QR-3-90

Quarterly Progress Report:

THIRD QUARTER FISCAL YEAR 1990

DOE SOLAR THERMAL ELECTRIC TECHNOLOGY PROGRAM

Submitted By:

Sandia National Laboratories
Albuquerque, New Mexico

Solar Energy Research Institute
Golden, Colorado

Issued July, 1990

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FOREWORD

The research and development described in this report was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. This document is prepared jointly and reports the work of both major field laboratories, Sandia National Laboratories (SNL) and the Solar Energy Research Institute (SERI), and their contractors.

With the recent reorganization within the Department of Energy's Office of the Assistant Secretary for Conservation and Renewable Energy, the Solar Thermal Technology Program was divided into two separate efforts. One is aimed at solar thermal electric application and the other focuses on industrial applications of solar technologies. This report describes only that work directly related to the Solar Thermal Electric Program.

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MANAGEMENT STATUS REPORT

Structure of the Solar Thermal Electric Technology Program

The Solar Thermal Electric Technology Program is structured to focus on commercialization opportunities for the technology while maintaining a baseline of research and development which is essential to achieving the long-term technological goals. The elements of the program are shown below. Their numbering and designations are maintained as shown in the Solar Thermal Technology Program FY 1990 Annual Operating Plan.

2. CONCENTRATOR DEVELOPMENT

    Task A. Heliostats
    Task B. Parabolic Dishes
    Task C. Optical Materials
    Task D. Structural Dynamics

3. ELECTRIC SYSTEMS DEVELOPMENT

    Task A. Central Receiver Technology
    Task B. Distributed Receiver Technology
    Task C. Conversion Technology

4. TECHNOLOGY DEVELOPMENT

    Task A. Next-Generation Commercial Systems
        Subtask A-1. Project Development
        Subtask A-2. Partner-Driven Research and Development
        Subtask A-3. Design Assistance and CORECT Support

    Task C. Advanced Electric Technology
        Subtask C-1. Technology Identification
        Subtask C-2. Joint-Venture Consortia
        Subtask C-3. Development Requirements
        Subtask C-4. System Experiments

Field Management—Structure and Responsibilities

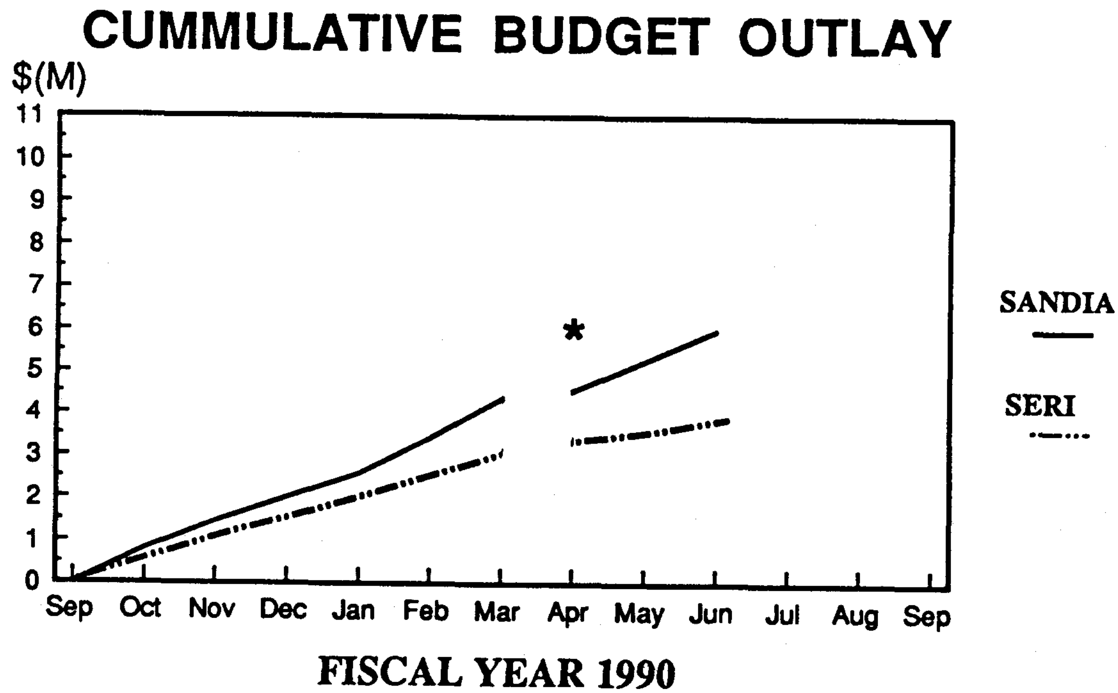
Specific implementation of the Solar Thermal Electric Technology Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the Solar Energy Research Institute in Golden, Colorado. Together, these two field laboratories are responsible for implementation of the research and development 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.

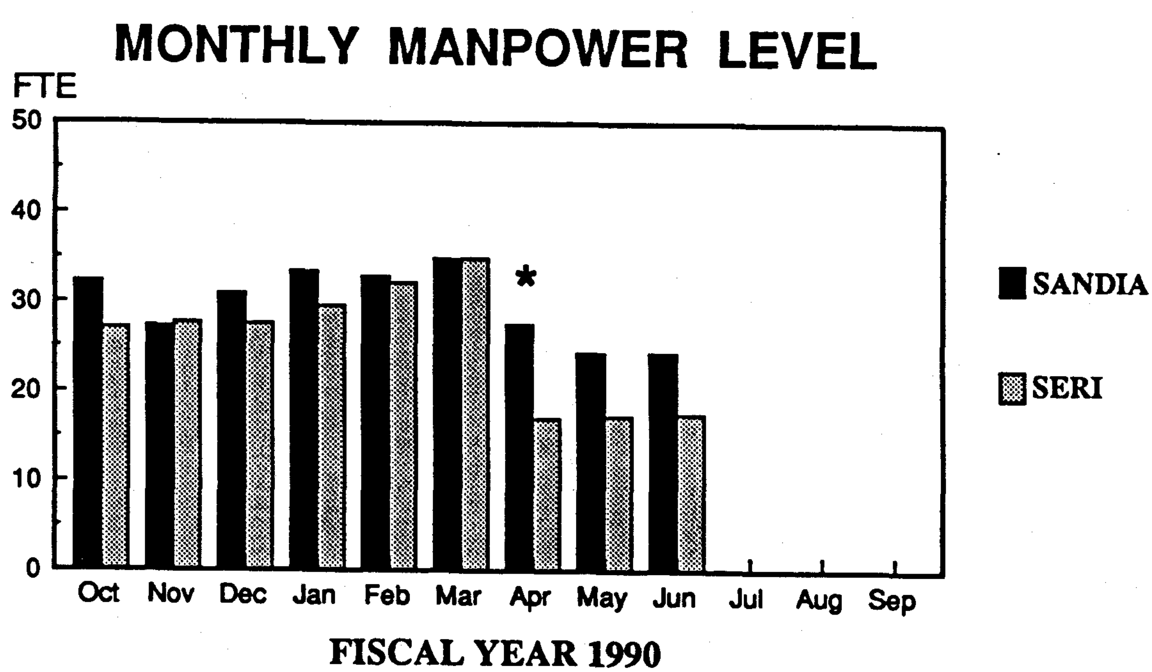
A field Laboratory Management Council (LMC) provides the focus for interaction with the DOE program management and for planning and coordination of the field activities. The LMC is co-chaired by a senior management representative from each laboratory. In order to provide a clear delineation of management responsibilities for each program activity, a lead responsibility is assigned by laboratory for each of the current program activities.

SOLAR THERMAL ELECTRIC TECHNOLOGY PROGRAM WORK BREAKDOWN STRUCTURE

PROGRAM ACTIVITY	LEADER (Individual)
2. CONCENTRATOR DEVELOPMENT	C. Tyner, SNL/M. Carasso, SERI
A. Heliostats	
B. Parabolic Dishes	
C. Optical Materials	
D. Structural Dynamics	
3. ELECTRIC SYSTEMS DEVELOPMENT	P. Klimas, SNL
A. Central Receiver Technology	
B. Dish Receiver Technology	
C. Conversion Devices	
4. TECHNOLOGY DEVELOPMENT	
A. Next-Generation Commercial Systems	J. Holmes, SNL
C. Advanced Electric Technology	P. Klimas, SNL

Resource Summary





*Note: For March and prior months, costs and manpower levels include both electric and non-electric projects; for April and later months, only electric costs and manpower are included.

Procurement Summary

SOLAR THERMAL ELECTRIC SUBCONTRACTS

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1990 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
Con. Dev.	Replaceable Membrane	IST	SNL42-9690	$50	$50	--	11/89 - 06/90	Small	TBD	D. Alpert
Con. Dev.	Heliostat Integration	Solar Kinetics, Inc.	SNL42-9691	$100	$100	--	10/89 - 04/90	Small	TBD	D. Alpert
Con. Dev	Heliostat Fabrication	SAIC	SNL54-5780	$540	$400	$140	01/90 - 09/90	--	TBD	D. Alpert
Con. Dev.	NSTTF Technician Services	Ewing Technical Design	SNL63-5487	$1,350	$450		04/89 - 04/92	--	TBD	E. Rush
Con. Dev.	Coll. Supp. Struc.& Ped.	WGAssoc	SNL42-9813	$190 (est.)	--	$190	09/89 - 06/91 (est.)	--	TBD	T. Mancini
Con. Dev.	Faceted Dish Development	SKI SAIC	SNL42-9814	$234 $191	-- --	$234 $191	09/89 - 06/91 (est.)	Large	TBD	T. Mancini
Con. Dev.	Low-Cost Drive	Peerless-Winsmith	SNL90-5753	$487	--	--	Active	--	--	J. Grossman
Con. Dev.	Stretched-Membrane Dish Dev.	Solar Kinetics, Inc.	SNL55-2495	$1,851	$500	--	04/88 - 12/89	Small	SAND88-7035	T. Mancini
Con. Dev.	Solar Coll. Ped. Fab	TIW Fab. & Mach.	SNL57-4436	$57	--	--	12/87 - 12/89	Large	--	T. Mancini

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1990 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
Elec Tech	Reflux Heat-Pipe Rec.	Stirling Ther. Motor	SNL33-3036	$225	$101		04/87 - 6/90	Small	--	R. Diver
Elec Tech	DAR Design Studies	Foster Wheeler	SNL06-0312	$136.9	10		6/87 - 9/89 (Extended to 09/90)	Large	SAND88-7038	J. Chavez
Elec Tech	Molten Salt Subsyst/Comp. Test Exper.	B&W	SNL91-4687	$7,884	30		03/84 - 09/89 (Extended to 06/90)	Large	SAND87-2290	J. Chavez
Elec Tech	Volum. Rec. Furnace Test	NMSU	SNL66-9967	$30	-0-		01/90 - 08/90	Univ.	--	J. Chavez
Elec Tech	PRE Panel/ Manifold	Hufman, Inc.	SNL70-8957	$20	$20		Closed	Small	--	J. Chavez
Elec Tech	STM4-120	Stirling Ther. Motor	SNL53-8452	$300	$15		07/86 - 12/89	Small	--	K. Linker
Elec Tech	2ndSTM4-120	Stirling Ther. Motor	SNL75-8851	$360	--	--	04/89 - 06/90	Small	--	K. Linker
Elec Tech	ASCS Design	NASA LeRC	DOE Inter-agency	$750	--	--	01/89 - 01/93	Govt.	--	K. Linker
Elec. Tech.	Solar Test Support	EG&G	SNL05-4912	$150	$150		12/88 - 10/93	Large	--	C. Cameron
Elec Tech	Electrical Support Service	J & S Electric Co., Inc.	SNL75-7415	$120	$60		02/89 - 02/92	Serv. Support	--	J. Stomp, Jr.

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1990 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
Elec Tech	Solar Rec. Heat Loss Testing	California Polytech	SNL02-5759	$105	$30		09/86 - 02/90	Univ.	ASME and ISES papers	A. Heckes
Elec Tech	STEP Test Program	Georgia Power	SNL42-4859	$42	$42		06/89 - 03/90	Large	Final Test Report	A. Heckes

KEY
Con. Dev. = Concentrator Development
Elec. Tech. = Solar Electric Technology

NOTE - This list contains subcontracts exceeding $25,000.

Major Milestone Schedule

For reference, milestones identified in the FY 1990 AOP for each program task are given below. This set of milestones forms the basis for progress reporting and tracking in this Quarterly Progress Report. Quarterly reports focus on the status of each milestone for the current quarter in the "Significant Accomplishments Summary."

Fiscal Year 1990

Lab	Date	Activity-Task Reference	Descriptive Title
First Quarter, FY 1990			
SN	October, 1989	3B	Complete bench tests of heat-pipe receivers.
SN	November, 1989	2A	Initiate fabrication of first prototype of SAIC's 100-m^2 market-ready heliostat.
SN	November, 1989	3A	Complete installation of the PRE.
SN	November, 1989	3B	Complete on-sun testing of a reflux pool boiler at the STTF.
SN	November, 1989	4C-1	The responses to the Request for Information will be evaluated.
SN	December, 1989	4A-1	Award multi-year R&D system improvement contracts with one or more industrial partners.
Second Quarter, FY 1990			
SN	January, 1990	2A	Complete testing and documentation of two improved prototype stretched-membrane mirror modules.
SN	January, 1990	2D	Complete documentation of initial wind load studies.
SN	January, 1990	3A	Initiate the salt flow testing on the PRE.

