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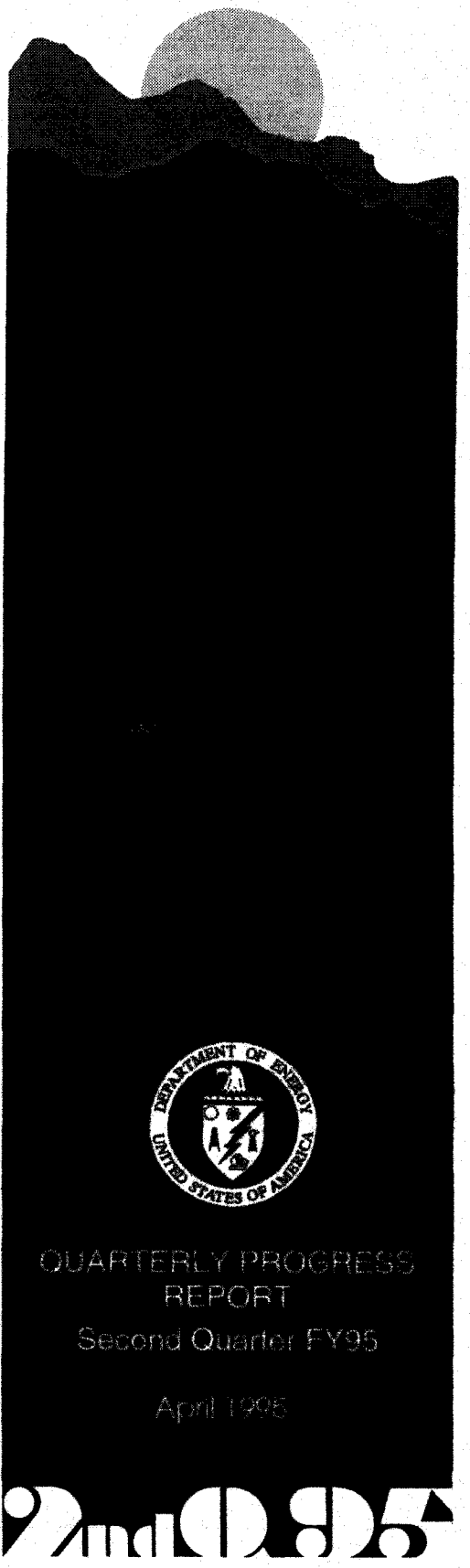
QR-2-95



QUARTERLY PROGRESS REPORT

Second Quarter FY95

April 1995

Sandia National Laboratories
Albuquerque, New Mexico

National Renewable Energy Laboratory
Golden, Colorado

SUMMARY OF ACCOMPLISHMENTS: SECOND QUARTER FY95

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

Solar Two

- Solar Two is approximately 70% complete; engineering is 93% complete; Phase 4, Construction, is 51% complete.
- Sandia assisted Rockwell with application of Pyromark® paint to the receiver, analyzed several options for reducing parasitic energy consumption, and is working on corrosion test chambers for the project.
- Sandia implemented refined facet canting procedures for heliostats at Solar Two.

Dish/Engine Joint Venture Programs

- Phase 2 of Cummins' DSJVP was completed.
- Cummins completed the final design of its Utility Scale Joint Venture Program concentrator.
- Science Applications International Corporation (SAIC) tested its dish at its Golden, Colorado, test site.
- Cummins Power Generation, Inc. (Cummins) requested that NREL help evaluate the ultraviolet durability of an anti-corrosion coating to protect structural elements of its dish/Stirling system.

System Operation and Maintenance (O&M) Cost Reduction

- $42- to $100-million in O&M cost savings has been projected based on program progress.
- A method for in-situ repair of broken HCEs was developed and a performance test attempted.
- A report quantifying fugitive emissions from oil-based parabolic trough technology was completed.
- Assessment of flowmeters for the solar field was completed.
- Remote plant operation was demonstrated.

Concentrator Technology

- On-sun testing of the SAIC dish and aperture plate were completed.
- An industry advisory panel has been assembled for the optical materials research activities at NREL.
- Cummins has reported encouraging delamination resistance results for ECP-305+ used in its tensioned dish membrane facets.
- Activation of a sixth outdoor site representative of coastal environments is proceeding on schedule.
- A cost-shared subcontract was awarded to SAIC for the development of a process for high volume production of enhanced-lifetime solar reflective materials.

Power Conversion Technology

- Nitrate-salt component testing of a ball valve for use at Solar Two has been completed.
- Analysis of off-design efficiency of molten-salt power towers was performed.
- A report on molten-salt panel and component experiments was completed.
- NREL staff will make a presentation on hybrid power towers to the Solar Two Commercialization Advisory Board.
- NREL and Sacramento Municipal Utility District (SMUD) have completed the Phase 1 study of a Combined Cycle/Power Tower for SMUD's service territory.
- Stirling Technology Company completed reinstallation of its hybrid pool boiler at its facility in Richland, Washington, following completion of the on-sun tests at the NREL High Flux Solar Furnace.
- Sandia tested a Cummins heat-pipe receiver to 115 kW_t throughput on the solar power tower.
- Sandia has designed and is fabricating second-generation felt-wick heat-pipe receivers.
- Cummins successfully completed ground testing and on-sun testing of its hybrid heat-pipe receiver.
- On-sun testing of the STM 4-120 Stirling engine was completed.
- Two proposals submitted under the "Heliostat Manufacturing for Near-Term Markets" solicitation are currently in contract negotiations.
- NREL staff have pulled together a detailed description of the next SolMat solicitation that will address manufacturing issues for solar thermal electric components (other than heliostats).
- A Design for Manufacturing and Assembly workshop was held at Cummins in Abilene, Texas.
- Sandia received two "best paper" awards at the ASME solar conference.

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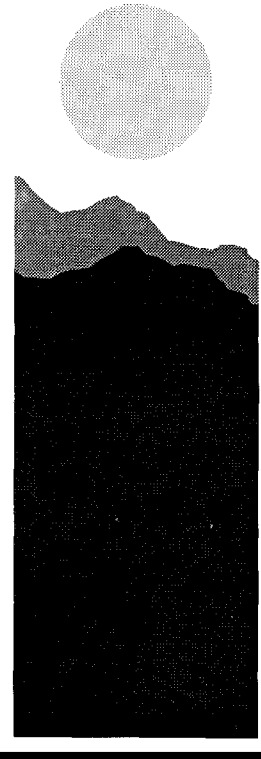

Contracts over $100k

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	SNL 69-7763	8563	6045	1100	6491	06/91-05/96	Large	Phase	R. Diver
IB	USJVP	SAIC	SNL AB-8717A	8828	3256	3500	3084	12/93-12/96	Large	Phase	T. Mancini
IB	USJVP	Cummins	SNL AB-8717B	8990	3100	2600	1741	01/94-11/97	Large	Phase	D. Gallup
IC	O&M cost reduction	KJC	SNL AB-0227	3154	2132	780	1673	07/92-09/95	Large	Phase	G. Kolb
II	Solar Test Support	EG&G	SNL AH-5081	990	199	100	212	10/93-11/95	Large	N/A	S. Rawlinson
II	Electrical Support Service	J&S Electric Co., Inc.	SNL 75-7415	450	410	40	417	02/89-06/95	Serv. Support	N/A	W. Kolb
IIA3	Optical Materials	IST	NREL AAR-4-14019	126	126	0	66	07/94-07/95	Small	—	G. Jorgenson
IIB2	Hybrid receiver	Cummins	NREL ZA-2-11120	537	537	0	530	03/92-04/95	Large	—	M. Bohn
IIB3	STM Engine	DDC	SNL AE-5963	132	132	0	125	03/93-09/95	Large	Final	S. Rawlinson
IIB3	Brayton Engine solarization	NREC	SNL AG-0408	611	413	198	337	08/93-12/95	Large	Phase	D. Gallup

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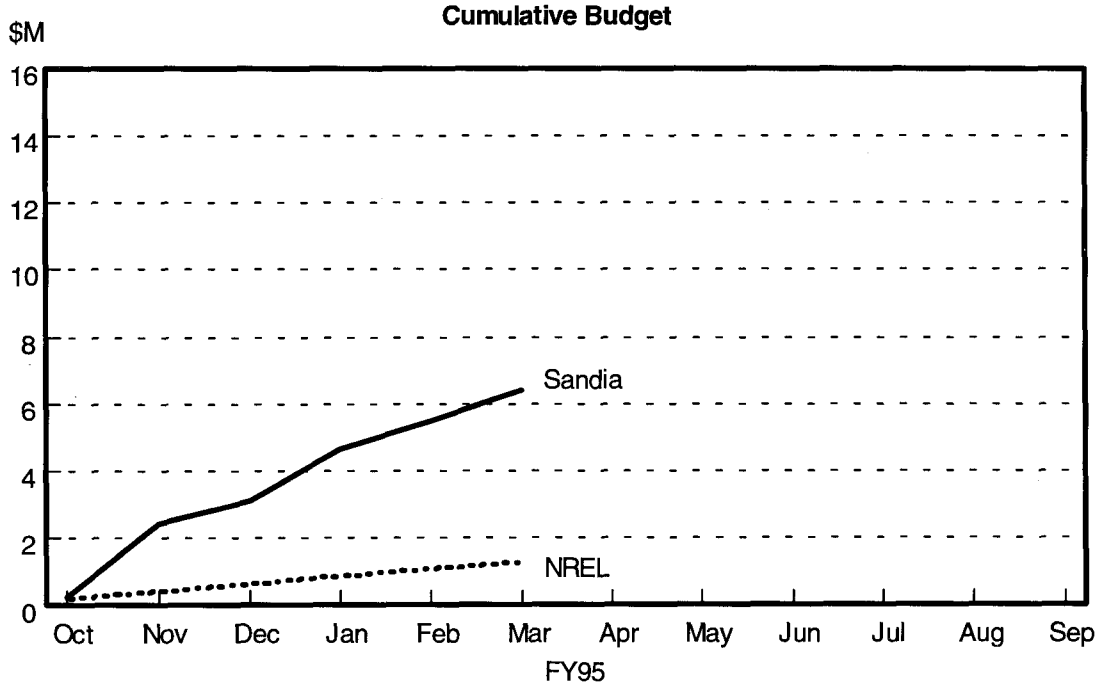
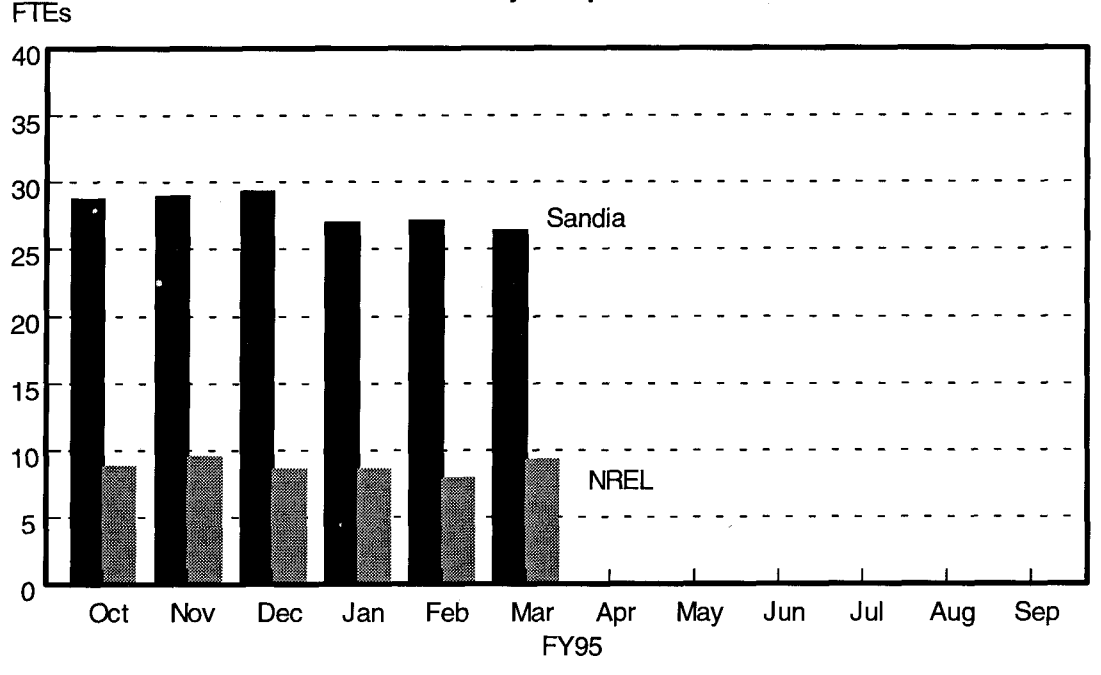
Solar Thermal Electric Program
Cumulative Budget



Solar Thermal Electric Program
Monthly Manpower



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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 (STE) and other alternative energy technologies in the years ahead.

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

OUR VISION

Our vision for solar thermal electric technology is the large-scale acceptance and installation of U.S.-designed and 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

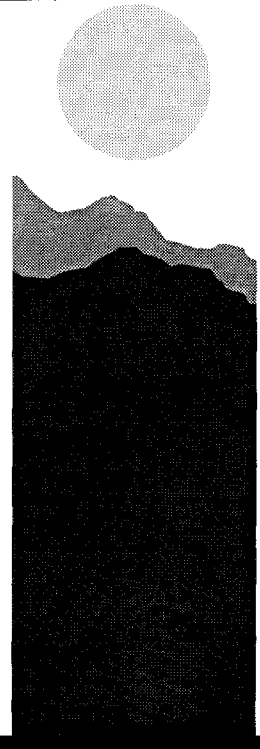
The Solar Thermal Electric Program strategy is consistent with the objectives set forth by the Office of Solar Energy Conversion in *Solar 2000—A Collaborative Strategy.*[1] The Department of Energy (DOE) and its field laboratories (Sandia National Laboratories and the National Renewable Energy Laboratory) 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 (SCE) will provide the technical base for Solar 100, the first 100-MW power tower plant.

The Cummins Power Generation, Inc. (Cummins) 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 (USJVP) for 25-kW_e dish/Stirling systems will field initial hardware, with the last phase of this program resulting in at least



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

one megawatt of dish/engine system capacity installed by utilities.

The operations and maintenance cost reduction study with the Kramer Junction Company Operating Company (KJCOC) 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 solar thermal technology base and the user, supplier, and decision-making constituency. Specifically,

  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.

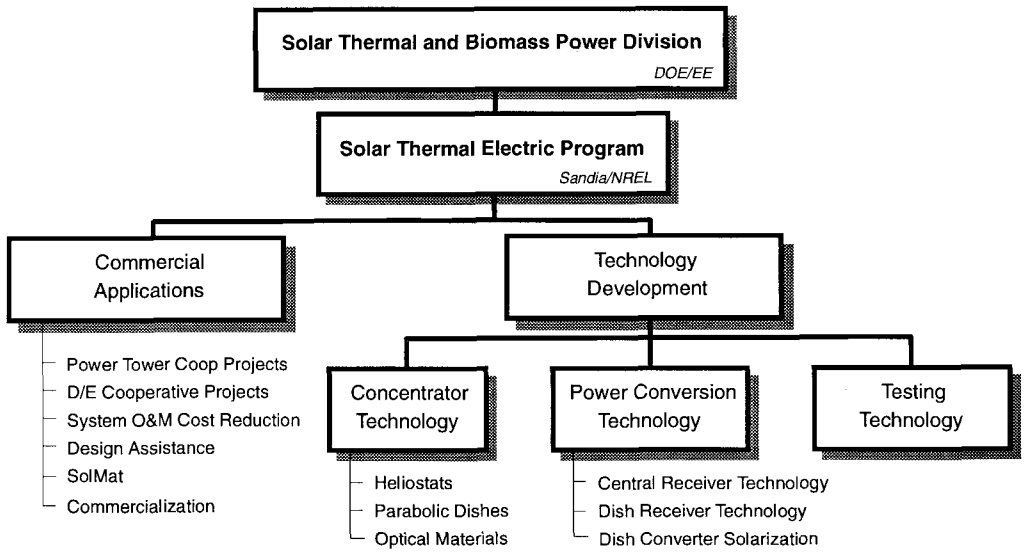
  Information exchange through conferences, road shows, and publications will be used to bring the technology to the attention of regulators, potential users, and the public.

