SOLAR • THERMAL • ELECTRIC •

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QUARTERLY PROGRESS REPORT

Fourth Quarter FY95

October 1995

Sandia National Laboratories
Albuquerque, New Mexico

National Renewable Energy Laboratory
Golden, Colorado

SUMMARY OF ACCOMPLISHMENTS: FOURTH QUARTER FY95

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

Solar Two

- Construction of Solar Two was completed.
- Startup, checkout and acceptance of Solar Two hardware began.
- Phase 6, Operation, of the project began.

Dish/Engine Joint Venture Programs

- Thermacore initiated cycle testing of full-scale heat-pipe receivers for the DSJVP.
- SAIC and STM successfully operated their system at full power for 150 hours. The maximum net power output was 17.9 kW_e.
- SAIC and STM completed Phase 1 of their USJVP. The Phase 2 decision will be made based on plans that are currently being finalized.

Solar Manufacturing Technology

- SAIC made significant cost reductions in its heliostat as a result of manufacturing and design improvements.
- Rockwell International Corporation started work on a component manufacturing effort for central receivers.

System Operation and Maintenance Cost Reduction

- A new mirror facet was developed.
- Severely degraded mirrors were successfully cleaned.
- A water-use study was completed.
- *In situ* repair of heat collection elements was successfully demonstrated.

Concentrator Technology

- The Solar Kinetics Inc./Allied Signal project to develop a dish/Brayton system was started and two planning meetings were conducted.
- The review of 14 proposals for the Advanced Concentrator Procurement was completed. Contracts should be placed next quarter.
- Sun♦Lab provided optical characterization support for SAIC (flux mapping) and for Cummins Power Generation, Inc. (SHOT).

Power Conversion Technology

- Support for Solar Two Test and Evaluation continues with the start of the first test, Storage Tank Thermal Stresses, during the hot tank preheating, salt melt, and salt conditioning.
- The CRADA with Rockwell International Corporation on advanced central receiver development continues with the characterization of advanced materials.
- An alternative heating system called impedance heating has been designed and installed at Sandia to compare its performance and reliability relative to heat trace.
- The first phase of experiments to investigate transient freezing of flowing molten salt in cold pipes has been completed.
- We delayed testing of the STM engine with a heat-pipe receiver to allow time for STM to correct a defect in the heater-head configuration.
- We determined the cause of a hot spot on the second-generation felt-wick receiver and have developed a design that alleviates the problem.
- We terminated testing of the felt-wick durability heat pipe after 1,995 hours when a hot spot developed on the heated surface. We are investigating the cause of the problem.
- We completed the design and have begun fabrication of heat-pipe test capsules for evaluation of different materials combinations and cleaning techniques. These tests will address long-term life issues.

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INTRODUCTION

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

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

OUR VISION

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

OUR MISSION

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

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

OUR STRATEGY

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

- increase, through cooperative ventures, industrial participation in both the planning and execution of program elements. Specifically,
  - — *The Solar Two molten-salt power tower project led by Southern California Edison will provide the technical base for Solar 100, the first 100-MW power tower plant.*
  - — *The Cummins Power Generation, Inc. 7-kW_e dish/Stirling system, designed for both remote and grid-connected applications, will be operated at utility and industrial sites.*
  - — *The Utility-Scale Joint-Venture Program for 25-kW_e dish/Stirling systems will field initial hardware, with the last phase of this program resulting in at least one megawatt of dish/engine system capacity installed by utilities.*
  - — *The operations and maintenance cost reduction study with the Kramer Junction Company Operating Company will provide for lower levelized energy costs for power tower and dish/engine solar systems as well as trough plants.*
- utilize the analytical and experimental capabilities of the program to support and enlarge the solar thermal technology base and the user, supplier, and decision-making constituency. Specifically,

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

— *Industry/laboratory teams will extend the performance and reliability of critical system components (concentrators, receivers, optical materials, etc.) through focused research and development.*

— *Industry and user requests for assistance will be addressed by the Solar Thermal Design Assistance Center and other program resources.*

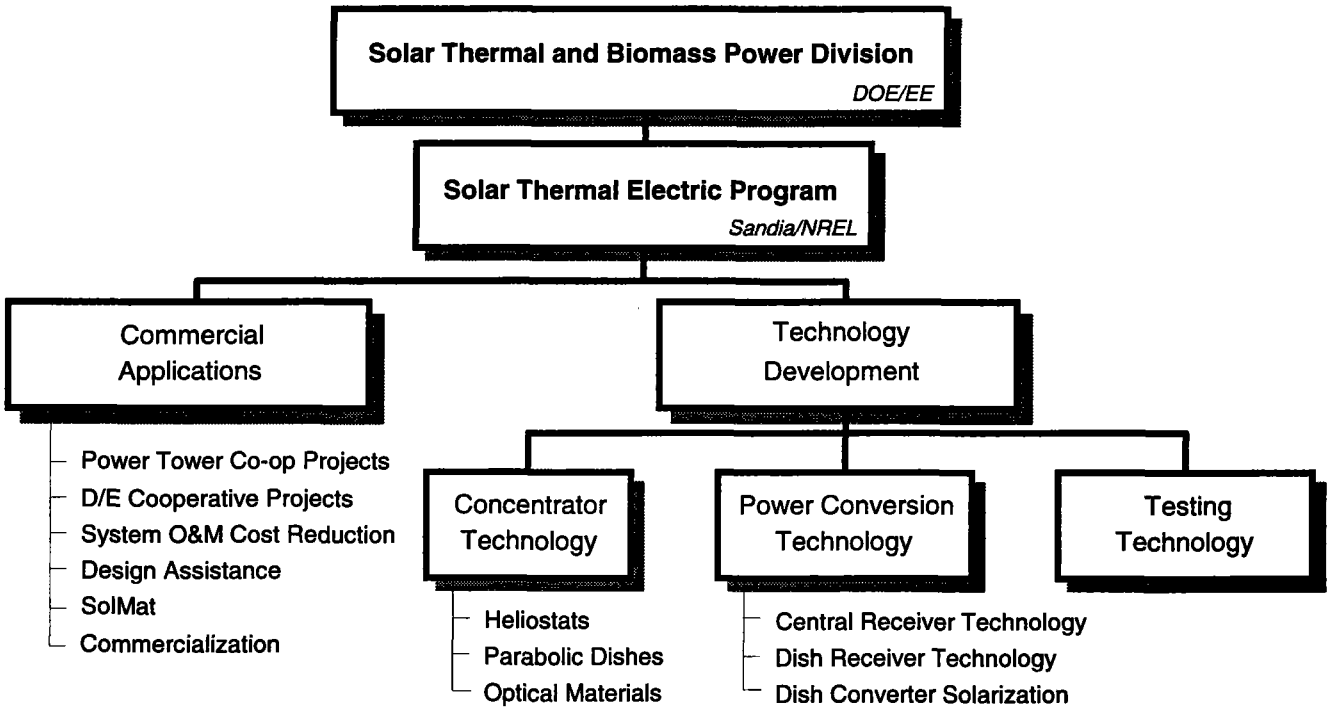
— *Information exchange through conferences, road shows, and publications will be used to bring the technology to the attention of regulators, potential users, and the public.*

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

This report describes the progress made during the fourth quarter of FY95 toward acceptance of solar thermal electric technology as a serious candidate for cost-competitive electric power generating options by utilities, industry, and other manufacturer/user groups.