Lab	Date	Activity-Task Reference	Descriptive Title
SN	February, 1990	2B	Complete fabrication of the seven-meter single element module.
SN	February, 1990 (April, 1990)	3C	Initiate final design of Advanced Stirling Conversion System.
SN/ SE	March, 1990	4A-3	Participate in the SOLTECH90 joint meeting.
Third Quarter, FY 1990			
SN	April, 1990 (Sept., 1990)	2A	Complete testing and documentation of the low-cost drive.
SE	May, 1990	2B	Complete validation of SHOT.
SN	May, 1990 (Sept., 1990)	2B	Complete on-sun testing of the seven-meter single element module.
SN	May, 1990 (Oct., 1990)	3A	Complete the comparative study of salt and air receivers.
SN	May, 1990	3B	Decision on heat-pipe versus pool-boiler receivers for further development.
SN	May, 1990	3C	Initiate Final Design of ASCS
SN	June, 1990 (Aug., 1990)	2A	Complete design of SKI's market ready prototype heliostat.
SE	June, 1990	2B	Complete computer model of the faceted dish support structure.
SN	June, 1990 (Oct., 1990)	2B	Complete optical testing of the facets for the faceted dish.
SN	June, 1990	3A	Complete the Phase 1 solar testing of the PRE.

Lab	Date	Activity-Task Reference	Descriptive Title
SN	June, 1990	3A	Complete 4000 hours of operation on the molten salt pump and valve hot loop; complete 2000 hours of operation on the cold loop.

Fourth Quarter, FY 1990

Lab	Date	Activity-Task Reference	Descriptive Title
SN	July, 1990 (Sept., 1990)	2A	Complete fabrication of SAIC's prototype of 100-m^2 market-ready heliostat.
SN	July, 1990 (Dec., 1990)	2B	Program decision point: Dish designs to fabricate and test.
SN	July, 1990 (Cancelled)	2C	Complete the Sol-Gel mirror production cost study.
SN	July, 1990 (Oct., 1990)	2C	Complete and document replaceable film study.
SN	July, 1990	3B	Complete preliminary design of a hybrid reflux receiver.
SE	August, 1990	2B	Complete validation of OPTDISH and ODMF optical codes using the data from SHOT.
SN	August, 1990	3A	Complete testing of an optimized volumetric receiver absorber.
SN	September, 1990	2A	Initiate fabrication of first prototype of SKI's market-ready heliostat.
SN	September, 1990	2A	Complete testing and documentation of two large-area glass-mirror heliostats.
SE	September, 1990	2C	Complete and document preliminary evaluation of ultraviolet-enhanced mirrors for photochemical applications.
SE	September, 1990	2C	Document studies of polymer film-to-silver adhesion.

Lab	Date	Activity-Task Reference	Descriptive Title
SN	September, 1990	3C	Initiate on-sun testing of the STM 4-120 Stirling.
SN	September, 1990 (Nov., 1990)	3A	Complete a draft report describing US/FRG collaborative study of second-generation central receiver technology.

Fiscal Year 1989 (Rescheduled to FY 1990)

Lab	Date	Activity-Task Reference	Descriptive Title
		C2-2 (December, 1989)	Report on evaluation of LaJet innovative dish performance.
		C2-1 (January, 1990)	Topical report on Sandia's optical and environmental evaluation of SAIC and SKI improved 50 m^2 membrane mirror modules.
		C3-1 (January, 1990)	Initiate six-meter DAR salt flow testing.
		C2-1 (Aug., 1990)	SKI contractor report on the design of a market-ready integrated aluminum membrane heliostat based on test results for the improved 50 m^2 mirror module.
		C2-2 (June, 1990)	Deliver seven-meter-diameter aluminum membrane dish optical element for testing at the STTF.
		C2-3 (Cancelled)	Document cost potential of silvered metal structural mirrors.
		C2-2 (Sep., 1990)	Decision point—begin commercial scale design or refine seven-meter optical element design to improve performance.

Lab Date	Activity-Task Reference	Descriptive Title
	C2-4 (Sept., 1990)	Topical report on innovative heliostat drive system performance.
	M1-1 Deleted	Complete contract negotiations and award contract.
	M1-2 Deleted	Complete an R&D plan and initiate R&D activities.

Note: Dates that are in parentheses indicate a rescheduling.

SIGNIFICANT ACCOMPLISHMENTS SUMMARY

MAJOR MILESTONES	Planned	Actual
FY 1990		
TASK 2. Concentrator Development		
• Complete fabrication of the seven-meter single element module. SN(2B)	02/90	06/90
• Complete validation of SHOT. SE	05/90	05/90
- This milestone was completed as scheduled.		
• Complete computer model of the faceted dish support structure. SE	06/90	
- This milestone has been recommended for deletion.		
TASK 3. Electric Systems Development		
• Initiate the salt flow testing on the PRE. SN(3A)	01/90	
• Initiate final design of Advanced Stirling Conversion System. SN(3C)	02/90 (04/90)*	
- Sandia and NASA/LeRC were scheduled to award contracts for the final design of the Advanced Stirling Conversion System (ASCS). Due to a delay in funding, this contract was not placed.		
• Complete on-sun testing of a reflux pool-boiler at the NSTTF. SN(3B)	11/89	5/90
• Complete the comparative study of salt and air receivers. SN(3A)	5/90 (10/90)*	

*** Rescheduled to this date.**

MAJOR MILESTONES (continued)	Planned	Actual
• Decision on heat-pipe vs. pool-boiler receivers for further development. SN(3B)	5/90	5/90
• Complete 4000 hours of operation on the molten salt pump and valve hot loop. SN(3A)	6/90	4/90
• Complete 2000 hours of operation to molten salt pump and vlave cold loop. SN(3A)	6/90	

TECHNICAL STATUS REPORT

2. CONCENTRATOR DEVELOPMENT

Objective

The objective for Concentrator Development is to develop cost-effective concentrators and optical materials to support a variety of solar thermal applications.

TASK 2A. HELIOSTATS

Accomplishments

- **Solar Power Engineering Co.'s 200 m^2 heliostat reinstalled at the National Solar Thermal Test Facility.**

  On May 14, Solar Power Engineering Co.'s 200-m^2 heliostat was reinstalled at the National Solar Thermal Test Facility. Daryl Bielenberg of SPECO used the NSTTF's heliostat characterization system to cant and align the heliostat's 36 mirror modules. Sandia began an evaluation of the optical performance of the heliostat including the quality of its beam, its tracking accuracy, and its stability in windy conditions. (SNL)

- **Science Applications continued the fabrication of its 100-m^2 market-ready stretched-membrane heliostat.**

  SAIC continued the fabrication of its 100-m^2 fully integrated stretched-membrane heliostat. The heliostat's drive was delivered by Peerless-Winsmith, specification of the control system was completed, and major components fabricated. The market-ready heliostat is scheduled to be installed at the NSTTF for Sandia's evaluation in September 1990. (SNL)

- **Solar Kinetics, Inc., continued the design of its 50-m^2 market-ready stretched-membrane heliostat.**

  SKI continued the design of its 50-m^2 fully-integrated stretched-membrane heliostat. Design drawings for major components were completed and estimates of heliostat costs were developed. The design is scheduled to be completed in August 1990. (SNL)

Planned Activities for Next Quarter

- Testing and evaluation of SPECO's 200-m^2 heliostat, ATS's 150-m^2 heliostat and the Winsmith low-cost heliostat drive will be completed and documented.
- SAIC will install the first prototype of its 100-m^2 market-ready, stretched-membrane heliostat.
- SKI will complete the design of a 50-m^2 stretched-membrane heliostat

TASK 2B. PARABOLIC DISHES

Accomplishments

- **7-Meter stretched-membrane optical element assembled at Sandia.**

  Solar Kinetics Inc. (SKI) of Dallas, Texas assembled the 7-meter diameter, stretched-membrane optical element at National Solar Thermal Test Facility (NSTTF) in Albuquerque, New Mexico.

  The 7-m optical element was formed in Dallas using an iterative process in which uniform and nonuniform loads, vacuum and hydroforming with water, respectively, were applied to plastically form the metal membrane into a parabolic shape. (Figure 2.1 is a picture of the dish being formed in Dallas.) Three 7-meter membranes have been formed, and each has demonstrated improved performance over the previous

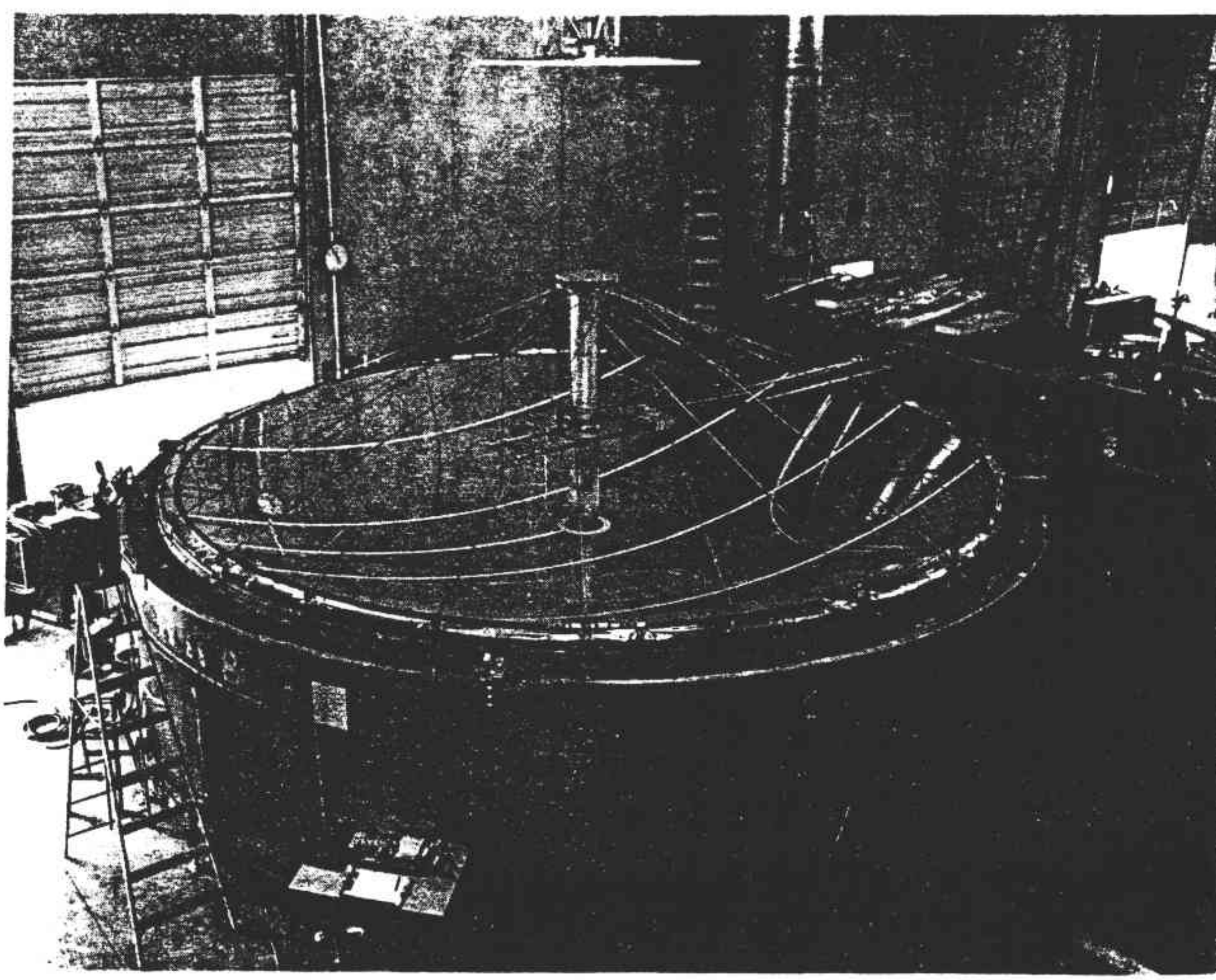


Figure 2.1 7-m Stretched Membrane Dish Being Formed in Dallas, TX

ones. With the third membrane in place, the optical element was tilted to a vertical position and its slope error measured using a video-ray-trace (VRT) system. The VRT scans the surface of the dish with a laser beam and records the location on a target plane of the reflected image. The comparison of the position on the target plane of the reflected beam with the position that a beam would be reflected from a *perfect* parabolic dish allows us to determine the slope error for the dish. Using a scan of 1000 points over the surface, SKI measured a 3.6 milliradian 1σ slope error for the dish. This measurement includes both the slope error for the dish and the specularity of the aluminized polyester optical film.

After testing was completed in Dallas, the optical element was disassembled, shipped to Albuquerque, and reassembled at the NSTTF. The test fixture for tracking the optical element on sun has been fabricated and checked out. The optical element will be placed on the test fixture and on-sun testing will begin early in the next quarter.

- **Faceted stretched-membrane dish design meeting held.**

A faceted dish design team meeting was held at Sandia National Laboratories in Albuquerque, New Mexico on May 8, 1990. The meeting was attended by Solar Kinetics Inc. (SKI) of Dallas, Texas, Science Applications International Corp. (SAIC), of San Diego, California, and WGAssociates (WGA) of Dallas, Texas, and staff from SERI and Sandia.

Phase 1 of the Faceted Stretched-Membrane Dish Project is the development and testing of facets fabricated by SKI and SAIC and the development of facet support structure and pedestal designs by WGA. Solar Kinetics is developing 3.6-meter diameter, stretched-membrane facets using the plastic forming techniques that they have successfully demonstrated for the 7-meter dish. SAIC is fabricating elastically formed facets similar in construction to those developed for the stretched-membrane heliostats. WGA is designing the facet support structure and pedestal for the 12-facet dish.

The following design decisions were reached at the review meeting:

- The dish will be designed to operate with an uninterruptible power supply (UPS).

- The use of an UPS eliminates the need to design the dish to sustain stow loads at any orientation, in the event that power is lost during normal operation.

- The LTV, JPL, and MIT drag-coefficient data will be used to calculate the wind loading on the solar concentrator. These data have been used for a number of years to design many communications antennae. There have been no reported failures of communications dishes due to wind loads, although some dishes have been subjected to hurricane-force winds.

One could be concerned that the LTV, JPL, and MIT drag-coefficient data are conservative and, perhaps, overly so for solar concentrator design. However, the Colorado State University wind-tunnel data are even more conservative. Without field measurements to verify wind-load coefficients, we are constrained to use the *best* drag-coefficient data that we have available. The design may be conservative, but this will allow us to reduce any over-design based on experience with the prototype concentrators.