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 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 second 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 (O&M) cost reduction. The 354 MW of installed Solar Electric Generating Systems (SEGS) 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)**

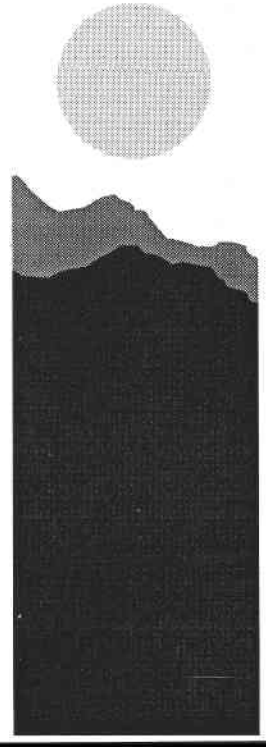
B. **Cummins Power Generation, Inc., and Science Applications International Corporation (dish/engine systems)**

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

A. POWER TOWER COOPERATIVE PROJECTS

This 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. Department of Energy 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, 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 3-year test period, is $48.5 million. The plant is expected to be on line in late 1995.



Accomplishments

Construction of Solar Two is advancing at a brisk pace

During this quarter, tremendous advances were made in the construction of Solar Two (see Figures 1 and 2):

- The new receiver tower elevator was installed and permitted.
- The 6.1-m deep concrete sump containment was poured and backfilled. The hot and cold pump sump vessels were installed. Also, the preheater and superheater were delivered and the preheater was installed on its pedestal.
- All of the 108 Lugo heliostat pedestals were erected and 76 of the heliostats were installed by Modern Alloys, one of the project's heliostat contractors. Thirty-two Solar One heliostats were relocated on their new foundations. The Industrial Company, the general contractor, has started laying power cable to the Lugo heliostats and the 32 relocated Solar One heliostats. Also, Modern Alloys received delivery of all of the Carrizo Solar mirror facets; these facets will be used for the Lugo heliostats, as replacement glass for damaged and missing Solar One heliostat mirror facets, and as spares for Solar Two.
- The foundations, including the cooling and insulation systems, were completed for both the hot and cold tanks. The tank floors were completed and the tank walls are currently being erected.
- Rockwell completed demolition of the Solar One receiver.
- Rockwell completed fabrication of the first tube panel for the Solar Two receiver.
- The diesel-powered emergency generator was delivered and installed on its concrete pad.

The Technical Advisory and Steering Committees met this quarter

The Technical Advisory Committee (TAC) met on February 22 and reviewed construction and engineering progress. Bechtel indicated that it would soon be closing out its engineering effort at the home

Figure 1. Construction of salt storage tanks at the Solar Two Project: cold-salt tank (left) is carbon steel; hot salt will be stored in a stainless-steel tank (right).

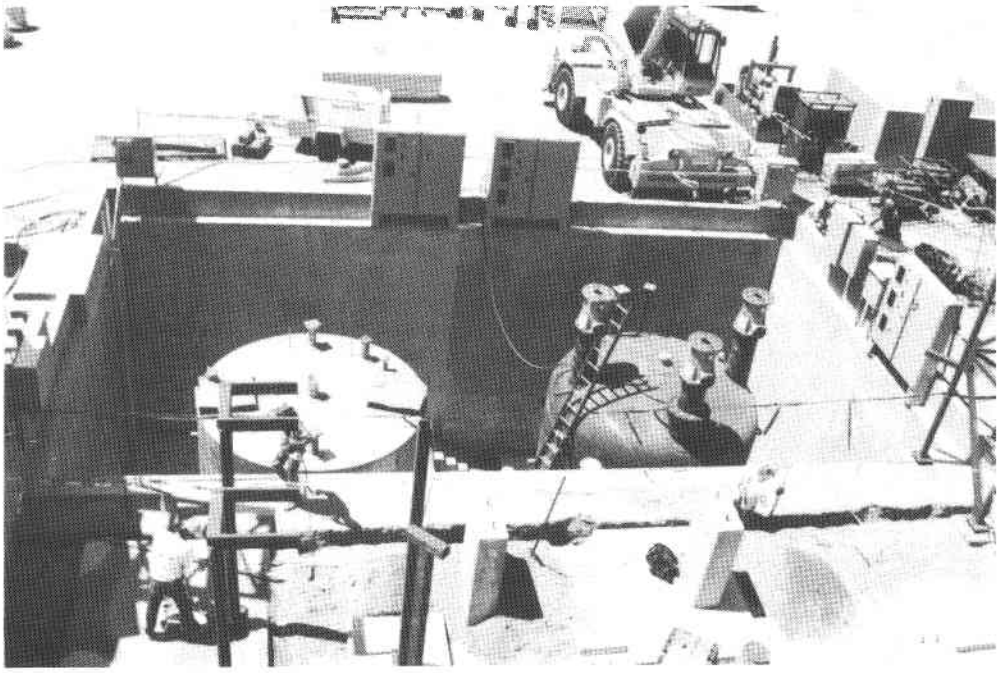


Figure 2. Sump vessels for hot (left) and cold (right) salt pumps at Solar Two.

office prior to beginning start-up in March. Most construction activities and the cost forecasts were reported to be on track. Sandia presented information on the importance of regular heliostat cleaning, recommending biweekly spraying with demineralized water. Paul Sutherland of Southern California Edison indicated how this information would be included in the forthcoming operation and maintenance (O&M) scope of work. Bill Gould of Bechtel described the Solar Two Test and Evaluation (T&E) Plan as a precursor to soliciting the project participants to contribute human resources to the T&E phase of the project.

At the Steering Committee meeting on March 2, 1995, Paul Sutherland reported that negotiations with the Chilean Nitrate Corporation were continuing but that it was becoming imperative that the salt be ordered to avoid any delays. The committee then agreed that the best avenue for procuring this critical-path item was to issue a purchase order while continuing negotiations. Consequently, 3.5 million pounds of nitrate salt have been ordered. Paul also reported that the project had firm commitments of $44,438,000 with potential contributions of $1,200,000. The meeting also contained a description of the status of the Commercialization Advisory Board (CAB) by Ray Dracker of Bechtel. The CAB was established to explore possibilities for ensuring the near-term commercial application of solar thermal technology. A major activity of the CAB will be the Solar Plan, a 10-month project to examine and aggregate various market entry pathways for solar power towers looking at regional and international markets and opportunities at the Solar Enterprise Zone.

Solar Two participants review O&M plans

A meeting was held to review the operation and maintenance statement of work for the O&M solicitation. The successful contractor will be responsible for operating and maintaining the plant and supporting the T&E plan. Meeting attendees discussed details and incentives of the agreement. Bonuses will be awarded to the contractor based on plant availability, plant performance, operations, maintenance, and safety. The statement of work is expected to be issued in May.

Development of the T&E plan continues

The Solar Two T&E plan was prepared. It defines the 21 tests to be carried out during the 3-year T&E phase of the Solar Two project. Its objectives are to validate the technical characteristics of a nitrate-salt central receiver; to simulate the design, construction, and operation of the first 100-MW_e power plants; to improve the accuracy of economic projections for commercial projects; to distribute to U.S. industries the

knowledge gained; and to stimulate the formation of a commercialization consortium.

The tests are broken down into five test phases: (1) familiarization, (2) characterization, (3) optimization, (4) power production, and (5) post operation. The first three test phases that comprise the majority of the tests (15) are scheduled to be completed during the first year of operation. The power-production test phase will last two years and consist of three tests. The post-operation test phase will take place after the power-production phase and could include any additional tests if funding is available. Also this quarter, the T&E subcommittee developed a detailed schedule of individual tests for the participants to use in planning their involvement.

Sandia support activities continue

Sandia provided Rockwell with manufacturing assistance on the application of Pyromark® paint to the receiver panels. Pyromark® consists of metallic oxides in a silicone resin and must be cured at 540°C to stabilize its crystal structure, adhesion, and optical properties. Previous studies by Sandia on the Solar One receiver and laboratory samples indicated that the coating exhibits better long-term optical stability when completely cured. The Solar One receiver was not properly cured and exhibited a 10% reduction in absorptance in 4 years of operation. At Rockwell's request, Sandia engineers recommended requirements for substrate preparation and cleaning, coating thickness, and curing schedule. As a result, Rockwell successfully coated its receiver panels. Sandia is continuing to provide on-site consultation and optical properties measurement expertise to assist with quality assurance and characterize the starting condition of the panels before installation. Sandia will continue to monitor the quality of the paint during operation of the Solar Two receiver.

In order to reduce parasitic power consumption during the operation of Solar Two, Sandia performed a detailed analysis on the need for heat tracing the high-pressure air tank that supplies air to the Solar Two inlet vessel. This study resulted in a reduction in the heating temperature for the tank and suggested several low-energy-consumption alternatives that will be tested during the T&E phase of the project.

Sandia's activity to provide Solar Two with corrosion test chambers is progressing well. Fabrication of the two pump sump chambers was completed, while detailed design of the chambers for the other two locations is nearing completion. Completion and final delivery of all four chambers is expected next quarter.

Other Sandia activities, specifically those related to heliostat issues, are described elsewhere in this report.

Planned Activities for Next Quarter

- Construction next quarter: Complete both salt storage tanks; deliver and install the Beam Characterization System; install steam-generation heat exchangers; remove, inspect, and refurbish the turbine; install the receiver outlet vessel; begin receiver installation; continue heliostat refurbishment; and make final delivery of corrosion test chambers.
- TAC subcommittee reviews of the T&E plan, Bechtel's Molten-Salt Central Receiver Design Guide, and Bechtel's Start-up and Checkout Plan.
- TAC meeting: May 10, 1995, at the Solar Two site.
- Steering Committee meeting: May 23, 1995, at Solar Two.

Major Milestones

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

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	600	0	0	600
Contracts	0	0	1500	1500
Total	600	0	1500	2100

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., underway since 1991, will develop a 7.5-kW dish/Stirling system primarily for remote application. Two Utility Scale Joint Venture Program (USJVP) contracts with Science Applications International Corporation and Cummins will develop 25-kW dish/Stirling systems for utility application. These are discussed separately below.

DSJVP Accomplishments

The primary objective of the DSJVP is the commercialization of the Cummins 7-kW_e dish/Stirling system for remote power applications. The DSJVP is a 5-year, $17-million effort. The Cummins-led industrial consortium and the U.S. Department of Energy are each sharing approximately 50% of the total program costs. During the final phase of this program, production-level dish/Stirling systems will be field tested at host test sites across the United States. During the quarter, Cummins continued to resolve Stirling engine issues and finalized plans for moving to a new 4,500-m^2 facility in Abilene, Texas.

Cummins plans move to new facility

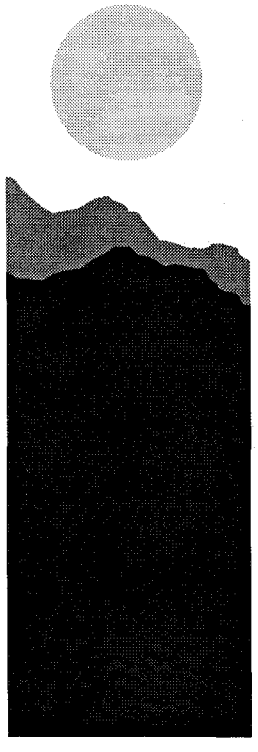
Cummins entered into a two-year lease agreement with the City of Abilene's Economic Development Board, which will enable Cummins to move into its new facility later this year. Besides a nearly six-fold increase in floor space, this new facility will feature eight engine test cells and an expanded outdoor testing capability. Also, the number of Cummins' personnel is projected to double by the end of 1995. While additional staffing is needed in all areas, engine development and installations/customer service will receive particular attention.

Stirling engine piston ring issues resolved

Significant progress was made on key Stirling engine issues during the quarter. Displacer and power piston ring designs, which have demonstrated insignificant wear after more than 50 hours of operation, were implemented. Engine performance is still limited by flow distribution problems in the engine. However, Sandia flow analysis has provided valuable insights; design modifications that incorporate Sandia recommendations were initiated. To date, the maximum engine output has been 5.1 kW_e at 21% efficiency. The design modifications will be required to improve performance to 7 kW_e and 30+% efficiency. These will probably not be implemented until the next quarter. Hardware needed to support the Phase 2 deliverables, the early Phase 3 deliverable to Central and South West Services, Inc., and the Strategic Environmental Research and Development Program (SERDP) deliverable to Ft. Huachuca, Arizona, have been manufactured and are available. Design of a next generation 9-kW_e machine has also been initiated.

Cummins hardware continues to operate

Hardware testing at the Cummins-South Solar Test Facility continued throughout the quarter. At the end of March, Cummins-South's "northeast," "northwest," "southwest," and "southeast" concentrators had accumulated 5,384, 5,532, 2,796, and 483 hours of tracking time, respectively. The Sandia-provided felt-wick durability heat-pipe receiver had operated on the "northwest" concentrator for 293 hours with no apparent degradation. The concentrator, system controller, and cold-water calorimeter installed at the Texas Utilities Solar Park located near the Dallas-Fort Worth International Airport have accumulated 1,297 hours of on-sun tracking time. Until the engine is ready, the solar concentrator is operating with a cold-water calorimeter and a water-to-air heat exchanger. Operation is fully automatic with practically no human intervention. The system starts, shuts down, and responds to faults on its own. Cummins technicians monitor this unit via remote modem and download appropriate data on a daily basis. Once per month, Cummins technicians conduct a thorough on-site, hardware inspection. The concentrator and system controller installed at California State Polytechnic University (Cal Poly), Pomona, California, have accumulated 2,550 hours of on-sun tracking time. The Thermacore, bumpy-nickel-powder durability heat-pipe receiver has operated on this concentrator for 408 hours. A total of 18,743 hours have been demonstrated on Cummins concentrators in this program.



DSJVP Planned Activities for Next Quarter

- Deliver CPG-460 to Central and South West Services, Inc., Ft. Davis, Texas, test site (May 1995).
- Deliver Power Conversion Unit to Texas Utilities (Jun 1995).
- Deliver Power Conversion Unit to Cal Poly (Jun 1995).

SAIC USJVP Accomplishments

The objective of the Utility Scale Joint Venture Project is to develop 25-kW_e dish/Stirling systems for use in utility markets. The Energy Projects Division of Science Applications International Corporation (SAIC) in Golden, Colorado, leads a team comprising 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, the second-generation faceted stretched-membrane dish. Stirling Thermal Motors is developing the third generation of its kinematic Stirling engine for the project. Stirling Thermal Motors and SAIC are also exploring possible working relationships for marketing the dish/Stirling systems.

The $17.6-million contract is a 3-year, 50/50 cost-shared activity between the design team and the Department of Energy (Sandia) for Phases 1 and 2 of the project, Proof of Concept and Pre-Production Prototype Development. Based on the results of Phases 1 and 2 of the project, Sandia and SAIC will consider whether or not to enter into negotiations for Phase 3, the deployment at utility sites of 1 MW_e of dish/Stirling systems.

The project is currently nearing the end of Phase 1. Two dish-drive failures have resulted in the project being delayed. Consequently, SAIC is requesting a no-cost extension to Phase 1 of the project in order to complete testing of the Phase 1 prototype system.

Complete optical characterization of the dish using BCS and calorimetry

The original plan was to use the Sandia Beam Characterization System (BCS) to measure the flux distribution produced by the dish during the month of January. However, the problems with the dish-drive system delayed flux mapping. The drive problem has been addressed by repositioning the center of gravity of the dish, repairing the drive, and limiting the drive's operational envelope.

