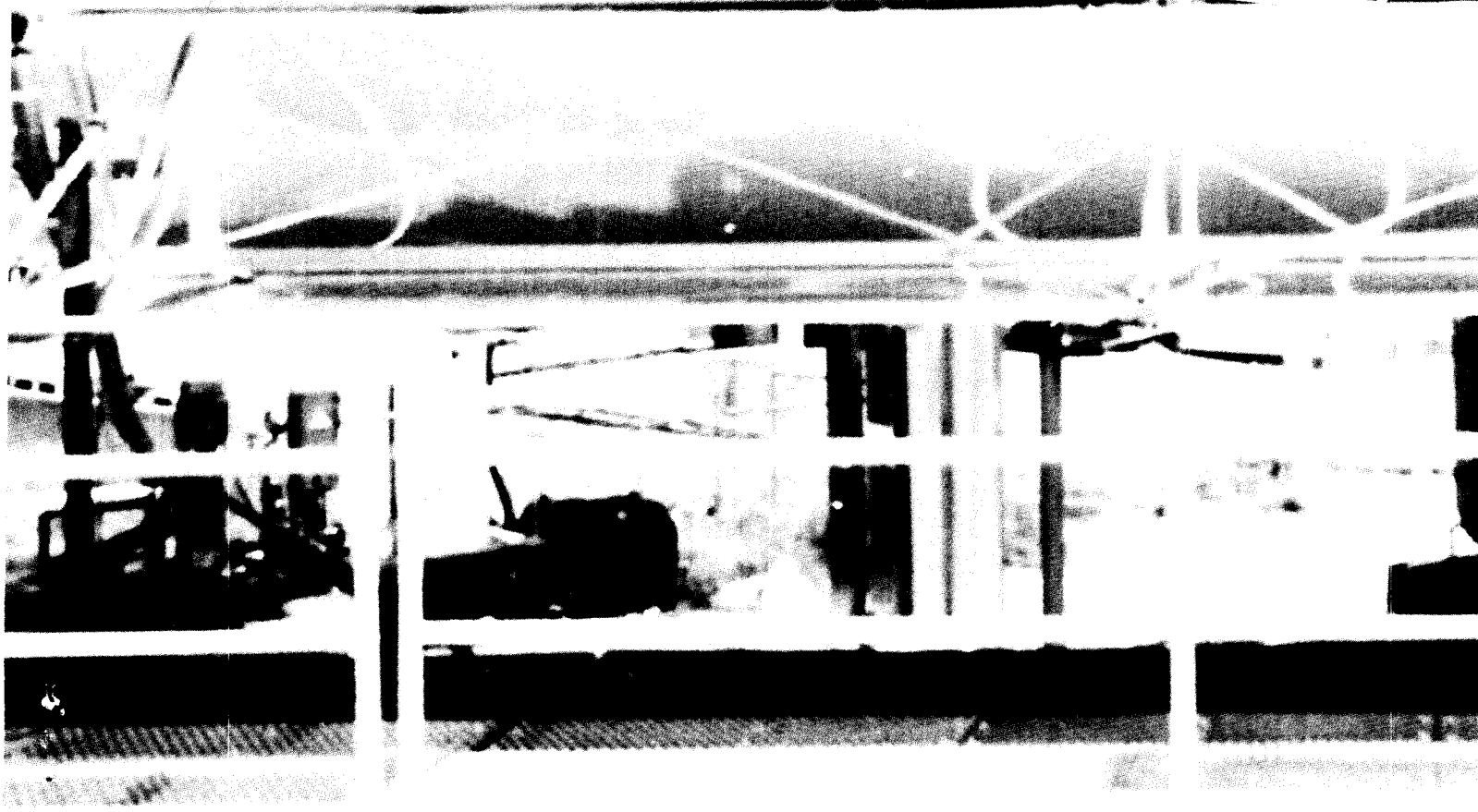
STDAC

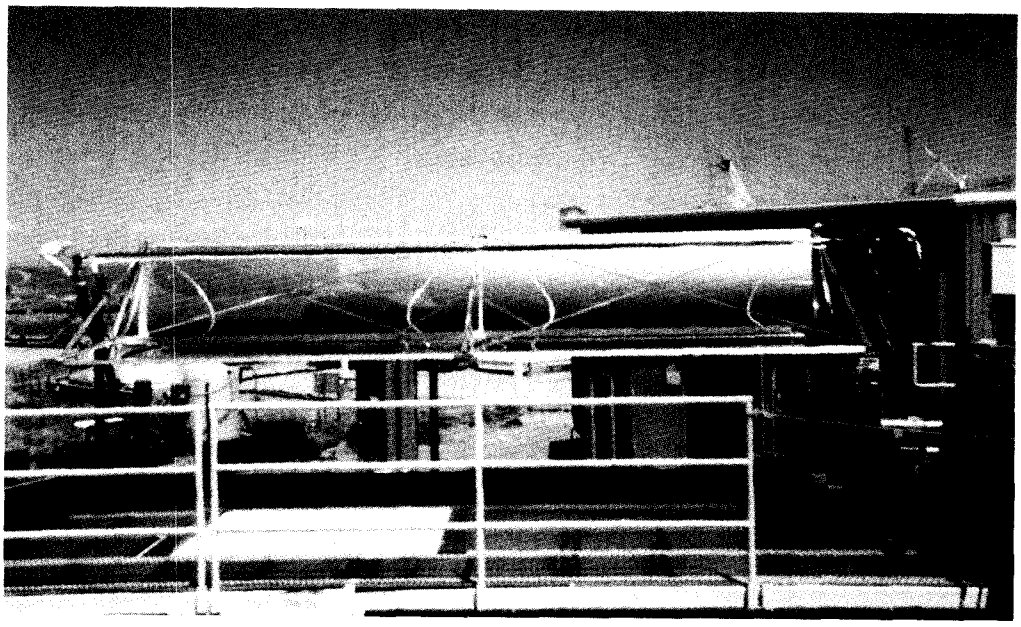
solar thermal design assistance center

Annual Report

fiscal year 1994



Department of Energy and Sandia National Laboratories



IST Parabolic Concentrator mounted on the AZTRAK platform at the National Solar Thermal Test Facility, Sandia National Laboratories, Albuquerque, New Mexico.

Introduction

The Solar Thermal Design Assistance Center (STDAC) at Sandia National Laboratories (SNL) is a resource provided by the US Department of Energy's (DOE's) Solar Thermal Program. The STDAC's major objective is to accelerate the use of solar thermal systems by

- providing direct technical assistance to users in industry, government, and foreign countries;
- cooperating with industry to test, evaluate, and develop renewable energy systems and components; and
- educating public and private professionals, administrators, and decision makers.

This fiscal year 1994 (FY94) report highlights the activities and accomplishments of the STDAC.

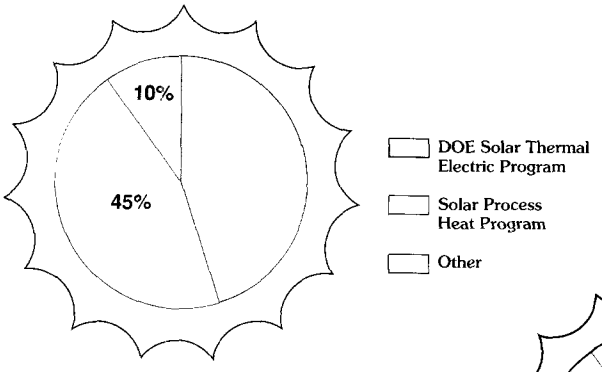
In 1994, the STDAC continued to provide significant direct technical assistance to domestic and international organizations in industry, government, and education. Applying solar thermal technology to solve energy problems is a vital element of direct technical assistance. To this end, the STDAC provides information on the status of new, existing, and

developing solar technologies; helps users screen applications; predicts the performance of components and systems; and incorporates the experience of Sandia's solar energy personnel and facilities to provide expert guidance on design and installation. By providing services upon request, the STDAC directly enhances the United States (US) solar industry's ability to successfully bring improved systems to the marketplace. By collaborating with Sandia's Photovoltaic Design Assistance Center (PVDAC) and the National Renewable Energy Laboratory (NREL), the STDAC is able to offer each customer complete service in applying solar thermal technology.

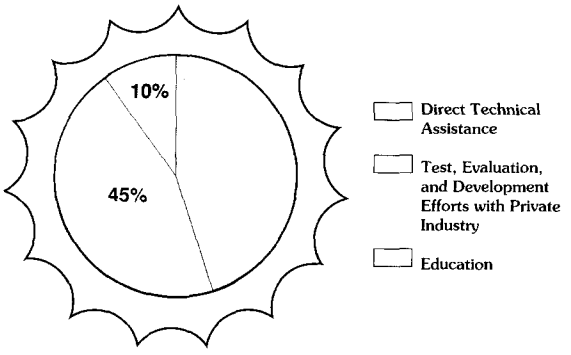
Evaluations are conducted in close cooperation with manufacturers, who in turn benefit from the improved design, economic performance, and operation of their solar thermal technology.

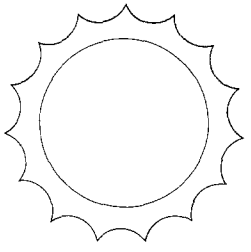
At the National Solar Thermal Test Facility at SNL, the STDAC tests and evaluates new and innovative solar thermal technologies. Evaluations are conducted in close cooperation with manufacturers, and the results are used to improve the product and/or quantify its performance characteristics. Manufacturers, in turn, benefit from the improved design, economic performance, and operation of their solar thermal technology. The STDAC provides cost sharing and in-kind service to manufacturers in the development and improvement of solar technology.

Funding for the STDAC in FY94 Totaling $1.5M



Allocation of STDAC Resources

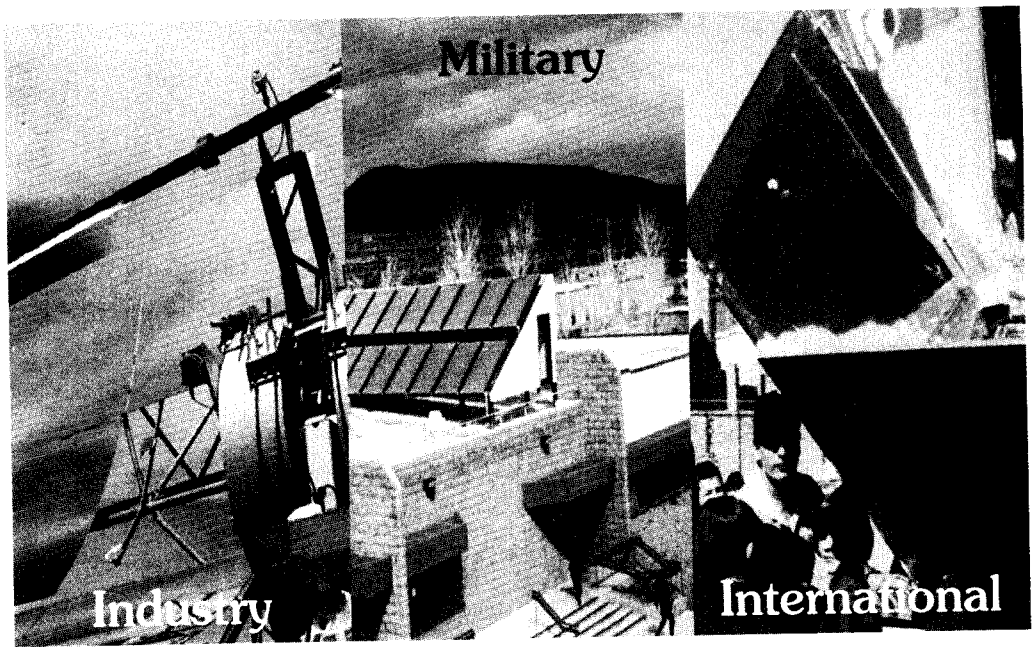




Funding and Personnel

Many of the STDAC activities reported here are supported by (1) the Solar Thermal Electric Program, (2) the Solar Thermal Industrial Program, or (3) both programs. The DOE Office of Technology and Financial Assistance (OTFA) and Sandia's Technology Transfer and Educational Outreach Programs provide additional resources. Information about activities for both the Solar Thermal Electric and Solar Thermal Industrial Programs are reported together for completeness and in recognition that boundaries are often not distinct within each activity.

Funding for the STDAC in FY94 totaled about $1.6M with about 45% from the DOE Solar Thermal Electric Program; about 45% from the Solar Process Heat Program; and about 10% from other sources including OTFA, reimbursables from the Department of Defense (DoD) and internal Sandia programs. The STDAC funds are allocated to these three areas in the following proportions: direct technical assistance (45%); test, evaluation, and development efforts with private industry (45%); and education (10%). STDAC personnel include 3 full-time engineers and 5 part-time engineers and technicians for a total of about 6 full-time equivalent engineers.