– The Winsmith Low-Cost Drive, developed for heliostats, will be used for the dish azimuth drive. The elevation drive for the dish will be a linear actuator, either a screw jack or ball screw.

SERI completed the initial characterization of the first-generation facets for the faceted stretched-membrane dish with the Scanning Hartmann Optical Testing instrument. The slope error values for the two facets at 3 focal lengths each were found to be 3.5 milliradians or better. These data are discussed in more detail below. Both facet contractors are proceeding to develop a second-generation facet with the objectives of simplifying fabrication and improving performance.

WGA is proceeding with the detailed design of the facet support structure, drives, and pedestal. There has been substantial interaction among WGA, SAIC, and SKI on drives and controls.

- **SERI completed the optical characterization of prototype faceted-dish facets from Solar Kinetics, Inc., and Science Applications International Corporation.**

SERI researchers have completed the optical characterization of two prototype facets for the stretched membrane faceted dish program. One was fabricated and supplied to SERI by Solar Kinetics, Inc. (SKI), and one by Science Applications International Corporation (SAIC). Each facet has a nominal diameter of 3.5 meters and a focal length of 10.60 meters. Each was delivered to SERI by its manufacturer, was ready for testing, and was tested in the condition that it was delivered, without alteration (except for pumping down).

Optical characterization included Scanning Hartmann Optical Test (SHOT) measurements and extensive data analysis and interpretation. Each facet was tested three separate times, one for each of the expected focal lengths for facet groups on the dish structure. Each test resulted in a laboratory report consisting of a summary of pertinent data about the SHOT measurements, facet characteristics, and most importantly, test results, findings, and discussion. In addition, each report also contained a number of selected, colored graphics--data which researchers think are useful in understanding the test results and can be used to improve particular features of facet optical performance. Finally, the reports included an Appendix containing a detailed definition of each of the parameters used in the laboratory reports and an explanation of the same.

The single, most important parameter characterizing the optical performance of each facet is the "Equivalent Slope Error". This is the slope error of a best-fit parabolic surface which gives an RMS spot size at the target plane having the same spot size predicted by OPTDSH when using the results of actual SHOT measurements from the test article. Using this criterion for optical performance, both facets had equivalent slope errors below 3.5 mrads.

- **SHOT validation was completed, and the results are very satisfactory.**

SERI researchers have successfully validated the measurement accuracy of the SHOT instrument. The results of the validation indicate that SHOT is indeed an extremely accurate as well as a rapid-acting instrument for measuring the optical accuracy of concentrators with an f/D ratio between .5 and 3.0. The results indicate an excellent reproducibility of measurements, as well as a high confidence in the absolute error in regard to the quality of the slope error of optical surface measured. This validation is now complete and documented. The material can be made available to interested parties upon request.

It is common practice to "validate" an instrument by comparing its measured value to a measurement done by a standard of some kind, that is, against the value obtained by an instrument whose performance is somehow "known." In the absence of such a standard (it would have been expensive to acquire an optical surface of "known" slope error to use as a standard), SERI researchers devised a scheme for accomplishing the validation by using an existing stretched-membrane dish, but mathematically conducting a conclusive validation.

- **SERI declined a Request for Proposal by Harris Corporation, a NASA subcontractor, to bid on its facet development support.**

SERI received a Request for Proposal (RFP) to measure a number of optical parameters of a facet for Harris Corporation, Government Aerospace Systems Division in Melbourn, Florida. Since the RFP was sent simultaneously to a number of private organizations, SERI was prohibited from competing. However, at the request of the project manager at Harris, SERI sent a package describing its capabilities in this area.

Planned Activities for Next Quarter

- Sandia will start on-sun testing of the 7-meter diameter optical element.
- SKI and SAIC will fabricate and deliver second-generation facets for the faceted dish to SERI for SHOT evaluation.
- SERI plans to conduct the optical characterization of additional facets supplied by SKI and SAIC. In addition, work will be completed on the validation of the OPTDSH and ODMF models.

TASK 2C. OPTICAL MATERIALS

Accomplishments

- **Industrial Solar Technology continued its evaluation of alternative materials for a replaceable reflective film.**

  IST is evaluating alternative polymers and adhesives to be used as a substrate for a replaceable reflective film. The film will use 3M's improved reflective film, ECP-305, and should be applicable to heliostats, dishes, and troughs. Several candidate materials have been selected and are being subjected to mechanical and delamination tests. A complete replaceable membrane is scheduled to be installed on a 50-m^2 membrane heliostat at the NSTTF in October 1990.

- **Proposals received for solar reflector cost study.**

  An RFQ was issued for a Solar Reflector Cost Study to develop production cost estimates for sol-gel mirrors on stainless steel and silver acrylic polymer film laminated to thin stainless steel.

  At the end of the bid period, no proposals were received, and the bid period was lengthened by 3 weeks. Two proposals were received at the end of the extended bid period. Of the two proposals, neither was considered to be responsive to the RFQ. Therefore, the procurement action was cancelled.

- **Several new experiments have been initiated to investigate tunneling of silver reflector materials.**

  Under some conditions, silver polymer reflector materials can exhibit a failure mechanism known as tunneling whereby the silver layer delaminates from the polymer film. Various factors have been proposed as causing such failures, for example, mechanical stress between the two layers and/or the presence of moisture. A number of parameters associated with the test samples are thought to contribute to this process. These conditions include sample size, substrate material, edge-cutting technique, edge-sealing method, and construction of the reflector material. Given a large variation in tunneling test results, it is important to control sample parameters sufficiently well to assure success in understanding how best to deal with the tunneling problem.

  The first series of new experiments explored three anti-tunneling strategies. Samples were prepared having inner seams 18 inches long of ECP-305 material (from the 3M Company) mounted on 304 stainless steel (40 mil thick) substrates (Figure 2.2). Three replications each were prepared and use edge tape, a solvent (methylene chloride) weld, and a thermal weld along the inner seams. An attempt to prevent initiation of tunneling along the outer perimeter was made by holding the outer edges fixed by angle brackets (1-inch wide) tightened by C-clamps which sandwich the substrate/ECP-305/rubber gasket materials. Samples were placed in an immersion tank for the soak part of a wet/dry schedule of one to two cycles per week.

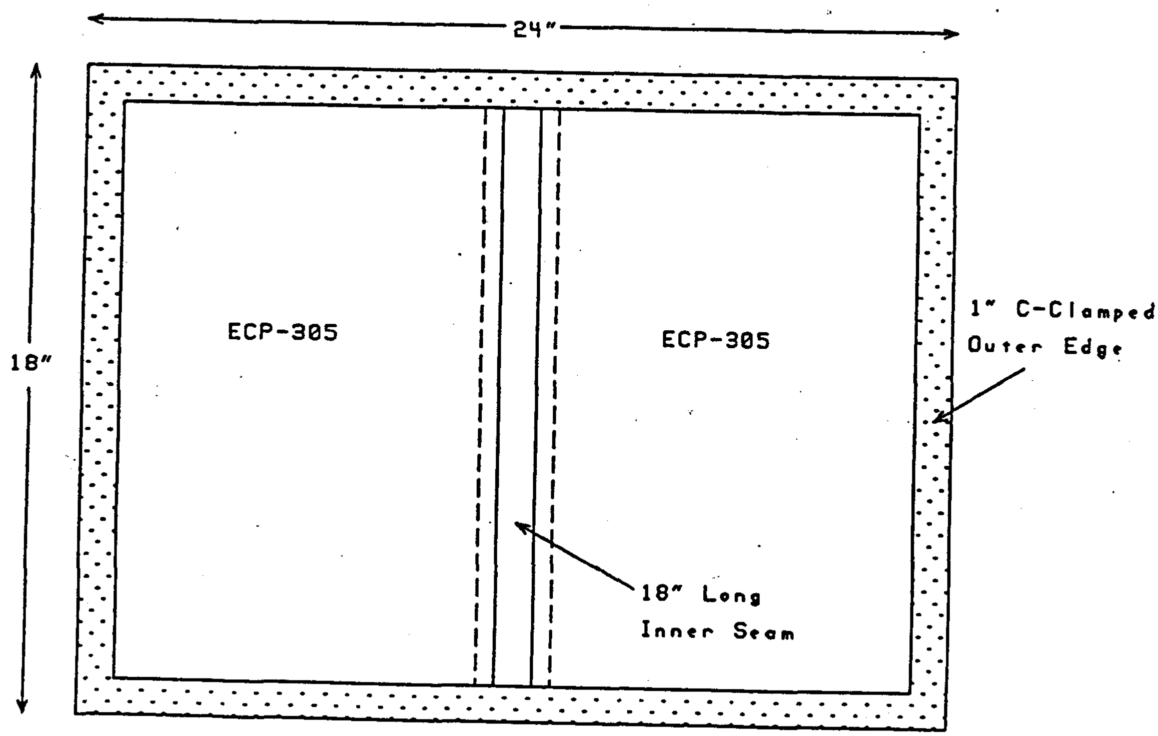


Figure 2.2 Tunneling Test Sample Construction

A second tunneling test was a Latin square statistical test designed to compare substrate materials, cutting methods, and edge-sealing techniques. Preliminary results suggest that to a 95 percent confidence level, heat sealing is an effective means of mitigating tunneling of silvered polymer reflectors. A modified replicate of this test is planned to remove limitations associated with the test design.

It is suspected that damage during service (for example, hail or vandalism) may accelerate the tunneling process. A preliminary investigation of one way to diminish this effect has been carried out. Two sample sets (sample size was 8 inches by 20 inches) were prepared. One sample set (six replicates) was standard ECP-305, and the other (five replicates) had a special material between the polymer film and the silver layer which was designed to avoid or delay tunneling. All samples were mounted on bare aluminum. To exaggerate the potential for failure, samples were severely abused by drill holes, hammer blows, and knife scratches. In the case of the ECP-305, these assaults occurred prior to immersion in water; the other sample set experienced 29 days of water soaking (with no failures) before being assailed.

All six ECP-305 samples had greatly tunneled within four hours of soaking. Of the other set, four showed no evidence of tunnels, and one had a small tunnel after 33 days of water immersion. These preliminary results suggest a promising approach to tunneling abatement during real-world operation.

- **Accelerated exposure of a SERI-prepared, altered-mirror construction continues to demonstrate excellent optical durability.**

Compared with earlier silver-polymer reflector materials (ECP-300A), a more recent material (ECP-305) continues to exhibit better optical durability during accelerated weathering. SERI has demonstrated an even more dramatic improvement in resistance to degradation by providing an effective protection layer behind the silver layer. Mirrors of the older type ECP-300A have maintained reflectance over 90 percent for over four years at sites near Denver, Colorado. At harsher sites such as Phoenix, Arizona, performance was maintained for about two years. The present results suggest that the newer films can resist corrosion of the silver to meet the durability goal of five years.

Accelerated exposure in SERI's Weather-Ometer for up to seven months of samples mounted on bare aluminum substrates shows dramatic improvement in performance for production ECP-305 relative to ECP-300A. Additionally, significantly increased durability is exhibited by 3M silvered X09105 having a SERI-deposited protective back coating (Figure 2.3). The excellent performance of this latter reflector material offers an alternative to the coil-coated metal substrates which also demonstrate good corrosion resistance.

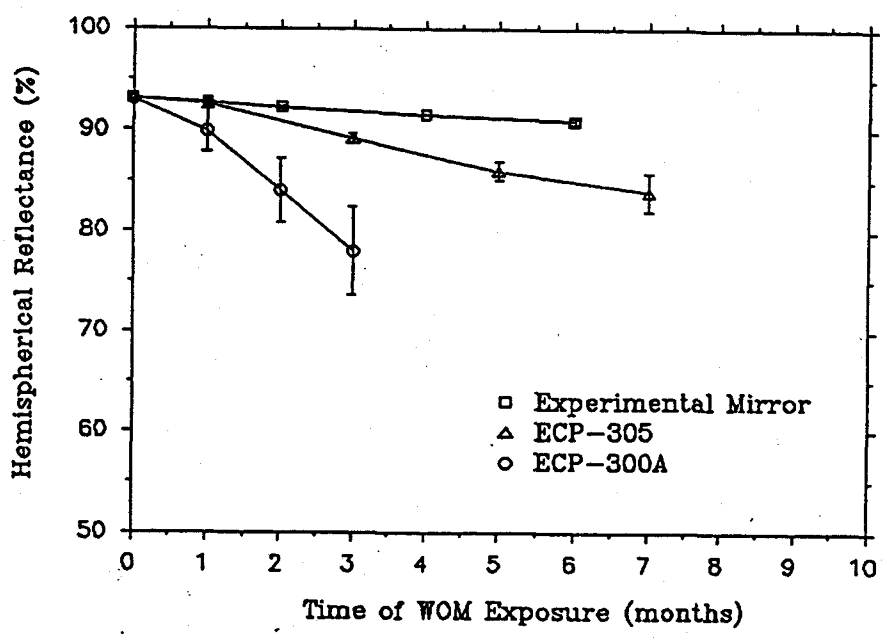


Figure 2.3 Weather-Ometer Experiment; Solar-Weighted Hemispherical Reflectance Measurements

Results for SERI's silvered X09105 samples which have the same protective backing discussed above and have experienced extended exposure in the solar simulator chamber are also very encouraging. Samples mounted on both bare aluminum and bare 304 stainless steel substrates (3 mil thick) show remarkable optical durability for exposure times of 800 to 1000 hours in this extremely harsh (80°C, 75 percent relative humidity, 25 to 50X solar intensity) environment (Figure 2.4). Indications are that a second protective interlayer (between the polymer and the silver) effectively isolates the silver and provides even greater resistance to optical degradation.