After drive changes were made, the BCS was used to measure the flux distribution produced by the 16 facet SAIC dish. The dish was initially aligned by SAIC using a laser alignment technique based at two times the focal length of the dish. When the BCS flux maps were produced, it became clear that the facet alignment and focus were not correct. At that time, the BCS was also used to align and focus the facets. Subsequent evaluation of the receiver-plane flux maps indicated that the flux profiles were not compatible with the requirements of the direct-illumination receiver, i.e., the peak fluxes were too high. The flux on the receiver tubes varied by a factor of 2.0 to 2.5, and the peak flux values were estimated to be about 1100 kW/m^2.

Further evaluation of the flux profiles indicated that the facets are most likely not aligned or focused correctly. Consequently, the alignment and focus will be checked and adjusted using the distant-light-source method. If it is necessary to adjust the facets, the dish will be flux-mapped again following these changes.

Complete installation of the dish control system

The dish control system has been installed and initial checkout completed. The control system is accurately tracking the sun, although there is a small anomaly, which may be caused by pedestal tilt or structural deflection. This anomaly will be investigated further during the flux-mapping and checkout of the dish.

Complete 100-hour endurance testing of STM engine; deliver PCS to SAIC

The 100-hour endurance test of the STM power conversion system (PCS) was completed in January. In fact, the PCS has achieved more than 400 total hours of operation in a test cell operating on natural gas (more than 200 hours at full load). In addition, more than 25 hours have been accumulated with the direct insolation receiver (DIR), albeit at a reduced power level, on quartz lamps.

The PCS will be delivered to SAIC for on-sun testing once the power distribution produced by the solar concentrator meets the requirements of the DIR.

Install PCS on the solar concentrator and start on-sun testing

The PCS was not installed on the dish as planned during this quarter. The PCS is expected to be delivered and installed on the dish during late April or early May.

Fabricate parts and assemble hybrid receiver

The design of STM's hybrid receiver was completed during this quarter. All of the parts for the receiver, except for the detailing of some sheet metal connectors, have been fabricated. However, the receiver has not yet been assembled as planned. Assembly of the hybrid receiver at STM is now scheduled for late May with gas-fired testing to begin in June.

SAIC USJVP Planned Activities for Next Quarter

- Install the PCS on the dish and begin testing.
- Begin gas-fired testing of the hybrid receiver.

Cummins USJVP Accomplishments

Cummins Power Generation, Inc., is developing a totally new solar concentrator design for its USJVP. The design includes a "true" parabolic mirror surface and employs an azimuth/elevation drive system. The parabolic mirror will be constructed from glass/metal gore sections that will be placed on a space frame. To address the manufacturing issues associated with making the glass/metal panels (or gores), Cummins has contracted with Solar Kinetics, Inc., which developed metal gore sections while under contract to Sandia in the late 1980s.

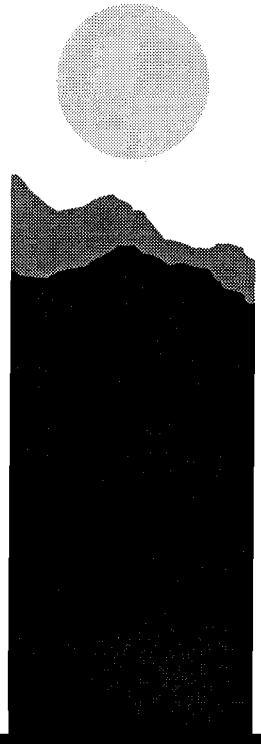
Construction of the concentrator structure for two concentrators was begun in this quarter. The first structure is complete and needs to be galvanized. The second structure is about two weeks behind the first structure. In addition, more detailed design work on the mirror was completed and improvements in the design were identified that will decrease the cost of the panels. Material for construction of the panels has been ordered and should be available early next quarter. In an effort parallel to the ongoing panel design, Sandia is working on a backup structural design that consists of styrene foam board sandwiched between two sheets of steel.

Design work on the Clever Fellows Innovation Consortium (CFIC) 30-kW_e Stirling engine was completed in the last quarter. This design addresses difficulties that have arisen with the 7.5-kW_e CFIC engine that is being tested in the DSJVP. The final design review for the 30-kW_e engine was held in early February; the design was approved by Cummins with only minor changes for purposes of instrumentation. The decision was made at this meeting to begin ordering parts for the engine. In addition, Cummins decided to include the Aisen-Seiki 25-kW_e kinematic Stirling engine as a backup to the CFIC engine. Several meetings with Aisen-Seiki have been held to address interface issues with the remainder of the system.

Design work on the control system is nearly complete. The design to be used in the USJVP will draw extensively from the DSJVP control system.

Cummins USJVP Planned Activities for Next Quarter

- Move to the new Cummins facilities in Abilene, Texas.
- Begin construction of solar concentrators.
- Begin construction of the CFIC 30 kW_e engine.
- Continue design of the 90-kW_t Thermacore heat-pipe receiver.
- Construct a heat pipe with a gas-gap calorimeter.
- Complete design of the Stirling engine cooling system.
- Continue design of the solid-state control and conditioning system.



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 Jun 95.*	Mar 94 *Delayed*	
Fabricate/test Cummins USJVP prototype control systems.	Mar 95 *Delayed*	
Begin integrated operation of the complete SAIC dish/Stirling system.	Apr 95	
Deliver Cummins 7-kW_e system to Central and South West's Ft. Davis test site.	Apr 95	
Initiate back-up Northern Research and Engineering Corporation Brayton engine test cell testing at Cummins.	Apr 95 *Delayed until Sep 95.*	
Complete SAIC USJVP Phase 1; begin Phase 2.	Jun 95	
Install and test two prototype USJVP concentrators at Cummins.	Jul 95	
Fabricate first Cummins prototype 25-kW_e Stirling engine.	Sep 95	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	550	30	0	580
Contracts	7583	65	368	8016
Total	8133	95	368	8596

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, operation and maintenance (O&M) costs account for greater than 20% of the SEGS electricity costs. Reductions in O&M costs would enhance the marketability of solar thermal technologies currently being developed by the Department of Energy (DOE). An example of a DOE technology that would benefit is the Solar Two demonstration project and commercial power tower plants. Power tower plants have many of the same subsystems contained within a SEGS plant, and the O&M of these subsystems would be similar.

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

Accomplishments

Performance test for repaired HCEs attempted

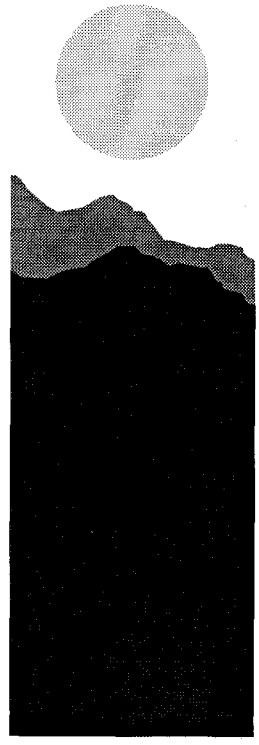
Early in this joint-venture program, tests conducted at Sandia indicated that heat losses from the trough heat-collection elements (HCEs) increased by a factor of 2 to 4 if the glass envelope surrounding the receiver tube breaks. An analysis indicated that breakage of this glass is the most important cause of energy and revenue losses at the five KJCOC plants. Consequently, Sandia and Industrial Solar Technologies (IST) developed a method of in-situ repair of the glass envelope.

The repair method involves installation of a split-glass sleeve. Glass tubes manufactured by Pyrex are cut along the length of the cylinder. With the use of spacers, springs, and high-temperature adhesives, the two half cylinders are rejoined in the field around the existing metal receiver tube.

Last quarter, six prototypes of the glass reglazing kit manufactured by IST were installed on the test loop at SEGS VI. During the present quarter, tests were conducted to measure the effectiveness of the repairs. However, it was found that the test loop at Kramer Junction, California, is not sensitive enough to measure the performance impact. Though Sandia expects performance to be restored to the level of an HCE with lost vacuum, final assessment will have to be deferred until a more sensitive measurement technique is developed.

Heat-rate optimization task continues

A solar thermal power plant rarely operates in a steady-state condition. The primary reason is because positions and insolation levels of the sun vary throughout the course of the operating day. These solar variations, as well as changes in operating temperature, cause the efficiency of solar collection and power conversion to vary throughout the day. Optimum overall plant efficiency occurs when the product of solar collection efficiency and power-conversion efficiency is at a maximum. The goal of the heat-rate optimization task is to develop an on-line analysis tool that identifies the values of the plant operating parameters, which then yield the maximum overall plant efficiency during full- and part-load conditions. The result of this activity is installation of software developed by Black and Veatch, Inc. at SEGS VI and VII. The software will be improved to include an on-line analysis tool for the solar field. The solar field tool will be developed by Sandia and KJCOC.



During the quarter, the final contract with Black and Veatch was approved by KJCOC and Sandia.

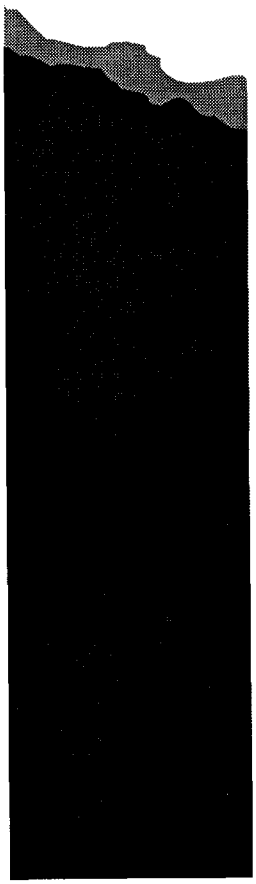
In parallel with contract negotiations, Sandia met with KJCOC to discuss the development of the solar field analysis tool. At the joint meeting, participants decided that the tool could be based on the model Sandia developed during the test of the LS2 collector

in 1993. To determine if this model is appropriate, Sandia will determine if its previous model for a single collector can be extended to accurately model a single ΔT loop composed of 84 collectors. Comparison of the extended model with plant data will be conducted next quarter.

Report completed that describes fugitive emissions from parabolic troughs

A small fraction of the heat-transfer oil used within parabolic trough technology is lost through volatilization. These "fugitive" emissions are classified as VOCs (Volatile Organic Compounds) and the Environmental Protection Agency (EPA) is interested in the quantity that emanates from oil-based solar plants. The KJCOC is also interested in tracking oil losses because this fluid is relatively expensive ($13/gallon). During the quarter, a report was completed by AeroVironment, Inc. for the O&M cost reduction program. This study indicated that fugitive losses are much lower than estimates based on EPA emission factors. This data will be particularly useful for emission estimates of future installations using a hydrocarbon heat-transfer fluid (HTF). The report was also issued to the operators of the other SEGS plants located at Daggett and Harper Lake, California.

Assessment of flowmeters for solar field completed



Accurate measurement of flows within the solar field are critical to the analysis of solar field efficiency. Reliability of the flowmeter is important to ensure that power production is not reduced because of equipment failures. And finally, the meter must be easily maintained to keep maintenance costs to a minimum. Several types of flowmeters, including vortex shedding, turbine, and acoustic, have been evaluated over the past 1.5 years as part of the O&M Cost Reduction Program. Based on the results of this task, a standard set of flowmeters has been selected for the Kramer Junction SEGS plants. The inlet of each half of the solar field will have two meters for redundancy—an acoustic meter and a turbine meter—and the outlet side will have a single turbine meter for the full field. The acoustical manufacturer, Panametrics, has agreed to increase warranty operating temperatures from 260°C to 316°C. All meters can be removed and maintained without breaking the integrity of the HTF system. This standardization will improve reliability and decrease the required spare parts inventory.

Remote monitoring demonstrated

The Field Supervisory Control software was expanded to provide the ability to monitor plant operation remotely, similar to the needs in a solar power park. The solar field operation of any of the five plants can now be monitored from any location on the site network. For example, KJCOC management can now readily observe status and performance of the solar field, including the daily history of selected parameters. In addition, the Distributed Control System can be monitored via the network that shows key data from the power block. These capabilities include monitoring only; as a safety measure, control functions intentionally are not included.

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	
Complete automation of key subsystems at SEGS VI.	Aug 95	
Complete and document engineering analysis of optimized efficiency.	Sep 95	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	90	30	0	120
Contracts	780	20	100	900
Total	870	50	100	1020

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.

Accomplishments

Sandia manufacturing team organized to help solar industry reduce costs

On February 3, members of Sandia's renewable energy team met with representatives of Sandia's Advanced Manufacturing Center. The result of the meeting was the formation of a team that agreed to work together to assist the renewable energy industry in lowering the cost of its systems and improving reliability.

Paul Klimas, manager of Sandia's Renewable Energy Office, opened the meeting with a short briefing about renewable technology that focused on how and why work in advanced manufacturing is appropriate for the state of the technology. Paul made the case that most renewable technologies are sufficiently developed and have been proven to work, but have not been optimized for manufacturability. He also suggested that some work was needed to improve the reliability of components and reduce the cost of installation.

Representatives of each of the renewable energy technology areas then discussed specific information about how manufacturing could help. For example, although a common misconception is that photovoltaic (PV) modules are the most expensive part of a PV system, the largest costs are actually in the power-conditioning subsystem. Likewise, both wind and solar thermal systems have very high installation costs. The result of the discussion was a list of about 15 technical problem areas that adversely affect the cost of renewable energy systems. The manufacturing center representatives stated that they have the expertise to address most of the problem areas that were discussed.

The group also discussed a working strategy with special emphasis on identifying specific work tasks. One suggestion was to develop a "renewable energy manufacturing road show" in which members of Sandia's manufacturing and renewable energy departments would visit industry manufacturers to try to identify problem areas that Sandia could address. Each visit would basically consist of a brief presentation of Sandia's manufacturing capabilities while most of the effort would be spent listening to the manufacturer. There was consensus that this effort should focus on identifying one or two problem areas, regardless of size, in which Sandia could demonstrate a successful application of its manufacturing expertise. As a result, the group agreed to develop a list of renewable energy manufacturers and to prioritize it based on perceptions of the ones most likely to benefit from Sandia's help. The top few will be selected for a visit from a Sandia team consisting of both manufacturing and renewable energy personnel. Each team will be tailored to a specific manufacturer according to the manufacturer's expected needs. Following the visits, the results will be evaluated and potential projects identified. The process will be repeated with successive manufacturers on the list until one or two projects are identified. After the projects are identified, efforts will be redirected to solve the problems successfully.

The group also decided to use upcoming technical conferences to advertise Sandia's renewable energy/manufacturing capability. As a result, Sandia will prepare an exhibit for Soltech '95 in April as well as Windpower '95 in March. Each exhibit will show how Sandia's manufacturing expertise can be applied to solve industry's problems. The exhibits will be staffed by personnel from both the renewable energy and manufacturing departments.

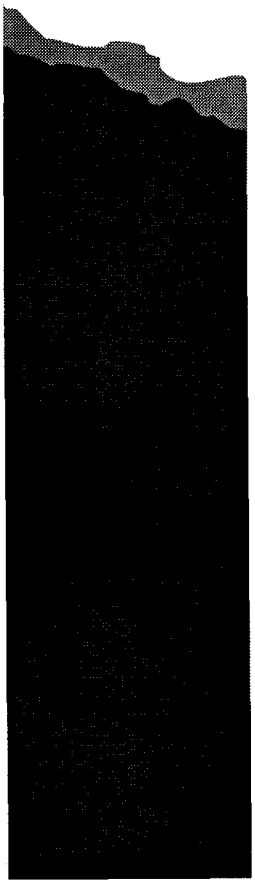
Sandia manufacturing team helps industry solve problems and reduce costs

Sandia has applied its manufacturing team capabilities to help industry in several problem areas. The first effort involved the

Solar Two receiver. Sandia advised Rockwell in the application of Pyromark®, the receiver's absorber paint coating, to help it maintain its absorptance properties and thus improve the long-term performance of the receiver system. Sandia's assistance involved advising Rockwell, the receiver manufacturer, on the paint's application and cure process. If this process is not followed, a 10% degradation in its absorptance properties can be expected within four years of operation.