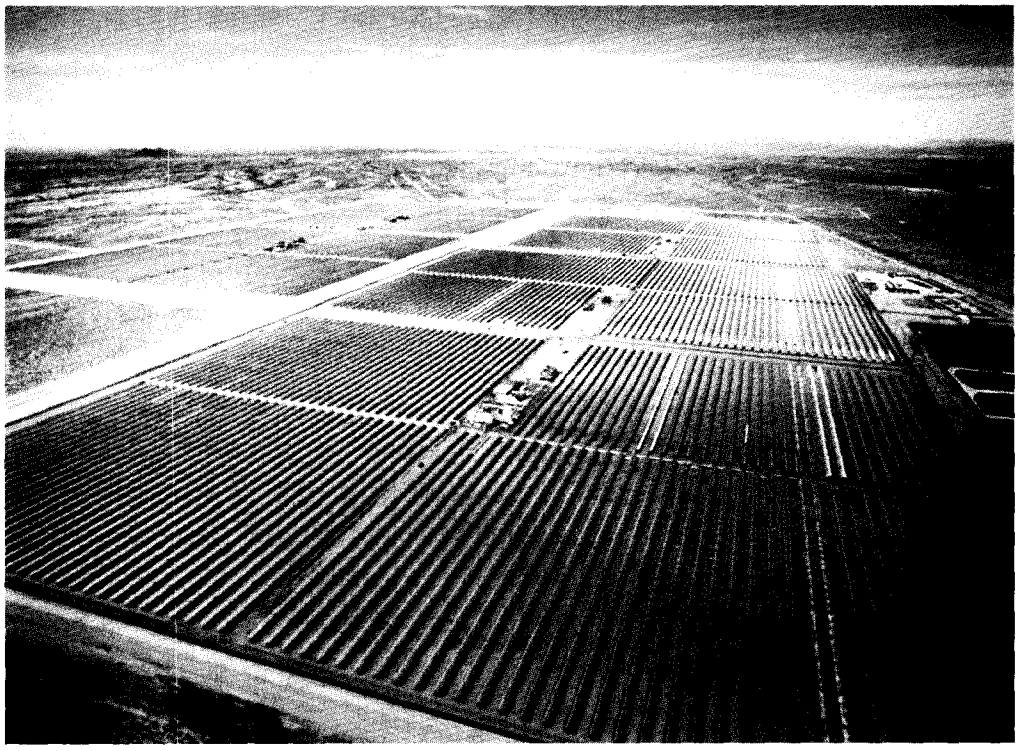


Direct Technical Assistance

The STDAC provides technical services to industry, government agencies, and end users by installing new solar fields and refurbishing existing fields. The services that the STDAC performed during FY94 in the direct technical assistance area are described in detail in this section along with plans for continued service during FY95.

This year, STDAC engineers assisted SEGS operators by investigating the cause of degrading heat collection elements (HCEs) and the quality of the parabolic collector tracking and mirror alignment. STDAC engineers discovered that deposits of molybdenum dioxide (MoO_2) caused the performance of the heat collection elements to degrade by reducing the amount of sunlight that reaches the receiver tube. Engineers are currently investigating what conditions lead to MoO_2 deposits so that a preventive strategy can be developed. This particulate residue reduces the solar transmittance of the envelope and consequently the thermal performance of the heat collection elements. The affected heat collection elements

fluoresce during on-sun tracking. The chemical composition of the residue will determine what solvents (if any) can be used to clean the interior of the tube without significantly degrading the absorber. Environment, safety, and health concerns will also be addressed.



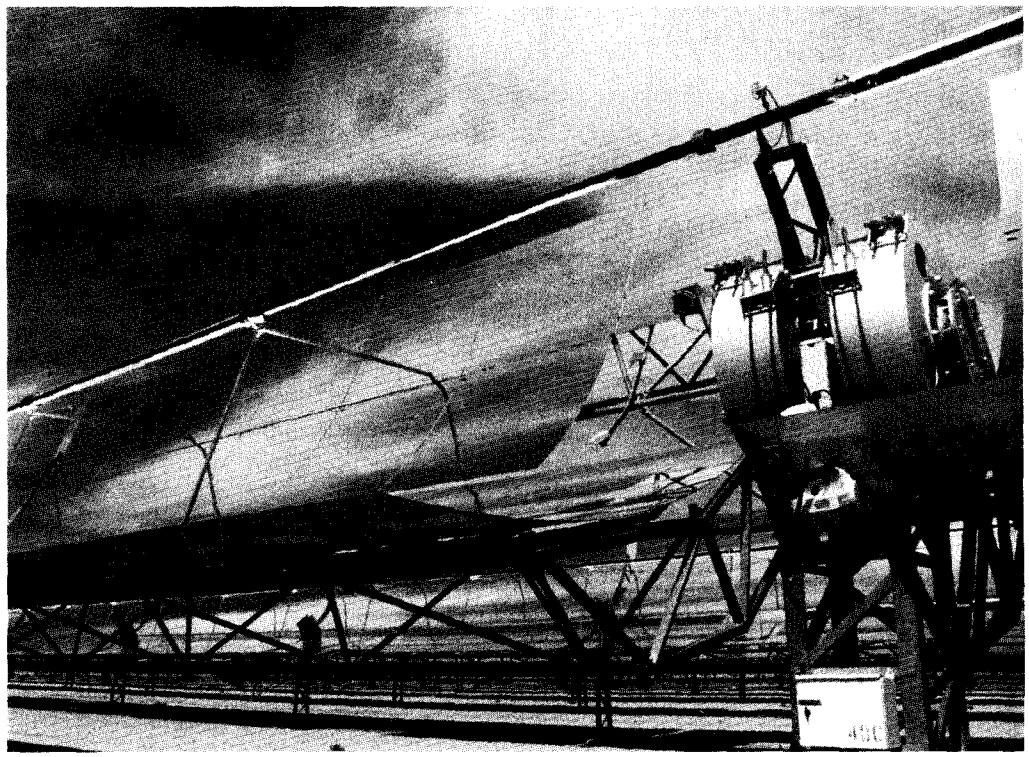
Aerial view of SEGS III through VII, Kramer Junction, California.

In the Landers earthquake of 1993, SEGS I and SEGS II facilities sustained significant damage that caused a loss of reflective surface. When Industrial Solar Technology (IST) personnel learned that original equipment manufacturers could not provide replacements for the damaged mirrors, IST and STDAC engineers collaborated to develop replacement mirrors. IST developed a prototype LS-2 replacement facet and delivered it to SEGS V for environmental tests. So far, replacement facets are performing well in the field tests, and the STDAC has future plans to assess the cost of producing the facets in a minimal number and subjecting them to longer-term testing in the field. These new facets are constructed of two pieces of aluminum sheet metal sandwiched around a phenolic resin-impregnated paper-based honeycomb substructure. 3M's ECP-305 silvered polymer reflective film is used as the reflector. The edges are sealed with a polymeric caulk. These new facets are designed for superior strength compared to the glass facets with about half the weight. After the facets were developed, Sandia tested them. The environmental tests were to determine how well the polymeric seal protects the substructure from moisture, which could destroy structural integrity. The tests, which were performed in one of Sandia's environmental chambers, involved extreme temperature and humidity cycling over a 6-week period. Cycling conditions ranged from -40°F to 150°F with relative humidity

When IST personnel learned that original equipment manufacturers could not provide replacements for the damaged mirrors, IST and STDAC engineers collaborated to develop replacement mirrors.

ranging from near 0% to about 95%. The tests were developed in cooperation with IST, Daggett Leasing Corporation (DLC), Kramer Junction Company (KJC), and Sandia, and closely resemble the acceptance tests LUZ Corporation used for the original mirror facets.

In another important project, the STDAC is providing technical assistance to UC Operations Services, the operators of the Harper Lake SEGS north of Barstow, California. The STDAC is solving operational problems and increasing the plant's profitability. Problems include identifying misalignments with the mirror facets and the solar collection assemblies (SCAs) leaking bonnet gaskets on some of the valves, broken and discolored receiver envelopes, ram pins that are dislodging from the drive rods, flexhose failures, oil freezes, wind damage, and excessive time required to measure mirror reflectivity. Because of STDAC's work at Kramer Junction and IST's Tehachapi system, it was possible to immediately address some of these problems without violating any of the existing proprietary information agreements with these two organizations. For example, the STDAC informed Harper Lake of the success at Kramer in replacing flexhoses with ball joints and provided Harper Lake with the specifications for the ball joints. The STDAC also discussed techniques for preventing oil freezes and bonnet leaks and loaned UC Operations a newly developed reflectivity measuring device for trial on the Harper Lake site. Other problems will involve a small amount of investigative effort on the STDAC's part. For example, Harper Lake SEGS will send the STDAC some of the broken ram pins and discolored receiver envelopes. The STDAC will then examine the pins and envelopes and suggest solutions.



SEGS parabolic trough collector field located in southern California. The nine SEGS plants, located in this region and covering hundreds of acres, use line-focus concentrator technology to generate over 350 MWe to supplement the electrical demands of the area.

While earthquakes can cause damage to solar structures, most damage is caused by high winds. Wind-induced mirror breakage along the peripheries of the SEGS IX solar field is a growing problem at Harper Lake. Unlike the SEGS facilities in Daggett and Kramer Junction, the plants at Harper Lake do not have a perimeter wind fence. The STDAC performed a literature search of wind screens and investigated whether stowing procedures could be altered to mitigate further damage. Several suggestions were provided to the operators. The STDAC may cost share the tests of some of these suggestions.

The STDAC is working to develop a simple technique to detect misalignments, which involves flying over the field and videotaping or photographing the image.

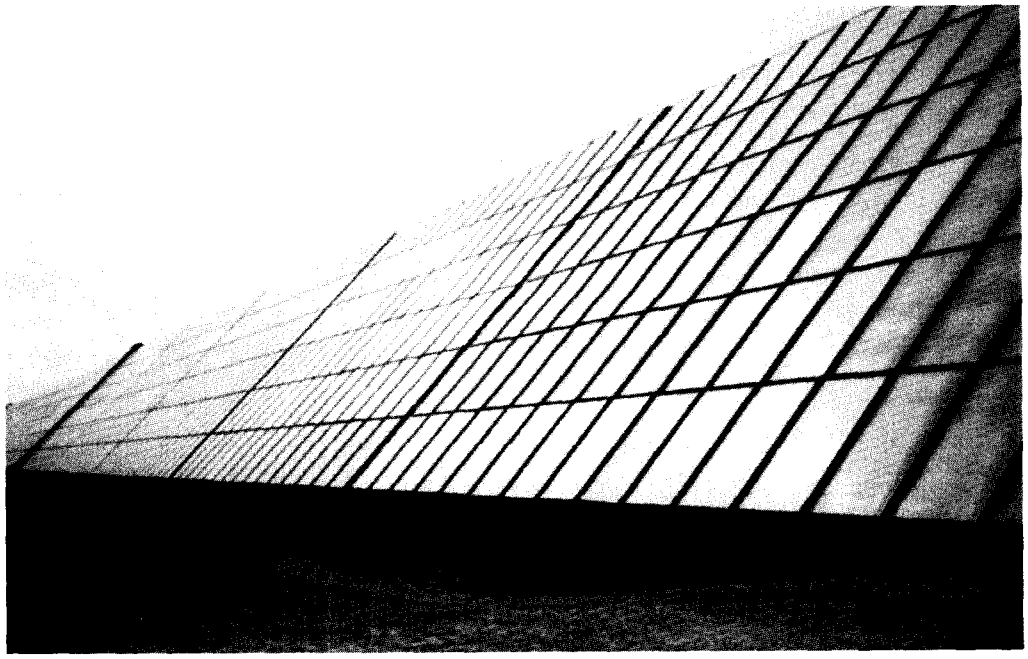
One of the more significant problems at the SEGS plants involves misalignments of the mirror facets and the SCAs. These misalignments cause some of the sunlight to miss the receiver and reduce energy output and revenues. The STDAC is working with Daggett Leasing and the other SEGS operators to develop a simple technique to detect misalignments. This new technique involves flying over the field and videotaping or photographing the image. An aerial flyover of the SEGS fields during operation is being organized to assess the problem. By observing the illuminated receiver of the collector from the appropriate flying altitude, a qualitative measure of collector alignment can be obtained. A commercial vendor has been selected for a video shoot using a helicopter, a gyrostabilized camera mount, and broadcast-quality video equipment. The images should contain visual evidence of misalignments. STDAC will test this technique sometime in spring 1995 at the Daggett Leasing field, and the results will be shared with all the plants.

In 1991, high winds damaged some of IST's solar collectors at Tehachapi, California. STDAC engineers used the Algor finite element model to develop a working model, which suggested that welds used to connect external support bars to module frames were deforming during wind events and causing damage to the trough structure. STDAC engineers have collaborated with IST to test this conclusion using a real collector on a static test stand. If the conclusion is supported, the STDAC will work with IST to develop structural improvements that could prevent future wind damage to the design.