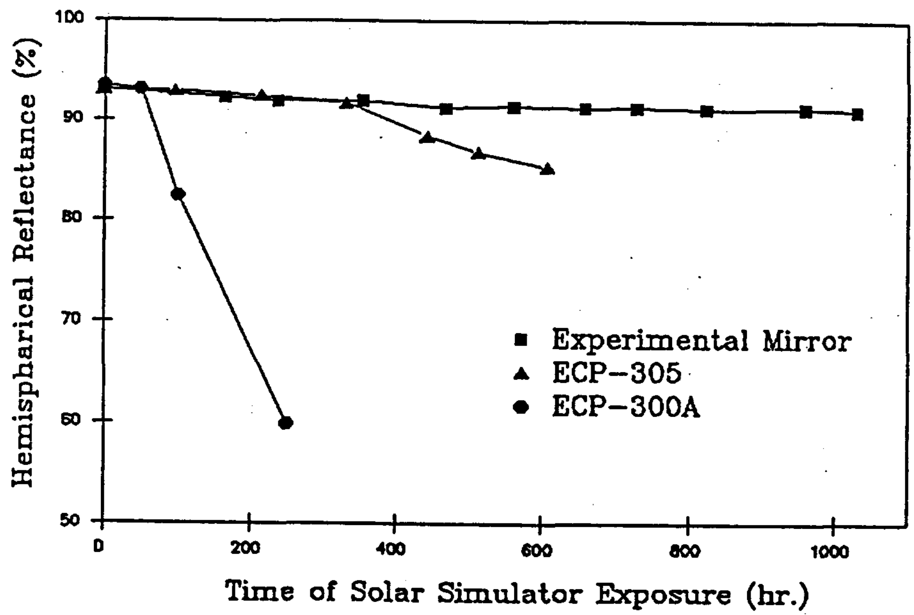


Figure 2.4 Solar Simulator Experiment; Solar-Weighted Hemispherical Reflectance Measurements

Use of protective back coatings may not only eliminate the need for coated substrate materials, but may also provide protection against contamination which may occur during the production process. Figure 2.5 presents a plot of representative solar simulator exposure data. The top layers of all three materials tested (1000Å of silver on X09105 PMMA film) were made at the 3M Company by using its production equipment. The X09105 PMMA is 3M's designation for production-line silvered PMMA before an adhesive layer is applied. The two samples which did not have the adhesive applied at 3M were handled identically at SERI except for deposition of a back protection layer on one of the samples. All samples experienced identical exposure conditions in SERI's solar simulator chamber. Additional data for other variations (in terms of substrate material, thickness of the protective layer, etc.) confirm the results shown in Figure 2.5. As can be seen, the protective backing is an extremely effective way of extending the durability of the production line mirror material.

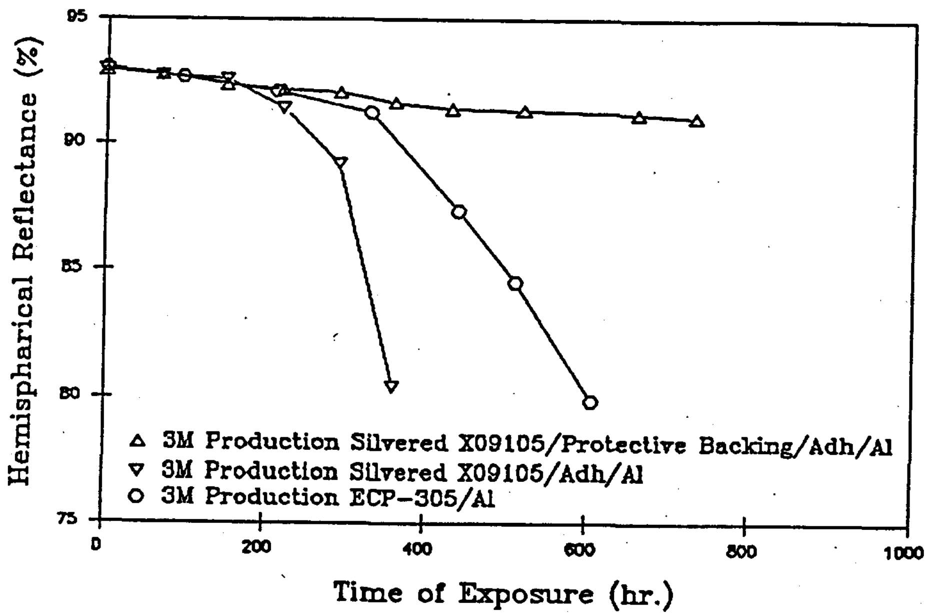


Figure 2.5 Optical Durability of Several Production Run Silver Polymer Reflector Constructions

- **Mechanical tests were conducted to determine the effects of cyclic stresses on the optical performance of ECP-305 mounted on 304 stainless steel substrates (3 mil thick).**

Cyclic mechanical testing of samples of ECP-305 reflector material mounted on 304 stainless steel substrates (3 mil thick) has been completed. These tests and results are important because they address concerns with regard to the effect upon optical durability of cyclic loads anticipated during normal operation of stretched membrane dish concentrators.

Tests were performed by Hauser Laboratories (located in Boulder, Colorado) under contract to SERI. Two test procedures were carried out and correspond to the proposed fabrication methods and service conditions of two industrial subcontractors. In one instance, samples were prestressed and then cyclically were loaded in a uniaxial manner. In the other case, no prestress was applied; samples were subjected to cyclic uniaxial loading about their unstressed state. The number of cycles corresponded to many years of outdoor service. Upon completion of these tests, visual inspection has not revealed any deleterious effects. Scanning electron microscopy is presently being used at Hauser Laboratories to evaluate the samples further (for example, to look for microcracks in the PMMA film and/or silver layer). In-house optical characterization of sample coupons is also planned.

Planned Activities for Next Quarter

- IST will finalize its evaluation of alternative materials to be used in a replaceable reflective film for heliostats, dishes and troughs.
- No further activities for sol-gel mirror development are planned at this time.
- Polymer film-to-silver adhesion studies and related tunneling experiments carried out at SERI will be documented.

3. ELECTRIC SYSTEMS DEVELOPMENT

Objectives

Objectives for work on Electric Systems Development involve continuing the development of the components and systems required to establish technical readiness of applications of solar thermal electric power production to penetrate major national and international markets by the late 1990s.

TASK 3A. CENTRAL RECEIVER TECHNOLOGY

Accomplishments

- **Molten salt pump and valve loops continue to operate—hot loop surpasses 5200 hours and cold loop surpasses 1700 hours.**

  Both the hot and cold molten salt pump and valve loops are continuing to operate in the auto-sequence mode at the Solar Thermal Test Facility. The hot loop now has over 5200 hours of operation and the cold loop has over 1700 hours. With the large number of cycles on the loops, the hot loop has the equivalent of five and a half years of motor starts and the cold loop has the equivalent of one and a half years of motor starts. The operation of these loops is demonstrating the reliability, performance, and maintenance of the molten salt transport systems for solar central receiver power plants. The molten salt pump and valve loop experiment consists of two loops sized for 30 MW_e, one to simulate the hot side (565°C) and one to simulate the cold side (285°C).

  Sandia achieved a milestone on the hot loop this past quarter, with over 5200 hours of operation. The hot loop began operation the First Quarter of FY88 and has been in continuous operation (24 hours/day) during the past year. There has only been one major failure during the past year when the pump shaft stressed-relieved itself after 2400 hours of operation. A new pump shaft was required to repair this failure. The valve packing materials have been working satisfactorily and some packing materials have been in service for over 3000 hours. The operation of this loop has demonstrated the reliability, performance, and maintenance of the molten salt hot loop transport system for solar central receiver power plants. Sandia will shutdown the hot loop in the near future for inspection of the valves and other components. After the inspection, this loop will be reassembled with new packing materials and operated until the end of this fiscal year. Budget guidelines for FY91 suggest that the loop will need to be shutdown at that time.

  The cold loop is continuing to operate and it has over 1700 hours of operation. The cold loop is operated from 8 p.m. to 8 a.m. Monday through Friday and continuously throughout the weekend; this operational schedule allows operation during utility off-peak hours. This is necessary because of the large electric motor on the cold pump. Sandia will continue to operate the cold loop until the end of the fiscal year. The cold loop will be shutdown and its components inspected at the end of the fiscal year.

A SAND report on the operation of the molten salt pump and valve test loops was published this quarter.

- **Panel Research Experiment—water flow testing and checkout completed.**

Water flow testing and system checkout of the panel research experiment (PRE) was completed this quarter. The PRE is a 3-MW_t experiment designed to evaluate the Direct Absorption Receiver (DAR) concept. This experiment was designed, built, and assembled at the NSTTF. The PRE will allow flow testing with water and molten salt and will provide a test bed for DAR testing with actual solar heating.

The major part of the PRE fabrication was completed last quarter. We have been conducting water flow testing and system checkout while the receiver assembly was completed. The panel is tilted back to 10° from vertical in preparation for testing. The entire PRE system has been checked out--a pump curve has been generated, the valves checked, the tensioning system is operational, the flow meters calibrated, and other instrumentation checked out.

A significant amount of time has been spent optimizing the inlet distribution manifold. Optimization of the inlet manifold has been difficult because a DAR test has never been operated with this high rate of flow (~7.6 kg/s/m [40 gpm/ft]). We have operated the PRE with water flow for about 100 hours. During the flow testing, the fluid flow appeared to be well behaved—even at the high flow rates. As expected, the waves grow and become larger near the bottom (approximately 4.5 meters down) of the panel; however, there does not appear to be any droplet ejection. Sandia has also completed the flow characterization and wave height measurements to compare with previous water flow measurements. The characterization results compare well with previous wave height measurements.

The intermediate manifold was installed on PRE and tested with water. The intermediate manifold was installed at 4-m down the panel and successfully collected and reintroduced the fluid onto the panel. The intermediate manifold, designed and fabricated at Sandia, is used to stop the fluid before the wave development on the panel becomes large enough to begin ejecting droplets. The manifold, designed to be nonpermanent so that it could be moved up or down the panel depending on the test results, will handle flow rates over 7.6 kg/s/m. The operation of the intermediate manifold was optimized and it was removed for the initial salt flow tests. After the panel has been tested without the intermediate manifold (to evaluate droplet ejection over the 6-m length), the manifold will be installed 4-m down the panel and the tests will continue.

We plan to start the salt melt in the sump and begin salt flow testing early next quarter.

- **Second Generation Central Receiver Study.**

The Second Generation Central Receiver Study is comparing the cost and performance of molten salt and volumetric-air central receiver power plants. The study is a joint U.S./F.R.G. effort and was initiated in the fall of 1989. The study is intended to provide guidance in directing future U.S. and F.R.G. government programs to develop solar-thermal-electric technology. The study will focus on 30 MW_e and 100 MW_e plants with capacity factors in the 40 to 50% range.

A meeting to discuss draft results was held at Deutsche Forschungsanstalt fur Luft- und Raumfahrt (DLR) in Cologne, F.R.G. from June 11-13, 1990. Results from analyses of the 30 and 100 MW_e volumetric-air plants were presented by DLR and Interatom. These results were compared with molten salt receiver results that were previously presented by Sandia. To date, it appears that salt plants will have a lower levelized energy costs primarily due to the expensive thermal storage system required by the air system. For example, thermal storage for the 100 MW_e air system is estimated to cost $88 M, whereas salt storage costs approximately $22M.

Sandia presented the results of an uncertainty analysis of a plant similar to the 100 MW_e salt plant analyzed in the U.S. utility study. Latin-Hypercube sampling and linear regression techniques were used to identify the analysis parameters that contribute most to the uncertainty in levelized-energy costs. Since the purpose of R&D is to reduce the uncertainty in cost and performance predictions, this importance ranking will help prioritize future central receiver research. Heliostat cost was the most important parameter. The following 7 parameters were approximately 1/2 to 1/3 as important as heliostat costs: 1) operations and maintenance cost, 2) controls repair time, 3) receiver absorptance, 4) receiver thermal losses, 5) electrical parasitics, 6) heliostat cleanliness, 7) tube leak repair time. Other parameters in the analysis were ranked below these seven.

- **Furnace testing of volumetric air receiver absorber materials continues.**

New Mexico State University (NMSU) is testing volumetric air receiver materials at its solar furnace. Last quarter Sandia contracted with NMSU to evaluate the heat transfer characteristics of various porous materials (e.g., ceramic foams, knit wire mesh, etc) in the solar furnace at the University. The test results will be used to select optimum materials and to validate computer models for future tests.

Testing was delayed last quarter because of the work required to prepare the furnace for the testing. However, preliminary tests have been performed to characterize the incident flux and optimize instrumentation outside of the volumetric air receiver test apparatus. The porous ceramic materials are being instrumented for testing and will be tested in the apparatus early next quarter. Material will be tested with incident flux of up to 800 kW/m^2.

- **Performance evaluation standards for solar central receivers held in Cologne, FRG.**

  A final technical review meeting on the IEA/SSPS report entitled "Performance Evaluation Standards for Solar Central Receivers" was held in Cologne, FRG. M. Carasso of SERI is the task leader and principal coordinator of this report. The meeting took place June 5 through 8 and involved all principal authors with the exception of Jim Chavez and Dave Smith from the U.S. During those three days, all technical issues and editorial questions were resolved. The report will be published by Springer-Verlag, probably in August of this year, and includes international agreements on definitions and nomenclature as well as on standards for conducting performance evaluations.

Planned Activities for Next Quarter

- As agreed with Hughes, the company is free to use the RTEC closed loop in its current automotive work. SERI's only involvement is monitoring progress in improving cell efficiency. A final report is expected from Hughes.
- Complete testing of the molten salt pump and valve loops. Inspect valves and pumps of both loops for wear and corrosion. A draft of the final report will be prepared.
- Salt flow on the PRE will be initiated next quarter. Flow testing will be conducted with and without the intermediate manifold.
- Final results for the salt and air plants will be calculated. Draft versions of approximately two-thirds of the chapters of the final report will be written. A meeting will be held in Davos, Switzerland, after the solar conference in August, to discuss and revise these chapters.
- Furnace testing of the porous ceramic and wire mesh material will be completed.
- The Receiver Standards document will be finalized and sent to the publisher next quarter.