The Solar Two receiver is currently being manufactured by Rockwell International Corp. in Canoga Park, California. The fabrication process is in full swing with multiple stations set up to leak-test, fit, assemble, and weld the individual tubes to the fluid manifolds (each panel consists of 32 tubes with a manifold assembly at the top and bottom of the panel). The completed receiver will consist of 24 individual panels assembled on the tower at the Solar Two site. The final steps in the panel manufacturing process are to coat the receiver tubes with Pyromark® flat black paint and temperature-cure the entire panel.

Rockwell asked for Sandia's assistance because of its expertise with the paint. Sandia engineers provided recommendations regarding requirements for substrate preparation and cleaning, coating deposition thickness, and the temperature curing schedule. Based upon these recommendations, a special furnace was fabricated by Rockwell to enable temperature curing of the paint layer at the manufacturing facility. Sandia will continue to provide on-site consultation and optical properties measurement expertise to aid in quality assurance and to baseline the paint properties before installation at the Solar Two site. Sandia engineers will also continue to monitor the optical properties of the paint during the operation of the power plant.



Pyromark® consists of metallic oxides in a silicone resin and must be temperature cured at a temperature of 540°C before the coating stabilizes in crystal structure, substrate adhesion, and optical properties. Previous studies by Sandia scientists of Pyromark® on the Solar One receiver, as well as laboratory prepared samples, indicated that the Pyromark® coating exhibits better long-term optical stability when completely cured. The Solar One receiver was not cured before assembly on the tower and demonstrated a 10% decrease in absorptance in the first 4 years of operation.

Another effort involved two small solar heat manufacturers. Engineers from Sandia's National Solar Thermal Test Facility and Materials and Process Science Center recently helped Thermal Conversion Technologies (TCT) solve an assembly line welding problem resulting in a 20% reduction in TCT's production costs for each solar module. In addition, the Sandia team helped TCT optimize its welding machine to increase its output by about 45%. This optimized performance will allow TCT to increase its production output from 175 collectors per month to nearly 250 without purchasing another $70,000 welding machine. According to the manufacturer, this assistance will result in increased revenues of close to $1 million over the next two years and will create a dozen new jobs. Support for the Sandians involved in this effort was shared between Sandia's Manufacturing Technologies and Technology Transfer Centers as well as through the Department of Energy Solar Program.

At the request of American Energy Technologies (AET), Sandia engineers visited its facility and provided critical manufacturing process consultation and development assistance to aid AET in establishing a new, nickel-based absorber coating technology that will be part of a new high-volume, solar-collector manufacturing line.

American Energy Technologies, located in Green Cove Springs, Florida, is a company that manufactures a variety of fin-on-tube solar collectors that are used in active systems to supply heat for large and small applications. After an extensive market assessment, AET concluded that a very large market exists in Europe for high-performance solar collectors that use an absorber coating other than black chrome. As a result, AET has decided to develop a new nickel-based coating absorber technology into its manufacturing line. Because of Sandia's experience in solar-selective absorber coating development and manufacturing expertise, AET contacted the Solar Thermal Design Assistance Center (STDAC) for manufacturing assistance. Again, cost for the effort will be shared by Sandia's Manufacturing Technologies and Technology Transfer Centers and the DOE Solar Program

New Sandia techniques help optimize SEGS operations

Sandia has developed a new model for use in the Solar Electric Generating Systems (SEGS) plants that will optimize the maintenance of the collector strings. The computer model is written in Quatro Pro and computes the energy performance/heat loss

characteristics of a certain string of collectors based on the amount of broken glass envelopes, broken mirrors, and the optical properties of the receiver tube. Based on this information, the operators can decide if it is cost effective to remove the string from service to repair the various damaged components.

Additionally, Sandia has loaned a new reflectometer to each of the SEGS plants that will help optimize the mirror washing schedules. This reflectometer is easier to use and more quickly collects reflectivity measurements from the mirror surfaces. This allows the operators to produce a broader assessment of the reflectivity of the field and, therefore, to direct the washing activities to those areas where they are most needed.

State cooperative activities

Solar Thermal Design Assistance Center staff has recently developed a simple screening tool for evaluating the economic potential of solar water heating projects. This tool consists of a set of tables that relate the installed cost of a solar heat system to the cost of the displaced fuel. The table is configured for more than 200 locations in the United States and yields the simple payback for the installation. The methodology is also coded as a spreadsheet program for those who have Excel 5.0 software on their computer.

This work was done in support of STDAC's Work For Others (WFO) project for the U.S. Army Corps of Engineers (COE). This tool will be used as an alternative to the solar feasibility code SOLFEAS and the COE's Generic Study, which are currently used for a preliminary evaluation of solar hot-water applications. The SOLFEAS code can be cumbersome to use and can provide results that indicate solar water-heating systems are more expensive than they really are.

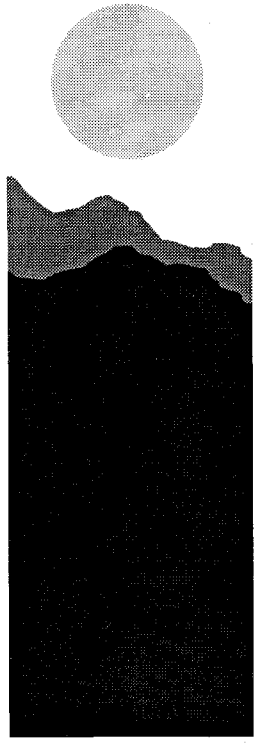
This screening tool incorporates American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) published performance data for flat-plate and evacuated tube collectors for various parts of the United States, and calculates a simple payback as a function of various fuel (electric or fossil fuel) and system installation costs. The advantage of this technique is that it allows mechanical designers or architecture and engineering consultants to quickly assess the potential economic payback of solar heat systems for specific projects without expending large amounts of resources to conduct a detailed feasibility analysis. If the results of the preliminary screening show that a solar heat system may potentially be cost effective, then the user can proceed to a detailed analysis to determine more exactly the economic parameters of the project.

Some of Sandia's customers have requested assistance on screening potential renewable energy projects. In many of these cases, these customers have money for feasibility studies, but do not want to waste effort studying projects that have very low potential economic payback. For example, the state of Virginia's energy office has asked Sandia for a screening tool that can be used to evaluate the economic potential of renewable energy projects. Sandia plans to use the basic structure of this new analysis tool to develop appropriate screening criteria for Virginia's needs.

Military and federal installation activities

The STDAC completed the review study of the COE solar thermal system evaluation methodology, the system that the COE uses to determine the applicability of solar heat systems. As a result, several recommendations were forwarded to improve the methodology, which may help more solar systems to be applied within federal government facilities. The recommendations included a new solar economic screening tool and 25 suggested improvements to the COE's design/installation specifications. The recommendations were based on Sandia's experience along with suggestions of six solar companies from around the United States and the Army's Civil Engineering Research Laboratory (CERL), which reviewed the COE's methodology and recommended improvements. This work was funded through a WFO project between Sandia and the COE.

The COE needed this review study because some solar industry officials had criticized their methodology as being biased against solar systems. They chose Sandia for the effort based on its reputation for unbiased, technical expertise. The review study involved three closely related tasks: (1) review the COE's Generic Study, a fundamental screening criteria for identifying potentially cost effective solar systems in the Department of Defense; (2) review SOLFEAS, the COE's computer program—used to assess, in detail, the feasibility of a proposed solar system; and (3) review the COE's solar system design/installation specifications.



A large part of Sandia's effort was concentrated on the Generic Study because the first level of screening recommended

against solar systems most of the time. The Generic Study is an economic evaluation of a hypothetical, low-cost solar system in each of DOE's 10 economic regions. The generic study concluded that for all regions, solar hot-water systems would have 25- to 30-year paybacks. The COE liked the study because it is easy to use—i.e., simply refer to the study and a solar system can be rejected. The problem is that it did not account for niche applications in which a solar system would be cost effective (i.e., less than a 10-year payback). Therefore, a goal of this part of the evaluation was to develop a simple, easy-to-use screening tool that can be used for individual projects.

The STDAC developed such a screening tool, which is an Excel 5.0 spreadsheet that uses ASHRAE/Solar Energy Industries Association-published flat-plate collector performance for water heating in various cities throughout the United States. The Excel program uses collector performance data, the displaced fuel costs for the application, and a rough estimate of installed system costs to yield the simple payback for the application. The same information is made available in tables if the user does not have the Excel package. Based on the results of the simple payback analysis, the COE can decide if additional evaluation is warranted. By using the simple payback approach, the COE will be able to perform a forthright screening of solar projects at a minimum cost and identify those niche applications where solar systems have cost-effective potential.

The STDAC also reviewed the COE's system design and installation specifications for solar heat systems. In addition to an in-house review, Sandia contracted to six major solar manufactures/installers to review the specifications and recommend changes. Additionally, CERL was consulted on the review. The results were consolidated and 25 changes were recommended. In general, Sandia and CERL agree that the revised specifications are reasonable for the types of solar systems for which they are intended.

The final results will be presented to the COE in a final report in May. If required, Sandia will continue to work with the COE to implement the changes to the specifications and to train COE personnel on the use of the screening tool. Currently, the COE has recommended that Sandia oversee the applications of the new specifications for a new solar hot water project at Ft. Huachuca, Arizona. The purpose of the project is to evaluate the applicability of these new specifications. This project will be funded by CERL. System construction will be documented and a lessons-learned report will be provided to CERL and the COE. Sandia is evaluating the request and will decide how much additional funding, if any, will be required from the COE to complete the effort.

Sandia also assisted a number of U.S. federal facilities. A summary of each effort is included below.

The STDAC is providing technical consulting to the Environmental Protection Agency to install a new solar system on the main building they rent at Waterside Mall, in Washington, DC. The proposed system will be around 77 m^2.

Sandia engineers consulted with the Bay Pines Veterans' Administration Hospital in Georgia, concerning the possible refurbishment and development of an energy service contract of an existing 810-m^2 solar system. Sandia engineers measured the heat load and estimated yearly energy savings. Sandia also provided the hospital's engineers with the names of local contractors that were obtained from SEIA who may be interested in entering into an energy service contract with the VA Hospital.

In California, the STDAC is consulting with Camp Pendleton regarding the refurbishment of a large number of solar systems on the base. The base Energy Resource Manager asked for help because neither on-site personnel nor the consulting architecture and engineering contractors are experienced enough with solar technology to know what equipment to salvage and what to replace.

Sandia is consulting to the Deputy Civil Engineer of Altus Air Force Base located near Oklahoma City, Oklahoma, to help determine if an existing, non-operational, evacuated tube solar system should be repaired or removed.

The STDAC is assisting the National Park Service in the design, construction, and initial operation of a solar system at a camp site in Chickasaw, Oklahoma. The goal of this project is to identify the best solar system design regarding its campsite applications.

International renewables support

This quarter, Sandia launched an effort to facilitate the introduction of solar thermal electric technologies into the Mexican market. This effort will focus on

two solar thermal electric technologies, trough/electric and dish/Stirling. Its purpose is to familiarize Mexican decision-makers with the technologies, the current level of maturity of these technologies, and the status of ongoing market activities in Mexico. It is expected that by providing technically accurate and up-to-date information, Sandia can facilitate the process for the adoption of the technologies.

The effort will consist of a series of briefings which will be provided to individuals and groups in key Mexican institutions. Work was begun on the development of a high-quality Spanish presentation that will be used for these briefings. A Spanish-language pamphlet is also being prepared on the status of dish/Stirling technology.

In addition, Sandia has begun work to identify a dish/Stirling demonstration project in Mexico. In this effort, Sandia will meet with a selected group of Mexican institutions to elicit interest and possibly involve them in a demonstration project. This effort will focus on institutions with policy and decision-making power, whose missions encompass public energy policy, rural electrification, and rural development. These agencies may include the CFE (the Federal Electric Commission), the energy branch of SEMIP (the Secretariat for Energy and Mines), and pertinent secretariats in selected state governments.

The Solar Energy Laboratory of Mexico's Autonomous National University has agreed to lead in the field testing of the dish/Stirling system. This is important because testing of this system by a Mexican institution will provide credibility to others considering a dish/Stirling demonstration program.

Analysis, testing, and technology development activities

At the request of ASHRAE, Sandia developed a set of trough test standards. These standards are based on actual trough testing experience at the National Solar Thermal Test Facility and will be used to supplement those used for testing flat-plate solar systems. The development of these standards was requested by ASHRAE's Solar Utilization Technical Committee because currently no trough test standards are available. Sandia was asked to draft the standards based on its experience testing trough systems.

STDAC contacts

The STDAC had 270 total contacts with the private sector this quarter. The contacts were distributed in the following areas:

Central Receiver	11
Concentrator	8
Dish/engine	24
General information	76
Industrial process heat	57
Insolation	5
Modeling	3
Solar absorption cooling	5
Solar education	16
Solar thermal systems	33
Testing	35
Utilities	8

Planned Activities for Next Quarter

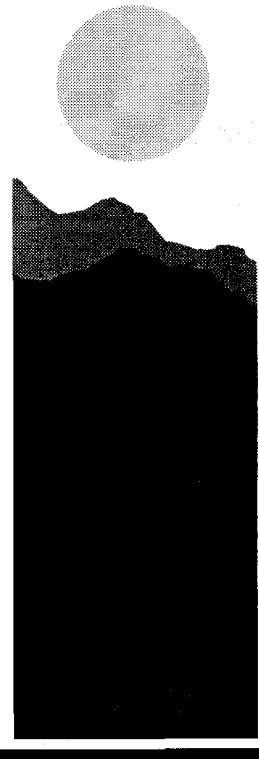
Current plans are to accelerate the application of Sandia's manufacturing expertise to help the solar heat industry reduce the cost of its products and improve their reliability. The STDAC plans are to continue to provide direct technical support to those organizations with which they are currently working.

Major Milestones

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

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	500	130	0	630
Contracts	270	0	350	620
Total	770	130	350	1250



E. SOLAR MANUFACTURING INITIATIVE

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

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

Accomplishments

Heliostat manufacturing

Negotiations continue with two potential industry partners although contracts were not awarded as planned for this quarter. Efforts to complete negotiations have been slowed by (1) the partners' reluctance to provide required lower-tier information, (2) late identification of proprietary proposal sections, and (3) claims for patented technology with ensuing negotiations. At present, there appears to be no obstacles, and NREL could issue letters of intent (LOI) to allow work to begin in the near future.

General manufacturing issues

NREL staff have pulled together a detailed description of the next SolMat solicitation, which will address manufacturing issues for solar thermal electric technologies other than heliostats. The detailed description covers all pertinent issues relative to the request for proposal (RFP). This description will be presented to the SolMat advisory board during the upcoming April Soltech meeting for concurrence. Preparation of the RFP, which should be fairly rapid, will follow.

Design for manufacturing and assembly

A Design for Manufacturing and Assembly (DFMA) workshop was held at Cummins Power Generation, Inc., Abilene, Texas, on January 17-20, 1995. The workshop was sponsored by the NREL SolMat initiative and is the second such workshop held for solar manufacturers. A total of 16 people participated, plus the Hughes Aircraft staff who facilitated the workshop. Attendance included Cummins staff from Abilene and from Cummins headquarters in Columbus, Indiana, and NREL and Sandia staff. The Cummins workshop focused on the Cummins 7.5-kW system, specifically the concentrator, mirror modules, and the support structure. Significant cost reductions, as well as some new cost elements, were identified. In addition, several ideas were developed that can significantly improve system reliability, which was identified as the most important customer requirement. Based on these, a list of action items was developed to implement the ideas. Further DFMA workshops involving more detailed study of the concentrator subsystems as well as the entire system are planned.

Planned Activities for Next Quarter

- Issue RFP for general LOI under SolMat.
- Cummins will complete hybrid on-sun testing.