STDAC engineers recently began receiving performance data from Packerland's new control computer, data that will help STDAC form recommendations to keep Packerland's solar hot water competitively priced.

Late this fiscal year, the STDAC agreed to consult with Packerland Solar in Green Bay, Wisconsin, the operators of the largest flat plate, industrial process heat system in the world. With over 165,000 square feet of collector surface, Packerland Solar provides solar hot water to a local meat packing company at a set percentage less than the price of hot water produced by natural gas. However, based on a contractual agreement, Packerland must increase the discount on the hot water it supplies to the packing plant. This will reduce Packerland's profits. STDAC engineers recently began receiving performance data from Packerland's new control computer that will allow STDAC engineers to define the

A small portion of Packerland's solar process heat system at Green Bay, Wisconsin. The actual system includes over 5000 on-line collectors (165,000 ft²) that deliver approximately 250,000 therms annually.



system's performance level and help develop a real-time optimization control program to keep Packerland's solar hot water competitively priced.

Inner Solar Roof Systems, Inc. in Florida is attempting to develop a solar collector that resembles Spanish roof tiles and can be used to heat swimming pools. The STDAC is helping the company by testing a prototype of the collector with the objective of optimizing its design. The market for this distinct product is the southern US, where many homes are designed in the Spanish architectural style and have swimming pools. In addition to providing technical analysis of the collector's performance, the STDAC is providing Inner Solar Roof Systems a model of the collector. The model may be used to predict the energy performance of the module.

In Aspen, Colorado, and other locations that receive heavy snowfall each year, local ordinances require snow melting systems to keep drives and walkways clear. This year, the STDAC is working with Foltz Engineering in Estes Park, Colorado, to develop a solar-powered snow melt system. STDAC is currently working to develop a model of a snow melt system that would use the ground as storage. Engineers believe that if snow melting systems incorporate storage tanks, the system becomes more cost effective. The model will be used to refine the performance of the system and estimate its cost effectiveness.

STDAC engineers are continuing to work with engineers from Gould Electronics, Inc.'s Foil Division to increase the operating efficiency of their solar process heat system. STDAC

engineers are also assessing the feasibility of upgrading Gould's control system. In early 1995 STDAC engineers will travel to Gould in Phoenix, Arizona, to install a data acquisition system and collect data for one month to measure system efficiency.

New control boards using state-of-the-art computer technology will be smaller, more reliable, fully programmable, and will allow control strategies to be changed as conditions warrant.

Additionally, at Gould's request, the STDAC agreed to help develop new control boards that control the system's operation. The current boards are fully hardwired and allow only a few switch options to change control strategy. These older boards are failing rapidly, and replacements are expensive. Consequently, the STDAC has begun a program to develop new control boards for use in this and similar systems. These new boards will use state-of-the-art computer technology to replace the 1980s circuitry. In addition to being smaller and more reliable, these new boards will be fully programmable, thus allowing control strategies to be modified as conditions warrant.

The STDAC continues to work with the New Mexico Energy, Minerals, and Natural Resources Department and the New Mexico Solar Energy Industries Association to refurbish state-owned, nonoperating solar systems. State officials estimate that perhaps 20 systems may be refurbished under this program. The STDAC was instrumental in helping the state initiate this program, and its current role is to provide consulting and training regarding the refurbishment process.

At Eastern New Mexico University at Portales, the STDAC and state engineers determined that the solar system has a low performance level. Engineers were able to make their determination by measuring how much energy the system delivers to the campus underground heating loop. The STDAC will work with state engineers to further assess the system and determine the cause of the low performance level.

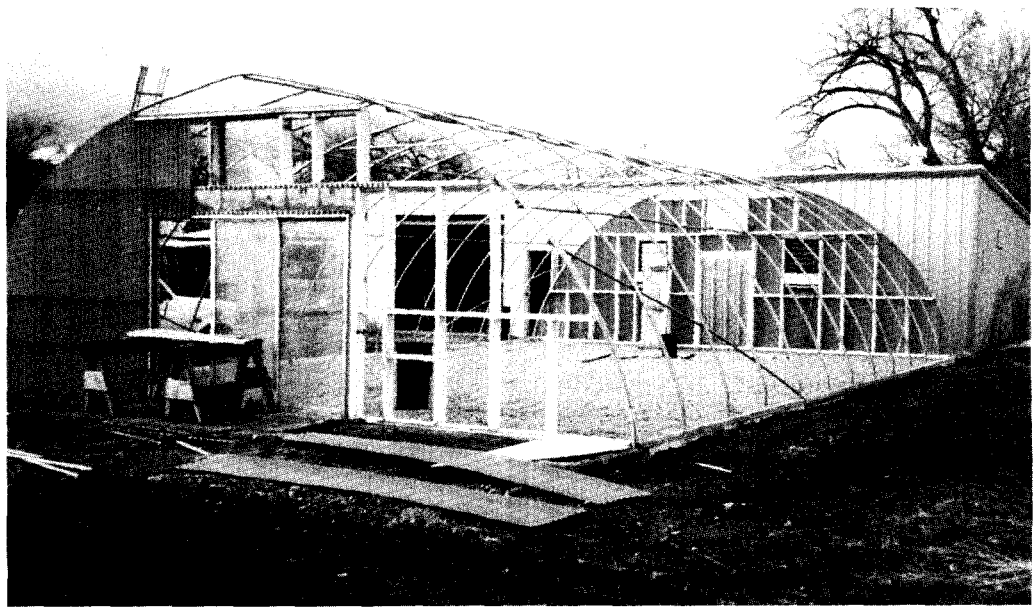
At the Central New Mexico Correctional Facility in Los Lunas, the STDAC is providing technical assistance to refurbish a 21,520-ft^2 system. The facility has accepted STDAC engineers' recommendation to make field piping changes. The piping changes, which are essentially complete, are currently undergoing pressure testing. Additionally, STDAC engineers suggested control system modifications to improve system performance. Quotes for implementing the control system upgrades are being evaluated, and a contract should be awarded in early 1995.

The STDAC has been instrumental in helping New Mexico initiate its solar refurbishment program.

The New Mexico legislature has appropriated funds to create an energy research alliance. One of the alliance's proposed objectives is to propel New Mexico into a prominent position in the application of solar technology. Two possible projects involve New Mexico's participation in the dish/Stirling and Solar Two programs. The New Mexico legislature asked Sandia to develop a conceptual plan detailing how the alliance will work. Sandia's plan, presented to state officials late this year, suggested an alliance comprising officials from state government, state universities, Sandia National Laboratories, and Los Alamos National Laboratory. The alliance is to meet regularly, and it may pursue a solar thermal or photovoltaic project in New Mexico.

The STDAC is assisting San Juan Pueblo Agricultural Cooperative to design, construct, and evaluate a prototype solar dryer. The pueblo uses the abundant solar energy available in northern New Mexico to dry fruits and vegetables for commercial sale. Sun drying crops has been a traditional way for the pueblo to process its harvest; however, the pueblo's coop is searching for new technologies to successfully compete in the current market. STDAC engineers helped the pueblo develop a system that will augment their current natural-gas dryers, using a greenhouse structure to produce the heat for drying the crops. The facility will be used for commercial-scale dehydration throughout most of the year and converted in the spring to nourish seedlings prior to planting. STDAC engineers calculated the sizes necessary for the components and structure of the system to provide optimum solar drying.

The STDAC will also provide technical guidance in monitoring the system's performance. The pueblo will test and monitor the system and report its findings to Sandia. If



San Juan Pueblo greenhouse under construction. The greenhouse will act as the collector area where air will be heated. The hot air will then be ducted into the dryer box, where crops will be dried.

performance of this prototype solar dryer is favorable, the San Juan Agricultural Coop will incorporate a solar system in its future efforts in large scale crop drying. Also, the resulting technical data will have a high potential for use in Sandia-sponsored international renewable programs. Sandia's Technology Transfer program is also providing funding for this project.

The STDAC is participating in a collaborative project to demonstrate a solar absorption air conditioning system in a commercial building in Sacramento, California.

In Sacramento last year, a project began to demonstrate a solar absorption air conditioning system in a commercial building. The project is a collaboration between the California Energy Commission (CEC), the Sacramento Municipal Utility District, the DOE solar programs, and Bergquam Energy Systems. The project is taking place at the building owned by Bergquam Energy, which currently operates a 14-ton solar absorption air conditioning system. This absorption system is powered by flat-plate collectors. However, because the flat plate system cannot produce the high temperatures needed to optimize system performance, the absorption system produces only about 9 tons of cooling.

In this demonstration, the flat plate system will be replaced with a parabolic trough that can produce the higher temperatures needed to allow the absorber to produce optimal cooling. Because the troughs are concentrators, they require clear skies to operate and must track the sun throughout the day; thus, they have more complex operational hardware and are potentially prone to more down time than flat plate systems. The purpose of this project is to assess whether the troughs can produce a net improvement in the performance of the absorption cooling system.

Bergquam Energy Systems has submitted its first quarterly report, and the parabolic trough collectors are scheduled to be installed prior to the 1995 cooling season.

Another CEC initiative seeks to implement a new commercialization program to accelerate the market adoption of solar absorption air conditioning systems. Sandia participated in a CEC-sponsored focus group designed to identify barriers to commercialization and determine a prioritized list of actions to address the barriers.

A new storage tank was installed at the site, and the heat exchanger was reconfigured to allow the system to operate at a higher efficiency.

The STDAC provided technical assistance to the Virginia Department of Energy in a program to purchase and install new solar hot water systems at several state facilities. The State of Virginia approved funding for the purchase of the solar thermal systems, which cost around $200,000. Several systems were installed under this program. STDAC engineers consulted on the operation of these systems by reviewing performance data and advising system modifications to improve performance. One system in particular, a solar process heat system at the Caroline Prison near Richmond, had several operational

problems caused by a leaking storage tank and problems with the heat exchanger, which caused the system efficiency to be lower than expected. STDAC engineers worked with Correction and Energy Department officials and the contractor to identify appropriate corrections. As a result, a new storage tank was installed at the site, and the heat exchanger was reconfigured to allow the system to operate at a higher efficiency. These changes were made in October 1994. STDAC engineers are reviewing the performance data to help quantify the resulting amount of system performance improvement.

Solar process heat system recently installed at the Caroline Prison near Richmond, Virginia.

Professors at the University of Puerto Rico at Mayaguez have been investigating solar absorption cooling for application in the Caribbean with assistance from the STDAC and Bergquam Energy Systems in Sacramento, California. The Puerto Rican Electric Power Authority, the sole power supplier in Puerto Rico, needs demand-side management alternatives because its aged peaking generation capabilities are approaching capacity. Absorption cooling and dehumidification with solar are potential technologies for displacing peaking loads because air conditioning loads constitute a significant portion of the utility's peaking usage. The hot, high-insolation, high-humidity climate on the island is a good match for this moderate-temperature application. At the industrial level, the use of solar energy in Puerto Rico has been almost nonexistent, partly because of a lack of expertise in investigating and evaluating options.

Puerto Rico's hot, high-insolation, high-humidity climate is a good match for solar absorption cooling.

In August 1994, Sandia sponsored two University of Puerto Rico professors to spend several days taking data and observing an operating solar absorption cooling system in Sacramento, California, fabricated by Bergquam Energy Systems. The professors were able to

develop and validate a model of an absorption system. Using insolation data for Puerto Rico, the professors were able to predict performance of a solar-assisted absorption system for a Caribbean climate. Their preliminary conclusion is that such a system could operate in Puerto Rico.

Through this work, the professors have now gained the necessary experience and have written a proposal to the Puerto Rico Administration of Energy Affairs, a local Puerto Rican government agency, to study solar absorption cooling in Puerto Rico. The amount of the requested funding is approximately $60,000. The university will match the $60,000 to support this activity. The university plans to purchase a few collectors (flat plate and evacuated tubes), install them at a local site, and measure their performance. The university also plans to optimize the design of a system for tropical climates, to develop more detailed numeric models of thermodynamics of the cycle, and to evaluate the performance of candidate collectors. These collectors will provide some basis for sizing and estimating the performance of a solar absorption cooling system in Puerto Rico. With the help of the STDAC and a solar system developer, University of Puerto Rico professors plan to establish a field laboratory where solar-absorption cooling and dehumidification systems can be tested, demonstrated, and further improved. The field laboratory will also serve as a point of contact in the Caribbean to attract interest and support for solar thermal technologies by local industry and the utility. The site under consideration is the Cabo Rojo National Wildlife Refuge, operated by the US Fish and Wildlife Service, located 20 miles from the university.

University of Puerto Rico professors plan to establish a field laboratory where solar-absorption cooling and dehumidification systems can be tested, demonstrated, and further improved.

After gaining experience with solar thermal hardware and more extensive system models, the professors, allied with the Puerto Rico Administration of Energy Affairs, other agencies, and possibly commercial parties, plan to approach the DOE with a joint venture proposal to install and evaluate a full size solar-assisted air conditioning system in Puerto Rico.