TASK 3B. DISTRIBUTED RECEIVER TECHNOLOGY

Accomplishments

- **Decision on heat-pipe versus pool-boiler receivers for further development.**

  A decision has been made to continue to support development of both heat-pipe and pool-boiler receivers. At this time it is clear that both reflux receiver concepts have advantages as well as uncertainties, especially with respect to life and reliability issues. In addition, industry is pursuing both concepts. Evaluation criteria have been developed and applied to prototype designs and have indicated nominally equal potential for meeting the DOE levelized energy cost goals. Sandia will continue to work with industry and provide technical guidance in areas of its expertise. As a result of recent budget reprogramming, in-house work on heat pipe receivers has slowed and the preliminary design of a hybrid receiver milestone scheduled for July will be delayed until the first quarter of FY91.

- **Completed X-ray tests of reflux pool-boiler receiver.**

  Sandia engineers developed a method using discrete X-ray detectors to determine the boiling void fraction in the critical areas of the pool-boiler receiver. On-sun data were taken during start-up and steady operation at several temperatures. The data analysis awaits additional X-ray shots after the receiver is drained of sodium, in order to establish a baseline X-ray absorptivity.

- **Video real-time thermography performed on pool-boiler receiver.**

  Sandia engineers used an Inframetrics 525 infrared video camera to map the pool-boiler receiver absorber surface temperatures during start-up and operation. The infrared (8 to 12μm) video images clearly show uniform steady-state temperatures across the surface of the dome and are similar to videos made of the Cummins/Thermacore heat pipe receiver. Comparisons with similar videos of a United Stirling directly-illuminated heater-head tube receiver (performed at the Edwards Air Force Base, CA in 1982) clearly show the isothermal advantages of reflux receivers. During start-up, temperature fluctuations can be observed and appear to be associated with boiling and the sloshing of relatively cool liquid against the absorber. These fluctuations disappear as the operating temperature is approached.

- **Full-scale pool-boiler receiver testing completed.**

  The full-scale proof-of-concept receiver was tested for a total of about 50 hours at the Sandia Solar Thermal Test Facility. All objectives of the test program were met, with the exception of extended performance testing. During performance testing, the receiver developed a leak on the absorber face, ending the test. The hole appears to be at an artificial nucleation site (stress concentration), and appears to be a crack rather than a melt. The material used, 316L stainless steel, has limited life at the operating temperatures but had been deemed suitable for proof-of-concept testing. In addition to the 50 hours at temperature, the receiver experienced over 20 starts from ambient temperature and over 100 hot restarts (real and simulated cloud transients). Absorber surface temperatures in excess of 900°C were measured on several occasions. This first-of-a-kind test-bed receiver demonstrated the pool boiler concept and high efficiency operation. Results from this milestone test will be used to validate receiver performance models, to develop boiling initiation and stabilization methods, and to study boiling characteristics. The receiver performed well under conditions designed to "push the limits" of the technology. A next-generation pool boiler will be designed, taking advantage of information gathered from this test, as well as from follow-up bench tests.

- **Next-generation materials studies provide promising results.**

Haynes-230 alloy has been identified by Sandia scientists as the leading candidate for the structural materials for the next-generation reflux receivers. Primary concerns with Haynes-230 include its weldability, formability, and boiling enhancement preparation.

- Sandia engineers have conducted manual gas-tungsten-arc (GTA) welds with Haynes-230 to itself, to Inconel 601, and to 316 stainless steel. The welds were sectioned and found to be excellent, with no evidence of cracking.

- Haynes-230 is easily formable. Tubes 1 3/4" in diameter are being rolled from 0.049" sheet stock for bench scale testing of the pool boiler.

- Sandia engineers have experimented with a wide range of surface modification techniques for boiling enhancement. One method of boiling surface enhancement demonstrated by Thermacore, Inc. is to add a layer of sintered powder metal to the inside surface of the receiver. After many tests at Sandia, the parameters for achieving the required adherence of an Inconel 600 powder to itself and to the Haynes 230 alloy have been determined. This has been accomplished without plating the Haynes 230 prior to sintering.

  Another method of boiling surface enhancement is to drill a hole in the wetted surface of the receiver/absorber. Using a YAG laser, holes 0.004" in diameter and 0.015" deep have been made with a high degree of repeatability.

- Sandia scientists aged a sample of Haynes-230 in an air furnace and measured the solar absorptivity. The resulting solar absorptivity was 92% after 280 hours and exceeds 316L stainless (86%) and Inconel (about 85%). This improvement will directly effect receiver performance.

- **Completed development of dish-receiver thermal models.**

In support of the pool-boiler and heat-pipe reflux receiver development, two numerical models describing the energy transfer within these receivers have been developed. Both models are applicable to axisymmetric geometries and consider the radiative and convective energy transfer within the receiver cavity, the conductive and convective energy transfer from the receiver housing, and the energy transfer to the receiver heat transfer fluid. In these models, the radiative transfer within the receiver is analyzed using a two-band (solar and infrared) model. The more detailed model accounts for the conduction heat transfer within the receiver walls through the use of a two-dimensional finite control volume method, whereas the simpler model uses a one-dimensional thermal resistance approach. Although the detailed model yields the temperature distribution throughout the receiver, it requires considerable effort to specify the receiver model geometry (nodes and elements). In contrast, the simplified model yields only the cavity surface temperatures but requires significantly less effort to specify the receiver geometry.

Good agreement between the models is demonstrated by comparison of computed results for typical operating conditions of the reflux receivers being tested at Sandia. In particular, the receiver thermal efficiency agrees to within 1% and the average receiver cavity temperature to within l.3%. The energy transfers associated with each of the submodels (solar and infrared losses, convective losses, conductive losses, and collected energy) are also in agreement.

Using the simplified model for the Cummins reflux heat-pipe receiver with a 6-inch aperture and operating at 750°C sodium vapor temperature with 29 kW thermal input, the results indicated a thermal efficiency of 84%. In the following figures, the receiver geometry is shown as a projection onto the r-z plane. Also, the computed result is projected onto the "backwall" of the graph, providing quantitative results. Figure 3.1 shows the computed surface temperature distribution within the receiver. Figure 3.2 shows the convective heat loss from the receiver, computed using the Stine and McDonald correlation.

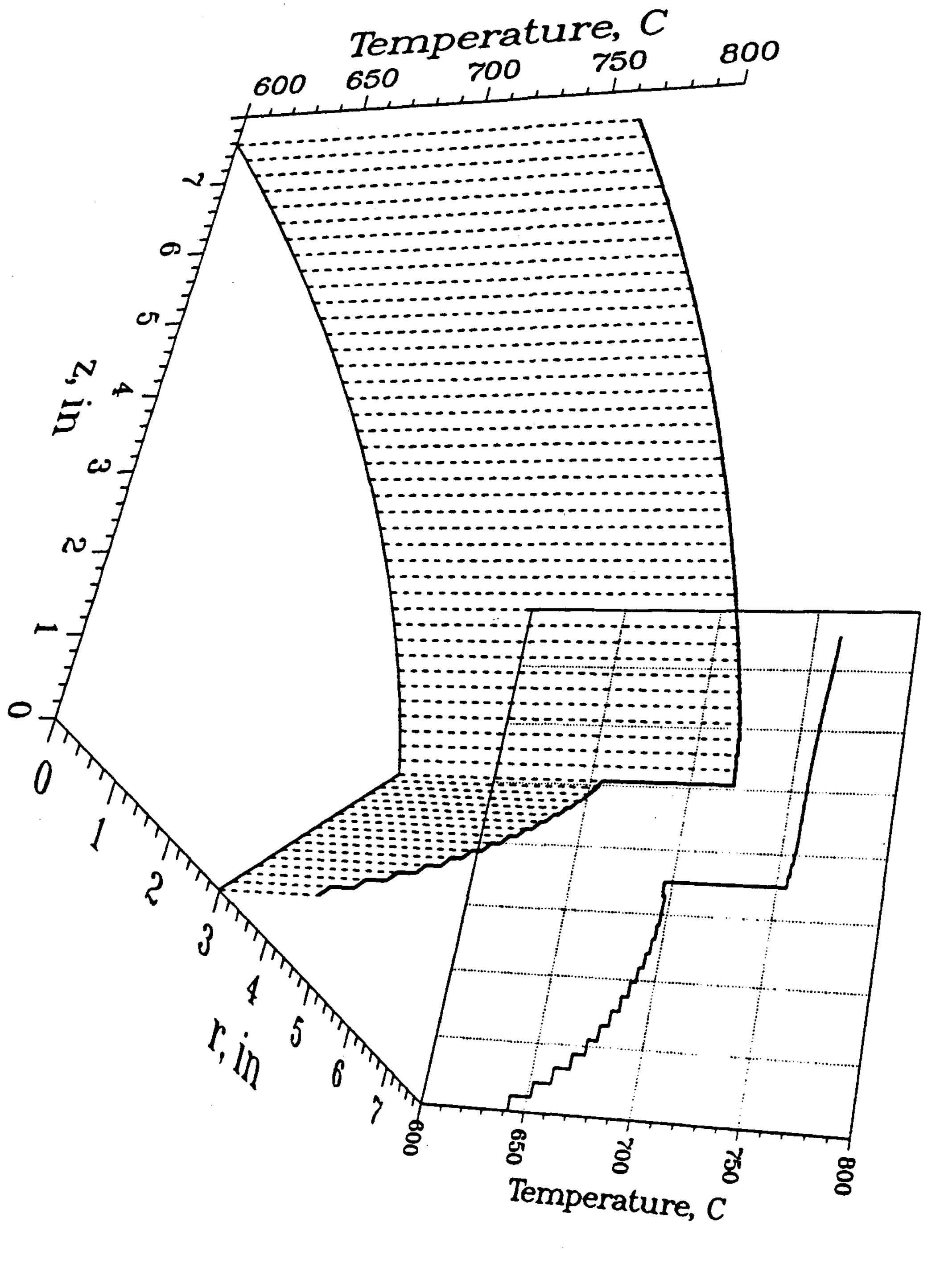


Figure 3.1 **Predicted surface temperature along the sidewall and absorber surfaces.**

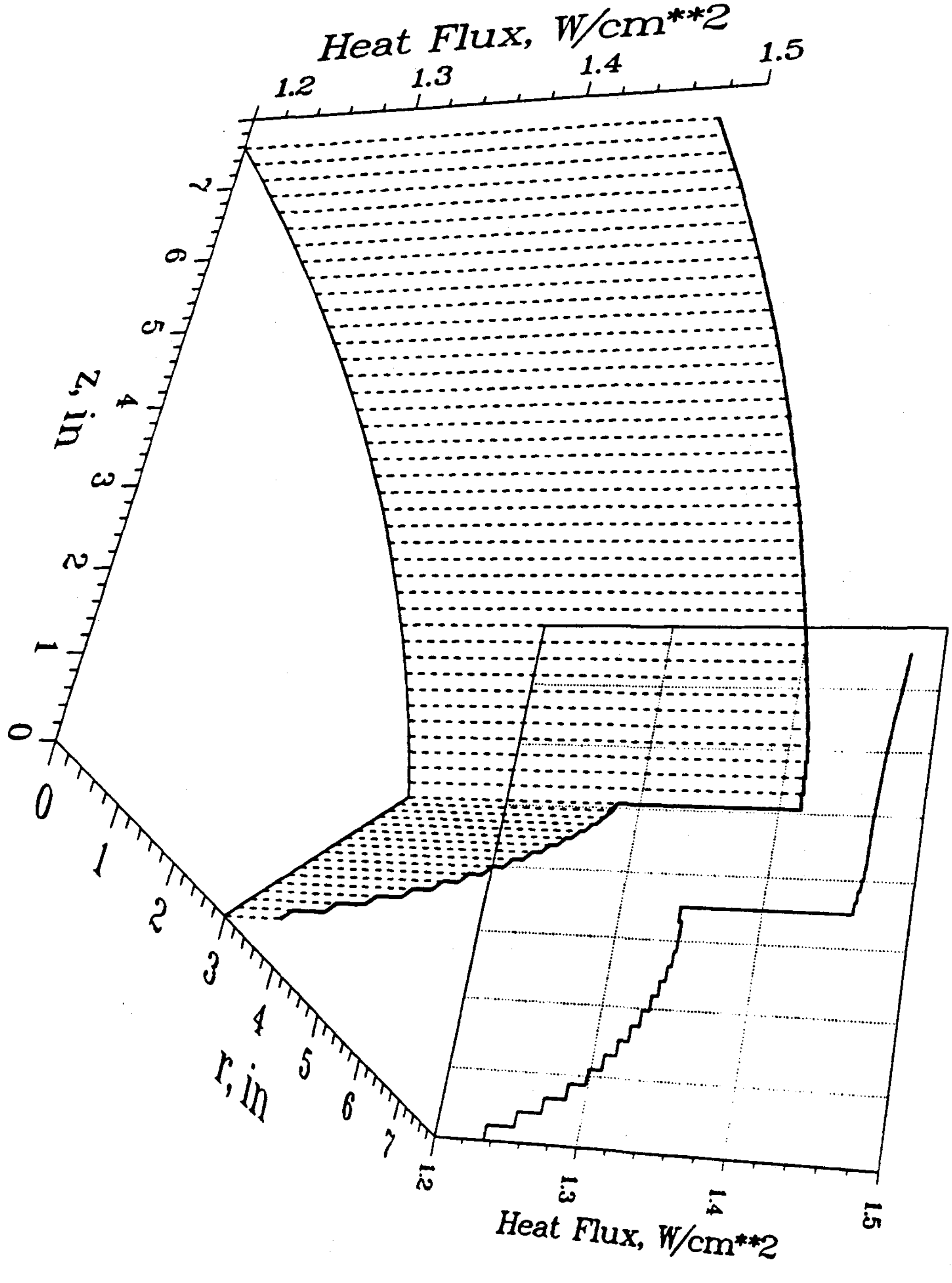


Figure 3.2 **Predicted convective losses along the sidewall and absorber surfaces.**

- **Testing successfully completed on a bench-scale heat-pipe receiver.**

A second bench-scale heat-pipe solar receiver was constructed at Sandia and tested at the Solar Thermal Test Facility. The purpose of the bench-scale test was to assess a new method of forming wicks for full-scale heat-pipe solar receivers. The latest bench-scale receiver has an innovative screen artery system that is mounted on top of a thin (0.5-mm) distribution wick. Artery segments were formed by wrapping fine screens around a central core of coarse screens, and then hot-pressing the assembly to fasten and seal the edges. The segments were linked by simply clamping their ends together, and the artery system was attached to the surface wick with ordinary resistance welds. An electromagnetic (EM) pump was also installed on the second bench-scale receiver to explore alternate methods of transporting liquid sodium in a heat-pipe.