Major Milestones

Milestone	Planned	Actual
Complete first DFMA class and evaluate effectiveness.	Jan 95	Dec 94
Award contract on SolMat heliostat solicitation. *Rescheduled to Mar 95 with DOE concurrence.*	Mar 95 (R) *Additional delays expected.*	
Release first RFP for manufacturing improvement projects.	Apr 95	
Initiate Phase 1 heliostat contract.	Jun 95	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	150	200	0	350
Contracts	0	1512	165	1677
Total	150	1712	0	2027

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 resources 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.

FY95 Task Descriptions

Independent Power Producers. A task will be undertaken to engage independent power producers (IPPs) in pursuing renewable technologies. This task will include (1) gaining an understanding of the strategies, operations, motivations, and concerns of IPPs, and (2) establishing contacts within the IPP industry in an effort to interest them in renewable technologies. The ultimate objectives of this task will be to gain IPP participation in the Nevada Solar Enterprise Zone project and to encourage IPPs to pursue renewable technologies in the commercial arena.

World Bank Funding of Solar Energy Projects. This task will strive to understand how the World Bank can be used as a mechanism to fund solar thermal electric projects in developing nations. The vehicle will be the ongoing project to fund the construction of a solar parabolic trough plant in Mexico, defining the methodology for World Bank funding. Potential barriers to using these funding sources will be identified with recommended solutions.

Regulatory Agencies As They Affect Renewable Energy Technologies. This commercialization task is an information gathering and dissemination effort targeted at regulatory groups. These groups were chosen because they are numerous and complex, and their support is vital to the success of any renewable energy technology. Through this task, Sandia seeks to better understand (1) the regulations and policies affecting renewable energy technologies and (2) the trends and visions of these agencies. The initial approach will be to develop a road-show-style briefing package intended to update and inform regulators on the status and potential of various renewable energy technologies. Potential audiences include public utility commissions, public service commissions, and state regulatory agencies. In meeting with regulators to present this briefing, Sandia will solicit their feedback on the issues and opportunities they see regarding the successful deployment of renewable energy technologies within their jurisdictions.

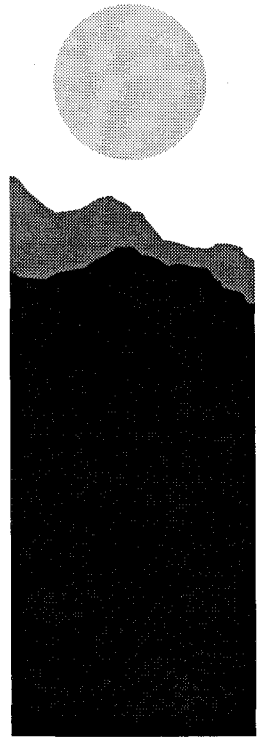
Executive Order 12902—Energy Efficiency and Water Conservation at Federal Facilities. The final area of this commercialization activity is targeted toward understanding Executive Order 12902 and its implementation at federal facilities such as Sandia National Laboratories. The task will involve soliciting input from the internal and external organizations involved in implementing the plan, including Sandia Facilities and renewable energy technology personnel, the Department of Energy/Albuquerque, Kirtland Air Force Base, and Federal Energy Management Program representatives, as appropriate. The task will seek to identify barriers and potential solutions, and develop a draft action plan in partnership with Sandia's Facilities organizations to move toward implementation of the Executive Order. This action plan may aid in the development of a model implementation strategy to meet the required elements of the Order; the plan may also be distributed to other affected sites for input and validation, with recommendations for implementation—including examples of design guidance and contract language that are supported by the applicable Facilities organization.

Accomplishments

World Bank funding of solar energy projects

Mexico

Spencer Management Associates (SMA) is leading an effort to recommercialize parabolic trough power plant technology. During 1994, SMA conducted Phase 1A of a study that concluded that the solar parabolic trough industry could be re-established on a cost-competitive basis with other renewables if (1) a single order is placed for an approximate 200,000-m^2 solar field in Mexico and (2) one or more commitments are made from among the existing formal expressions of interest of 35 MW in India, 80 MW in Morocco and Iran, and the pending interest of 135 MW in Spain and 280 MW for the U.S. Solar Enterprize Zone.



Consequently, SMA is currently conducting Phase 1B of the study that will graduate the project from a pre-feasibility stage into a viable opportunity for a project in Mexico. In June 1994, the World Bank expressed its support to the Mexican government for installing a trough plant in Mexico, and the Mexican department responsible for energy, mines, and industry (SEMIP) formally and affirmatively responded to that expression of interest in July 1994.

Phase 1B is being cost shared by SMA, Mason Willrich, the Rockefeller Foundation, and Sandia National Laboratories. Assuming success of Phase 1B, the project will be at a stage where a Preliminary Project Assessment Report will be funded by the World Bank's Global Environmental Facility (GEF). Ultimately, the project is seeking a $50 million grant from the GEF to make the first plant in Mexico cost competitive with comparable fossil technologies.

During this quarter, Sandia established a $200,000 contract with SMA to conduct Phase 1B. Sandia's cost share is 33%. Shortly after establishing the contract, the devaluation of the Mexican peso caused a significant distraction with Sandia's Mexican contacts and a consequent slowing of the project momentum. However, project personnel are planning to attend the Mexican trade mission led by Deputy Secretary Bill White on June 19-23, 1995. At that time, Sandia will have a better idea for schedules and Mexico's interest.

India

During the quarter, the World Bank asked Sandia to review a proposal by a business consortium of SOLEL (Israel) and BHEL (India) to install a 35-MW parabolic trough plant in Jodhpur, India. The consortium is seeking a grant from the GEF, much like the Mexican project discussed above. Sandia's major comments were that (1) the proposal lacked a plan to show how a successful demonstration project will lead to wide-spread deployment of solar trough technology in India and (2) the performance projection in the proposal is too high (by ≈25%). These comments were forwarded to the business consortium during a World Bank trip to India in February. Sandia understands that India has been sanctioned by the World Bank to continue its feasibility studies. During the next phase the consortium will respond to comments by the World Bank and Sandia.

Regulatory agencies as they affect renewable energy technologies

In support of the Solar Enterprize Zone project, Sandia is investigating taxation issues for solar power plants within the state of Nevada. The financial models previously developed by the California Energy Commission and Sandia to study tax issues for the state of California were adapted to perform the analysis.

During the present quarter, the taxes paid by a hypothetical combined-cycle natural gas plant, a solar-only power tower plant, and a hybrid-combined-cycle power plant were compared. All plants were assumed to come on-line in southern Nevada in the year 2000. For example, the levelized taxes paid to provide the solar heat vs. gas heat (i.e., "fuel") to the plants' respective 150-MW_e power conversion turbines are compared in Figure 3.

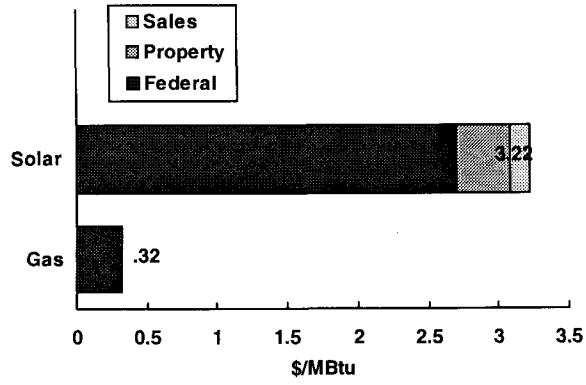


Figure 3. Comparison of "fuel" taxes paid by solar and fossil power plants.

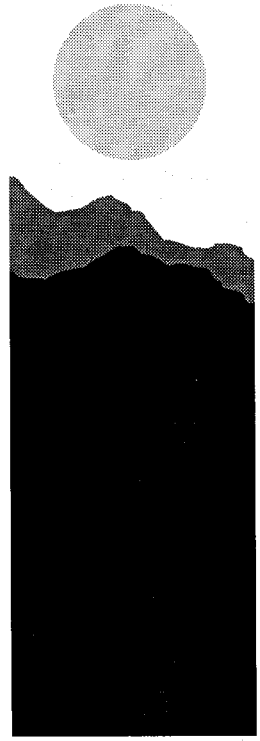
For the case presented above, solar heat is taxed approximately 10 times more than gas heat. Natural gas is not subject to sales tax and because gas is not considered property, property tax is not paid. The only tax paid resulting from gas use is federal income tax due to profit made on the sale of gas to the power plant by the gas provider. Solar heat, on the other hand, is taxed differently than gas heat. Because it takes capital equipment and a maintenance crew to provide solar heat (i.e., mirror field, tower, receiver, mirror washers, etc.), significant taxes are generated. For example, financial institutions and equity investors pay federal income tax on the profit made on loaning money to install capital equipment; annual property tax is paid according to the value of the solar equipment; maintenance crews pay federal and FICA taxes; and sales tax is paid during purchase of the solar equipment.

Another finding of the initial study is that significant property taxes will be paid by a solar plant installed in Nevada. Before initiating the study, Sandia thought Nevada had a law exempting solar plants from property tax. However, the law only exempts the plant for the first 10 years. During the first 10 years, the value of the property is allowed to escalate according to inflation. At year 11, property tax payments commence based on the escalated value of the property.

The taxes presented in Figure 3 can be thought of as a "Btu (British thermal unit) tax" paid by natural gas and solar forms of heat. The Clinton administration attempted to add a Btu tax to fossil fuels to equalize tax burdens paid by renewable and fossil technologies. This was an unpopular idea that died in Congress. Rather than *adding* taxes to fuel, another approach to equalizing tax burdens would be to *reduce* Btu taxes inherent in the construction of renewable energy systems. In the next phase of the analysis, Sandia will estimate how the economics of power towers are improved by reducing taxes to the level paid by natural gas.

Planned Activities for Next Quarter

- Spencer Management Associates will attend a trade mission in Mexico.
- Sandia will perform sensitivity studies for tax equity in Nevada.



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. Because of their importance in developing high-performance and cost-efficient concentrator designs, optical materials development is also an important part of concentrator development.

1. HELIOSTATS

Accomplishments

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

Sandia trains Bechtel and TIC technicians on Solar Two heliostat operation

During February, Sandia engineers and technicians trained Bechtel and The Industrial Company (TIC), the subcontractor selected to repair the heliostat field at Solar Two, on the operation of the heliostat field, the heliostat remote control (called a stimulator) and heliostat canting.

To improve the performance of the system at Solar Two, it is necessary to re-cant (adjust the positions of the facets on the heliostats) the inner 17 rows of heliostats. Sandia developed a camera-based look-back technique and trained Bechtel and TIC in its use. The flat replacement facets will be aligned using an on-sun approach because their poorer optical quality precludes the use of the look-back technique.

It is also necessary to align the facets on the Lugo heliostats, but this has been delayed until next quarter when power is installed to the heliostats and stimulator software is delivered to Solar Two.

Sandia engineers and technicians have made several trips after training to support canting and heliostat troubleshooting by Bechtel and TIC. The canting progress has been slow because of frequent malfunctions of the old Solar One heliostats.

Recommendations for operations and maintenance of Solar Two heliostats provided to Bechtel

Sandia provided input to Bechtel for the operation and maintenance bid specifications, which are scheduled for release during the third quarter of FY95. The heliostat field should be maintained at 98% availability, where availability is defined as proper functional operation with an annual average cleanliness of 95%. The Beam Characterization System (BCS) will also measure heliostat tracking errors near solar noon four times each year.

Cleaning strategies investigated

Sandia performed an analysis of the value of cleaning the heliostats at Solar Two and provided the information to Bechtel for use in the development of its plant operation and maintenance (O&M) specifications. Some of the information provided to Bechtel includes the following:

- Data from the Kramer Junction Company (KJC) trough plants show that an 11.9-point reduction in trough reflectivity results in a 16% reduction in thermal output of the field.
- Rain wash provides 90% annual cleanliness for the heliostat field.
- Solar One experience showed that biweekly brush cleaning could maintain 97% annual cleanliness.

- KJC cleaning tests on a Solar One module showed high pressure spray cleaning to be effective but slightly less than brush cleaning.
- The $75,000 value of the additional 1.5-MWhr/yr energy produced with heliostat cleaning more than offsets the cost of cleaning, which is estimated to be between $32,000 and $64,000 annually.

Sandia recommended that O&M operators have freedom to decide how to best meet the 95% goal, which would be confirmed with periodic field reflectivity measurements.

BCS preparations for Solar Two

Sandia has started work on the Solar Two BCS ahead of schedule and will install the system at Solar Two in May 1995. (The scheduled milestone for this activity is August 1995.)

The streamlined Solar Two BCS will measure heliostat tracking errors routinely during plant operation. The Solar One heliostat bias values were stored in the Heliostat Array Controller and the data are not recoverable. Therefore, the BCS will also be used to determine the tracking offset errors of heliostat during start up of the plant. Bias errors will also be determined during canting for about half of the field.

Hardware upgrades and software changes are underway at Sandia for the new Solar Two BCS. The system was successfully tested at Sandia on March 30, 1995.

Planned Activities for Next Quarter

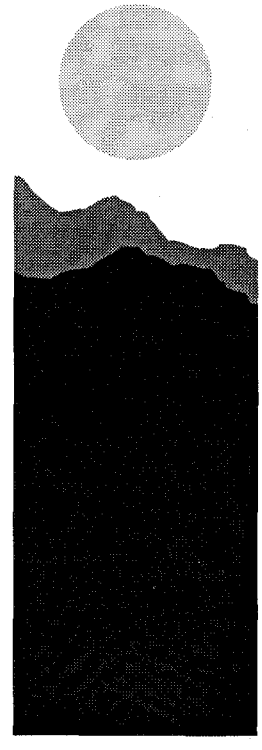
- Install BCS at Solar Two.
- Ongoing support of heliostat canting.
- Refine optical model of Lugo heliostats.

Major Milestones

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

Accomplishments

Parabolic dish development includes support for the Utility Scale Joint Venture projects and the development of advanced solar concentrator concepts.

On-sun measurements of SAIC's solar concentrator

Sandia performed several series of on-sun, flux-mapping tests of the Science Applications International Corporation (SAIC) dish at the test site near Golden, Colorado, during January and February 1995. (Some of these tests are described in the Dish/Engine Cooperative Projects section of this report.) Testing was interrupted by problems with the dish drive. The initial dish alignment did not achieve the desired flux pattern for the direct insolation receiver. Sandia is working with SAIC to revise the aiming strategy and improve the flux distribution. Several flux mapping tests are planned for April 1995.

On-sun measurements of Cummins concentrator

The reason for flux-mapping the Cummins Power Generation, Inc., solar concentrator was to evaluate the effects of moisture on the focus of the facets. Cummins has observed a change in tension of its facets because of moisture. Flux maps of the dish confirmed that moisture does affect the flux distributions and peak fluxes produced by the dish.

CBD announcement for advanced Point-Focus Concentrator Development

An announcement of Sandia's intent to release the Advanced Point-Focus Concentrator Procurement was placed in the Commerce Business Daily (CBD). To date, more than 40 parties have expressed an interest in receiving the request for quotation (RFQ). The RFQ has been delivered to Sandia's purchasing department and is currently under review. It should be released for bid during the next quarter.

2-*f* targets and side-by-side comparison with SHOT using SAIC and Cummins facets

New 2-*f* targets have been made for use with the Cummins and SAIC facets. Side-by-side tests of these facets with NREL's SHOT system and the 2-*f* method have been delayed and are currently scheduled at NREL in early May 1995.

Planned Activities for Next Quarter

- Continued on-sun testing of the SAIC dish in Golden, Colorado.
- Release the Advanced Point-Focus Concentrator RFQ.
- Side-by-side comparison of 2-*f* and SHOT methods using SAIC and Cummins facets.