In FY93, the US Army Corps of Engineers contracted the STDAC to collaborate on a project to review the Corps of Engineers' basic methodology for assessing the applicability of solar systems within DoD facilities worldwide. The US Army Corps of Engineers Mobile District (COEM) is the lead Corps of Engineers organization for renewable energy; it is responsible for maintaining the methods and procedures used by all DoD installations (except some Navy facilities) regarding feasibility assessments, standard design, and application of solar thermal systems. Based on a recent internal study, the COEM determined that it should review and update three of its standard methods, including a solar economic analysis program, a best-case analysis of solar thermal potential, and standard

solar design specifications. The COEM's general concern is that the default cost, design, and application guidance used in the three methods may unfairly represent solar thermal potential in various applications. COEM's particular concern is that the current feasibility assessment tools are too general to properly screen solar applications. Thus, appropriate applications may be overlooked while inappropriate ones may receive detailed and expensive follow-up studies.

The STDAC's preliminary analysis indicates that the Corps' methodology is limited; only flat plates for domestic hot water applications are considered. The STDAC's initial review of the COEM's generic solar feasibility study shows that the study may need to be revised to include not only flat plate solar thermal collectors, but also concentrating collectors, and possibly evacuated tube collectors. The STDAC will provide the COEM with suggestions for replacing its generic study with a simple method of doing a first-cut evaluation of a solar system. The STDAC is also working with US solar industries on reviewing the COEM's guide specifications for solar thermal systems and will provide the COEM with results from this review and suggestions on changes to its guide specifications. Other concerns involve systems costs. STDAC engineers will critically review how systems costs are derived and how those costs compare to known systems costs.

The U.S. Army Corps of Engineers invited STDAC engineers to participate in this project based on Sandia's reputation for providing "forthright and unbiased information about solar thermal technology."

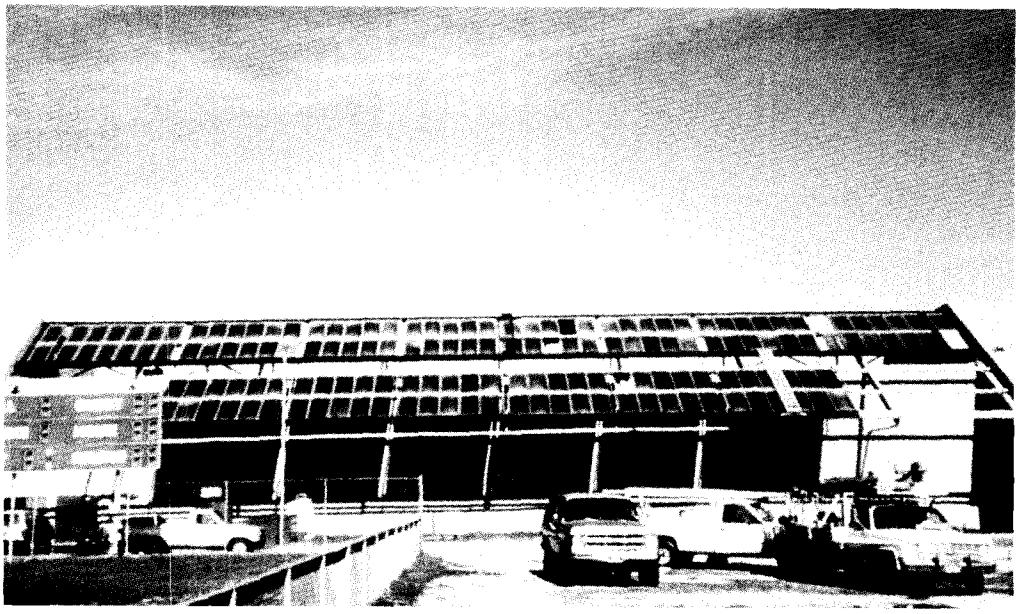
Methodology improvements could result in many new solar applications within the DoD. The US Army Corps of Engineers invited STDAC engineers to participate in this project based on Sandia's reputation for providing "forthright and unbiased information about solar thermal technology." This Work For Others project will be completed in March 1995.

STDAC engineers have been assisting officials at Peterson Air Force Base near Colorado Springs, Colorado, to identify and analyze potential applications for solar thermal industrial process heat systems. Two possible solar applications were identified; however, the systems did not meet the Air Force's economic acceptance criteria, which is an energy savings payback period of 10 years or less.

During FY94, the program assisted Luke Air Force Base, Arizona, in refurbishing three solar trough water heating systems. At the conclusion of this effort, Luke personnel asked for technical assistance from the program in refurbishing the existing Btu monitoring system.

Program engineers worked with base personnel and a local controls contractor to refurbish the energy monitoring systems. The monitoring system is important because it provides information about the cost savings of the solar system. This information is used to help Luke officials decide if solar systems can perform economically and if future projects are worthy of consideration. This project was completed this quarter and the monitoring system is operating normally.

Direct Technical Assistance



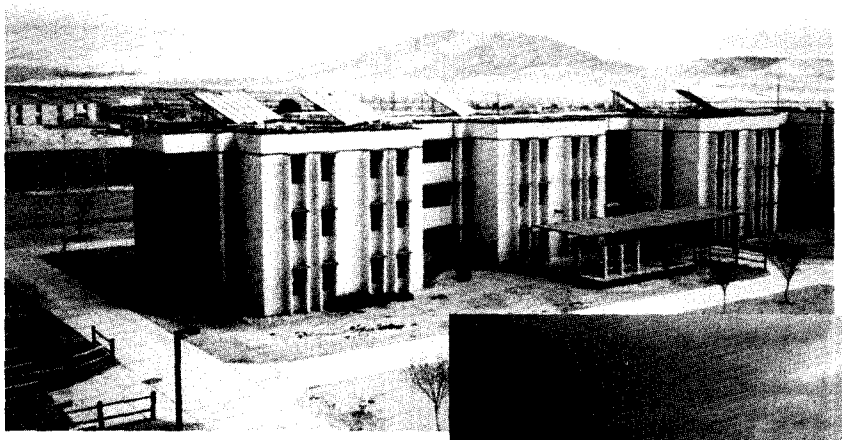
The gymnasium at Luke Air Force Base, Arizona, where solar collectors are used to heat domestic hot water, primarily for showers.

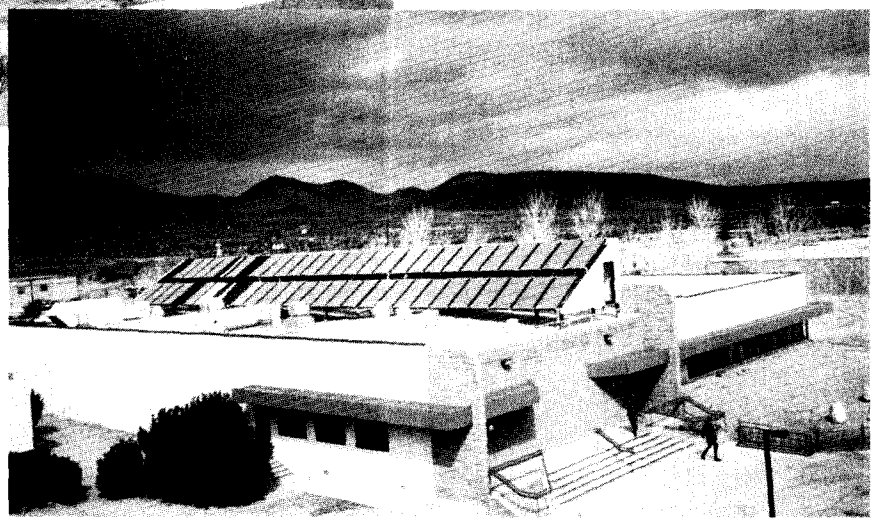
STDAC engineers and Florida Solar Energy Center (FSEC) visited McDill Air Force Base near Tampa, Florida, this fiscal year to identify and analyze solar thermal applications. The base has $300,000 available for solar thermal projects that meet the DoD's Energy Conservation Investment Program acceptance criteria, that is, projects with payback periods of 10 years or less. However, the engineers concluded that none of the possible projects on the base met the acceptance criteria. A report was provided that documented the analysis and conclusions.

Working with Department of Public Works officials at Fort Irwin, California, STDAC engineers are assessing the feasibility of re-applying existing nonoperational solar systems. Sandia engineers are helping base officials identify applications to redeploy collectors from nonoperating systems. STDAC engineers helped identify several potential redeployment applications and have finished preliminary performance and economic analysis on the applications. Two of these applications have the potential to meet the government's 10-year payback criteria. STDAC recommended that a 55-collector system at the cafeteria be converted to a drain-back configuration. In another project, the STDAC will consult officials about retrofitting 16 collectors from a maintenance facility for a year-round pool heating system. Work scheduled for FY95 includes pressure testing of the array, to more precisely determine the economic feasibility of refurbishment.

STDAC engineers are completing an evaluation of the Carbondale, Illinois, Federal Building's 5133-ft^2 evacuated solar tube collector used for process heat. This system supplies hot water

Solar system at the Bachelor quarters at Fort Irwin Army Base, California.





Solar heat system at the dining facility at Fort Irwin Army Base, California.

for the building's heating, cooling, and hot-water needs, but the collectors have experienced widespread water leaks. Building officials asked STDAC how to proceed. The STDAC evaluated the life-cycle cost for refurbishing the existing collectors or replacing the collectors with new state-of-the-art evacuated tube collectors. Engineers determined that replacing the existing collectors with new collectors would not meet the requirements of a simple payback of less than 10 years and a Savings-to-Investment Ratio greater than 1.0. However, engineers found that refurbishing the existing collector field would be feasible if the cost of refurbishment was less than $100,000. The feasibility of system refurbishment greatly depends on whether the collector leaks can be cost-effectively repaired. Sandia's organic materials lab determined that the cause of leaks was degradation of the collector tubes' seals and gaskets. They believed that the degradation was caused by a combination of heat, sunlight, and contaminants in the working fluid (tap water). The organic materials lab suggested a high-grade silicon rubber or butyl-rubber as a more suitable material for these gaskets. The STDAC will provide operating personnel at the Carbondale building with sample seals and gaskets made of high-grade silicon rubber and butyl-rubber for testing in the existing system. Successful results from these tests (i.e., if seals and gaskets do not fail prematurely) will indicate that the system may be cost-effectively refurbished.

Energy officials from the US Army Corps of Engineers funded STDAC engineers to provide engineering assistance in reviewing all potential applications for solar thermal technology at Fort Huachuca, Arizona. The analysis involved a review of all base facilities for potential solar thermal applications, with the objective of selecting about 6 to 12 applications for detailed analysis. The first phase of the effort, a preliminary review of all the base facilities, was completed and several potential applications were identified. A final report was also completed. Studies showed that all the projects had paybacks of over 10 years. Although the projects were not cost effective, the base energy manager was able to use the information to identify the price at which these solar systems will compete with natural gas.

In support of FEMP efforts to promote the use of renewables in federal facilities, the STDAC has conducted a cost analysis of a solar system planned to be installed at Sandia National Laboratories. New information shows that solar systems may be much more expensive when installed in federal facilities, because of significant additional costs necessary to comply with federal regulations. Additional costs can more than double a project's cost and extend the payback period to well over 20 years, more than twice the minimum required payback period for solar projects in federal facilities. Additional costs from federal regulations include the Davis-Bacon Act, which requires that all federally funded projects over $2,000 pay workers union wages. Other costs include mandatory Environment, Safety, and Health and oversight inspections. To determine whether these mandatory cost additions are typical in federal facilities, the STDAC contacted the US Army Corps of Engineers Civil Engineering Research Lab (COE/CERL). The COE/CERL monitors costs for construction projects for most military and many civilian federal facilities. They confirmed that a variety of mandatory construction requirements that are prevalent throughout the federal sector substantially increase the cost of solar projects in a federal facility.

The federal sector is a large potential market for solar systems, and these cost additions could impact future sales. As a result, Sandia will team with NREL and FEMP to more carefully document the extent of the mandatory cost additions within the federal sector and to identify ways to reduce or eliminate the additions. This new effort will begin in earnest in FY95.

Sandia will team with NREL and FEMP to identify ways to reduce or eliminate the mandatory cost additions incurred in complying with federal regulations.

In August 1994, as part of Sandia's cooperative effort with the University of Sonora (UNISON), the STDAC sponsored a training workshop for Mexican engineering professors and students on how to monitor solar systems. The three-day workshop covered the

fundamentals of monitoring systems and included hands-on experience. The workshop was held at New Mexico State University in Las Cruces, and was attended by about 10 Mexican engineering professors and students from UNISON and the Universidad Autonoma de Chihuahua. These professors and students are likely to be involved in monitoring solar thermal and photovoltaic projects in Mexico. Other ongoing Sandia efforts in Mexico include supporting efforts to commercialize dish/Stirling technology, evaluating the social and economic compatibility of the solar oven and ice-maker, and facilitating the use of solar thermal technologies by state governments such as Sonora and Chihuahua.