Using the system illustrated in Figure 3.3, a 3-cm x 10-cm spot on the bench-scale receiver was subjected to average flux levels of about 60 W/cm^2. Peak fluxes were on the order of 80 W/cm^2. The lamps were raised along the absorber surface to force sodium to flow further through the wick. At an average flux level of 60 W/cm^2, the wick was able to lift sodium 40 cm to cool the heated surface. Tests showed that the EM pump was working, but it was not needed for the system to operate properly. Capillary pumping alone was sufficient to transport the sodium against hydrostatic and frictional forces. High flux transients did not adversely affect the heat-pipe receiver's operation.

Pumping elevations and flux levels in the bench-scale system were representative of those encountered in a full-scale heat-pipe solar receiver. It was apparent from the bench-scale tests that the wick structure was suitable for a full-scale system. The design for a full-scale heat-pipe solar receiver has been transmitted to Stirling Thermal Motors in Ann Arbor, Michigan, for fabrication.

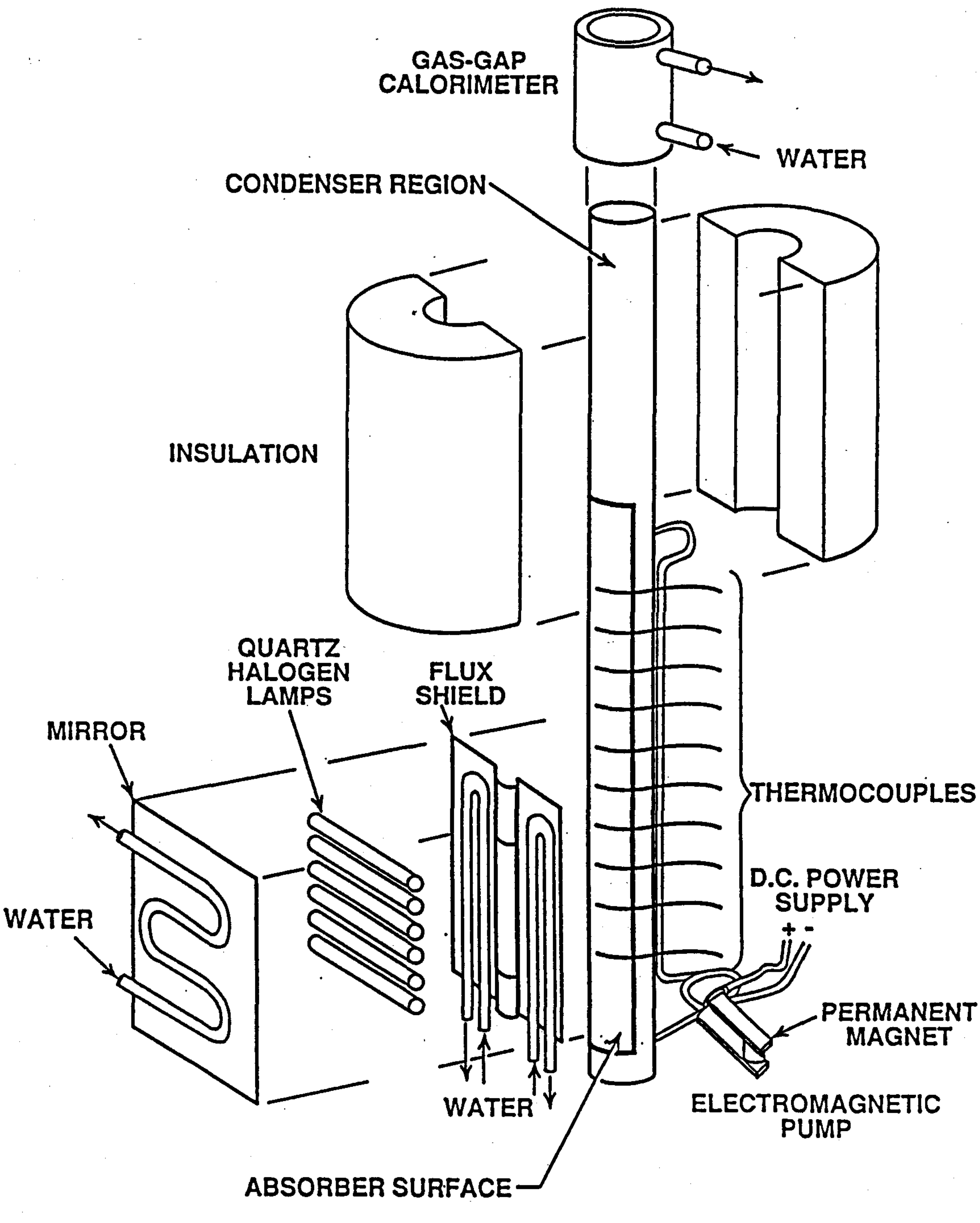


Figure 3.3 **High flux test system for bench-scale heat-pipe receivers. Quartz halogen lamps provide heat to a 3 cm x 10 cm section on the heat pipe's absorber surface. A gas gap calorimeter removes heat from the system and controls the vapor temperature of the heat pipe.**

Planned Activities for Next Quarter

- Sandia will determine the parameters for sintering a stainless steel powder to Haynes 230. We do know that the stainless steel powder will not adhere to the Haynes 230 unless the Haynes 230 has been Ni plated.

- Sandia engineers will construct a bench scale pool boiler using Haynes 230. Various surface modifications will be added to the inside surface and tested in order to determine how they affect boiling stability.

- Sandia scientists will continue to dismantle the on-sun pool-boiler receiver and study the crack in the dome surface. Other areas of concern, including the edge weld and the boiling initiation cavities, will be metallurgically studied.

- Sandia engineers will begin the design of the next-generation on-sun pool-boiler receiver.

- Sandia engineers will complete the data analysis of the on-sun X-ray and infrared thermography testing.

TASK 3C. CONVERSION TECHNOLOGY

Accomplishments

- **A joint Hughes Aircraft/SERI presentation summarized project accomplishments for the Regenerative Thermo-Electrochemical Converter (RTEC).**

  A presentation was attended by DOE representatives from the Industrial, Electricity, and Automotive Programs and was given jointly by Hughes Aircraft Corporation and SERI researchers on May 24, 1990. The presentation summarized the accomplishments of the project to date and provided continuity in the RTEC research at Hughes currently supported by the Office of Transportation Systems. A number of significant results were discussed. A closed-loop system operation was demonstrated and included the regenerative thermo-electrochemical converter cell, the regenerator, and the condenser. The closed-loop system's peak power output of 16 W was measured as compared to the target of 10 W. A cell current density of over 200 mA/cm^2 at maximum power density was measured against the target level of 50 mA/cm^2. Finally, an overall system efficiency of 10 percent was obtained. This fell short of the target efficiency of 30 percent, primarily due to the excessive permeability of the DuPont membranes that were used.

- **Testing of the STM4-120 at Stirling Thermal Motors**

  Stirling Thermal Motors (STM) is presently operational testing a recently constructed STM4-120 kinematic Stirling engine for the Gas Research Institute (GRI). This engine is identical to the engine Sandia is currently testing in Albuquerque. During the brief testing, STM has approximately 40 hours of operation on the GRI engine. Over this period, the engine delivered the following performance

  25 hours between 10 and 14 kW_{shaft}

  12 hours between 14 and 18 kW_{shaft}

  2 hours at 18 kW_{shaft}

  1/2 hour at a peak of 19.5 kW_{shaft}

  The engine efficiency (from heat into the engine to shaft power out) during this testing was determined to be between 35 and 40%, with the 40% occurring at the peak 19.5 kW level and a cycle pressure of 100 bar. All of these measurements were taken at a heater head temperature of 790-800°C and a cooling water temperature of 30°C. STM intends to increase the engine cycle pressure as soon as possible, to the maximum of 120 bar to demonstrate the 25 kW_{shaft}.

The performance STM has obtained from this engine is similar to that measured on the Sandia STM4-120. Figure 3.4 shows the power that both STM and Sandia have measured. This close agreement indicates that the STM4-120 at Sandia should attain the 25 kW power output level.

STM provided a recently fabricated, forty-finned heat pipe evaporator on which Sandia conducted nondestructive testing on the welded areas. Evaluation of previously failed heat pipes revealed that several welded areas did not have full weld penetrations. This resulted in heat pipe failures after several hours of operation. Utilizing ultrasound testing, Sandia will try to identify problem areas in this new heat pipe. Testing at this stage could help reduce or eliminate future heat pipe failures due to bad welds.

- **Finite element analysis conducted for STM4-120.**

SNL analyzed several critical engine and heat pipe components that are used in the STM4-120 Stirling engine test program. The purposes of the analyses were to:

1. provide an independent quality check on the components,
2. eliminate reliability problems in the future, and
3. ensure safe operation of the engine and heat pipes.

To analyze the components, a finite element code was needed. Of the many finite element analysis (FEA) programs on the market, the SNL solar group wanted a program that could run on a PC, provide powerful pre-processing for model generation, analyze rather complicated problems, and present the results in graphical form. Personnel in SNL's stress analysis division recommended COSMOS/M as the FEA code which met the above requirements, and was user-friendly. COSMOS/M has powerful functions for creating 2-D and 3-D models, and included automatic mesh and volume generation. The actual analysis is fairly quick, although the amount of time accessing the disk and writing files is time consuming. The results are presented in the form of the model being painted in various colors corresponding to different values of stress, displacement, or temperature. The results are also available in tabular format if desired. Stresses and displacements were all found to be satisfactorily small, confirming the earlier analyses performed by Stirling Thermal Motors.

We feel that the analyses were very worthwhile. The results of this independent check give us some confidence in the engine design and personnel safety. After the current problems with the heater head bellows and evaporators are solved, the engine should be more reliable. It is important to realize that the engine is still in development and relatively few operating hours have been achieved. It would not be surprising to run across some additional problems. However, since the critical components appear to be sound, we feel that these problems can be overcome fairly easily. SNL and STM have learned a great deal and solved many problems to improve the engine during the last year.

- **Initiated final design of the Advanced Stirling Conversion System.**

A Task II kick-off meeting was held for the Advanced Stirling Conversion System during the quarter at Stirling Technology Company (STC). Both Sandia and NASA/Lewis Research personnel attended the meeting. Task II calls for the final design, fabrication, assembly, and delivery of one (1) ASCS to Sandia. A 24 month schedule from initiating the final design to delivery of a system is anticipated for this task. The final design is to be completed during the second quarter of FY91. For the final design of the ASCS, STC teamed with Westinghouse's Advanced Energy Systems Division. Westinghouse will provide manufacturing capabilities, materials expertise, and the system controls for the Task II effort. Westinghouse is interested in the technology because they have identified a niche market for dish/Stirling systems for worldwide remote electric power applications. NASA/Lewis Research Center is providing project management, Stirling engine, and materials experts on the ASCS project. Sandia will provide technical direction for the entire project. Monthly review meetings have been scheduled, alternating between STC and NASA/LeRC.

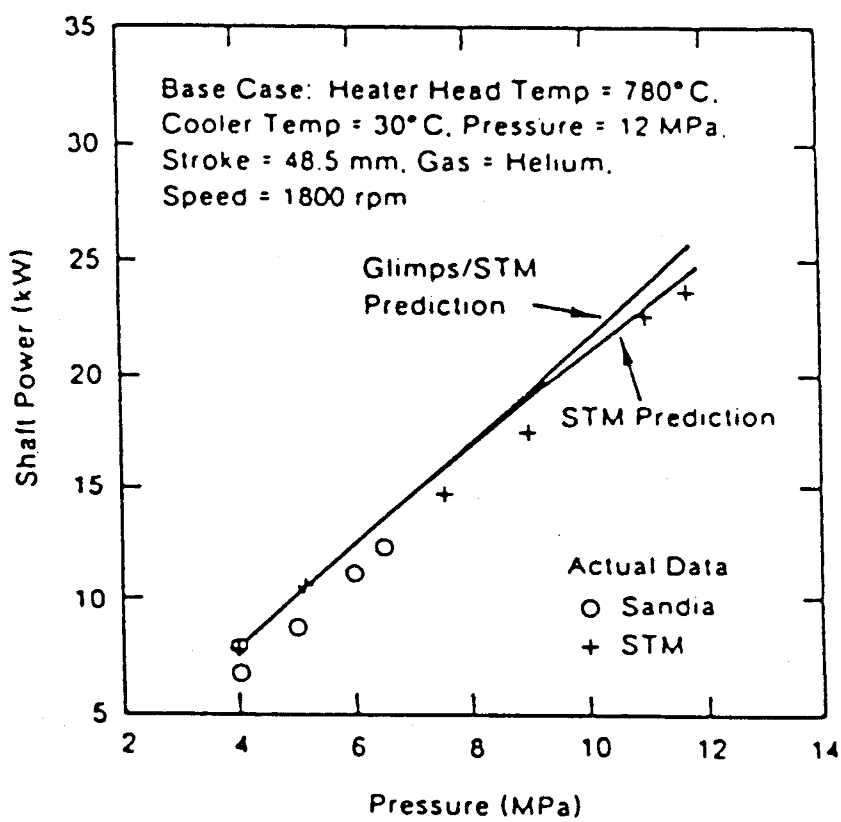


Figure 3.4 Measured vs Predicted Performance

Planned Activities for Next Quarter

Operation of the Stirling Thermal Motors' STM4-120 kinematic Stirling engine will continue at Sandia's Engine Test Facility (ETF). Monitoring the power, efficiency, and reliability will continue. With upgraded heat pipe parts, an increase in cycle pressure is scheduled to obtain higher power levels.