OUR MANAGEMENT STRUCTURE

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



I. COMMERCIAL APPLICATIONS

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

The program emphasizes cost-shared activities where there is significant industrial involvement in the planning and execution of the activities. These government/industry partnerships represent teams that are uniquely qualified to rapidly advance each technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of the government laboratories. Presently, five major 50/50 cost-shared cooperative activities are underway within the program with a total value of $150 million. The following organizations are the private sector leaders of these joint activities:

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

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

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

A. POWER TOWER COOPERATIVE PROJECTS

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

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

Status

Highlights this quarter included the completion of construction, the initiation of startup and checkout, and the initiation of Phase 6, Operation.

Accomplishments

Construction

- Bechtel Corporation completed construction of Solar Two this quarter.
- The Rockwell receiver panels, piping, header heaters, and electronics were installed.
- Heat tracing and insulation of all piping was completed.
- The master control system was delivered by Queue Systems and its installation and checkout began.
- Delivery of the nitrate salt was completed.
- Canting of the Solar One heliostats was completed. Canting of LUGO heliostats continued.

Startup, Checkout, and Acceptance

- Early system startup and checkout activities involved the following systems: control loops, electrical supply systems, circulation water systems, fire protection systems, feedwater and demineralized water systems, the chemical control system (steam), turbine, and heliostat controls.
- Plans were made to address the salt outgassing problem (see Issues below).

Programmatic

- Phase 6 of the project was initiated. Phase 6 includes management of the operation and maintenance (O&M) contractor, completion of the Test and Evaluation (T&E) Plan, plant operation for three years, and shutdown.
- A Steering Committee meeting was held on July 28, 1995. At this meeting, the Steering Committee approved transition to Phase 6, discussed the need for more volunteers among the participants to support T&E, and discussed delays related to the problem with the stainless-steel piping. Delays in the selection of the O&M contractor were also discussed.
- The Technical Advisory Committee (TAC) held its quarterly meeting on August 15, 1995, at the Solar Two site. TAC responsibilities in support of T&E were identified.

Sun♦Lab Support

- We provided technical assistance regarding proper installation of heat tracing.
- We provided assistance troubleshooting the heliostat field and the heliostat-control communications.
- We assisted with performing tilt measurements and canting for the LUGO heliostats.

- We identified the cause for thermal outgassing of the Solar Two salt and helped identify solutions.

Planned Activities for Next Quarter

- The receiver with flowing salt will be exposed to solar energy for the first time.
- The O&M contractor will be selected (delayed from this quarter).
- The salt will be melted and thermally conditioned.
- The entire salt-flow network will be tested and tuned with flowing water.
- The heliostat field will be tested using moon tracking at night.
- Steering Committee and TAC meetings are scheduled to take place at the site on October 27 and November 15, 1995, respectively.

Issues

- It was discovered that approximately 427 m of installed stainless-steel piping did not comply with material specifications. Over a period of about one month, the problem was resolved employing corrective actions that included pipe replacement and evaluation under different code sections. A schedule delay of about one month resulted.
- Additionally, it was discovered that the Solar Two salt outgasses at high temperatures, producing NO_x. Laboratory research performed at Sandia determined that 500 ppm magnesium in the salt causes the problem by thermally decomposing nitrate to NO_2 and O_2. A plan was developed to thermally pretreat the entire salt inventory using a recirculation heater attached to the hot storage tank. The tank will be physically isolated from the rest of the salt flow system so that water-flow testing can proceed in parallel with salt melt and thermal conditioning.

Major Milestones

Milestone	Planned	Actual
Complete Phase 3, Final Engineering and Initial Construction.	Nov 94	Nov 94
Initiate Plant Startup process.	Jul 95	Jul 95
Complete Phase 4, Plant Construction, and begin Phase 5, Startup.	Sep 95	Sep 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	600	0	0	**600**
Contracts	0	0	1,500	**1,500**
Total	**600**	**0**	**1,500**	**2,100**

B. DISH/ENGINE COOPERATIVE PROJECTS

The objective of the dish/engine cooperative projects is to commercialize dish/engine solar thermal electric systems. The approach is to form joint ventures with industry, utilities, and other users. The Dish/Stirling Joint Venture Program (DSJVP) with Cummins Power Generation, Inc. (Cummins), underway since 1991, will develop a 7-kW$_e$ dish/Stirling system primarily for remote application. Two Utility Scale Joint Venture Program (USJVP) contracts with Science Applications International Corporation (SAIC) and Cummins will develop 25-kW dish/Stirling systems for utility application.

DSJVP

Status

The DSJVP team continued to struggle with the Clever Fellows Innovation Consortium (CFIC) Stirling engine/linear alternator. Although engine/alternator efficiency has improved, performance continues to be erratic. Because of continued problems with the CFIC engine, Cummins has resumed discussions with Sunpower, Inc., which recently had success with a 2.5-kW$_e$ single-cylinder free-piston Stirling engine. Installation of power conversion units (PCUs) continues to be delayed until engine problems can be resolved.

Accomplishments

- The DSJVP team determined the root cause of the durability problems with the CFIC Stirling engine/linear alternator.
- We initiated several near-term solutions for the CFIC engine problems.
- Cummins continued to operate dish-concentrators and calorimeters at the test sites of Central and South West Services, Inc. (Ft. Davis, Texas), California State Polytechnic University (Cal Poly) (Pomona, California), and Texas Utilities (Dallas, Texas).
- Cummins continued to durability test CPG-460 concentrators at its Abilene, Texas, test facility.
- Thermacore initiated full-scale thermal-cycle testing of felt-wick and sintered-powder-wick heat-pipe receivers on quartz lamps at its Lancaster, Pennsylvania, facility.

Planned Activities for Next Quarter

- Cummins will implement changes to the CFIC engine design that hopefully will resolve the engine's durability problems.
- Cummins and Sunpower will discuss fabrication of a Sunpower 5-kW$_e$ engine for evaluation at Cummins' Abilene test facility.
- Cummins will deliver PCUs to the Central and South West Services, Cal Poly, and Texas Utilities test sites.
- We will continue design of a Cummins glass/metal dish for the 7-kW$_e$ system.
- Cummins will move into its new 4,500-m^2 facility in Abilene, Texas.

Issues

- Because of technical problems and delays, Cummins will not be able to field its preproduction system deliverables within the DOE's five-year contract period. After Cummins estimates the amount of time required, Cummins and Sandia will request an exemption from the five-year limitation.
- Cummins' planned move to its new facility in November will hinder technical development activities.

SAIC/STM USJVP

Status

The objective of the USJVP is to develop 25-kW dish/Stirling systems for use in utility markets. The Energy Projects Division of SAIC in Golden, Colorado, leads a team comprised of Stirling Thermal Motors (STM) of Ann Arbor, Michigan, and several utility partners. SAIC is the systems integrator and is also responsible for developing the solar concentrator and the second-generation faceted stretched-membrane dish. STM is developing the third generation of its kinematic Stirling engine for the project. STM and SAIC are exploring potential working relationships for marketing the dish/Stirling systems.