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	
Complete development of color 2-*f* system.	Jun 95	
Place several small contracts to evaluate advanced concentrator concepts.	Sep 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

Accomplishments

Coastal site selected for outdoor exposure tests

Activation of a sixth outdoor test site, representative of coastal environments, is proceeding on schedule. Selection was narrowed down to two sites. The first site was the South Florida Test Service, 18 mi. inland from Miami. The second site under construction was the Laque Center for Corrosion Technology at Kure Beach, North Carolina, 244 m from the surf. Advantages of the South Florida site were its tie-in with a wealth of historical data and its recognition as a de-facto "standard" site by the weathering industry (automotive, paint, and coating manufacturers, etc.). The Miami site has historically been better linked to solar-type material exposure testing. Although the Kure Beach site is much closer to the ocean, it represents an aggressive "marine" exposure site and is typically involved with metal corrosion testing. Following consultation with representatives from the solar industry, the Florida test site has been selected for the sixth exposure installation. Service life data collected from the site is particularly important because of the solar industry's expressed interest in remote coastal sites for solar thermal generation of electricity.

Optical materials trade-off study initiated at NREL

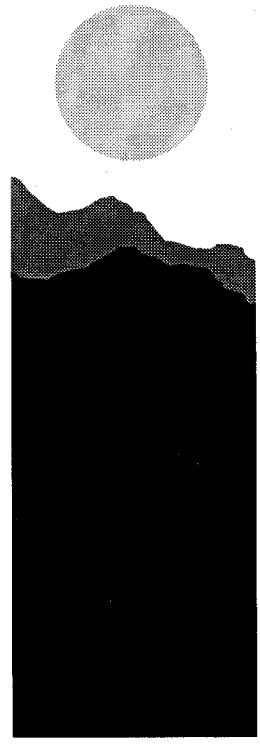
NREL staff are initiating a systems analysis study with the intent of developing a better understanding of the economic trade-offs among reflective material parameters such as cost, performance, and durability. Because the optical characteristics, weatherability, durability, and weight of reflective materials directly or indirectly influence the design of concentrating systems, choice of reflector materials can significantly influence the overall design and cost, and therefore, the levelized energy cost of the overall system. The scope of the effort currently includes analysis of dish/Stirling, power tower, and parabolic trough technologies. First priority will be given to dish/Stirling systems because the technology is nearing commercialization and because the solar industry is currently struggling with design issues related to the selection of reflector materials. Researchers plan to use the analysis as a tool (1) to guide current and future research and development activities for the Advanced Optical Materials Task at NREL and (2) to support the needs of the solar industry by investigating the impact of various reflective material designs currently under consideration.

UV durability of anti-corrosion coatings supports solar industry

Cummins Power Generation, Inc., has requested that NREL help evaluate the ultraviolet (UV) durability of an anti-corrosion coating that Cummins would like to use to provide protection to structural elements of its dish/Stirling system. The system is currently being developed under the Utility Scale Joint Venture Program. The coating, an aluminum lake-filled epoxy, is designed for use with galvanized steel. Two panels were provided for accelerated UV exposure in NREL's XENO test chamber. The integrity of the coating will be monitored as a function of exposure time, and results will be provided to Cummins. Communicating this and related data to Cummins will be a priority as the data collection proceeds. NREL has added Cummins to its internal e-mail network so that current and future results can be rapidly conveyed.

Planned Activities for Next Quarter

- Install sixth outdoor test site at coastal location (Annual Operating Plan milestone).
- Report on delamination tests of Cummins' facet configuration (anti-tunneling strategies).
- Prepare and initiate testing of next round of organized molecular assembly samples.
- Begin an experiment to investigate possible electrochemical component of corrosion of silvered polymer reflectors resulting from reflective layer/substrate material interactions.
- Initiate subcontract on advanced reflector materials to investigate diamond-like carbon protective coatings.
- Initiate optical materials trade-off study for dish/Stirling systems.
- Hold industry advisory panel meeting to review and advise optical materials activities at NREL.



Industrial Contacts

Contact	Company	Address	Phone #	Date	Topic
Frank Mast	HTC Solar	Germany	7621 5727 (fax)	03/27/95	ECP-305+
Robert Cambria	ELF	280 Park Ave., 36th Floor, New York, NY 10017	212-922-3000, ext. 3049	03/27/95	Advanced reflectors
Monte McGlaun	Cummins Power Generation, Inc.	Abilene, TX	915-690-6501	03/23/95	Accelerated testing of steel coat
Robert McDonough	EarthStar	Walderboro, ME		03/09/95	Reflector matls.
Gary Cline	Lorin Industries	Muskegan, MI		02/27/95	Reflector matls.
Ron Scully	Scully Assoc.	Hingham, MA	617-749-8599	02/17/95	Reflector matls.

Major Milestones

Milestone	Planned	Actual
Activate fifth outdoor test site.	Oct 94 *Rescheduled*	Dec 94
Establish industry research collaborative.	Dec 94	Dec 94
Activate sixth outdoor test site.	Apr 95	
Document status of outdoor testing activities.	Aug 95	
Document alternative reflector materials research and development progress.	Sep 95	
Document advanced reflector materials system study.	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 National Solar Thermal Test Facility (NSTTF). Power tower receiver development is focusing on advanced salt-in-tube receivers, molten-salt film receivers, and volumetric air receivers. Dish receiver development, particularly of the reflux type, is critical to the long-life reliable operation of parabolic dish/Stirling engine systems. The heart of a solar thermal dish/engine system is the subsystem that converts thermal energy into electricity: the engine generator. While the program does not directly support development of these converter subsystems, it provides testing and solarization support to industry.

1. 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.

Accomplishments

Analysis of off-design efficiency of molten-salt power towers performed

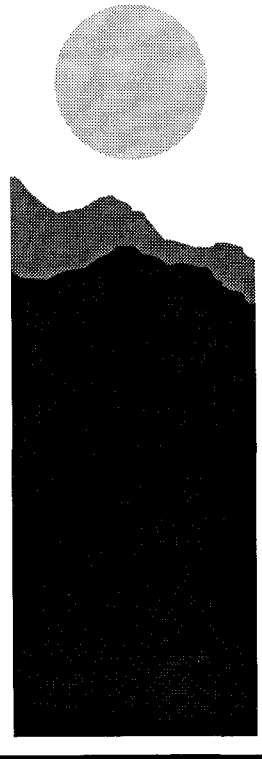
The design of a molten-salt power tower calls for the receiver outlet temperature to be 566°C. This temperature is the maximum that can be tolerated while preventing degradation of the molten salt. Conventional wisdom states that outlet temperature should be maintained at this highest possible point to maximize the thermodynamic conversion efficiency. However, because solar collection efficiency decreases as operating temperature increases (because of higher thermal losses in the receiver) and Rankine cycle efficiency increases as operating temperature increases, maximum conversion efficiency is determined by calculating the highest mathematical product of these two efficiencies. This phenomena was observed during operation of the Solar One Pilot Plant; operators claimed they could reduce receiver outlet temperature from 510°C to as low as 416°C without seeing any significant changes in daily energy output.

During the quarter, Sandia performed an analytical investigation to determine the effect that changing receiver operating temperature has on overall plant efficiency. The Solar Two power plant was selected as the basis of this study. A spreadsheet model of the receiver performance was combined with a detailed thermodynamic model of the Rankine cycle. The computer code called EASY, developed by the Center for Solar and Hydrogen Research (ZSW) in Germany, was used to calculate the efficiency of the Rankine cycle given a variety of receiver/storage temperatures. The results of the analysis indicate that daily plant efficiency is fairly constant over a temperature range between 490°C and 566°C. These following findings may have an impact on the design and operation of future power towers:

1. By reducing receiver outlet temperature, the lifetime of receiver panels can be extended.
2. Because useful energy can be delivered to the hot storage tank at a lower temperature than previously thought, losses during morning startup can be reduced.
3. A salt mixture with a lower maximum operating temperature and corresponding lower freezing temperature could be used.

It should be noted, however, that lowering the salt temperature below the maximum value has the disadvantage of decreasing the capacity of the thermal storage system. For example, if the hot tank temperature is reduced by 38°C, storage capacity is reduced by 20%.

The analysis was documented in a draft report. The findings will be used to develop a test at Solar Two to determine if the actual plant behaves like the analysis predicts.



Dual element heat trace testing continues

Testing of three sections of dual-element heat trace purchased from Raychem and installed

in the molten-salt flow loop at Sandia's National Solar Thermal Test Facility has begun to validate performance relative to single-element heat trace. The heat-trace sections have been installed on a relatively straight section of pipe, a valve bonnet, and a section with components that has a considerable number of bends. After almost three months of testing, there have been no failures or concerns.

Simple element freeze/thaw tests completed

Experiments have been completed to quantify damage inflicted to samples of receiver tubes under various freeze/thaw sequences. In molten-salt systems, components and piping can be damaged if the nitrate salt freezes and then is thawed. Unlike water, nitrate salt expands upon thawing. Depending on the conditions, there can be either no damage or complete yielding of the material. Considering that there are multiple drain valves in the receiver, the likelihood that a panel could fail to drain during nightly shut down is high over the life of the receiver. From previous panel freeze/thaw experiments, Sandia measured permanent strains as high as 4% after 2 cycles.

A two-chamber oven was used to test freeze/thaw methods. Salt was melted and frozen with this oven sequentially in upper and lower sections of each tube to measure permanent strain to the tube. Five series of tests were completed. The first four series were focused on understanding the freezing and thawing phenomenon and finding methods to mitigate damage. The most severe freeze/thaw cycle occurred when the salt in the lower part of a tube is frozen, followed by the freezing of the upper section, then the salt in the lower section is thawed followed by the thawing of the upper section. Sandia also found that if there is a free-liquid salt surface in a tube adjacent to a section that is frozen with salt, the salt will expand freely without the tube yielding when the frozen section is thawed.

In the fifth series, Sandia measured the damage to several representative receiver materials with a range of tube diameters and wall thicknesses under the most severe freeze/thaw conditions. Most materials ruptured after 10 to 16 cycles. The permanent strains at rupture varied between 13% and 25%. The implication of these results to the life of a receiver is that a certain amount of permanent strain must be accounted for in the design life of a receiver.

Sandia receives two best paper awards at the 1995 ASME/JSME/JSES International Solar Energy Conference

The 1995 American Society of Mechanical Engineers (ASME)/Japanese Society of Mechanical Engineers/ Japan Solar Energy Society International Solar Energy Conference was held in conjunction with the Thermal Engineering Conference on March 19-24 in Maui, Hawaii. There were 29 technical sessions with 156 papers in the Solar Energy conference from an international arena of authors. This year, Sandia received two best paper awards. The ASME Solar Thermal Power committee awarded James E. Pacheco, Mark Ralph, and James Chavez best paper among its five sponsored technical sessions for *Investigation of Cold Filling Receiver Panels and Piping in Molten-Nitrate-Salt Central-Receiver Solar Power Plants.* The ASME Testing and Measurement committee gave Richard B. Diver the best paper award for *Mirror Alignment and Focus of Point-Focus Solar Concentrators* from the two sessions it sponsored.

Hardware fabricated for transient freezing tests (cold-pipe fill tests)

Hardware was fabricated to validate a correlation between the distance a fluid can flow through a pipe that is below the fluid's freezing point and the effect of pipe-heat capacitance on the penetration distance. This information will enable us to determine the feasibility of using cold-start piping in a molten-salt central receiver plant. Cold starting can be an advantageous method for reducing parasitic power consumption.

The system consists of a 50-gallon ASME pressure vessel that will hold molten-salt and two 18-m vertical lengths of tubing (heat traced, instrumented, and insulated). This system will enable Sandia to (1) vary the pressure and flow rate in the vessel and (2) flow molten salt through tubing at several initial temperatures to measure how far the salt will travel through the tube before freezing the pipe closed.

Report on molten salt panel and component experiments completed

A report entitled *Results of Molten Salt Panel and Component Experiments for Solar Central Receivers: Cold Fill, Freeze/Thaw, Thermal Cycling and Shock, and Instrumentation Tests,* by James Pacheco, Mark Ralph, James Chavez, Sam Dunkin, Earl Rush, Cheryl Ghanbari, and Matt Matthews, was completed and published as a Sandia National Laboratories

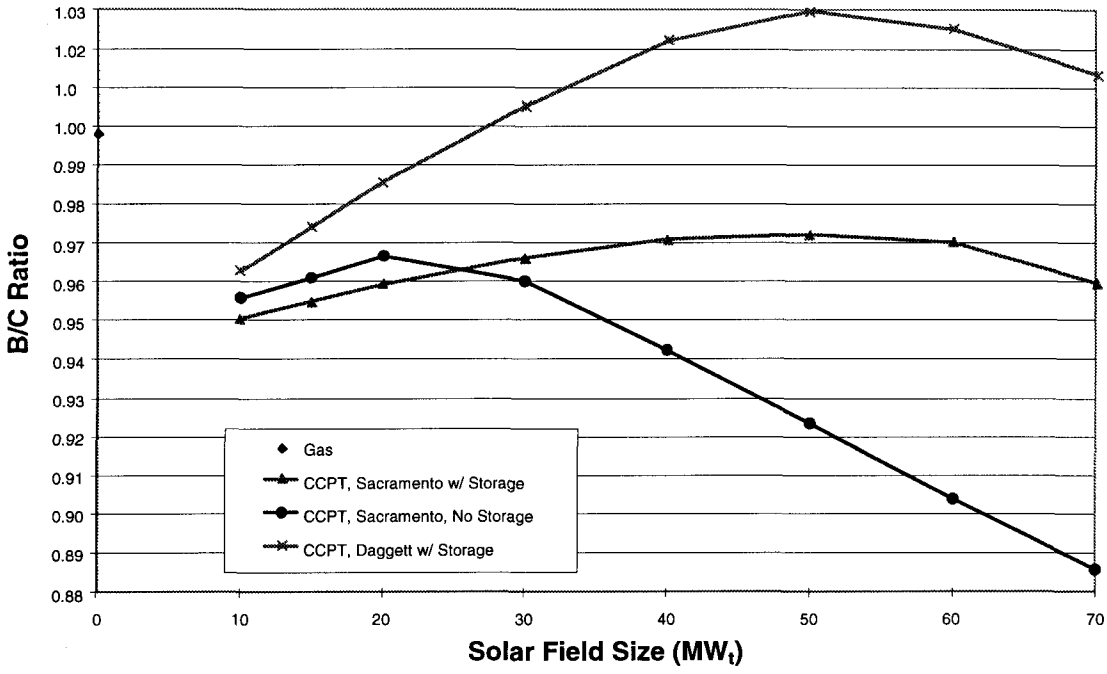


Figure 4. Benefit-to-Cost Ratio—Base cost assumptions with $250/m² heliostat.

report. This report summarizes tests done (1) to determine if a receiver can be started at temperatures below the salt freezing point, (2) to develop methods to recover from a freeze event in the receiver, and (3) to test several components, such as flanges and valves, and instrumentation, such as flowmeters and pressure transducers.

SMUD/NREL complete solar power tower study

The Sacramento Municipal Utility District (SMUD) and NREL have completed the Phase 1 study of a Combined Cycle/Power Tower (CC/PT) in the SMUD service territory. The CC/PT is a new solar thermal electric concept that offers the potential for very low energy cost, rapid commercialization, and expanded markets for power tower technology. The CC/PT uses conventional nitrate-salt power tower technology to provide combustion air pre-heating for a combined cycle gas turbine power plant.

Phase 1 of the study was a conceptual evaluation of a small (30-MW_e) commercial plant suitable for SMUD's Rancho Seco power plant site near Sacramento, California. Results of the study are extremely encouraging. The first plant could be built with solar hardware costs between $12 million and $38 million, and with a benefit-to-cost ratio near 1.

The study looked at various sizes of solar plants with and without thermal storage for plants located in Sacramento and Daggett, California. Figure 4 shows the calculated SMUD benefit-to-cost ratio for a range of solar plant sizes, configurations, and locations. For a Sacramento location, a 50-MW_t solar plant with thermal storage gives the best benefit-to-cost ratio. This configuration would have an annual solar fraction of 15% for a plant operating at a 90% capacity factor. This plant has a levelized energy cost for solar-generated electricity of 8.6 cents/kW_ehr.