In October 1994, the STDAC participated in Mexico's National Solar Energy Association (ANES) Conference in Hermosillo, Sonora, as part of the effort to accelerate the use of renewable technologies in Mexico. The STDAC, together with Mexican technologists, presented a one-day workshop on productive end-user technologies, including trough and flat-plate systems, solar ovens, and ice-makers. Mexican government officials, technologists, professors, and university students participated in the conference.

The STDAC's bilingual renewable energy technology booth had a steady stream of visitors and received requests for more than 1,000 pieces of literature.

On the day of the workshop about 120 people participated in a noon-time tour that highlighted a photovoltaic-powered water pumping site. During the tour, STDAC representatives talked with some of the participants about solar thermal technologies and their possible applications in Mexico. In a 3-day conference following the workshop, Sandia's bilingual renewable energy technology booth had a steady stream of visitors and received requests for more than 1,000 pieces of literature. Adjacent to the booth, UNISON's Energy Group teamed up with Sandia to demonstrate solar oven and ice-maker technologies. Visitors were treated to solar-oven-baked "coyotas" (a Sonoran-style cookie) and snow cones from solar-made ice. On loan to UNISON from Sandia, the US-made solar systems were provided as part of a cooperative program allowing exchange of technical information and projects between Sandia and UNISON. The Sandia/UNISON cooperative venture was formalized by a Memorandum of Agreement signed in May 1994. To create a favorable climate for the growth of Mexico's solar market, STDAC is helping develop UNISON's solar engineering resources. In turn, the university will be able to provide

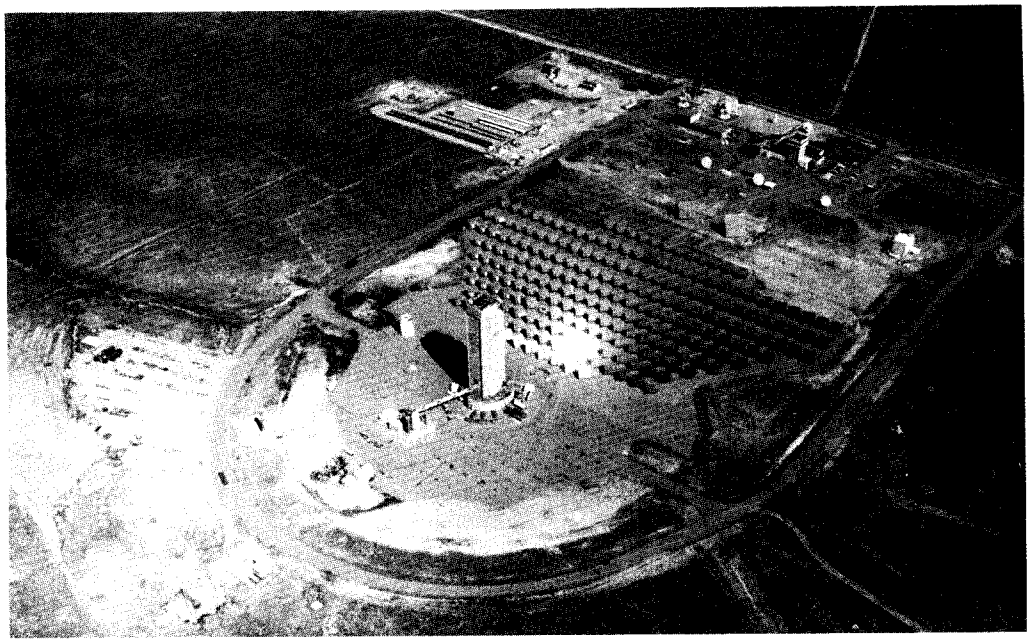
Visitors examine the solar ice-maker and solar oven at the joint University of Sonora/Sandia technology display at the ANES Renewable Energy Conference in Hermosillo, Sonora.

Mexican schoolchildren attending the exhibit at the ANES Conference in Hermosillo, Sonora, Mexico, in October 1994. Shown here are the smaller Global Sun Oven and the much larger Villager Sun Oven, weighing in at 700 lb. The Sun Ovens are manufactured by Burns-Milwaukee, Inc.

the technical expertise to Mexican government agencies and nongovernment organizations in implementing solar thermal technology.

STDAC engineers are also collaborating with staff from Sandia's International Renewable Energy Program in the application of solar thermal technology within the USAID/Mexico program. In this multimillion dollar program, solicitations will request that renewable energy systems be installed in Mexico. Program engineers are participating in planning meetings and will cooperate in the execution of the program.

The STDAC performs its test and evaluation work at the National Solar Thermal Test Facility at Sandia National Labs.

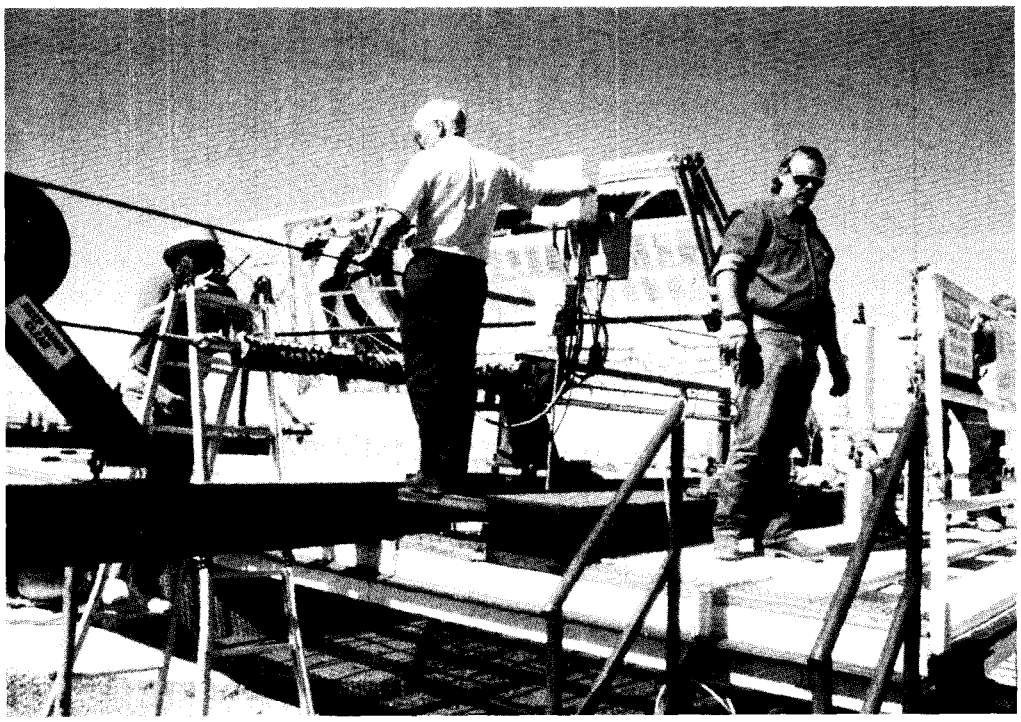


Testing, Evaluation, and Technology Development

STDAC engineers have completed tests on IST's trough collectors and the thermal performance characteristics of Albuquerque AAA Solar heat exchanger tests. New projects have begun as well; testing is currently underway on American Sun Company's trough collector, and engineers are upgrading the rotating platform at the National Solar Thermal Test Facility at Sandia National Laboratories. The STDAC is also developing a low-cost Btu metering system to monitor the performance of small to medium solar systems.

The first phase of testing is completed on IST's trough collectors. Two troughs have been tested on the rotating platform at the National Solar Thermal Test Facility. Both troughs consist of standard structural elements. However, one of the troughs uses ECP-305 reflective film and the other uses aluminized SA85 film. Two receiver envelopes were tested on each trough. Two receiver tubes were also tested, one with the new black nickel receiver and

the other with black chrome. A Sandia report documents the resulting improvement in performance using the anti-reflective (AR) solgel coating, silver film, and black nickel receiver. Results show that these technology improvements (silver film, black nickel, and solgel coating) have caused an approximate 18% improvement in the IST trough performance from a baseline solar-to-heat optical conversion efficiency of around 66%. These measurements are based on optimal test conditions. The STDAC has not yet analyzed the effect these improvements have made on field performance; however, the STDAC does expect to see a significant improvement over the existing design. The second phase of the tests will include all of the trough improvements outlined above plus an evacuated receiver.



An IST parabolic trough collector is positioned on the AZTRAK Rotating Platform at Sandia's National Solar Thermal Test Facility.

The STDAC has completed testing on the thermal performance characteristics of a heat exchanger manufactured by a small Albuquerque company. The local solar manufacturer lacked the measurement expertise to characterize the thermal performance of its heat exchanger and originally approached Sandia's Technology Transfer and Commercialization Program (Tech Transfer) for assistance. Tech Transfer funded the STDAC to complete the tests. The heat exchanger consists of three copper tubes fabricated into a double wall, counterflow configuration. The exchanger is designed to heat the water in a residential domestic hot water (DHW) tank by flowing a solar heated propylene glycol/water mixture from a roof-mounted collector system through the heat exchanger system. The thermal performance characteristics of the heat exchanger are critical to size and implement the solar systems supplied to the company's residential customers. A thermal model was

engineers did not expect any significant enhancement in the new oven. A 10% increase in total collector area would likewise not facilitate performance enhancement. However, the new oven's collector arrangement simplifies oven assembly and start-up.

Comparison of small, family-size Global Sun Oven with large, institutional-size Villager Sun Oven. Villager will be capable of baking over a hundred loaves of bread per day or boiling hundreds of liters of water per day (for purification). Villager is equipped with a standby propane gas unit, for inclement weather or night-time operation.

The STDAC is continuing a 50%/50% cost-shared contract with IST to develop an advanced receiver. The effort involves the development of a commercial solgel AR coating process for trough receiver envelopes; a black nickel process to replace black chrome; and a commercial evacuated receiver.

The solgel AR coating work has been completed and represents a significant technology transfer success. IST has almost completed the black nickel receiver, and efforts now focus on developing an improved black nickel coating that is more stable at higher operating temperatures (around 500°F). Improved stability is expected to extend field life. Shortly after the arrival of prototype evacuated receiver tubes in early 1995, thermal performance testing will begin. The STDAC's testing goal is to evaluate the performance improvements between evacuated and nonevacuated receivers.

STDAC engineers are developing a low-cost Btu metering system. Currently available, highly accurate Btu metering systems cost approximately $3,000. Owners of small- to medium-size solar systems need to monitor the performance of their systems, but they cannot justify the expensive Btu metering systems. A less expensive system, however, would be an affordable tool to determine thermal production for smaller solar systems. STDAC engineers are targeting $300 as the price for their low-cost Btu metering system. A prototype system is currently being tested for measurement accuracy. This work will continue into FY95 and will include testing several of these units on real systems throughout the country.

STDAC engineers have completed the second annual report on the Tehachapi Solar Thermal System. The report details the operational performance of IST's parabolic trough field used in a solar process heat system at the California Correctional Institution in Tehachapi. For nine months during 1993, recorded plant availability was above 94%. For 1993, the plant delivered a total of 4,373 MMBtu (million Btu) of thermal energy, with a peak delivery of 36.5 MMBtu recorded on July 28th. Because the solar system is operating near its full potential, routine monitoring of the system will be turned over to NREL for long-term monitoring and archival of performance data.

The State of California Department of Corrections asked the STDAC to monitor the performance of a new evacuated-tube solar collector system at the Richard A. McGee Prison Guard Training Facility in Galt, California. The monitoring was requested because these collectors are the first of their kind at a California prison facility and officials wanted to confirm their performance. They plan to use this information to decide whether similar systems will be installed in other facilities. The STDAC agreed to monitor the effort because there is little available information about the field performance of these types of systems. This monitoring system consists of an Ascension Technology, Inc. Rotating Shadowband Radiometer equipped with a Campbell data logger for recording solar measurements, water flow, natural gas usage, and the delta-T across the solar array. The monitoring system will help in the field evaluation of the performance of SUN Utility Network's evacuated solar tube collectors. The solar array was designed to meet approximately 50%

of the facility's kitchen hot water load, and consists of 15 PK-40 SUN Utility evacuated tube collectors with a total volume of approximately 1200 gallons. The monitoring project will continue through FY95 with a final report due out in FY96. The information gained from this project will be very valuable in obtaining field performance data for a state-of-the-art evacuated solar tube collector.

During the first month of operation (May 1994), the solar thermal system displaced approximately 41% of the kitchen hot water load. The gross solar collector efficiency for the month of May was 36.8%. This efficiency is computed by dividing the amount of thermal energy produced by the solar system by plane of array insolation. However, because the system is designed to preheat the cold water supply to the building, the flow rate through the collectors varies with hot water demand. As a result, the system efficiency varies with hot water demand. The reported system efficiency is an average for the system over the reporting period. Consequently, it is difficult to compare this efficiency with efficiencies computed from systems with more constant flow conditions. This reported system efficiency will determine, when compared with future efficiency ratings, if system performance has degraded.