Accomplishments

- SAIC and STM operated the system at full power for nearly 150 hours and achieved a net power output of 17.9 kW$_e$.
- We conducted the Phase 1 Project Review on July 19 and 20, 1995, in Denver, Colorado.
- The decision of whether or not to proceed with Phase 2 of the project is on hold pending the completion of the Phase 2 plan by SAIC, STM, and a

possible commercial partner. We expect to have the detailed Phase 2 plan by late October.

Planned Activities for Next Quarter

- We will make the decision of whether or not to proceed with Phase 2 of the project.

Issues

- SAIC's commitment to commercialization of the technology is somewhat in question because of its unwillingness to put financial resources into the project.

Cummins USJVP

Status

Phase 1 of the Cummins USJVP is scheduled to be completed in another three-to-four months. As a result, a very large amount of activity is currently under way. The first of two concentrators was erected at the new Cummins facility in Abilene. The second concentrator will not be erected until early 1996 because of financial constraints. All of the components for the CFIC engine have been received and assembly is under way.

Accomplishments

- Cummins erected the first of two 15.2-m concentrators at Cummins-South.
- Thermacore modified the design for the Aisin-Seiki heat pipe to eliminate excessive stresses at the heat-pipe/engine interface.
- CFIC received all remaining components for constructing its 29-kW_e engine.
- Thermacore completed construction of an on-sun heat-pipe receiver with a gas-gap calorimeter.

Planned Activities for Next Quarter

- Cummins will complete the move to its new facilities in Abilene, Texas.
- We will begin flux mapping of the first concentrator.
- Test cell operation of the CFIC 29-kW_e engine will begin.
- We expect to begin assembly of the NREC 30-kW_e Brayton engine.
- We will conduct on-sun operation of a heat-pipe receiver with a gas-gap calorimeter.
- We will conduct on-sun operation with the Aisin-Seiki Stirling engine.

Issues

- The as-built focal length of the inner concentrator facets is short by 17 in. As a result, the concentrator power level and flux pattern are off-design.
- A large number of activities must be completed to finalize Phase 1. As a result, the project schedule may slip.

Major Milestones

Milestone	Planned	Actual
Install/test an SAIC dish concentrator.	Nov 94	Nov 94
Complete Phase 2 of the DSJVP.	Dec 94	Dec 94
Deliver a Cummins 7-kW_e system to Texas Utilities' Dallas test site. *Concentrator delivered Nov 94; engine delayed until Dec 95.*	Mar 94 *Delayed until Dec 95.*	
Fabricate/test Cummins USJVP prototype control systems.	Mar 95	Jul 95
Begin integrated operation of the complete SAIC dish/Stirling system.	Apr 95	Jun 95
Deliver Cummins 7-kW_e system to Central and South West's Ft. Davis test site. *Concentrator delivered Nov 94; engine delayed until Dec 95.*	Apr 95 *Delayed until Dec 95.*	
Initiate backup NREC Brayton engine test cell testing at Cummins.	Apr 95 *Delayed until Jan 96.*	
Complete SAIC USJVP Phase 1; begin Phase 2.	Jun 95	Jul 95
Install and test two prototype USJVP concentrators at Cummins.	Jul 95	Aug 95
Assemble first Cummins prototype 25-kW_e Stirling engine.	Sep 95 *Delayed until Dec 95.*	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	550	30	0	**580**
Contracts	7,583	65	368	**8,016**
Total	**8,133**	**95**	**368**	**8,596**

C. SYSTEM OPERATION AND MAINTENANCE COST REDUCTION

The nine solar electric generating systems (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 solar thermal plants have a significant influence on the economic viability of the technology. For example, O&M costs account for more than 20% of the SEGS electricity costs. Reductions in O&M costs would enhance the marketability of solar thermal technologies currently being developed by the DOE. Examples of DOE technology that would benefit are the Solar Two demonstration project and commercial power tower plants. Power tower plants have many of the same subsystems contained within a SEGS plant, and the O&M of these subsystems would be similar.

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

Status

No single task was given primary emphasis during the present quarter. Instead, we made progress in several areas aimed at improving plant efficiency and reducing maintenance expenditures. This progress is summarized below.

Accomplishments

- The 35 split-glass heat collector element (HCE) envelopes manufactured by Industrial Solar Technologies continued to operate flawlessly. Because of the successful performance, KJCOC plans to purchase approximately 200 additional envelopes (from internal funding sources other than this cost-reduction program) and will use them as a temporary fix for broken-glass HCEs until replacement is deemed necessary. This temporary fix method reduces heat losses by a factor of three.

- The manufacture of film reflector replacement facets (constructed of silvered ECP-305+ reflective film and a layered aluminum/plastic composite understructure) was completed by Industrial Solar Technologies, and 180 facets were installed at Kramer Junction, California. Facets were installed in areas of the field that are subjected to abnormally high breakage rates for glass mirrors (caused by high-wind forces) to determine if they are a cost-effective solution to the glass breakage problem. If we are successful with these panels, KJCOC will use internal funds to install another 1,160 facets.

- The cost of water used at the 150-MW Kramer Junction site is almost $1 million per year. This amount is between 6% and 8% of the annual O&M budget. In this quarter, we completed a detailed water flow analysis that determined how all of the water at the site was used in the last year. The results indicated that more than 93% of the water is used by the wet cooling towers contained within the Rankine cycle. Mirror washing only accounted for 1.3% of the total water use. Because of the cost of water, KJCOC recommends that a future plant at Kramer Junction should use a combination wet/dry cooling tower arrangement. KJCOC will use the results of this study to optimize water at the site.

- On-line heat rate optimization software identifies the values of the plant operating parameters that yield the maximum overall plant efficiency during full- and part-load conditions. The software was developed by Black and Veatch, Inc., and the solar field model was developed by Sandia. During the quarter, all hardware was delivered to the site and all predictive performance models were completed. Debugging and interface with the distributed process control system will occur in November.

- A hydrofluoric-acid-based cleaning agent (a 3% solution) was used to clean the SEGS VI mirrors located within the severe environment next to the cooling towers. The solution was applied in a gel-like state and washed off with a neutralizer agent after about five minutes. Reflectivity before cleaning was 10% to 15% and was restored to 88% after cleaning. Although KJCOC was successful in cleaning these severely dirty mirrors, it has been unsuccessful in finding an anti-soiling agent that would prevent the mirrors from becoming severely soiled in the future. KJCOC recommends that future plants should not

have the cooling towers located so close to the mirror field.

Planned Activities for Next Quarter

- We completed an interim report that summarizes all technical accomplishments made during FY95.
- We will continue with the installation and debugging of heat-rate optimization software.

Issues

- We have experienced significant delays in heat rate optimization because of problems in establishing the contract with Black and Veatch, Inc. This caused a slip in the April, August, and September 1995 milestones. A no-cost contract extension was established between Sandia and KJCOC that allowed us to continue work on this project through September 1996.