The Sacramento Municipal Utility District reported the results of the Phase 1 study were significant because they showed the relatively low capital cost required to develop the technology. Also, the small size of the projects fits with the accelerating trend toward distributed utility resources and looks good as either a utility or independent power producer project. Because many utilities throughout the Southwest could gain solar power experience using this concept, the technology could prove to be the project that launches a U.S. solar industry. The Sacramento Municipal Utility District and NREL agreed to proceed with Phase 2 of the study, which will refine design parameters for the project and develop a commercialization pathway.

Hybrid presentation to Solar Two Commercialization Advisory Board

NREL staff gave a presentation to the Solar Two Commercialization Advisory Board (CAB) on March 24, 1995, on the subject of hybrid power towers. The CAB is considering hybrids as an alternate path for commercializing power tower technology and in particular as part of the SolarPlan study proposed by Bechtel. The NREL presentation covered the history of hybrid power towers, several methods of hybridizing power towers, and results of the recently completed Phase 1 SMUD/NREL study. The latter involved 30-MW_e plants using the NREL CC/PT Kokhala concept; the study showed the potential of the NREL concept for 10 times reduction in at-risk capital for the first power tower plants. Three utilities present (Arizona Public Service, Southern California Edison, and SMUD) confirmed the "small is beautiful" concept, presented at the NREL Hybrid Workshop last November, based on scarce capital and risk-adverse end-users. In addition, the idea of having multiple commercialization paths was embraced. Caution was expressed that "solar advocates" may respond negatively to design approaches that require the use of fossil energy. Proper packaging and presentation of hybrid concepts appears to be the correct approach. Response from the CAB was very positive, and Bechtel believes it has the go-ahead to proceed with the SolarPlan proposal preparation with emphasis on combined-cycle hybrid plants.

Planned Activities for Next Quarter

- Begin transient freezing tests.
- Continue tax-equity studies for Solar Enterprize Zone.
- Initiate Phase 2 of the SMUD/NREL CC/PT 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 Sacramento Municipal Utilities District service territory.	Jun 95	
Complete study of tax equity for state of Nevada.	Jul 95	
Complete testing of Solar Two heat trace.	Aug 95	
Complete testing of the 500-kW_t RAS internal molten-salt film receiver at the Plataforma Solar de Almeria.	Sep 95	
Complete the Transient Salt freezing in pipes and planned thermal cycling corrosion testing of stainless steels.	Sep 95	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	460	263	0	723
Contracts	390	81	0	471
Total	850	344	0	1194

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 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 the demonstration of reflux receiver technology on-sun at scales appropriate for current dish/Stirling projects and to directly compare the performance of a reflux receiver with a directly illuminated heater head through application to the Stirling Thermal Motors power conversion system 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

Successful testing of the Sandia/Porous Metal Products felt-wick technology has continued. On-sun testing has demonstrated short-term performance, while long-term testing has begun to demonstrate durability. Sandia tested a Cummins/ Thermacore 75-kW_t heat-pipe receiver to 115-kW_t throughput on Sandia's solar power tower, setting a new record for solar heat pipe throughput. Sandia began fabrication of two second-generation felt-wick heat-pipe receivers. Cummins Power Generation, Inc., is also fabricating two receivers of a similar design. Sandia is supporting materials and stress analysis and advanced receiver development for the joint venture programs.

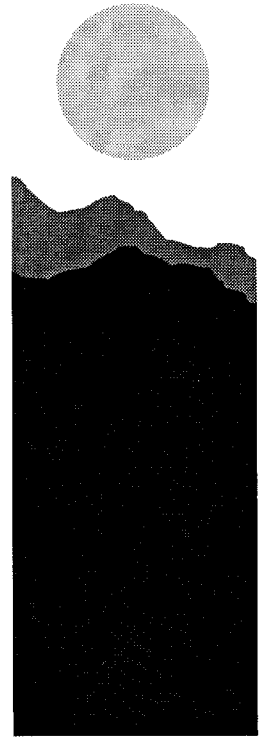
Cummins 75-kW_t heat-pipe receiver reaches 115-kW_t throughput on Sandia's power tower

Sandia successfully limit-tested the second-generation 75-kW_t Cummins/Thermacore heat-pipe receiver using the solar power tower at Sandia's National Solar Thermal Test Facility (NSTTF). The receiver throughput reached 115 kW_t before dryout occurred. This is a new heat-transport record for heat-pipe receivers, breaking the old record of 65 kW_t held by the same receiver on one of Sandia's two Test Bed Concentrators (TBCs).

The Thermacore 75-kW_t heat-pipe receiver was constructed under contract to Sandia for application to the STM 4-120 engine, and had a design operating point of 65-kW_t throughput. The receiver incorporates Thermacore's "bumpy powder" wick, Sandia-specified refluxing, and a redundant circumferential artery. The receiver was mounted on Sandia's solar power tower, and the heliostat field was used to simulate a large parabolic dish. The throughput was measured with gas-gap cold-water calorimeters. The throughput reached 115 kW_t, at which point a dryout was detected by thermocouples and Sandia's solar-blind infrared (IR) camera. The test was repeated the next day with similar results. Figure 5 shows the thermocouple data from the second test. The IR camera showed an extremely isothermal absorber dome up to the point of dryout.

This series of tests utilized many of the capabilities that Sandia has developed over the past few years. The receiver wick was modeled with Sandia's wick performance code, and 110- to 120-kW_t throughput was predicted prior to the test. Sandia optical codes were used to plan the heliostat control file to best simulate a dish. Instrumentation, primarily the solar-blind IR camera and the gas-gap calorimeters, was used to determine receiver performance and prevent damage to the receiver upon dryout. The receiver was initially tested on Sandia's TBCs to prove its operational status. The power tower tests provide a measure of the receiver design margin, an important capability that is unmatched at other facilities.

This test was also a significant test of Sandia's wick modeling capabilities. While the wick model predicted the measured performance almost exactly, the operation of a heat pipe at these power levels nearly doubles that of previous tests. The dryout occurred very near the predicted dryout power level and location. This goes a long way toward confirming Thermacore's claims that boiling in a non-uniform pore-size wick is beneficial to operation of the heat pipe.



Testing continues on the full-scale solar receiver with a felt metal wick

Felt metals are now being explored as a potential wick structure for a solar receiver. Felt metals are typically made with fine fibers

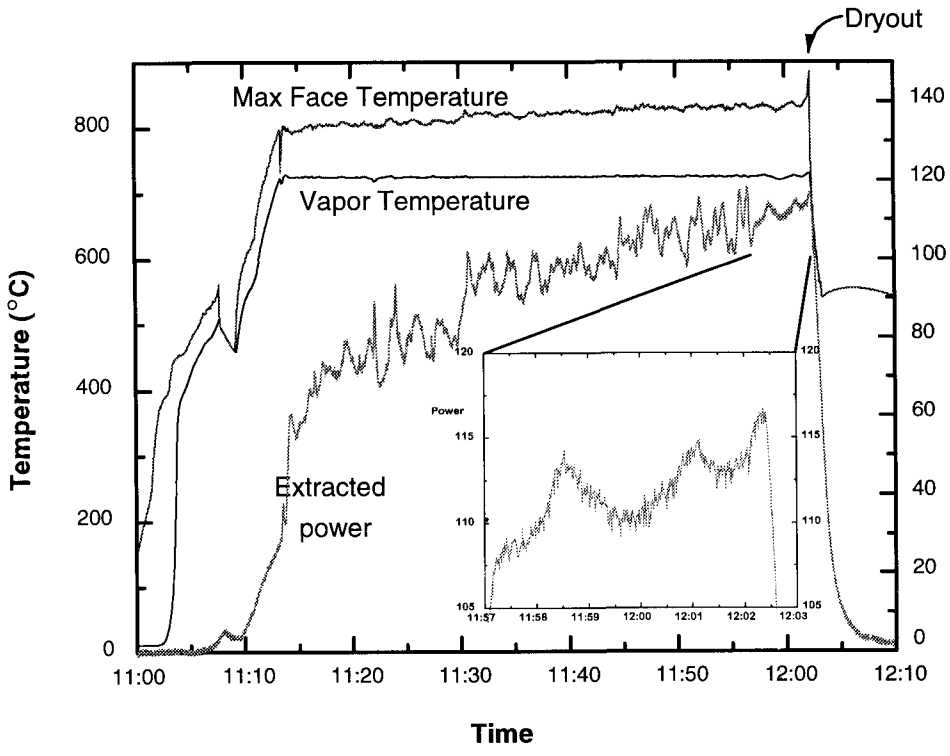


Figure 5. Temperature and power data from the tower test. The calorimeter controls maintain a constant vapor temperature, resulting in some oscillations in the power extracted. At about 11:55, control was switched to manual, smoothing out the power at the expense of some variation in temperature. The face temperature is measured with a brazed-on thermocouple, which runs slightly hotter than the actual surface. The dryout was centered on a surface thermocouple.

(≈4 to 10μm) that are loosely laid down to form a mat with a high porosity. Felt metals are commonly used in filtration applications.

In an unsintered state, felt metals are extremely pliable so they can easily conform to the shape of a receiver dome. A wick-covered dome provided by Porous Metal Products (PMP) in Jacksboro, Texas, and a condenser provided by DTX Inc. of Lancaster, Pennsylvania, were integrated by Sandia into a full-scale heat-pipe solar receiver. The receiver successfully completed a series of high-flux tests on a TBC at the National Solar Thermal Test Facility. The receiver previously operated at 50-kW power throughput through multiple power cycles and hot restarts, and withstood 40-kW_t start-ups from a frozen state. The maximum steady-state throughput power measured was 61 kW_t, which matched Sandia's wick simulation model.

Cummins is now performing durability tests on the felt-metal solar receiver in Abilene, Texas. To date, the system has performed flawlessly in Abilene. Test time has been limited by weather. The heat pipe has been tested approximately 300 hours, with 75 starts. The receiver throughput in Abilene has been approximately 26 kW_t.

Fabrication of second-generation Sandia felt-wick heat-pipe receiver

In the first quarter of FY95, a full-scale felt-metal wick solar receiver performed successfully on a TBC at the NSTTF. The felt for this receiver used a 4-micron diameter stainless-steel wire that was loosely formed into a high-porosity mat. The material is commonly used in filtration applications, but the tests at Sandia demonstrated that this felt can perform well as a wick in a liquid-metal heat pipe.

A second-generation felt-wick heat-pipe receiver was designed to increase power throughput while improving manufacturability. The receiver dome

angle was reduced from a full hemisphere to a 70-degree half-angle, reducing materials and aiding in the application of the wick. The weld ring was removed, reducing the stresses at the rim. Refluxing was incorporated to increase receiver throughput. The Sandia wick model predicts a maximum receiver throughput of about 130 to 140 kW_t, without the use of arteries.

A contract was placed with PMP to fabricate the wick onto the dome and weld the aft support dome to prevent wick damage during shipping. Domes for two receivers and one scrap were procured. The design of the supports and ducting to connect to the STM 4-120 engine were completed, and the aft support domes were machined to accept the ducts. A fixture was fabricated for locating the reflux ducts on the wick.

Sandia will fabricate two second-generation receivers. The first will be for proof-of-limit testing, both on the TBC and the power tower. The second will be integrated with the STM 4-120 engine to demonstrate the improvements in performance over the direct insolation receiver (DIR) system currently in use. In addition, Thermacore is purchasing two absorber/wick assemblies from PMP, which will be incorporated into its small-scale systems for bench and on-sun testing. The Thermacore receivers will use the same absorber and wick design as the Sandia receivers.

Bench-scale durability tests of metal felt-wick materials

Work that was performed at Hughes Aircraft Company back in the late 1970s showed that felt metals degraded little in a high temperature liquid-metal (700°C potassium) environment after 10,000 hours of operation. While this early work indicates that felt-metal wicks are durable, it is unknown if felts can withstand operating in a solar application. Frequent thermal cycles and higher operating temperatures in a sodium environment may cause the structure of the wick to degrade over time. The felt that was tested at Hughes also had a wire diameter of roughly 10 microns.

Two bench-scale heat-pipes have been constructed to determine the durability of felt-metal wick materials in a liquid-metal environment. One system was built to study freeze/thaw cycling on the wick structure and the second pipe was built to study long-term continuous operation at elevated temperatures and high flux levels.

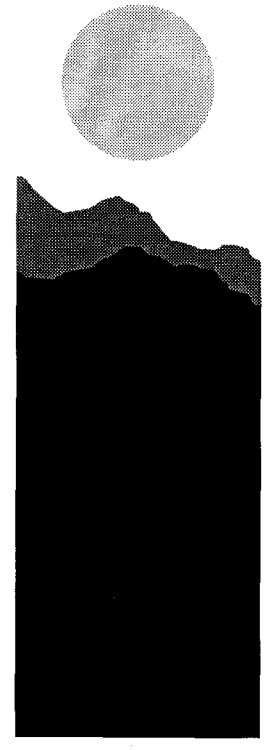
The density of sodium decreases as it melts from a frozen state. There are concerns that freezing and thawing of sodium in the wick could cause the fine wires (4-micron diameter) of the wick to ratchet apart and away from the absorber wall after a few thousand cycles. In the freeze/thaw test pipe, a sodium-saturated felt wick structure was subjected to 13,000 frozen start-ups over the course of a month. A high-flux (60-W/cm^2) quartz lamp system was used in the system to simulate the thermal gradients across the wick that can be expected in a full-scale system. After the 13,000 cycles, sodium was distilled from the pipe and the pipe was cut open. An examination revealed the thickness of the wick decreased to 4 mm from an initial thickness of 5 mm. This change in the thickness was opposite of what was anticipated, but reduction may have been caused by the initial introduction of sodium to the wick. Even with the reduced thickness, the wick would still meet the anticipated long-term requirements of a full-scale solar receiver.

The bench-scale heat pipe for studying long-term durability is still under construction. The first unit that was constructed for this purpose was damaged during the closure weld. Welding problems have been rectified, and fabrication of a second unit is almost complete. Testing on the second unit will begin in late April or early May 1995, and it will continue for at least 10,000 hours.

Absorber buckling analysis for reflux receivers

An effort is underway to accurately determine the buckling pressure of real reflux-receiver absorbers. Significant improvements in cost and reliability will accrue if the results indicate that a pressure-relief safety device is not necessary.

In the last report period, buckling analysis for the second-generation pool-boiler receiver was performed, and plans were completed for up to two tests to verify the room-temperature predictions. In the present period, the buckling analysis has been documented in a memorandum report. One of the test articles is partially completed, having been cut out of the second-generation pool-boiler receiver after draining the NaK and steam cleaning the receiver.



Nickel wick mechanical properties

This work is in support of (1) Sandia's collaboration with Thermacore to develop a 75-kW_t heat-pipe receiver and (2) the Dish/Stirling Joint Venture Program. The determination of strength requirements of a Thermacore-type thick nickel wick awaits completion of fatigue tests. Complications in placing the contract with the testing lab have delayed this effort.

A spherical-powder nickel wick receiver from Thermacore that has been on-sun tested at Cummins' Abilene facility for approximately 2,000 hours is being metallurgically examined. After draining and removing sodium residue by vacuum distillation, the receiver was sectioned. A powdery scale was found on the wick surface. The scale is distributed along the wick-model-predicted locus of liquid-sodium stagnation points. Wick cracking was also found, generally widespread, but particularly concentrated where the scale was. Measurement of wick pore size and permeability, and chemical and metallurgical analyses, are underway.

Alkali-metal compatibility of nickel alloys in reflux receiver environments

The compatibility of nickel alloys with alkali-metals in reflux receivers has been addressed by a few long-term studies, including Sandia's successful 7,500-hour bench-scale pool-boiler test of Haynes Alloy 230, Thermacore's ongoing nickel and nickel-aluminide capsule tests, and capsule tests conducted under the Advanced Stirling Conversion Systems program. These last tests were completed but not fully analyzed. Of particular current interest are some capsules that included Iconel-alloy 625. Negotiations have been completed to obtain these artifacts for metallurgical analysis. The artifacts have been obtained from Stirling Technology Company and metallurgical analysis at Sandia has begun.