Evacuated tube solar process heat system at the California Department of Corrections Training Facility at Galt, California.

Jannette Lloyd and Peggy Valencia of Sandia answer questions at the STDAC booth at Soltech 94.

Education

In January 1994, the STDAC helped sponsor a solar cooling seminar at the annual ASHRAE meeting in New Orleans. Hosted by ASHRAE's technical committee on Solar Utilization, the seminar featured talks by industry, NREL, and the STDAC on the applicability of solar absorption air-conditioning. The seminar was an excellent opportunity to promote solar thermal technology to architects and engineers.

About 90 people attended the seminar. Questions and responses indicated that there is a great deal of interest in solar absorption air conditioning among engineers and manufacturers. Consequently, ASHRAE invited Sandia to write an article about solar thermal technology for the ASHRAE journal. The article will describe the technology, discuss how

systems are designed and operated, and provide information on how to analyze system cost and energy performance. The ASHRAE journal is one of the more popular and widely read engineering journals in the world. Through Sandia's article in the journal, thousands of engineers may be enlightened about applying solar thermal heat technology. Because engineers are often critically positioned to choose solar systems, this article could influence the installation of many new solar thermal heat systems.

STDAC engineers are writing the recommended document for the measurements of solar concentrators for the ASHRAE. The ASHRAE asked the STDAC to write these new standards because current test standards are not adequate for troughs. Methods have been developed at the National Solar Thermal Test Facility and will include recommendations based upon the STDAC's experience measuring the thermal performance of solar concentrators. A section detailing analyses that use experimental measurements will also be included. The work is being performed for ASHRAE's Technical Committee on Solar Utilization.

The major objectives of the workshops are to make participants familiar with available systems, present examples of successfully operating systems, describe refurbishment projects, and discuss methods to acquire financing.

STDAC engineers participated in the "Alternative Energy for Arkansas" workshop held in June 1994, and in the "Procurement of Renewable Energy Technology" workshop for Alabama state and local government personnel held in August 1994. The major objectives of each workshop were to make participants familiar with commercially available solar systems, present examples of successfully operating systems, describe refurbishment projects, and discuss innovative methods for acquiring and financing solar projects. STDAC engineers presented the majority of information regarding solar heat technology.

About 40 people attended the Arkansas workshop; about 12 people attended the Alabama workshop. The attendees were primarily state and local government decision makers. As a result of the Arkansas workshop, government officials asked for STDAC assistance in refurbishing a solar heat system at the Veteran's Administration Medical Complex in Little Rock. The complex has a 4842-ft^2 solar process water system that operated for about 6 years, but was then shut down because of high maintenance requirements of the solar array. STDAC engineers have recommended a refurbishment plan.

In Virginia, Sandia engineers and the Renewable Energy Training Institute (RETI) organized and presented the "Renewable Energy Technologies Workshop," sponsored by the Commonwealth of Virginia Department of Mines, Minerals and Energy (VDMME). The workshop was held at the Virginia Power Innsbrook Technical Center. About 75 architects and engineers (A&Es) who design new state facilities and renovate existing buildings attended the workshop.

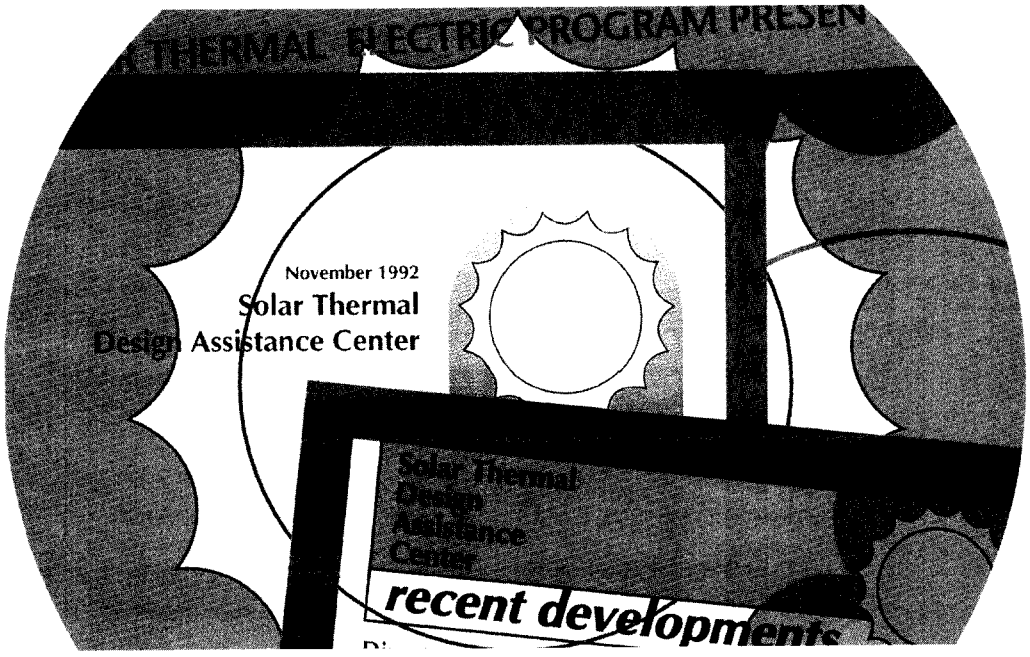
VDMME asked Sandia's Renewable Energy Office to provide an opening speaker for the workshop and to participate in the meeting. Paul Veers of Sandia's Wind Energy Technology

Department opened the workshop with an overview talk and other experts, including some from the STDAC, gave presentations in specific technical areas (e.g., solar thermal, ground-source heat pumps, and biomass). Each presenter provided detailed information and descriptions of tools necessary to assess and apply various cost-effective renewable energy options. Presentation materials and information were gathered from Sandia's and NREL's renewable energy programs and covered the following technologies: solar thermal electric, solar thermal heat, ground source heat pumps, photovoltaics, wind energy, and biomass. Sandia provided handouts on its Solar and PV/Wind Design Assistance Centers, as well as documents that identify points of contact for in-depth information on specific technologies.

Sandia engineers and VDMME conceptualized the workshop last fall. At that time, the VDMME had planned a one-day training workshop on energy efficiency, focusing on the new commercial/industrial building energy efficiency standards documented in ASHRAE Standard 90-1. Sandia suggested to VDMME that this would be an appropriate time to deliver an additional day of training to the architects and engineers. VDMME accepted the idea, and asked Sandia to develop the training program. As a result, Sandia solicited the Renewable Energy Training Institute's help in conducting the workshop and consulted with the Renewable Energy Training Institute, NREL, and VDMME to form the agenda and identify appropriate trainers. To provide information about renewable energy technology, STDAC members discussed the relationship between ASHRAE Standard 90-1 and renewables and answered specific technical questions from the audience.

The STDAC is working to organize training workshops for mechanical contractors on installing, repairing, and troubleshooting solar systems. The STDAC will collaborate with RETI to organize and conduct these workshops. Several of these workshops will be conducted across the country in 1995. One workshop is tentatively scheduled for March 1995 in Albuquerque.

In February 1994 the STDAC participated in SOLTECH 94, held at Ponte Verde Beach, Florida. STDAC personnel helped plan some of the solar electric and solar heat sessions, chaired some of the sessions, and presented papers.



Publications

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

On June 2, 1992, the Landers earthquake struck the Solar Electric Generating System II, located in Daggett, California. The 30-megawatt power station, operated by the Daggett Leasing Corporation, suffered substantial damage caused by structural failures in the solar farm. These failures consisted of the separation of sliding joints supporting a distribution of parabolic glass mirrors. At separation, the mirrors fell to the ground and broke. It was the desire of the Daggett Leasing Corporation and the STDAC to redesign these joints so that, in the event of future quakes, costly breakage will be avoided. To accomplish this task, drawings of collector components were developed by the STDAC, from which a detailed finite element computer model of a solar collector was produced. This nonlinear dynamic model, which consisted of over 8560 degrees of freedom, underwent model reduction to form a low order nonlinear dynamic model containing only 40 degrees of freedom. This model was then used as a design tool to estimate joint dynamics. Using this design tool, joint configurations were modified, and an acceptable joint redesign determined.

The results of this analysis showed that the implementation of metal stops welded to support shafts for the purpose of preventing joint separation is a suitable joint redesign. Moreover, it was found that, for quakes of Landers' magnitude, mirror breakage caused by enhanced vibration in the trough assembly is unlikely.

Dudley, V., *Test Results of the IST Parabolic Trough Collector*, SAND94-1117, Sandia National Laboratories, Albuquerque, New Mexico.

An example of the IST parabolic trough solar collector was tested to determine the collector efficiency and thermal losses with black chrome and black nickel receiver selective coatings, combined with aluminized film and silver film reflectors, using standard Pyrex and anti-reflective coated glass receiver envelopes. For each receiver configuration, performance equations were derived showing collector performance as a function of input insolation value, incident angle, and operating temperature.

Emrich, C., *Evaluation of Transparent Insolation Materials in Flat Plate Collectors*, SAND94-2552, Sandia National Laboratories, Albuquerque, New Mexico.

Polycarbonate rectangular honeycomb and acrylic capillary honeycomb, two types of transparent insulation material (TIM), were tested in flat plate collectors. The honeycomb was inserted between the cover plate and the absorber, leaving a one-centimeter air gap above the absorber to decouple radiative and conductive heat transfer modes. Four 4' x 8' collectors with selective black chrome absorbers were evaluated side-by-side using ASHRAE Standard 93-1986. They differed in thickness and type of TIM as follows: (1) no TIM, (2) one inch of polycarbonate, (3) four inches of polycarbonate, and (4) four inches of acrylic honeycomb. A second set of tests was completed using absorbers coated with moderately selective black paint, and a third set with flat black paint. Using first order collector efficiency equations for comparison, the best thermal performance was achieved by a collector containing a selective chrome absorber and four inches of acrylic honeycomb. The acrylic insulation yielded a higher intercept than the polycarbonate (indicating higher transmittance) and flatter slope (less heat loss) with all three absorber types. Increasing the thickness of the honeycomb sheet slightly decreased the intercept but markedly decreased the slope. The amount of improvement in thermal performance was greatest when TIM was added to collectors with flat black absorbers and decreased as absorber selectivity increased. Because small-cell honeycomb improves thermal performance by suppressing both convective and radiative transfer, combination with selective coatings is partially redundant because they are poor emitters. Furthermore, the unacceptably low melting temperatures of these TIMs preclude them from withstanding even a wet stagnation, thereby rendering this application impractical.

Rosenthal, A., *Monitoring Solar-Thermal Systems: An Outline of Methods and Procedures*, SAND94-0007, Sandia National Laboratories, Albuquerque, New Mexico.

This report discusses the objectives for implementing a solar thermal system monitoring program and describes the various levels of monitoring that are possible. For example, a level three monitoring station requires only an operation and maintenance log to record instances where a solar system had problems or was nonoperational. A level one station, however, may specify detailed, hourly monitoring of a solar system's performance. The report discusses how to determine the appropriate level of monitoring for a solar system and summarizes the requirements for each level.

Rosenthal, A., *Twelve-Month Performance Evaluation for the Rotating Shadowband Radiometer*, SAND94-1248, Sandia National Laboratories, Albuquerque, New Mexico.

This report evaluates the performance of Ascension Technologies' Rotating Shadowband Radiometer (RSR) over a twelve-month period. In summary, the RSR was a very reliable instrument and did not require any operator intervention, repair, or realignment. The RSR appears to be best suited for general purpose solar resource assessment, such as the system performance monitoring typically conducted by the solar thermal heat program. The RSR is not as accurate for short-term measurements, such as those required to determine real-time efficiency of a concentrating collector during a test at the National Solar Thermal Test Facility.