Major Milestones

Milestone	Planned	Actual
Document advances made in FY94.	Oct 94	Oct 94
Fully implement plant-efficiency-optimization software at SEGS VI.	Apr 95 *Delayed until Feb 96.*	
Complete automation of key subsystems at SEGS VI.	Aug 95 *Delayed until Jun 96.*	
Complete and document engineering analysis of optimized efficiency.	Sep 95 *Delayed until Aug 96.*	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	90	30	0	**120**
Contracts	780	20	100	**900**
Total	**870**	**50**	**100**	**1,020**

D. DESIGN ASSISTANCE

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

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

Status

During the quarter, negotiations continued with a small solar manufacturer regarding a Cooperative Research and Development Agreement (CRADA) to develop a new high- and low-temperature selective coating for solar receivers. Additionally, the STDAC initiated a new manufacturing assistance activity with a dish/Stirling manufacturer. The STDAC also continued its support of the SEGS plants with several new efforts. Lastly, Sandia engineers prepared papers concerning solar thermal energy technology to be presented at the Mexican National Solar Energy Society (ANES) meeting in early October.

Accomplishments

- We initiated a manufacturing support activity for solar electric manufacturers. A recent visit with Cummins identified a critical problem involving the displacer piston. Sandia's analysis of the problem showed that the counterbalancing spring on the piston is creating a sideload that is causing premature failure of the associated bushings. Various solutions are being considered.

- A CRADA is currently being negotiated with a flat-plate manufacturing company to commercialize a new solar selective coating using both a batch- and a strip-coating process. The new solar-selective coating demonstrates excellent thermal stability at temperatures of 350°C in air, which would enable this coating to be used in parabolic concentrator systems.

- Sandia engineers continued to modify SOLERGY code to predict SEGS plant outputs. The new code will be used to assess the value of proposed plant modifications at Daggett and Harper Lake, California.

- Sandia's manufacturing center analyzed failed welds on the LS-2 heat-collector element center-support stand to determine failure modes. The analysis showed that the welds are inadequate for normal thermal cycling of the heat-collector elements and we are working to develop a solution.

- We are assisting Daggett Leasing Corporation to reconfigure the nondamaged part of the field to optimize performance. This assistance involves developing a procedure to determine when certain loops should be repaired and when they should be taken out of service.

- In support of technology applications in Mexico, STDAC staff prepared three technical papers on trough/dish technologies for presentation at the Mexican ANES conference in early October.

- At the direction of DOE Headquarters (Bud Annan's office), Sandia supplied a solar ice maker and oven for the Secrets of the Sun public solar technology exhibition. The exhibition is still in progress and tens of thousands of visitors have attended.

Planned Activities for Next Quarter

- In support of the selective coating CRADA, Sandia will conduct limited systematic experiments to identify the solar selective coating process parameter space needed for production process control and scaling up the laboratory process to a limited-scale strip coating process that the manufacturer can test.

- The STDAC will initiate an effort to develop a comprehensive manufacturing support activity that will be integrated with Solar Thermal Manufacturing Technology. Initial meetings are aimed at developing a comprehensive plan.

- The main thrust of the SEGS activities will center on the development of the modified SOLERGY model for application at the three SEGS plants.

Issues

- Recent congressional action has altered the philosophy, scope, and character of the STDAC for FY96. The STDAC will become the Manufacturing and Technical Support team and focus most of the resources on providing manufacturing and technology development support to solar thermal electric industry manufacturers and users, such as SEGS.

Major Milestones

Milestone	Planned	Actual
Document FY94 STDAC activities.	Mar 95	Feb 95
Participate in Soltech '95.	Apr 95	Apr 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	500	130	0	**630**
Contracts	270	0	350	**620**
Total	**770**	**130**	**350**	**1,250**

E. SOLAR MANUFACTURING INITIATIVE

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

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

Status

By the end of the fourth quarter, three SolMaT subcontracts were in place. SAIC of Golden, Colorado, and Solar Kinetics, Inc. (SKI) of Dallas, Texas, are both developing manufacturing technologies for heliostats in two-phase, multi-year efforts. Rockwell International Corporation of Canoga Park, California, is developing improved manufacturing methods for central receivers in a nine-month effort. A fourth subcontract is in negotiation and should be placed during the first quarter of FY96.

Accomplishments

- SAIC made a significant manufacturing improvement to its baseline dual-module heliostat that promises to reduce reflective area costs by 20% for near-term markets. This investigation included a detailed costing study and an optical analysis to ensure heliostat performance. The main advantages to the multi-faceted approach are increased reflective area per heliostat, dual use of the facet manufacturing line, and a dedicated, centralized heliostat assembly facility. There are additional benefits such as elimination of focus control equipment as a result of the smaller facet size. SAIC and other SolMaT partners held a Concurrent Engineering/Design for Manufacturing session to investigate possible facet arrangements, truss designs, facet mounting methods, pedestal designs, and installation methods for further design optimization.

- One Component Manufacturing contract was awarded to the Rocketdyne Division of Rockwell International Corporation. Rockwell will investigate several manufacturing improvements for molten-salt central receivers, including improved methods for fabricating panel headers, forming receiver tube nozzles from the headers, insulating completed receiver panels, and simplifying receiver control equipment and control strategies.

Planned Activities for Next Quarter

- A second Component Manufacturing contract will be awarded.
- Technical monitoring of the SKI heliostat manufacturing contract will be transferred to a Sandia staff member.
- SAIC will hold its first Quarterly Review meeting to discuss progress on its heliostat manufacturing effort.
- SKI and lower tiers will participate in a Design for Manufacturing and Assembly (DFMA) workshop, conducted by Hughes Aircraft personnel, to optimize its large-area glass/metal heliostat for manufacturing.

Major Milestones

Milestone	Planned	Actual
Complete first DFMA class and evaluate effectiveness.	Jan 95	Dec 94
Award contract on SolMaT heliostat solicitation. *Rescheduled with DOE concurrence.*	Mar 95	Apr 95
Release first request for proposal for manufacturing improvement projects. *Rescheduled with DOE concurrence.*	Apr 95	Aug 95
Initiate Phase 1 heliostat contract.	Jun 95	Jun 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	150	200	0	**350**
Contracts	0	1512	165	**1,677**
Total	**150**	**1,712**	**165**	**2,027**

F. COMMERCIALIZATION

The objective of the commercialization subtask is to develop a deeper knowledge and understanding of the key issues in the commercialization of solar thermal technology by becoming a resource on subject matter in the following four areas: (1) independent power producers, (2) World Bank funding of solar electric projects, (3) regulatory agencies as they affect renewable energy technologies, and (4) Executive Order 12902—Energy Efficiency and Water Conservation at Federal Facilities.

Mexico

Status

Spencer Management continued to promote the Integrated Solar Combined-Cycle System (ISCCS) in Mexico. Mexico's Federal Electric Commission (CFE) began evaluating the economics of the ISCCS during the quarter. CFE's decision regarding the feasibility of an ISCCS project in Mexico is due in mid December 1995.

Accomplishments

- CFE began evaluating the ISCCS concept.

Planned Activities for Next Quarter

- CFE will decide whether to pursue the development of an ISCCS in Mexico.
- Sun♦Lab personnel will support the World Bank's Solar Initiative by providing training and answering questions regarding solar thermal technology.