Monthly reviews of the ASCS final design at STC and NASA/LeRC.

4. TECHNOLOGY DEVELOPMENT

Objectives

In collaboration with industrial partners the intent of this work is to develop systems that will result in (1) competitive solar thermal electric systems based on refinement and optimization of current commercially available systems; and (2) advanced solar thermal electric systems that will improve performance and cost competitiveness in the middle of the 1990s.

TASK 4A. NEXT-GENERATION COMMERCIAL SYSTEMS

Subtask 4A-1. Project Development

Accomplishments

- **Qualified bidders were unable to proceed to the successful conclusion of contract discussions for the Next-Generation Commercial Systems.**

  Four companies responded with proposals to a Request for Quotation (RFQ) issued in April, 1989, to sixteen potential candidates. Two companies were selected as qualified joint-venture partners for the Next-Generation User Systems Program. Contract negotiations were underway with both companies during the first quarter of FY 1990. Early in the current quarter, we were notified by one of the respondents that the company was unable to participate at the reduced level of funding proposed by the government. The second respondent's proposal was contingent upon its having a contract for the sale of electricity. This contract was unable to be negotiated by the end of the current quarter. Consequently, all respondents received notification early in the quarter that no contract award will be made on this Request for Quotation.

Subtask 4A-3. Design Assistance and CORECT Support

Accomplishments

- **Sandia staff continued assistance to Cummins Engine Co. (CEC).**

  Sandia personnel have been very actively involved with CEC and their contractors as CEC pursues its goal of commercializing their 5 kW_e dish/Stirling system. The bulk of the involvement concerned heat-pipe reflux receiver development, and included metallurgical analyses of a failed Thermacore receiver, identification of more appropriate absorber and artery materials and plans for a 500 hour durability test of a new Thermacore receiver. Cummins is prepared to fund two-thirds of the cost of this last activity, which will provide important receiver endurance and performance data.

- **Design assistance for the STM4-120 kinematic Stirling engine was accelerated.**

  SNL staff interacted with Stirling Thermal Motors (STM) on matters relating to their STM4-120 kinematic Stirling engine. Heat transport systems were emphasized with SNL giving guidance on gas-fired evaporator and heat-pipe bellows material issues, solar heat-pipe wick design and evaporator welding quality. SNL also advised STM on the procedures for handling sodium which should not result in contamination and the resulting failures which have been attributed to this occurrence.

- **Agreement signed for an industrial process heat system installation.**

  Industrial Solar Technology and United Solar Technologies have signed an agreement to install a solar thermal industrial process heat system at the California State Women's Prison at Tehachapi, California. The STDAC is assisting in the design and installation of a performance monitoring system for the new plant. Sandia staff are also consulting on various aspects of the plant's engineering design including the electrical control system, wind loading analysis, and structural analysis. As part of this effort, Sandia has provided engineering specifications for mounting a large heat exchanger on one of the prison walls and a thermal stress relief system for the hot water piping. The work will continue through this year.

- **Sandia and DOE/PSO working on solar absorption cooling system in America Samoa.**

  Sandia personnel are working with the DOE/Pacific Site Office (PSO) regarding the conversion of a solar absorption cooling system located at the LBJ Hospital in American Samoa. The flat-plate system has been inoperable for the last several years. It is now being considered for conversion to a hot water heating system. The DOE Conservation Program is supporting the effort under its program for schools and hospitals. The STDAC is providing technical assistance for the project.

  Currently, Sandia engineers are working with personnel from Rockwell's Energy Technology Engineering Center (ETEC) to agree on a system design. ETEC is under contract to DOE/SAN and DOE/PSO to provide advice on energy related matters. The design work is expected to be completed early next quarter. Construction is expected to begin late next quarter and should be completed by the second quarter of FY 1991.

- **Representatives of Industrial Credit and Investment Corporation (ICIC) visited National Solar Thermal Test Facility**

  Representatives of Industrial Credit and Investment Corporation (ICIC), an Indian organization responsible for identifying renewable energy technologies for use in India, visited the National Solar Thermal Test Facility in May. The visitors were most interested in the simple and most readily applied technologies such as troughs and the PKI steam engine system. They were also impressed with the potential for dish/Stirling and asked to be kept informed about technological developments.

- **Sandia and the California Energy Commission (CEC) continued discussing how the two organization can work together.**

  Sandia and the California Energy Commission (CEC) are discussing how the two organizations can work together. The initial meetings have been very productive and a number of areas of collaboration have been identified including planning, technical consulting, co-funded projects, and educational activities. A formal working agreement is expected to be finalized next quarter.

- **DOE/PSO and DOE/SAN Office sponsored a second annual Integrated Electric Utility Workshop.**

  The DOE/Pacific Site Office along with the DOE/SAN office sponsored a second annual Integrated Electric Utility Workshop (IEUW) on June 6. Attendees included the governors and energy ministers of the US territories in the Pacific Basin. The purpose of the meeting was to inform them about the potential for renewable technologies. Sandia presented information on solar thermal technology and many of the participants expressed interest in using solar thermal technology on their islands. The STDAC will continue to work with the DOE/SAN and the DOE/PSO regarding further efforts to promote the use of solar thermal technology on the Pacific Islands.

- **Sandia participates in Earth Day activities.**

  As part of the local Earth Day activities, Sandia was invited to present information about solar technology at two separate events. The first of the major local activities was sponsored by the university of New Mexico (UNM) and was held on the UNM campus on April 20 and 21. A second activity, called "Earth Fair," was coordinated by the City of Albuquerque and was held on April 28 at the Albuquerque Museum. Sandia provided exhibits for both events that included poster displays, models, a video tape, and handouts. Participation in these events provided an opportunity to speak directly to students, faculty, and the general public about solar thermal technology. About 1500 people visited the Sandia exhibits during the events.

- **SERI staff participates in Earth Day activities.**

  In conjunction with local Earth Day events, SERI held an open-house to display current research in solar technology and to explain the ecological advantages of renewable energy systems, recycling, and conservation. Over a dozen members of the Thermal Systems Branch volunteered time to coordinate and to staff and exhibit, explaining current solar thermal technology, one of 14 SERI displays. Turnout was excellent with over 400 local high school students visiting the SERI laboratories with later attendance by SERI family, friends, and area residents. In addition to promoting public understanding and awareness of solar technology, the open-house provided young students with an opportunity to interact with SERI staff involved in a variety of scientific careers.

- **STDAC personnel consult with Gould engineers on IPH system in Chandler, Arizona.**

  STDAC personnel are consulting with Gould engineers to solve some O&M problems with the IPH system located at their plant in Chandler, AZ. To help reduce flex hose failures, Sandia has recommended an advanced generation flex hose, and has provided several for testing at Gould. Sandia has also designed some simple changes to the control system to minimize unnecessary hose flexing. A site visit is planned in July to advise Gould personnel on the selection and installation of a BTU meter and to provide guidance on repairing delaminated sections of the reflective film.

- **Sandia initiated effort to verify and improve existing IPH computer simulation models.**

  Sandia has initiated an effort to verify and improve existing IPH computer simulation models. The objective of the effort is to develop a user-friendly, PC compatible IPH simulation model that can be used by field engineers to assess the long-term energy and economic performance of IPH and hot water systems. Several IPH simulation models currently exist, but have not been fully verified and do not operate efficiently on a PC. The initial effort will focus on verifying these codes and improving their PC operation.

- **Sandia continues to receive requests for assistance on exporting solar systems.**

  Several solar system organizations, including Sunsteam, have asked for Sandia's help regarding the licensing of this trough technology for overseas production. STDAC assistance is being prepared through the CORECT activity, as well as through SEIA. Work on this effort has begun and will continue through this calender year.

- **Procurement Summary:** In May 1989, Sandia awarded a contract to the Solar Energy Industries Association to develop documentation materials such as films, brochures, and poster materials that show the potential for solar thermal technologies. To date, work on this one-year effort has progressed normally. An extension to this contract is completed that requests SEIA's assistance in expanding the STDAC's capabilities.

  STDAC personnel are also monitoring another SEIA contract to produce a 20-minute film that describes the general benefits of solar thermal technology. The purpose of the film is to introduce semi-technical people (i.e., policy makers, planners, etc.) to the potential applications of solar thermal technology. The film is expected to be completed in March 1991.

- **STDAC CONTACTS THIS QUARTER:**

Technology/Subject	Requester	Affiliation
Central Receivers	B. Siraj	Pakistan
Concentrators	J. Harness	HOPE Inc.
Dish Drive Information	J. Goodman	Consultant
Dish/Brayton	J. Kesseli	Northern Res.
Dish/Stirling	H. Islieb	Consultant
Dish/Stirling	J. Kirloskar	Consultant
Distributed Receivers	A. Karandiker	Sunpower
FP/Samoa Project	J. Shupe	DOE/PSO
Heliostat Development	K. Drumkeller	Heliostat Inc.
Heliostat Drives	J. Goodman	Self
Heliostat Information	P. Gierow	SRS Technology
Heliostat Information	B. Billak	DOD Pentagon
IPH	P. Dremann	Self
IPH	E. Carillo	ITE (Mexico)
IPH	J. Downey	Consultant
Kinematic Stirling	R. Brown	Hughes Aircraft
MSEE Information	D. Appau	Univ. Prof.
NSTTF General Inform	R. Slater	Avco Research
NSTTF General Inform	D. Lorents	SRI Int.
NSTTF General Inform	B. Rhee	Teller Res.
Reflux Receivers	M. McGlaun	LaJet
Solar Detoxification	M. Aitken	Univ. N. Carolina
Solar Furnaces	R. Crane	Sunpower Inc
Solar Resource Monitoring	J. Michalsky	SUNY
Solar System Economics	K. Porter	Swarthmore Col
Solar Water Heating	E. Perez	Solar Uno

Technology/Subject	Requester	Affiliation
ST Export Packaging	A. Bronstein	Sunsteam Inc.
ST Program Information	C. Williams	LaJet
ST Workshops	M. Epstein	Weisman Inst.
STDAC Consulting	J. Leigh	NMERI
STDAC Consulting	A. Roy	Ben-Guron Univ
STDAC Consulting	E. Fletcher	U. of Minn.
STDAC help in No. Africa	L. Garden	US Dept Comm.
Stirling Technology	M. Forest	LCREDM
STT Export Information	R. Davenport	SAIC
STT General Information	J. Harness	HOPE Intl.
STT General Information	H. Zwirkowski	NERF
STT General Information	M. Comkling	Priv Arch.
STT General Information	O. Hudson	HYTEK
STT General Information	A. Childs	H&R Center
STT General Information	K. Knock	Morning Star
STT General Information	A. Roy	Ben-Gurion Univ.
STT General Information	F. Miller	DLR
STT General Information	K. Huder	DLR
STT General Information	M. Epstein	Weizmann Inst.
STT Program Information	R. Buck	DLR
Trough Technology	G. Lind	Sunmaster Tech
Trough Technology	B. Gross	UNM
Trough/Dish	C. Laporta	United Solar Tech
Volumetric Receivers	B. Pande	Hercules Aerospace

Planned Activities For Next Quarter

- The USAF is developing a plan for increasing the use of renewable energy generators on Air Force bases. NMERI is the prime contractor to the Air Force in this effort. Jerry Leigh, principal investigator, met with STDAC personnel to discuss how Sandia may assist in the effort. It was decided that the STDAC would be a primary technical consultant on the portion of the plan that covers solar technology. Work is scheduled to begin in August 1990.

- Paul Jaster of 3M is developing a plan for a U.S. government-sponsored, low-interest loan program for solar system manufacturers and installers. As currently conceived, the plan would provide construction and/or development loans for solar projects. An organization like Sandia would assist the lending agency in qualifying applicants. Paul asked for STDAC's critique of his plan before he presents it to Congress. A draft copy of the plan is expected to be sent to Sandia next quarter.

TASK 4C. ADVANCED ELECTRIC TECHNOLOGY

Accomplishments

In July 1989, a request for information (RFI) regarding potential program participants was released to the public. The RFI requested information about solar thermal technologies that have potential to participate in this joint venture program.

The Advanced Electric Systems evaluation team met in December 1989 to discuss the twelve responses to the Request for Information (RFI). They concluded that there is evidence that promising solar thermal technologies do exist and that this program can accelerate commercial application to the mid-1990s. Following evaluation of the responses, the team developed an outline of the contents of the Request for Proposal (RFP).

Based on the outline, a draft RFP package was delivered to DOE/HQ. Discussions have resulted in a procurement that focuses on the near-term goals of the program. One fundamental change to the request is that it now focuses on dish/Stirling systems in a non-utility application, rather than allowing any technology/ market combination to be proposed.

Planned Activities for Next Quarter

It is expected that the RFP will be finalized early in the next quarter. Release is expected to take less than one month, as much of the preliminary work in preparing the bidding package has already been completed. If this schedule is maintained, we expect to be evaluating responses toward the end of the fourth quarter.

5. REIMBURSABLE PROGRAMS

NATIONAL SOLAR THERMAL TEST FACILITY

Accomplishments

- **Nuclear hardness testing of military aircraft material samples was conducted using the windowed wind tunnel in Sandia's solar power tower.**

  Under the sponsorship of the U.S. Air Force and in conjunction with Northrop Corporation, Sandia National Laboratories used its windowed wind tunnel to expose military aircraft material samples to simulated nuclear thermal flash under simulated flight conditions. Two test series were conducted. The first was completed in early April. The second is underway and will be completed in early July.