CENTRAL RECEIVERS

Blanco, Manual	Spain
Bohn, Mark	NREL
Bortz, John	SAIC
Brinkley, Stephen	Consultant
Brower, Mark	North Carolina Solar Systems
Buck, Reiner	Consultant
Cesar, Paulo	Universität Paderborn
Chatter, John	"Partners in the Americas"
Chen, Gary	Consultant
Chiang, Ken	Rocketdyne
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GENERAL INFORMATION

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Erdalli, Yucel	Marmara Research
Ericksen, Fredik	Consultant
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Ford, Kim	SNL/TT
Flowers, Larry	NREL
Ford, Charity	Consultant
Ford, Freeman	FAFCO
Ford, Kim	SNL/TT
Francis, Lisa	A.D. Little

Contacts

Frank, Todd	Consultant
Gahris, David	Consultant
Garcia, Mike	DOE/AI
Garness, Steve	Denver Post
Gearanites, *Phil*	3M
German, John	Consultant
Gernadoz, Mike	Energy User News
Gestelli, Richard	SNL
Ghoren, Amy	Energy User News
Gibson, Bob	Tech Ventures Corp.
Goods, Steve	Consultant
Gorham, Robert S. Jr.,	Consultant
Graham, George	Consultant
Greer, George	Consultant
Greulich, Frederick	SNL
Grossman, Eric	Consultant
Gupta, Bim	NREL
Haeri, Ahmed	Bresler & Reiner, Inc.
Hague, Nabilah	DOE/HQ
Halcomb, Craig	Consultant
Hand, Don	Consultant
Haney, Raymond	Solar Power Info.
Hanks, Jerry	SNL/TT
Harkness, Tim	Consultant
Harnell, Skip	DOE/AL
Hartley, Dan	SNL
Harvey, Amanda	Consultant
Harvey, Carol	Consultant
Harvey, Joel	Consultant
Harvey, Mark	Consultant
Herbst, T.	Consultant
Hererra, Lorene	Consultant
Hey, Mike	SNL
Hightower, Mike	SNL
Hill, Roger	SNL/PV
Hill, Tony	SNL/2345
Hjilseth, Jane	Consultant
Hollick, John C., P.E.	Conserval Systems, Inc.
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Howell, Becky	ASES
Hughes, Bill	DOE/AL
Hundby, Kristin	Consultant
Hutchison, Tammie	*Consultant*
Irenar-Peterson, Suzanne	Consultant
Jadrijevic, Vladimir T.	The World Bank
James, Lee	Consultant
Jelaginski, Robin	Fletcher State
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Jones, James	Consultant
Jones, Jim	NREL
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Jurman, Kenneth S.	Institutional Conservation Program
Kanellopaulos, Sia	Full Circle
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Keane, Colleen	Tech Reps
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Leigh, Jerry	NMERI
Letendra, Steve	NY State Energy Office
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Lewis, Edward G.	Ted Lewis & Associates
Livett, Roger	*Consultant*
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Lowendowski, Al	NREL
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McInteer, Bob	SNL/Video
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Merrett, Ron	Consultant
Merritt, Ron	*State of NM*
Messon, Nema	Eco Expo, Inc.
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Miller, Kirk	Consultant
Miller, Troy	University of Utah student
Monson, Richard	RePsych Technologies
Montoya, Pat	*State Issues Director*
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O'Brien, Phil	Consultant
O'Canna, Migra	SNL
O'Cheskey, Fred L.	Southwest Public Affairs, Inc.
O'Chesky, Fred	State Senate
Onursal, Bekir	The World Bank
Orozco, Ron	NRECA
Otts, John	SNL/TT
Palmer, Jim	Greiner Engineering,
Paparoni, Hilda Maria	UN/DP
Parker, Terry	*Consultant*
Pastori, Joe	Pastori & Assoc.
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Petrovic, Michelle	Consultant
Pittie, Ravi	Pittie Solar Corp. PVT. LTD.
Pittie, Shrikant	Pittie Solar Corp. PVT. LTD.
Plympton, Patricia C.	USEPA
Polansky, Ann	SEIA
Poulson, Mark	Consultant
Quintana, Alicader	Consultant
Radford, George O.	Radco Products, Inc.
Ralph, Claire	Consultant
Reeves, Lewis	Eastern New Mexico University
Riley, Ann	State Senator
Riser, Steve	Solar Letter
Risser, Vern	Daystar
Roper, Mark	Colorado Energy Office Construction
Rose, Brad	Consultant
Rovero, Chris	Meridian
Roybal, Roderick	SNL
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Ruckert, Tom	DOE/HQ
Sanders, Grant	SNL
Sanders, Judy	SC
Saunders, Robin	City of Santa Clara, California
Schenkel, U.	TAMPOPRINT GmbH
Segal, Barry Jay	Segal's Solar Systems
Selber, Jennifer	EPA
Sheffield, Mike	Texhoma Communications
Sheinkopt, Ken	SEIA
Sherwood, Larry	ASES
Shivers, Rufus	DOE
Shsh, Amit N.	American Credit Corporation, Ltd.
Shugar, Daniel S., P.E.	APS, Inc.
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Sleeuwenhoek, Eric	Consultant
Smith, Chivon	Consultant
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Sorenson, Kurt	SNL
Spearman, Dawn	Consultant
Stafford, Byron	NREL
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Westby, Bob	NREL
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White, Andrew	LANL
Whitlow, Jeff	SNL
Wilhelm, Heidi	Connecticut Enterprises
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Wong, Carolyn	Consultant
Wood, Byard D.	ASU, CESR
Worl, Laura	Consultant
Wynn, Richard	*Consultant*
Yellowhorse, Larry	SNL
Young, William E.	Merrit Island, FL
Zorsie, Jon A.	SCUTU
Zuñiga, Ricardo Xavier	State Co-Director
Zygmunt , Stanley Jr.	LANL
Zyvoloski, George	LANL

INDUSTRIAL HEAT PROCESS

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Benson, Chris	Arkansas Energy Office

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Betten, Guy	RETI
Betton, Guy	Renewable Energy Training Institute
Bielick, Tim	SNL
Blummer, Robert	General Services Administration
Bradshaw, Robert	Consultant
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Brekke, Cal	Consultant
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Donahue, Bill	Meridian Oil & Gas
Ducey, Rock	Army CERL
Dunken, Cameron	Energy Effic & RF Clearinghouse
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Durrand, Steven	NMSU
Edgin, Bob	Huntsville Alabama
Edrol, Steve	Santa Fe A&E
Ericson, Don	Energy Concepts
Flores, Carlos	ANES (Mexico) Conference
Foltz, Ross	Foltz Engineering
Fox, Lucien	Ogden Power
Franey, Harry	CDC
Franey, Harvey	CDC
Frasier, Hilda	Florida Energy Office
Gee, Randy	IST
Giffor, John	Proctor & Gamble
Glissman, Lt. Mark	USAF
Gregory, Diana	Florida Dept. of Comm. Affair
Gonzalez, Jorge	University of Torebo
Gorman, Steven K.	American Energy
Guinn, Gerald	University of Alabama, Huntsville
Hage, Steve	Minnesota Zoological Garden
Hamasaki, Les	Sun Utility Network
Harkness, Tim	Consultant
Harmon, Bob	Corps of Engineers
Harrison, Kim	Topeka Kansas
Harrison, John	FSEC
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Hutchinson, Gus	SKI
Jane Hale, Mary	NREL
Jaromin, Dennis	U.S. General Service Administration
Johnson, Brian, P.E.	New Mexico Energy, Minerals, and Natural Resources Depart.
Johnson, Brian	NMEMD
Johnson, Leland	SNL
Jones, Jerry	Tinker AFB Industrial
Kaylor, Bud	CES/CEE
King, Jimmy	Jimmy King Boiler Service
Kulkarni, Promod	CEC
Lane, Richard	Packerland Solar Systems
LaPorta, Carlo	United Solar Technology
Larson, Doug	Consultant
Leonard, Bob	Passive & Active Solar
Lister, Larry	U. S. Army COE
Loague, Dan	Oklahoma Dept. of Commerce
Lowenthal, Peter	SEIA
Lowery, Robert	Dept. of the Army
Maiden, Miles	American Sun Co.
Mann, Clarence	ADECA-STED
Markham, Chuck	AAA Solar
Martinez, Rodolfo	ANES (Mexico) Conference
May, Randy Gee-Ken	IST
McCracken, Horace	U.S. Solar Industry
Mesmer, Phil	CEC
Miller, Jon	VA Hospital - Little Rock, AR
Mills, Evan	LBNL
Moore, Mack	SEIA
Moreno, Bob	Consultant
Nelson, Les	Cal. SECA
Ortiz, Nestor	SNL
Palmer, Sharon	Seed International
Peak, David	VA Air Collectors
Peebles, Craig	A&T
Proulx, Andrew	Consultant
Quinones, Rene	Department of Public Works, Fort Irwin, California
Raseman, Chad	Solar Sun, Inc.
Reed, Tracy	Enron Co.
Reeves, Lewis	ENMU
Ret, Doug	Phillips of Oklahoma
Ringle, Greg	Gould Electronics
Robinson, Dave	Consultant
Roltz, Ross	Roltz Engineering
Schenkopf, Ken	SEIA
Schertz, Paul	SKI
Schmitt, Jeff	AAA Solar
Schoen, Neil	Consultant
Schuller, Phil	Pennsylvania Energy Office
Segura, Anthony	City of Albuquerque
Senter, Bill	Sun Utility Network
Spacer, John	Consultant
Spalding, Bill	AET Rep
Spearing, Pat	Thermo Max
Starling, Bob	Corps of Engineers/ Huntsville
Stein, Bill	Ft. Huarachua, AZ Solar Collectors
Stern, Margorie	NRECA
Taswell, Ann	Sarasota Florida
Thomas, Warren	Tinker AFB Industrial Center
Thomas, Susie	VA Energy Office
Thompson, Charlie	Thompson Assoc.
Utley, Mel	Central NM Correctional Institute
Vaught, Russell	Tinker AFB Industrial Center
Velter, Paul	State of California
Wake, Matthew	Carbondale, IL
Welch, Julie	Arkansas Sci & Tech Authority
Wildin, Bud	UNM
Wildin, Maurice	Analysas
Wilkenson, Bob	Santa Barbara Solar

INSOLATION

Aguillar, Irene	NREL
Bahm, Ray	Ray Bahm Assoc,
Bolluk, Phil	Ascencion Technology
Cooley, Jim	Consultant
Crutcher, Frank	Consultant
Dolmier, Steve	N. Power Systems
Letendre, Steve	NY State Energy Office
Perez, Richard	State U of NY
Polanski, Ann	SEIA
Renae, Dave	NREL
Renee, Dave	NREL
Sockwell, Jimmy	U of Chicago
Stoefel, Tom	NREL

MODELING

Alleed, Dennis	Battelle NW Labs
Bolduck, Phil	Ascention Technology
Burns, Tom	Burns Milwaukee
Curtis, Bill	Consultant
Dunlop, John	SRRC
Fairchild, Chris	NMSEIA
Friend, Ed	Consultant
Habert, Joja	Consultant
Klein, Sandy	U of Wisconsin
Lippert, John	Advanced Sciences, Inc.
Little, Theresa	Consultant
Lotker, Michael	Consultant
Meindl, Ed	Algone Software
Walker, Graham	University of Calgary

SOLAR ABSORPTION COOLING

Block, Dave	FSEC
Bronstein, alan	Sunstream
Byam, John	Morgantown Energy Technology Center
Chabot, Ernie	DOE/HQ
Clark, Nolan	USDA
Cochran, Don	Roper Mount Science Center
Decker, Clarence	City of Albuquerque
Erickson, Don	Energy Concepts
Fiedemann, Tom	Florida Solar Energy Center
Gonzales, Jorge	U of Puerto Rico
Gotzi, Phil	Zamack
Hoffstatter, Lloyd S.	NY State Energy Office
Kakow, Burton	U of S. Florida
Kaylor, Bud	McDill AFB
Kitchar, Andy	Research, Inc.
Muhn, R.	Meridian
Nemmco, Bruce	FSEC
Nixon, Jack	Yuma Proving Ground
Taylor, Mark	Socorro
Thornbloom, Mark	Florida Solar Energy Center

SOLAR EDUCATION

Appenzeller, Michelle	Middleburg, Florida
Beck, Chirsteen	SNL/Educ
Benolt, D.	Barre, Vermont
Block, Dave	FSEC
Cantwell, Rebecca	Consultant
Cooley, A.	Barre, Vermont
Decker, Clarence	City of Albuquerque
Fiedemann, Tom	Florida Solar Energy Center
Gilbertson, Neil	SNL
Holley, Ken	SNL
Johnson, L.	Barre, Vermont
Key, Art	Consultant
Ladas, Linda	SEIA
Miller, Jennifer	Science Service
Milligan, B.	McIntosh Middle School Sarasota Florida
Nemmco, Bruce	FSEC
Olaxac, Jim	Showboard Inc.
Olsen, Kurt	SNL
Ordego, Sheila	Santa Fe Community College
Ross, Jeff	RETI
Schulties, Tom	SNL

Smith, Jeremy	High school student, Sevierville, TN
Thornbloom, Mark	Florida Solar Energy Center
Zeiloiskoski, Cherry	SIPI