India

Status

Sandia joined in a mission organized by the World Bank to review the status of the 35-MW parabolic trough project proposed for Mathania in Rajasthan, India. This project has strong support from several organizations. Grant money to buy down the capital cost (up to 50%) of the plant has been offered by the Global Environmental Facility (GEF), the government of India, and the government of Rajasthan. In addition, the German financial institution KFW has offered to provide soft loans to finance the remaining capital cost. The major findings of the review team are listed below:

- Before the solar plant can be financed, the state utility (Rajasthan State Energy Board) must undergo reform and become a financeable institution. Currently, the utility is running in the red and it would be difficult for it to guarantee payments to the solar plant for the electricity generated.
- The project proposed by BHEL and SOLEL, a business consortium of India and Israel, is too costly and it is highly likely that an operating subsidy would be required. If an operating subsidy is required, the GEF would not support the project and the soft loans offered by KFW would also be lost.
- The plant proposed by BHEL and SOLEL is based on a design concept that was popular in 1987. To reduce costs and to bring the technology up to date, the solar field should be integrated within a combined-cycle power block similar to that proposed for Mexico (see above). KFW plans to perform a study to evaluate the potential of switching to a combined cycle.
- The project should be opened to international competition. Switching to the combined cycle approach should help to achieve this objective.
- The World Bank was very appreciative of Sandia's participation in the mission. At the request of the bank, Sandia defined the terms of the reference for the KFW study.

Accomplishments

- We completed review of a 35-MW solar-thermal project proposed for India.

Planned Activities for Next Quarter

- The next phase of this project is to perform the combined-cycle study mentioned above.

II. TECHNOLOGY DEVELOPMENT

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

A. CONCENTRATOR TECHNOLOGY

The objective of concentrator technology development activities is to bring heliostat and parabolic dish concentrator designs to commercial readiness for use in solar thermal electric systems. The heliostat designs will be used in central receiver systems and parabolic dish designs in dish/Stirling applications. Optical materials development is also an important part of concentrator development because of the importance of optical materials in designing high-performance and cost-efficient concentrators.

1. HELIOSTATS

Status

This project is to support the Solar Two team with the refurbishment, canting, and evaluation of the heliostats at Solar Two.

Accomplishments

- We assisted Bechtel and its contractor, The Industrial Company, with Solar Two LUGO heliostat pedestal tilt measurement and canting.
- We helped Queue Systems, the subcontractor responsible for the new control software at Solar Two, with system troubleshooting.

Planned Activities for Next Quarter

- We will continue to help with the Solar Two heliostat control system, LUGO heliostats, and other startup-related heliostat issues.

Major Milestones

Milestone	Planned	Actual
Complete preparations and train the subcontractor on canting.	Feb 95	Feb 95
Complete installation and testing of the beam characterization system at Solar Two.	Aug 95	May 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	400	0	0	**400**
Contracts	400	0	0	**400**
Total	**800**	**0**	**0**	**800**

2. PARABOLIC DISHES

Status

Concentrator research and development is structured to develop new, innovative ideas and conceptual designs for solar concentrators that will lead to more cost-effective and/or high-performance heliostats and dishes. This task also includes the development of specialized instrumentation for optical measurement, optical materials, and concentrator evaluation techniques.

Accomplishments

- On July 17, 1995, we conducted a Kick-Off Meeting for the SKI/Allied Signal project.
- On August 28, 1995, a working-group meeting was held with Sandia, SKI, and Allied Signal to address questions about technology development for the dish/Brayton project.
- We completed the technical review of the 14 projects proposed for the Advanced Point-Focus Concentrator procurement. Contracts will be placed in November 1995 rather than September as originally planned.
- We modified the "east donut" of the National Solar Thermal Test Facility (NSTTF) power tower as a working space for fabrication of foam facets.
- We provided flux-mapping support for the SAIC USJVP in Golden, Colorado.
- Flux mapping of the Cummins USJVP dish in Abilene, Texas, was delayed until October 1995.
- We completed a report on the 2-*f* color-system test and evaluation.
- We completed the conceptual design of the Video SHOT laser ray-trace tool.
- We started the process of bringing the LFOCS system, a system for optically assessing the alignment of trough systems, back on line and begin the initial planning for a flyover of a SEGS plant.
- NREL modified its SHOT system and tested the rectangular- and gore-shaped facets of the Cummins USJVP dish.

Planned Activities for Next Quarter

- SKI/Allied Signal will down select to a single conversion technology.
- We plan to negotiate and place two or three contracts under the Advanced Point-Focus Concentrator procurement.
- We will make prototype facets and start testing for thermal shock resistance.
- We will continue development of the Video SHOT and hold a design review meeting.
- We will perform flux mapping of the Cummins USJVP dish in Abilene, Texas.
- We will make the LFOCS system operational and determine what modifications need to be made in order to characterize a field of SEGS trough collectors.
- Sun♦Lab staff will identify needed beam characterization system components, order equipment, and begin assembling the new system.

Major Milestones

Milestone	Planned	Actual
Complete initial testing of the SAIC dish.	Mar 95	Mar 95
Release the advanced concentrator request for quotation.	May 95	Jun 95
Complete development of color 2-*f* system.	Jun 95	Jun 95
Place several small contracts to evaluate advanced concentrator concepts.	Sep 95 *Delayed until Nov 95.*	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	370	0	0	**370**
Contracts	280	0	0	**280**
Total	**650**	**0**	**0**	**650**

3. OPTICAL MATERIALS

The objective of the optical materials task is to identify and develop advanced optical materials for solar-thermal applications that meet industry's goals of cost, performance, and durability. These advanced materials are necessary to achieve the cost and performance goals needed for commercialization of various solar thermal technologies. The optical materials team conducts basic research and analysis to better understand the fundamental properties that influence optical material performance; performs testing, characterization, and evaluation of candidate materials; and collaborates with the solar and materials industries to develop, test, and certify optical materials of interest.

Status

One of the key activities of the fourth quarter of FY95 was implementation of recommendations from the optical materials industry advisory panel. The panel, which met for the first time last quarter, was formed to solicit objective feedback to help clarify the optical materials task objectives and identify current and future activities of relevance to industry. Many of the industry panel recommendations were implemented as part of the FY96 Annual Operating Plan process. The result is that, in addition to investigating long-term reflector materials, the optical materials team will focus more of its efforts on investigating near-term reflector materials, increasing coordination with industry partners, and analyzing and developing selective absorber materials.

Other key activities include negotiating a modification of the SAIC (Washington, D.C.) subcontract for development of an alumina-hardcoat reflector to determine if the protected reflectors, deposited on PET or level stainless-steel substrates, are viable for solar concentrator applications. The modification will include support for SAIC's Golden, Colorado, office to consider manufacturing issues, attend design reviews, and support engineering-scale testing of materials developed under the subcontract. The advantage of this arrangement is that SAIC-Golden, the eventual end-user of the technology, will be brought on board early so that it can help guide the development of the material to ensure the final product matches its needs.

NREL is entering negotiations with 3M Company for further development of the all-polymeric reflector, supported last year in a subcontract with Dow Chemical Company. 3M has licensed a patent with Dow for further development of an all-polymeric reflector material. 3M is interested in applying the technology in the automotive and indoor lighting markets. NREL is currently holding discussions with 3M to find areas in which both groups can benefit from continued DOE funding of the technology for solar applications. Because 3M is interested in these large markets, this may provide a commercial path for the technology that doesn't rely on the solar "niche" market.