TBC re-lustering

The mirror facets on TBC-1 have now been re-lustered. The lustering process consists of bonding a new mirror to the existing TBC facet with a high-strength adhesive tape. During the previous quarter, this process had been completed. However, after being exposed to the weather for several weeks, many bubbles started to appear on the facet surfaces. It appeared that the adhesive was not sticking well to either or both of the mirror surfaces. Further investigation indicated the bond strength of the adhesive tape is highly dependent on the ambient temperature. In contrast to the TBC-2 facets that had been previously re-lustered, these facets had been re-lustered in a building that was significantly cooler. This issue was resolved by removing and vacuum-bagging the facets and placing them in an environmental oven for two hours. All the facets are now back on the dish. Calorimetry will begin within a week.

In addition, Sandia repaired approximately 75 facets on TBC-2 that had been damaged by the severe storm at the test site in August 1994. Calorimetry will also be performed on this dish.

TBC elevation failure protection

During the last year, there has been an effort to design a system that will protect the TBCs from an elevation drive failure—a failure in this system will cause the dish to rotate downward about the elevation axis and crash down onto its support structure because of the unbalanced moment.

The protection system is essentially a large shock absorber that parallels the elevation ballscrew. Under normal conditions, the fluid in the shock absorber is moving so slow that there is no additional load on the drive system. However, in the event of a drive failure, the speed of the dish rotation will be significantly reduced though the damped action of this shock absorber.

At this point, the design is complete and all parts have been ordered. Fabrication of the pieceparts has been started. Sandia expects to complete the installations on both dishes in the next quarter.

Science and Technology Alliance Graduate Research Assistantship Program startup

Meetings at Sandia and at North Carolina Agricultural and Technical State University (NCA&T) have resulted in the Graduate Research Assistantship Program under the DOE's Science and Technology Alliance. This program will enable Masters and Ph.D. students from NCA&T to do their thesis projects at Sandia. The first student candidate and her co-advisors at Sandia and NCA&T met with Sandia personnel in January to work out the details on the research to be conducted. The student is scheduled to be at Sandia for approximately three months beginning in late May.

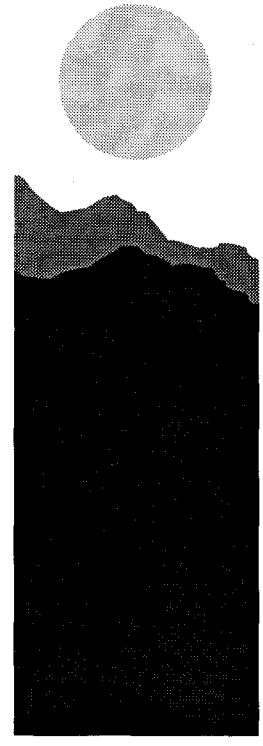
Hybrid receivers

Stirling Technology Company continues the installation of its hybrid pool boiler receiver in preparation for a series of detailed performance tests. During the past quarter, these preparation activities include installation of a system for charging/removing noncondensible gases, modification of the radiant lamp system, and the installation of additional burner and recuperator thermocouples, modification of burner software, and installation of the exhaust gas analyzer. Performance testing is scheduled to begin early next quarter.

Cummins Power Generation, Inc., successfully completed ground testing and preparations for on-sun testing of its hybrid heat-pipe receiver this quarter. Ground testing included 47 hours in the gas-only mode and 18 hours in the simulated hybrid mode (natural gas plus radiant lamps) for a total of 65 hours of operation. Orientation angles of 30, 60, and 75 degrees from stow, as well as the stow position, were tested. Maximum heat delivery to the calorimeter in the gas-only mode was 20 kW_t and in the hybrid mode 33 kW_t. These maximums were achieved at all receiver orientations. The low heat delivery for the gas-only mode is a result of the lack of a combustion air preheater. Cummins reported that the receiver was mounted on its concentrator in Abilene, Texas, on March 31 in preparation for starting on-sun testing. The testing was delayed for two days because of weather conditions, but Cummins has since carried out the tests, which were successful.

Planned Activities for Next Quarter

- A long-term high-temperature durability test of a felt-wick specimen will begin. The test is expected to continue for more than 1 year or 10,000 hours.
- Fabrication will be completed on two second-generation Sandia felt-wick heat-pipe receivers. One receiver will be outfitted with calorimeters, and testing is expected in June. The second receiver will be integrated with the STM 4-120 engine and testing is expected to begin in early July.
- Cummins will continue to test the first Sandia felt-wick heat-pipe receiver in Abilene, Texas, as dish availability permits. In addition, operation of complete systems in Abilene will continue to accrue hours on full-scale heat-pipe receivers.
- Sandia will perform post-test analysis of the Cummins artery-free heat-pipe receiver and failure analysis of the Cummins lamp-test durability heat-pipe receiver.
- Sandia will complete reports on the durability bench-scale pool boiler.
- Room-temperature fatigue life for the Thermacore thick nickel wick will be determined.
- Experimental verification of buckling analysis for the second-generation pool-boiler receiver will be conducted.
- Metallurgical analysis of alkali-metal capsule-test artifacts will be conducted.
- Sandia's hybrid-receiver-development support program for the USJVP will be formulated.
- Sandia will collaborate with the NCA&T masters student in the Graduate Research Assistantship Program.
- Sandia will continue supporting receiver development for the joint venture programs. This includes product improvement for the DSJVP with Cummins, advanced heat-pipe design for the Cummins USJVP, and DIR and heat-pipe design support for the SAIC USJVP.



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 *Expected Apr 95.*	
Begin testing of a durability bench-scale, felt-wick receiver.	Mar 95 *Expected May 95.*	
Complete planned TBC testing of a high-powered, felt-wick heat-pipe receiver.	May 95	
Complete integration and initial on-sun testing of the STM Power Conversion System with a heat-pipe solar receiver.	Jul 95	
Complete controls and safety upgrades of TBCs.	Sep 95	

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	1050	208	0	1258
Contracts	450	175	0	625
Total	1500	383	0	1883

3. DISH CONVERTER SOLARIZATION

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

Accomplishments

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

Brayton cycle power conversion system

A project is currently underway with Northern Research and Engineering Corporation (NREC) to solarize and test a Brayton cycle power conversion system (see Figure 6). The project builds on the highly successful co-generation (TURBOGEN) system developed by NREC with funding from the Gas Research Institute (GRI) and Southern California Gas. The German Aerospace Research Establishment (DLR) will supply a volumetric solar receiver for the PCS. The project has been structured for execution in two phases. Phase 1 was a technical and economic feasibility study to determine the system's potential for commercialization when mated with a point focus concentrator. A decision point was built into the project at the end of Phase 1. If the technical characterization or the economic study indicate that the system is not viable for solar use, Sandia had the option to terminate the contract before hardware is fabricated (and most of the project cost is incurred). Phase 2 will include the design, fabrication, and on-sun testing of a 30-kW_e Brayton PCS. The result will be a fully evaluated Brayton system that could potentially be used in the Utility Scale Joint Venture Program.

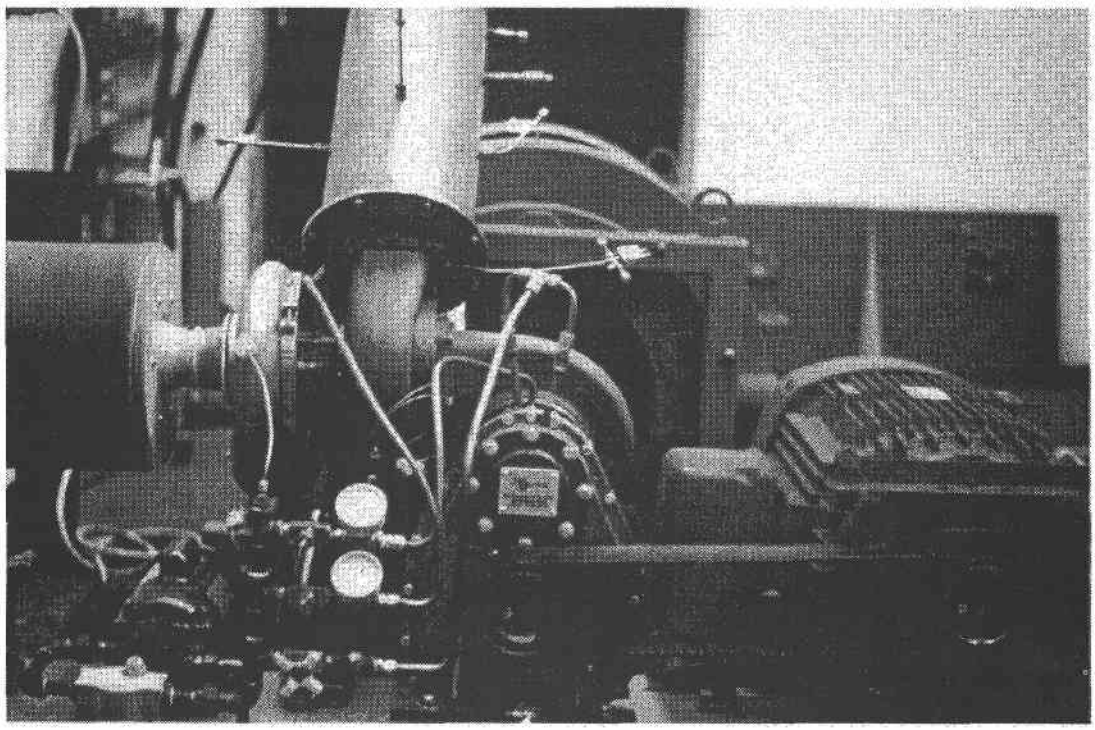


Figure 6. NREC's Brayton engine developed for the Gas Research Institute.

Phase 2 of the project continued this quarter. NREC is continuing the detailed design of the Brayton PCS. Included in the design work that has been done to date, the regenerator design has been finalized and the regenerator fins are being manufactured in conjunction with the fins for NREC's 60-kW_e GRI engine. Additionally, the turbocharger components that will go into the 30-kW_e solarized engine have been identified and ordered. Design of the combustion chamber, which will be used for hybrid operation, is nearing completion. NREC has also been interacting with DLR to provide interface details between the engine and solar receiver.

Stirling cycle power conversion system

Phase 1 of a cost-shared project with Detroit Diesel Corporation and its subcontractor, Stirling Thermal Motors, is complete. This project (see Figure 7) consisted of integrating a 25-kW_e Stirling engine (an upgraded STM 4-120) with a direct illumination receiver, an engine cooling system, an induction generator, and an engine control system into one package. This integrated package is called a power conversion system.

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

Testing of the PCS was done in three phases. Phase 1 consisted of system checkout and debugging. Power and temperature levels started out relatively low (600°C). Two of the specific objectives of this phase were to verify control stability and to verify a reasonable temperature distribution on the direct insolation receiver (DIR). An infrared camera system was used to view the receiver's temperature distribution. For this reason, the 220-mm aperture was removed. This removal increased thermal losses tremendously, but allowed a full view of the receiver during the shakedown tests. The infrared system was a great asset in the tests. After all personnel involved were satisfied with the tests, the 220-mm aperture was reinstalled and the engine operated at full input power.

Phase 2 consisted of performance mapping the PCS. Power output, PCS, and system efficiencies were mapped as a function of power input (mirror area) and receiver temperature. Phase 2 was completed last quarter.

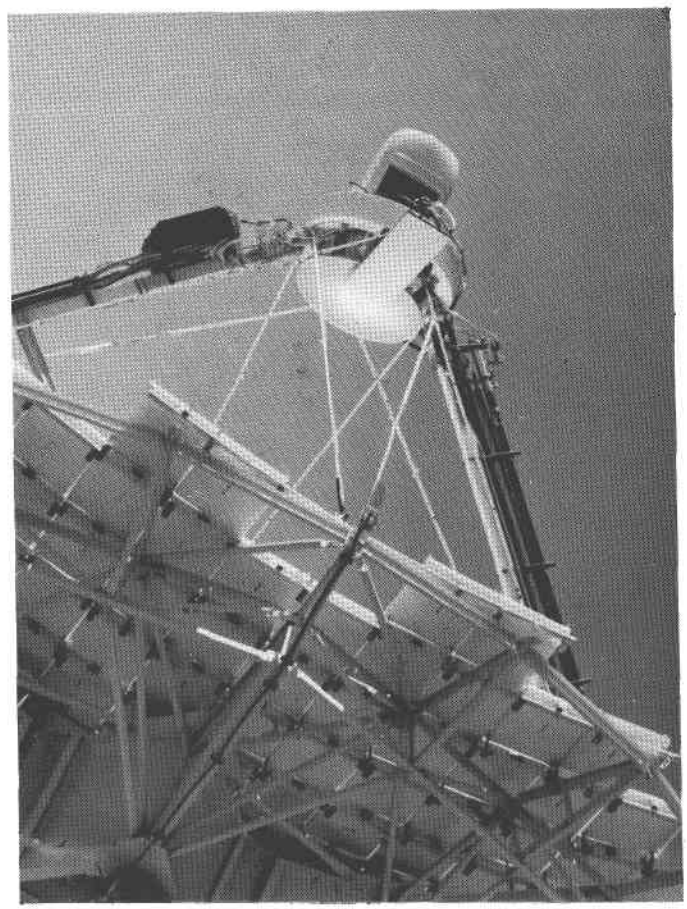


Figure 7. STM/DDC power conversion system testing at Sandia's National Solar Thermal Test Facility.

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

Because of time and resource limitations, Phase 3 of the project was eliminated. However, in cooperation with the Science Applications International Corporation USJVP, two additional tests will be carried out. First, the engine will be tested with hydrogen rather than helium as the working fluid. This change should enhance engine performance. Second, the engine will be tested with a heat-pipe receiver as reported in Section II.B.2.

The next tests that occur with the Stirling Thermal Motors PCS will be performed after the DIR has been replaced with a heat-pipe receiver. The heater head used with the heat pipe is similar to the gas-fired heater head, and it is anticipated that this testing will clarify whether or not the difference in the engine performance when tested with the DIR and gas-fired heater head are a result of the difference in the heater head geometries.

Planned Activities for Next Quarter

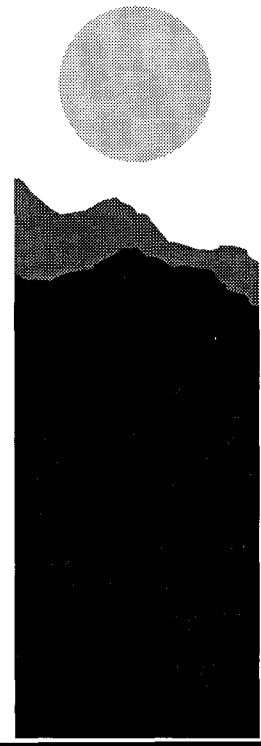
- Continue design of the NREC/DLR Brayton system and begin component procurement.
- Complete final report on the Detroit Diesel Corporation/Stirling Thermal Motors PCS development, design, fabrication, and bench-testing.

Major Milestones

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

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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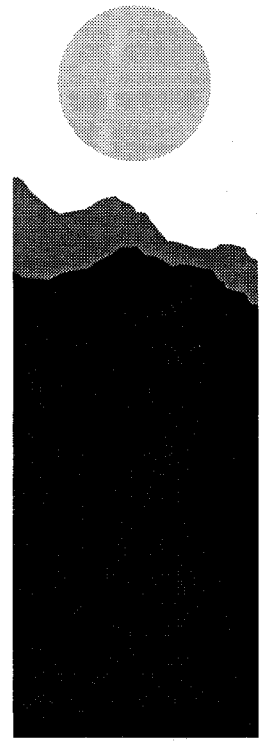

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