service or alternate site.	Jan 1993	Jan 1993
Installation of materials test racks at Sacramento Municipal Utility District or alternate site.	Feb 1993	Mar 1993
Document status of outdoor testing activities.	Apr 1993	Apr 1993
Document alternative reflector materials R&D progress.	Aug 1993	
Complete the Bechtel study of 100 MW_e molten salt steam generators and thermal storage systems.	Jan 1993	Jan 1993
Complete the 4000-hour molten salt corrosion and stability tests.	Feb 1993	Feb 1993
Complete testing of wire mesh materials at New Mexico State University.	Sep 1993	
Complete testing of the Bechtel volumetric air receiver at the Plataforma Solar (subject to SolarPACES approval). Underway, delayed until Oct 93.	Jun 1993	
Publish the Second Generation Central Receiver report.	Sep 1993	Apr 1993
Complete planned on-sun testing of Sandia 75kW_t heat-pipe receiver.	Dec 1992	Dec 1992
Test 10kW_t hybrid receiver on sun.	Aug 1993	
Complete fabrication and begin testing Sandia advanced-wick heat-pipe receiver.	Sep 1993	
Complete fabrication and begin testing on-sun boiling stability advanced concepts receiver.	Sep 1993	
Complete fabrication of the Detroit Diesel/STM PCS.	Dec 1992	Feb 1993
Complete integration of the PCS with a test bed concentrator.	Feb 1993	Apr 1993
Complete on-sun tests for the PCS with the directly illuminated receiver. Underway.	May 1993	
Complete integration of the PCS with an alkali metal solar receiver (subject to DDC/STM contracting agreement). Delayed until FY94.	Aug 1993	

Procurement Summary

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($k)	Prior Year Funds ($k)	FY93 Funds ($k)	Total Costs to Date ($k)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IA	Molten Salt System Study	Bechtel	SNL 87-5142	159	126	33	159	01/92-03/93	Large	Report	J. Chavez
IB	Dish JVP	Cummins	SNL 69-7763	7000	3500	2300	4070	06/91-03/94	Large	Phase Reports	R. Diver
IB	US-JVP	Competitive	SNLAB-8717	10,000	-0-	2458	-0-	05/93-05/98	Large	TBD	M. Powell
IIB1	Vol Rec Test	NMSU	AD-2165	59	-0-	59	59	09/93-09/93	Univ	TBD	J. Chavez
IIB2	75kW heat pipe	Cummins	AB-3348A	83	-0-	83	83	6/93-3/94	Large	Large	C. Andraka
IC	O&M cost reduction	Kramer Junction Company	SNL AB-0227	3162	650	700	661	07/92-09/95	Large	TBD	G. Kolb
ID	Tech Trans Documentation	SEIA	SNL 42-5186	175	55	120	175	02/92-03/93	non-profit	Three TT Rpts.	D. Menicucci
ID	Commercial-ization Support	Meridian	SNL AG-4525	175	-0-	175	-0-	06/93-06/95	Large	Final	P. Klimas
II	Solar Test Support	EG&G	SNL 05-4912	770	412	308	720	12/88-10/93	Large	N/A	C. Cameron
II	Electrical Support Service	J & S Electric Co., Inc.	SNL 75-7415	351	238	63	301	02/89-02/94	Serv. Support	N/A	L. Gillette
IIA1	NSTTF Technician Services	Ewing Technical Design	SNL 63-5487	1700	1350	121	1471	04-89-04-93	Serv. Support	N/A	E. Rush

Procurement Summary (cont)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value	Prior Year Funds	FY93 Funds	Total Costs to Date	Period of Performance	Contractor Type	Major Reports	Project Monitor
IIA1	Stretched-Membrane Dish Dev.	Solar Kinetics, Inc.	SNL 55-2495	1814	1686	123	1809	04/88-12/92	Small	88-7035	T. Mancini
IIA3	Direct Optical Materials	SAIC	NREL YF-2-11191	130	130	-0-	38	03/92-05/93	Large	TBD	G. Jorgensen
IIA3	Optical Materials	3M	NREL 2A-2-11031	139	139	-0-	38	9/10/92-6/9/93	Large	Final Report	G. Jorgensen
IIA3	Optical	IST	NREL	139	-0-	76	76	04/92-04/93	Small	TBD	G. Jorgensen
IIA3		PNL	DAT-3-132268-01	70	-0-	70	-0-	3/93-4/94	Govt	Final Report	G. Jorgensen
IIB2	Heat-pipe	Cummins	SNL AB3348	231	147	-0-	147	08/92-04/93	Large	Monthly	C. Andraka
IIB3	2nd STM4-120	Stirling Ther. Motor	SNL 75-8851	61	61	-0-	61	04/89-02/93	Small		M. Powell
IIB3	Stirling Engine Solarization	Detroit Diesel Company	SNL 67-9086	319	113	206	319	01/92-02/93	Large	TBD	M. Powell
IIB3	Dish/ Stirling	Cal Poly Pamona	SNL 67-3678	79	66	12	78	11/91-05/93	Univ	Final	P. Klimas
IIIB3	STM Engine	DDC	SNL AE-5963	83	-0-	34	34	03/93-09/93	Large		M. Powell

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