Accomplishments

- David King, Cheryl Kennedy, and Al Czanderna, all of NREL, were granted a patent for "Molecular Assemblies as Protective Barriers and Adhesion Promoting Interfaces."
- A modification to the current subcontract with SAIC-Washington for development of alumina hardcoat has been drafted. The modification will allow SAIC to investigate direct application of the hardcoated reflector material to stainless steel and will provide for formal coordination between the subcontractor and SAIC-Golden.
- We are continuing our collaboration with Spain's Centro de Investigaciones Energeticas, Medio-ambientales y Technologicas (CIEMAT) and Germany's Aerospace Research Establishment (DLR) on round-robin calibration and testing of outdoor weathered reflector materials. This collaboration is taking place under the auspices of the International Energy Agency.
- As a result of the industry advisory panel recommendations, we have generated the first draft of a newsletter discussing the status of Sun♦Lab's optical materials team activities. We plan to generate the newsletter semiannually and focus on technical issues of interest to the industry.

Planned Activities for Next Quarter

- We will initiate a subcontract with 3M Company for further development of all-polymeric reflector material.
- We will begin work on the extended subcontract with SAIC for development of an ion-beam-assisted, vapor-deposition-generated, alumina-hardcoated reflector material.
- We will begin the process of defining engineering-scale testing of near- and long-term optical materials.
- We will begin a report on the advanced reflector materials systems study.

Issues

- The optical materials team at NREL will consolidate the bulk of its equipment and laboratory space into the first floor of Building 16. This activity has been taken into account for the Annual Operating Plan process, but history has shown these moves to be very disruptive.

- The planned award of a subcontract with 3M Company for further development of an all-polymeric reflector material will depend on 3M's willingness to pursue the technology for solar applications. 3M is currently interested in the technology for large market applications and will be holding internal meetings to discuss this issue. We are planning to meet with 3M in early November after a decision has been made.

Major Milestones

Milestone	Planned	Actual
Activate fifth outdoor test site.	Oct 94	Dec 94
Establish industry research collaborative.	Dec 94	Dec 94
Activate sixth outdoor test site.	Apr 95	Apr 95
Document status of outdoor testing activities.	Aug 95	Aug 95
Document alternative reflector materials research and development progress.	Sep 95	Sep 95
Document advanced reflector materials system study.	Sep 95	Sep 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	0	654	0	**654**
Contracts	0	299	0	**299**
Total	**0**	**953**	**0**	**953**

B. POWER CONVERSION

Power conversion development efforts synchronize research and development 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 NSTTF. Power tower receiver development is focusing on advanced salt-in-tube receivers, molten-salt film receivers, and volumetric air receivers. Dish receiver development, particularly of the reflux type, is critical to the long-life reliable operation of parabolic dish/Stirling engine systems. The heart of a solar thermal dish/engine system is the subsystem that converts thermal energy into electricity: the engine generator. While the program does not directly support development of these converter subsystems, it provides testing and solarization support to industry.

1. POWER TOWER TECHNOLOGY

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

Status

Over the last quarter, the main efforts in Power Tower Technology have been to (1) support the Solar Two Project on technical issues and with the Test and Evaluation Phase, (2) design and install an impedance heating system, (3) complete first-phase testing of a system to validate correlations on transient salt freezing and modify the system for the second phase, (4) continue additional salt corrosion experiments, (5) procure an infrared camera for central receiver applications and for use at the Solar Two site, (6) continue the Rockwell CRADA, and (7) provide assistance to Spain with the internal film receiver.

Accomplishments

- The procedure and preanalysis for the first test at Solar Two, Storage Tank Thermal Stresses, were written and issued for review by the Technical Advisory Committee.
- A data acquisition system was set up at Solar Two for the first test to measure strains and tank temperatures on the hot storage tank during initial preheat, salt melt and conditioning, and during daily thermal cycling.
- Material characterization for Rockwell's CRADA on advanced central receiver development was initiated this quarter.
- The Plataforma Solar de Almeria (PSA) in Spain has completed reworking the entire molten salt internal film receiver test loop. Some problems with a controller and heat trace delayed the testing this quarter. Testing is scheduled to begin next quarter.
- Testing of three circuits of dual-element heat trace was completed in Sandia's molten-salt loop. The heat trace, which is similar to what is being used at Solar Two, has operated for over nine months without any failures or problems.
- The first phase of experiments has been completed to investigate transient freezing of flowing molten salt in cold pipes. These experiments aim to quantify the minimum receiver and piping startup conditions. The next phase will use tubes with different wall thicknesses. The system is undergoing modifications to incorporate the new tubes.
- An impedance heating system, which could be a potential alternative to heat trace, has been designed and installed in a section of piping for testing. This heating system is different from heat trace in that current flows through the pipe to heat it instead of heating mineral insulated cable that transfers the heat to the pipe. The impedance heating system is likely to be much more reliable and easier to install.
- Nitrate-salt corrosion experiments on evaporator materials continue.
- A purchase order for an infrared camera was placed for use at Solar Two and for evaluating receivers at Sandia.

Planned Activities for Next Quarter

- We will continue to provide technical support for Solar Two.

- Sandia will initiate testing of the impedance heating system.
- We expect to initiate the next phase of transient freezing experiments.
- We will continue corrosion experiments.
- Sandia will continue Rockwell CRADA activities.
- We will begin testing the internal film receiver at the PSA in Spain.
- NREL will complete the final report on the initial Sacramento Municipal Utilities District (SMUD) Kokhala study.

Major Milestones

Milestone	Planned	Actual
Hold hybrid workshop at NREL.	Nov 94	Nov 94
Report on salt component and panel tests.	Jan 95	Jan 95
Complete the freeze/thaw tests on receiver tubes.	Mar 95	Mar 95
Complete initial evaluation of CC/PT project for SMUD service territory.	Jun 95	Jun 95
Complete study of tax equity for state of Nevada.	Jul 95	Jul 95
Complete testing of Solar Two heat trace.	Aug 95	Jul 95
Complete testing of the 500-kW_t Recepto Avandazo de Sales internal molten-salt film receiver at Plataforma Solar de Almeria.	Sep 95 *Delayed until Jan 96.*	
Complete the transient salt freezing in pipes and planned thermal cycling corrosion testing of stainless steels.	Sep 95	Sep 95

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	460	263	0	**723**
Contracts	390	81	0	**471**
Total	**850**	**344**	**0**	**1,194**

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 flux results in a higher-than-average engine temperature, lower stresses, and fewer constraints on dish and engine 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 to demonstrate 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 power conversion system package. In the longer term, the program will pursue high-performance and low-cost concepts, develop design tools and hybrid receiver technology, and transfer the resulting technology to industry for commercialization.

Status

Based on short-term heat-pipe receiver successes, we are changing the receiver development program emphasis to long-term issues and hybridization. Our materials experts have completed several materials studies in support of the joint-venture programs, and the results have been reported to the customers. We continued durability testing of a bench-scale receiver and are developing a simple capsule test that will allow a broader matrix of simultaneous tests. We investigated several failure modes of felt-wick receivers and proposed solutions for future versions. Cummins significantly improved the performance of its hybrid heat-pipe receiver concept. Our system testing of a heat-pipe receiver on the STM engine was delayed by a defect in the heater heads.

Accomplishments

- We fabricated a felt-wick heat-pipe receiver for the STM 4-120 engine, along with fixtures for interfacing the receiver to the engine. STM is currently repairing a flaw in the heater head fabrication. We expect a considerable improvement in performance because of the uniform temperature distribution on the heater-head tubes.