- **A volumetric receiver was tested for private industry in Sandia's solar power tower.**

  Sandia National Laboratories' Solar Thermal Test Facility performed testing of a prototype volumetric central receiver in the 220 test bay of the solar tower under contract to private industry. The first test series was completed in mid-May. The receiver remains in place in the solar tower while the customer analyzes the data and develops plans for further testing. Details of the receiver design as well as test results remain sensitive, proprietary information and will only be released after being cleared with the client.

- **Applied Physics Laboratory completed a series of Hot Boresight Error Measurements at the National Solar Thermal Test Facility.**

  For several years, Johns Hopkins University Applied Physics Laboratory, a U.S. Navy contractor, has evaluated radar systems while the radome is being exposed to simulated aerodynamic heating at Sandia's Solar Thermal Test Facility. A water-cooled radome mount with rotational and slew capability is installed in the upper test bay of the solar tower and an antenna with rotational and translational capability is installed in a heliostat pedestal in the heliostat field. This system is used to measure hot boresight error over a range of antenna to radome angles while the flux from the heliostat field is dynamically changed to maintain constant heating. A successful series of tests was performed for APL in April and May.

- **A Proposal has been submitted for nuclear hardness evaluation of a British Aircraft canopy/cockpit at the National Solar Thermal Test Facility.**

  A proposal has been submitted to the Defense Nuclear Agency on using the heliostat field and high-speed shutter to evaluate the nuclear thermal hardness of a canopy/cockpit system from a British Buccaneer aircraft under a joint US/UK program. Funding has already been advanced to DOE/AL and the test series is expected to be performed in August.

- **Sandia has submitted proposals for design and test of two industry-funded thermochemical receivers.**

  Sandia has been requested to provide estimates for the design and testing of several novel wide spectrum, photochemical processes. Development of these systems is being done as a commercial venture by a company who needs to use the unique research and test capabilities at Sandia's National Solar Thermal Test Facility to demonstrate actual solar operation. Previous research has been performed at a small-scale in university laboratories sponsored by this company. Although the company is small, they have established contacts with major commercial industries and utilities regarding commercialization of these processes. Statements of work and preliminary cost estimates have been agreed to, and formal proposals are currently being submitted. Funding of both of these projects is considered highly likely.

- **LLNL Scientists visit sandia to discuss materials and component tests for solar space power applications.**

  Engineers from Lawrence Livermore National Laboratory visited Sandia's Solar Thermal Test Facility after receiving our recently published brochure. LLNL is quite interested in conducting tests related to various materials as well as for components intended for solar space power applications.

CONCENTRATORS

Accomplishments:

- **NASA STAR Facet and Panel Testing Project tested.**

  Sandia has been asked by NASA to test the STAR facets and panels for the space station Freedom in an on-sun environment. The facets are triangular in shape, 1-meter on-a-side, and have spherical or torroidal curvature. Each panel is populated with 24 facets and weighs about 80 pounds. Sandia will test 5 facets and 2 fully-populated panels at 3 locations each. Testing will be performed in FY 1991.

Planned Activities for Next Quarter

- Solar Thermal Test Facility Wind Tunnel

  The second series of military aircraft material hardness tests for Northrop/U.S. Air Force will be completed in early July.

- Nuclear Hardness Evaluation of Aircraft Canopy/Cockpit

  Evaluation of the nuclear hardness of a British Buccaneer canopy/cockpit system is tentatively scheduled to be performed at the Solar Thermal Test Facility in August.

- Industry-Funded Thermochemical Receiver Development and Test

  Sandia anticipates completing negotiations for development and test of proprietary thermochemical receivers for private industry. The programs will begin as soon as formal contracting arrangements are completed through DOE/AL.

TECHNOLOGY TRANSFER

Publications Completed in FY 1990

Alpert, D. J., R. M. Houser, A. A. Heckes, and W. W. Erdman, An Assessment of Second-Generation Stretched-Membrane Mirror Modules, SAND90-0183, Sandia National Laboratories, February 1990.

Andraka, C.E., et al., 1989, "Reflux Pool-Boiler as a Heat Transport Device for Stirling Engines: On-Sun Test Program Results," for presentation at and publication in the Proceedings of the 25th Intersociety Energy Conversion Engineering Conference, August 12-17, Reno, NV.

Bohn, M.S. and M. Carasso, 1989, Direct Absorption Receiver: Final Technical Report. SERI/TR-253-3438, 125 pp. Available NTIS: Order No. DE90000311. ACCNR: 10733.

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Diver, R.B. et al, "Trends in Dish-Stirling Solar Receiver Designs," for presentation at and publication in the proceedings of the 25th Intersociety Energy Conversion Engineering Conference, August 12-17, Reno, Nevada.

Kolb, G.J. and J.M. Chavez, "An Economic Analysis of a Quad-Panel Direct Absorption Receiver for a Commercial-Scale Central Receiver Power Plant, SAND89-2955C, Proceedings of the ASME Solar Energy Conference, April 1-4, 1990, Miami, FL.

Mahoney, A. R., and T. R. Mancini, "Facet Surface Optical Measurements," NASA Test Report, March 1990.

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Moreno, J.B., C.E. Andraka, R.B. Diver, W.C. Ginn, V. Dudley and K.S. Rawlinson, "Test Results From a Full-Scale Sodium Reflux Pool-Boiler Solar Receiver," SAND89-2772C, completed and approved for presentation at and publication in the Proceedings of the ASME Solar Energy Division International Solar Energy Conference, Miami, FL, April 1-4, 1990.

Rush, E.E., J.M. Chavez, and C.W. Matthes, An Interim Report on Testing the Molten Salt Pump and Valve Loops, Sand89-2964, Albuquerque, NM: Sandia National Laboratories.

Science Applications International Corporation, 1990, Selection and Design of a Stretched-Membrane Heliostat for Today's Markets, SAND89-7040, Albuquerque, NM: Sandia National Laboratories.

Solar Kinetics, Inc., Design and Demonstration of an Improved Stretched-Membrane Heliostat, SAND89-7028, Sandia National Laboratories, Albuquerque, NM. December 1989.

Smith, D.M., et al., "Metal Substrates and the Photo Degradation of Polymers," Solar Energy Materials, 19, 111, 1989.

Tyner, C.E., Status of the DAR Panel Research Experiment: Salt Flow and Solar Test Requirements and Plans, SAND88-2455, Albuquerque, NM: Sandia National Laboratories.

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Alpert, D. J., et al., "Solar Concentrator Development in the United States," SAND 90-0903A, submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

Alpert, D. J., et al., "The Development of Stretched-Membrane Heliostats in the United States," SAND90-0273J, invited paper submitted to Solar Energy Materials.

Andraka, C.E., et al., Sodium Reflux Pool-Boiler On-Sun Test Results, SAND89-2773, Albuquerque, NM: Sandia National Laboratories.

Ashley, C.S., S.T. Reed and A.R. Mahoney, Sol-Gel Mirror Development, Albuquerque, NM: Sandia National Laboratories.

Balch, C., C. Steele, and G.J. Jorgensen, Membrane Dish Analysis: A Summary of Structural and Optical Analysis Capabilities, SERI/TR-253-3432, Golden, CO: Solar Energy Research Institute.

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Cameron, C.P., Small Community Solar Experiment #2 Module Test Results, SAND88-2802, July, 1990, Sandia National Laboratories, Albuquerque, NM.

Carasso, M., "Applications of SERI Science and Technology: High-Flux Solar Furnace," SERI/MK-253-3739, Golden, CO: Solar Energy Research Institute. ACCNR: 11668.

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Chavez, J.M., D.K. Johnson, C.E. Tyner and W.A. Couch, Water Flow Testing of the Direct Absorption Receiver Concept, SAND88-3390, Albuquerque, NM: Sandia National Laboratories.

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Hull, J.L., Holographic Solar Concentrator Development - Phase II and III, SERI/STR-253-3326, Golden, CO: Solar Energy Research Institute.

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Jorgensen, G.J. and P.O. Schissel, Interlayer Coatings for Enhanced Performance of Metallized Polymer Reflectors, ACCNR: 10856, Golden, CO: Solar Energy Research Institute.

Kolb, G. J., D. J. Alpert, and C. W. Lopez, "Insights From the Operation of Solar One and Their Implications for Future Central Receiver Power Plants," SAND89-1532J, accepted for publication in Solar Energy.

Lewandowski, A., J. O'Gallagher, An Overview of Research on Secondary Concentration for Point Focus Dish System, Golden, CO: Solar Energy Research Institute.

Linker, K. L., K. S. Rawlinson, and G. Smith, Test Description and Preliminary Test Results of the STM4-120 Kinematic Stirling Engine, SAND90-1162, Albuquerque, NM: Sandia National Laboratories.

Mancini, T.R., Cameron, C.P, and V.R. Goldberg, The Feasibility of Testing the NASA Advanced Development Solar Concentrator (SCAD) in a Terrestrial Environment, SAND89-1724.

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Mancini, T.R. and K.R. Boldt, The LaJet Innovative Concentrator Design and Performance, SAND report in progress, Albuquerque, NM: Sandia National Laboratories.

Menicucci, D. and A. Van Arsdall, Solar One--A Solar Thermal Success Story, brochure, Albuquerque, NM: Sandia National Laboratories.

Menicucci, D. and A. Van Arsdall, Solar Thermal Systems for Today, Tomorrow, and the Future, brochure, Albuquerque, NM: Sandia National Laboratories.

Menicucci, D. and A. Poore, Dish-Stirling Brochure, Albuquerque, NM: Sandia National Laboratories.

Menicucci, D. and A. Van Arsdall, The Solar Thermal Design Assistance Center--A National Resource, brochure, Albuquerque, NM: Sandia National Laboratories.

Science Applications International Corp., An Improved Design for a Stretched-Membrane Heliostat, SAND89-7027, Albuquerque, NM: Sandia National Laboratories.

Skocypec, R.D., R. Boehm, J.M. Chavez, R. Mahoney and W. Kim, Heat Transfer Analysis of the IEA/SSPS Volumetric Receiver, SAND87-2969, Albuquerque, NM: Sandia National Laboratories.

Solar Kinetics, Inc., Development of a Stretched-Membrane Dish Task 1, Phase II Topical Report, SAND89-7031, Dallas, TX.

Wendelin, T.J. and R.L. Wood, LANSIR: An Instrument for Measuring the Light-Scattering Properties of Laminate Membrane Mirrors, ACCNR: 10570, Golden, CO: Solar Energy Research Institute.

Scientific Meetings and Presentations

Second Quarter FY 1990

Chavez, J.M., An Overview of Advanced Central Receiver Concepts, SAND 89-2870C, presented at the 1990 National Symposium of the Society of Mexican-American Engineers and Scientists, March 28-31, 1990, Albuquerque, NM.

Klimas, P.C., "Solar Electric Technology Readiness Program," presented at SOLTECH 90 Conference, Austin, TX, March 19-23, 1990.

Marshall, B.W., "Solar Thermal Design Assistance Center," presented at SOLTECH 90 Conference, Austin, TX, March 19-23, 1990.

Menicucci, D.F., "Solar Electric Program: Advanced Electric Technology," presented at SOLTECH 90 Conference, Austin, TX, March 19-23, 1990.

The Solar Thermal Design Assistance Center (STDAC) has initiated a semiannual newsletter that will review progress in solar thermal technology. The second newsletter (Winter 90) was released on March 19 and was distributed to the solar community and at SOLTECH 90. This color newsletter described the recent progress in dish and Stirling technology, some recent STDAC direct assistance activities, and the function of the STDAC.

The STDAC prepared a two-fold, color brochure on dish/Stirling technology. The brochure highlights the potential of Stirling technology and feature Sandia's solar thermal test facility, especially the engine test facility. It was distributed at the SOLTECH meeting and is available for distribution to the public as required.

Third Quarter FY 1990

Adkins, D.R. and T.A. Moss, "Measuring Flow Properties of Wicks for Heat-Pipe Solar Receivers," presented at the 12th Annual ASME International Solar Energy Conference in April, 1990.

Alpert, D. J., R. M. Houser, A. A. Heckes, and W. W. Erdman, "Status of Stretched-Membrane Heliostats," SAND89-1500C, 1990 ASME International Solar Energy Conference, page 87-93, April 1-4, Miami, FL.

Kolb, G.J. and J.M. Chavez, "An Economic Analysis of a Quad-Panel Direct Absorption Receiver for a Commercial-Scale Central Receiver Power Plant," presented at the 1990 ASME International Solar Energy Conference, April 1-4, Miami, FL.

<u>**Fourth Quarter FY 1990**</u>

Alpert, D. J., et al., "Solar Concentrator Development in the United States," SAND 90-0903A, submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

Chavez, J.M., "A Summary of the Design, Analysis, and Testing of Volumetric Air Receivers for Use in Central Receiver Power Plants," submitted to the 25th Intersociety Energy Conversion Engineering Conference, August 12-17, Reno, NV.

Chaza, C., and J.M. Chavez, "The Ceramic Foam Volumetric Receiver," submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

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Klimas, P. C., M. Becker, "Second Generation Central Receiver Technology Comparison," SAND90-0947A, submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

Kolb, G. J., "Reliability Analysis of a Salt-in-Tube Central Receiver Power Plant," SAND90-0971A, submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

Linker, K. L., K. S. Rawlinson, and G. Smith, "Evaluation of the STM4-120 Kinematic Stirling Engine," submitted to the 25th Intersociety Energy Conversion Engineering Conference, August 12-17, Reno, Nevada.

Marshall, B. W., and J. T. Holmes, "Testing and Design Assistance Support for U. S. Solar Thermal Industries," SAND90-0972A, submitted to the 5th International Symposium on Solar High Temperature Technologies, August 27-31, Davos, Switzerland.

Rush, E.E. and J.M. Chavez, "Design, Fabrication and Testing of the Direct Absorption Receiver Experiment," submitted to the 25th Intersociety Energy Conversion Engineering Conference, August 12-17, Reno, NV.

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