SOLAR FURNACE

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

SOLAR THERMAL SYSTEMS

Allegro, Joe	Inner Solar Roof Systems Inc.
Beanaman, Carl	Mississippi Energy Office
Beer, Gino	Consultant
Bentner, Lisa	Meridian
Bullock, Don	Texas Energy Office
Burns, Tom	Burns Milwaukee
Cabanillas, Rafael	U of Sonora
Cable, Bob	Kramer Junction Co.
Cawthorn, Tom	NREL
Christeen	Energy Office Clearing House
Clarity, Denise	Consultant
Clarkton, G.	DOE
Cohen, Gilbert	Kramer Junction Co.
Cole, Howard	Porous Metal Prod.
Cornwell, Terry	DOE
Coursen, Dan	GM Vacuum
Dawson, Dan	SNL/CA
Dutler, Derrick	Peco Gen
Fossum, Donna	CTI
Foster, Robert	NMSU
Frier, Scott	Kramer Junction Co.
Gee, Randy	IST
Guedes, Carlos Eduardo	IADB
Hanlon-Meyer, Chris	Consultant
Hertweek, Roy	SNL
Hulstrom, Roland	NREL
Ingersol, John	Consultant
Johnson, Brian	State of New Mexico
Johnstone, Rick	SEGS
Jones, Sandy	Earth Info.
Jurman, Ken	State of Virginia
Kanelloponlos, Sia	Full Circle
Kearney, Dave	Kramer Junction Co.
Kemp, Jim	Enron Corp
Korpelus, Eric	Full Circle
Lambert, Ken	PAL Engineering Services, Inc.
Laton, Wayne	Dagget Leasing
Lawson, Steward	Kramer Junction Co.
Lespron, Tony	Consultant
Machuca, Edwardo	CIEDAC
Markem, Chuck	AAA Solar
Mathis, Diane	Harper Lake
McCracken, Horace	McCracken Solar
McSorley, T.	Wash State Energy Office
Mebarek, Boukar	Ingenieur Thermicien Michigan
Mørner, Svein O.	Consultant
Machuca, Eduardo	CIEDAC
Martin, Christeen	Consultant
Mendivil, Jorge Ibarra	University of Sonora
Paquetta, David	Amita Corp.
Pearlson, Richard	Consultant
Petersik, Tom	DOE/HQ
Plympton, Patricia	EPA
Rodosovitch, Carol	PNM
Sater, Bernard	Consultant
Serantis, heather	Morinco Consulting
Sheikh, Nayeem	San Jose Office of Env. Mgmt.
Sivapalan, N., Dr.	Consultant
Tedesco, George	Consultant
Thomas, Susie	VA Energy Office
Torrecillas, Alfredo	CIEDAC
Williams, DeJuan	International Connection
Willis, Eric	Dagget Leasing Corp
Wirdzek, Phil	EPA

SOLAR THERMAL TESTING

Akerlof, Carl	
Ashley, Carol	SNL
Bahm, Ray	Ray Bahm & Assoc.
Beckman, Bill	U of Wisconsin
Bloyd, Cary	Pacific International Center for High Technology Research
Blum, Beverly L.	Solar Box Cookers
Blummer, Roger	GSA
Brundage, Don	Consultant
Campbell, Joy	Consultant
Delaplain, Gilbert	SNL
Donnelly, Hal	Virgil/Summer Co.
Drabka, Bob	MDAC
Edgin, Robert	Solar Ovens Inc.
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Epner, David	Epner Technologies
Erickson, Carl	Energy Concepts Co.
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Flachs, Sharlene	Consultant
Franklin, Tanya	Wescam Marketing
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Ganguli, T.S.	TARA
Gevnais, Bob	MDAC
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Henza, Charles	DOE/OFTA
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Jacob, John	Consultant
Jacobs, Jeff	Consultant
Johnson, Mike	Ray Chem
Johnson, Dave	Antenna Engineering
Johannson, Stefan	STM
Jones, Derry	Carlsbad Consultant
Jones, James	Consultant
Jozefowska, J.	CIC Victor Boreal Inc.
Karnowski, Peter	SNL
Keshishian, Vahe	Rocketdyne
Kirchner, Kelly	TMA
Lankford, Bill	George Mason University
LaNord, Roger	SNL
Lilly, Patty	Regional Economic Research
Lipinski, Thomas	Consultant
Mahuke, Mark	Antioch, CA
Maiden, Miles	American Sun Co.
Malone, Robert	LANL
Margaleze, Offa	Consultant
Markham, Michael	Consultant
Matthews, Steve	Consultant
McDonough, Pat	Consultant
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Morgan, Phyllis	Redi Communication
Neal, Janet	Technology Properties Limited
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Prechtl, William III	PCI
Rathswohl, Mark	CCC
Ray, Michelle	Black & Veatch
Reff, Maria Rachel	Consultant
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Roberts, Thomas A.	SMP Technology
Rodriguez, paul	solar Roof
Rosenthal, Andrew	NMSU
Rosocha, Louis	LANL
Sahasranaman, C.R.	Thermosol Equipments
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Sorensen, Kurt	Consultant
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Tachan, Bob	Consultant
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Turner, Dave	Consultant
Ulrich, Jim	STM
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Vasishth, Vin	Consultant
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Zhuang, Eagle	Consultant

UTILITIES

Barski, V.	CIC Victor Boreal Inc.
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Fox, Lucien	Ogden Power
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Haarklou, Olav	Utility Free
Haque, Nabilah	EPA
Harlon, Mark	PNM
Hayden, Herb	APS
Hayes, Jim	SMUD
Johnston, Glen	Energy Research Centre
Jones, Perry	WIPP Site - NM
Kearney, Dave	Kearney & Assoc
Lasiah, John	Solar Research Corporation Pty Ltd.
McCononey, John	KJC
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Murphy, Brian	NY State Energy Office
Pinkston, Diana	APS
Seki, Art	Hawaiian Electric Co.
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Wallace, Robert	Research Triangle Institute
Wildin, Bud	University of New Mexico
Williamson, Roy	Arizona Corp Commission

INTERNATIONAL

Barr, Summer	LANL
Barrett, Chris	LANL
Berger, Michael	LANL
Berr, Michael	Energy Technology Programs
Bitner, Lisa	Meridian Corp.
Booth, Steven	LANL
Branski, Joel	Inter-American Development Bank
Brown, Donald	LANL
Cabanillas, Rafael	U of Sonora
Christiansen, Amy	DOE
Cottinggame, William	LANL
Davies, Mac Cosgrove	World Bank
Duchane, Dave	LANL
Foster, Robert	NMSU
Galindo, Ing. Victor Tamayo	ENTEC
Gallegos, Richard	Consultant
Glasser, Robert	CNSS
Glassley, Bill	LLNL
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Machina, Eduardo	ENTEC (Mexico)
Meyers, C. Wes	LANL
Muhn, Rob	Meridian
Ochoa, Ing. Lopez	Sonora State Gov.
Peterson, Elias-Axel	Consultant
Rosenbert, Nina	LANL
Rovero, Chris	Meridian
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Stack, Desmond	LANL
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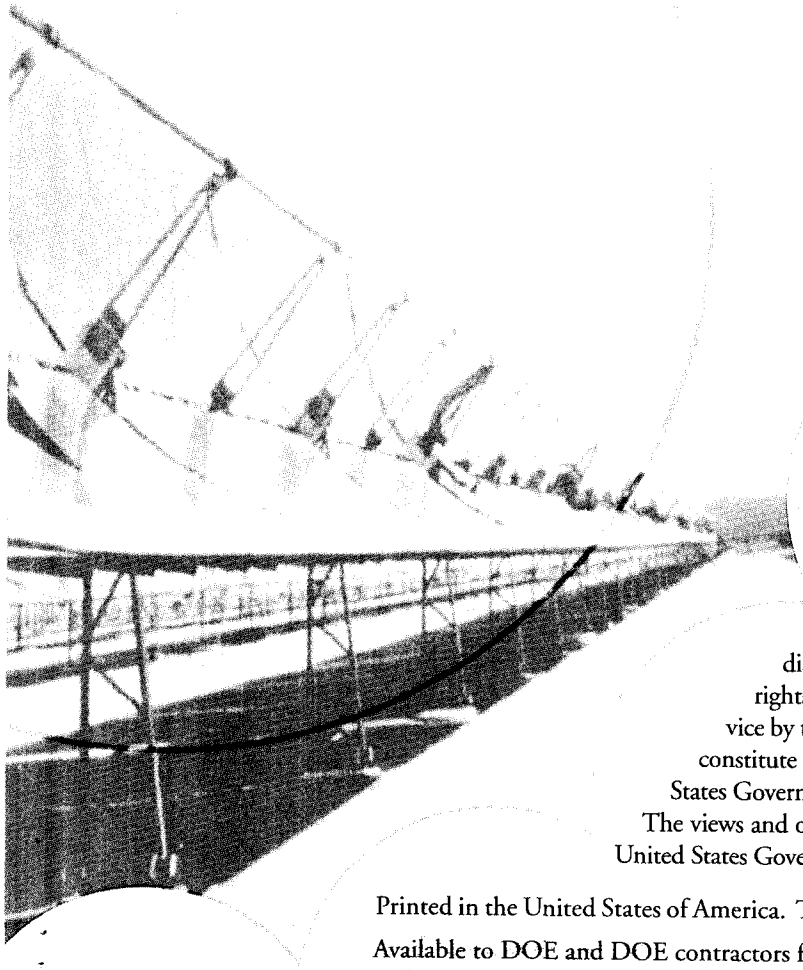

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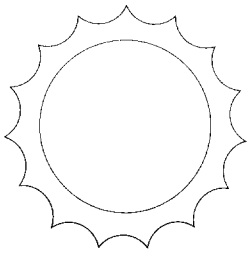

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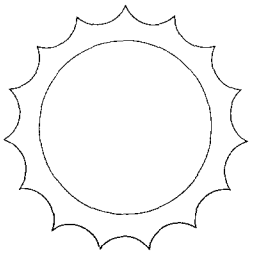

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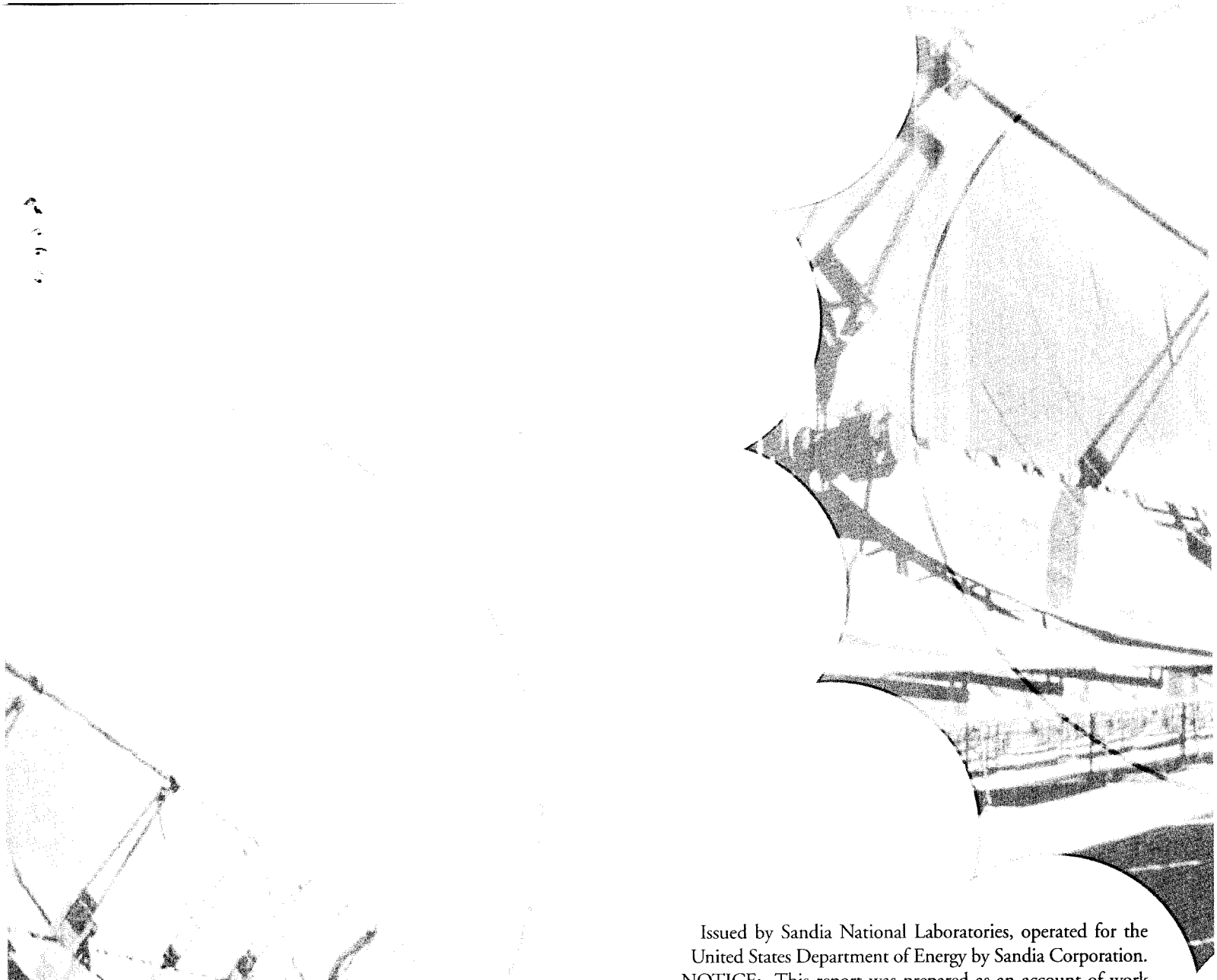

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