- We sectioned the second-generation felt wick to determine the cause of an isolated "hot spot." We found that the wick beneath the hot spot had a sparser distribution of fibers than other areas of the receiver. The manufacturer is investigating ways to reduce this effect.

- After 1,995 hours of operation, we terminated testing of the durability felt-metal bench-scale receiver. We observed an overtemperature condition on the heated surface during a routine startup. We will clean and section the specimen to determine the cause.

- We have begun designing simplified capsule tests to evaluate the sodium compatibility of wick and structural materials under reflux receiver operating conditions.

- We have agreed upon tasks and responsibilities for support of hybrid receiver development. Steve Vosen of Sandia's Livermore, California, Combustion Research Facility has accepted responsibility for combustion-system design and development.

- Cummins improved the thermal efficiency of its prototype hybrid heat pipe to 80% by increasing convective heat transfer from the combustion gases. The first generation hybrid heat pipe has now accumulated over 260 hours of test time.

- Stirling Technology Company (STC) identified and resolved problems with its radiant lamp power supply and has resumed testing of its hybrid pool boiler.

- NREL staff substantially completed installation of a burner test facility to be used in conjunction with an emissions measurement rack.

- Sandia's Steve Goods and Bob Bradshaw (Goods and Bradshaw) have written an interim report on the examination of the 316L stainless-steel capsule bodies and IN625 heater wells from the STC capsule tests. They found no significant corrosion, despite 10,000 hours of exposure to NaK at 700°C.

- Goods and Bradshaw completed a report on their metallurgical analysis of the Thermacore artery-free wick receiver (durability tested at Cummins). They saw some cracking of the wick and plugging by the reaction product Ni_3P, but the extent is not serious, and no corrosion was found.

- Goods and Bradshaw completed metallurgical analysis and a report on the Thermacore dual-artery receiver (cycle tested at Thermacore). Cracks in the wick are deeper, wider, and more extensive than in the artery-free receiver. Conversely, they found less Ni_3P in the wick interstices.

- AdTech Systems Research of Beaver Creek, Ohio, began elevated temperature fatigue tests on Thermacore's spherical-powder nickel wick.

- We briefed Thermacore and Cummins on materials analyses at a receiver materials and hybridization

meeting organized by Jim Moreno and Rich Diver of Sandia.

- We have constructed two mock-ups of a felt-wick receiver and accurately measured their surface shapes. We will use these mock-ups to experimentally verify our prediction of buckling pressures.

- We are completing negotiations to support the research of two graduate students in Mechanical Engineering at North Carolina Agricultural and Technical State University. Mona Fowler began work on her Master's thesis in artificial neural network modeling of solar receivers as a Sun♦Lab summer employee. Mary Murdock is considering a Ph.D. thesis on thermal stress during solar heat-pipe receiver startups.

Planned Activities for Next Quarter

- STM will complete the repair of the heater heads, and we will begin performance-mapping the STM engine with the felt-metal receiver.

- We will continue interface design details on the Northern Research and Engineering Corporation (NREC) Brayton engine (not due to Sandia until December).

- Porous Metal Products will fabricate a new felt-metal receiver for testing on the test bed concentrator, incorporating lessons learned from prior receivers.

- We will instrument the next felt-wick receiver test to determine thermal-wave departure from axial symmetry.

- We will begin testing on the first of a series of heat-pipe capsules to explore the impact of preprocessing (cleaning), materials selection, and operating conditions on the life of the receiver.

- We will complete preliminary design of a gas-fired hybrid heat-pipe receiver, with input from the Combustion Research Facility.

- Cummins will complete fabrication of its second-generation hybrid heat pipe.

- STC will complete its hybrid pool boiler investigation.

- NREL will install and become familiar with the emission measurement rack and perform tests on the Cummins second-generation hybrid heat-pipe burner.

- We will continue metallurgical analysis of the STC NaK capsule tests.

- We will complete elevated-temperature fatigue testing of the spherical-powder nickel wick.

- We will complete tests to verify buckling pressure of the felt-wick receiver.

- Sun♦Lab will continue to support receiver development for the joint-venture programs. This support includes product improvement for the DSJVP with Cummins, advanced heat-pipe design for the Cummins USJVP, and direct-illuminated receiver and heat-pipe receiver design support for the SAIC USJVP.

Issues

- Heat-pipe testing on the STM 4-120 engine has been delayed because a manufacturing flaw was discovered in the STM heat-pipe heater heads. The heads are being reworked by STM.

Major Milestones

Milestone	Planned	Actual
Complete planned on-sun testing of a 40-kW$_t$ felt-wick heat-pipe receiver.	Oct 94	Oct 94
Complete freeze/thaw cycling of a bench-scale felt-wick receiver.	Feb 95	Feb 95
Begin on-sun testing of Cummins/Thermacore hybrid heat pipe. *Rescheduled with DOE concurrence.*	Mar 95	Apr 95
Begin testing of a durability bench-scale, felt-wick receiver.	Mar 95	Jun 95
Complete planned TBC testing of a high-powered, felt-wick heat-pipe receiver.	May 95	Jun 95
Complete integration and initial on-sun testing of the STM power conversion system with a heat-pipe solar receiver.	Jul 95 *Moved to Feb 96.*	
Complete controls and safety upgrades of TBC.	Sep 95 *Delayed.*	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	1,050	208	0	**1,258**
Contracts	450	175	0	**625**
Total	**1,500**	**383**	**0**	**1,883**

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 ongoing 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.

Status

The project currently underway is the solarization of a Brayton engine using a volumetric receiver. NREC is supplying the 30-kW_e Brayton engine, and Germany's DLR is supplying the volumetric receiver. The design of the power conversion system (PCS) is essentially complete; however, some details of the control system still must be worked out. Most components have been received by NREC, and assembly of the engine is commencing. The assembly was delayed during manufacturing of the turbine housings because voids forming during the pouring process and some rework was required. DLR delivered the volumetric receiver this quarter for integration with the engine. Delivery of the PCS to Sandia is expected in December.

Accomplishments

- NREC completed the design of the Brayton PCS that will be delivered to Sandia. Sandia is developing instrumentation and interface plans for mounting the package on the test bed concentrator.
- DLR delivered the volumetric receiver to NREC for integration with the PCS.

Planned Activities for Next Quarter

- We will finalize the Brayton PCS Test Plan.
- We will assemble and check out operation of the Brayton PCS in an NREC test cell.
- We will install the Brayton PCS on a test bed concentrator at Sandia.

Major Milestones

Milestone	Planned	Actual
Complete on-sun testing of the Stirling PCS based on the STM 4-120 engine with a heat-pipe receiver.	May 95 *Delayed until Jan 96.*	
Complete construction of the NREC solarized Brayton engine.	May 95 *Delayed until Nov 95.*	
Complete on-sun testing of the NREC Brayton PCS.	Aug 95 *Delayed until Jun 96.*	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	350	0	0	**350**
Contracts	500	0	0	**500**
Total	**850**	**0**	**0**	**850**

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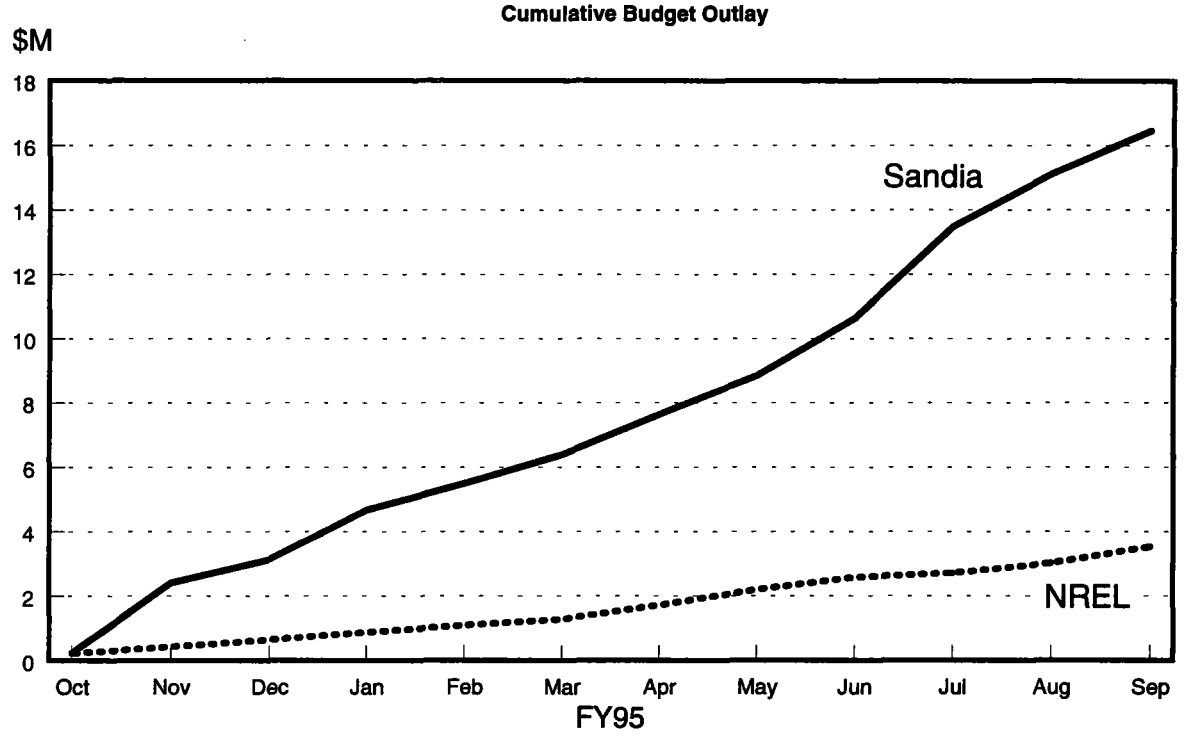
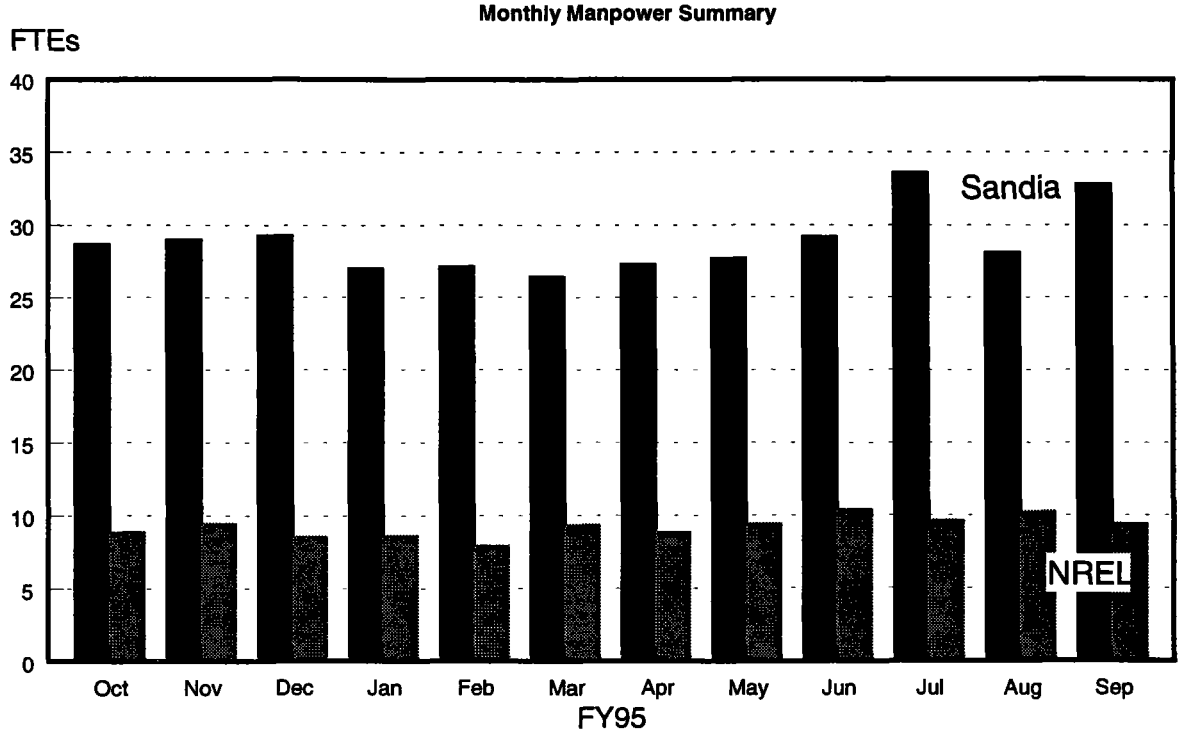
Solar Thermal Electric Program

Cumulative Budget Outlay



Solar Thermal Electric Program

Monthly Manpower Summary



Contracts Over $100K

4th Quarter, FY95

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($k)	FY95 Funds ($k)	Total Costs to Date ($k)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IB	DSJVP	Cummins Power Gen.	SNL 69-7763	8563	6045	1100	7661	06/91-05/96	Large	Phase	R. Diver
IB	USJVP	SAIC	SNL AB-8717A	8828	3256	3500	3985	12/93-12/96	Large	Phase	T. Mancini
IB	USJVP	Cummins Power Gen.	SNL AB-8717B	8990	3100	2600	3382	01/94-11/97	Large	Phase	D. Gallup
IC	O&M cost reduction	Kramer Junction Co.	SNL AB-0227	3162	2132	780	2902	07/92-09/95	Large	Phase	G. Kolb
II	Solar Test Support	EG&G	SNL AH-5081	990	199	100	300	10/93-11/95	Large	N/A	S. Rawlinson
II	Electrical Support Service	J&S Electric Co., Inc.	SNL 75-7415	450	410	40	441	02/89-06/95	Serv. Support	N/A	W. Kolb
IIA3	Optical Materials	Industrial Solar Tech.	NREL AAR-4-14019	126	126	0	125	07/94-09/95	Small	—	G. Jorgenson
IIB2	Hybrid receiver	Cummins Power Gen.	NREL ZA-2-11120	537	537	0	532	03/92-04/95	Large	—	M. Bohn
IIB3	STM Engine	Detroit Diesel Corp.	SNL AE-5963	132	132	0	132	03/93-09/95	Large	Final	S. Rawlinson
IIB3	Brayton Engine solarization	NREC	SNL AG-0408	611	413	198	459	08/93-12/95	Large	Phase	D. Gallup

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