Quarterly Progress Report:

FOURTH QUARTER FISCAL YEAR 1990

DOE SOLAR THERMAL ELECTRIC TECHNOLOGY PROGRAM

Submitted By:

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Albuquerque, New Mexico

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Golden, Colorado

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FOREWORD

The research and development described in this report were 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

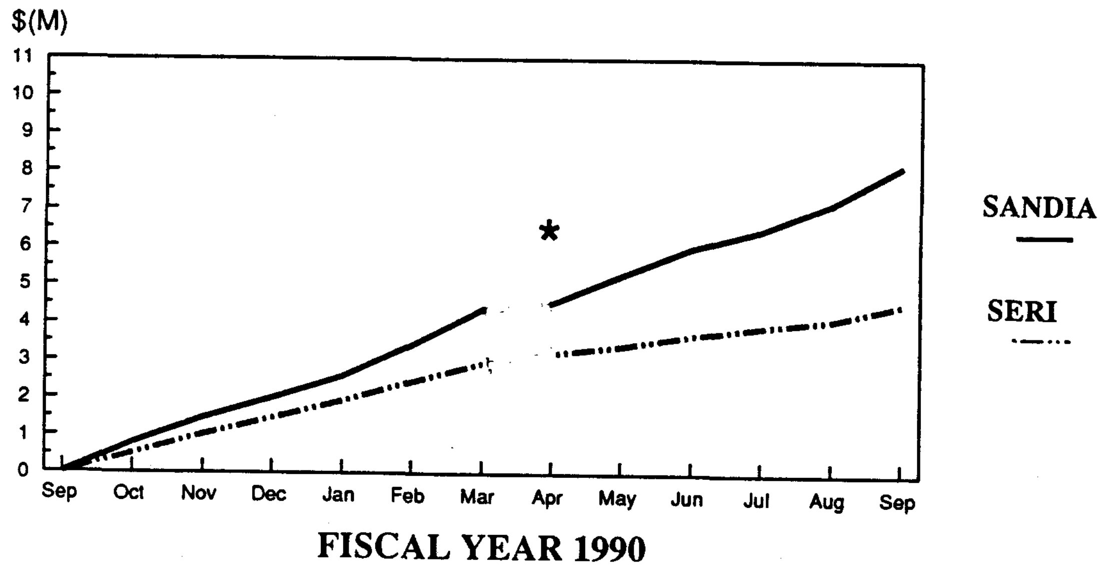
Specific implementation of the Solar Thermal Electric Technology Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the Solar Energy Research Institute in Golden, Colorado. Together, these two field laboratories are responsible for implementation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

SOLAR THERMAL ELECTRIC TECHNOLOGY PROGRAM WORK BREAKDOWN STRUCTURE

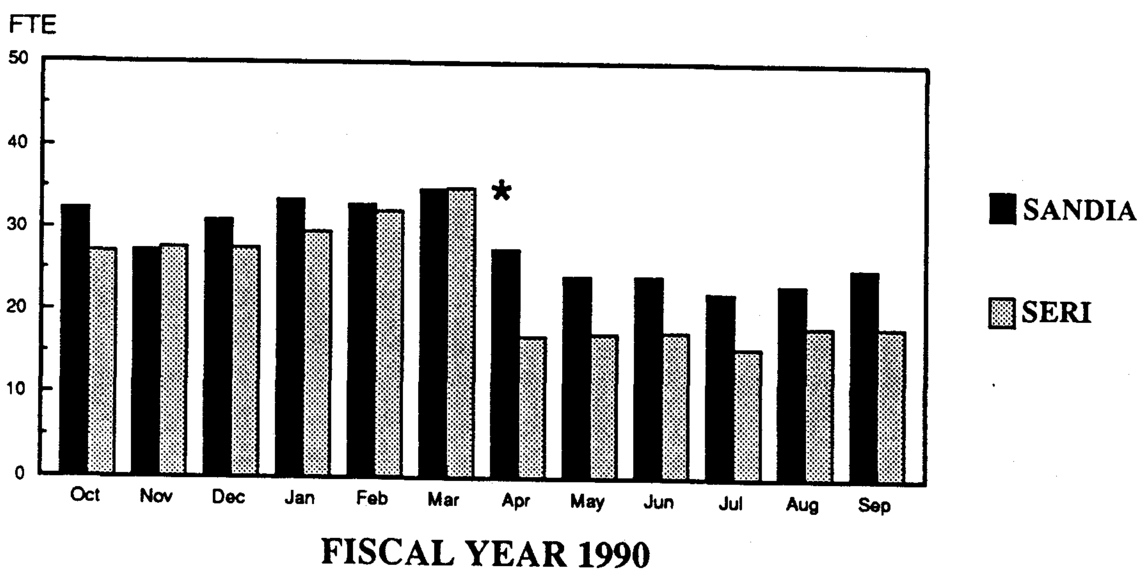
PROGRAM ACTIVITY	LEADER (Individual)
2. CONCENTRATOR DEVELOPMENT	C. Tyner, SNL/M. Carasso, SERI
A. Heliostats	
B. Parabolic Dishes	
C. Optical Materials	
D. Structural Dynamics	
3. ELECTRIC SYSTEMS DEVELOPMENT	P. Klimas, SNL
A. Central Receiver Technology	
B. Dish Receiver Technology	
C. Conversion Devices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

Resource Summary

CUMMULATIVE BUDGET OUTLAY



MONTHLY MANPOWER LEVEL



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*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 - 11/90	Small	TBD	D. Alpert
Con. Dev.	Heliostat Integration	Solar Kinetics, Inc.	SNL42-9691	$100	$100	–	10/89 - 11/90	Small	TBD	D. Alpert
Con. Dev	Heliostat Fabrication	SAIC	SNL54-5780	$540	$400	$140	01/90 - 11/90	–	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 - 11/91 (est.)	–	TBD	T. Mancini
Con. Dev.	Faceted Dish Development	SKI SAIC	SNL42-9814	$234 $191	– –	$234 $191	09/89 - 11/91 (est.)	Large	TBD	T. Mancini
Con. Dev.	Stretched-Membrane Dish Dev.	Solar Kinetics, Inc.	SNL55-2495	$1,851	$500	–	04/88 - 06/91	Small	SAND88-7035	T. Mancini
Con. Dev.	Solar Coll. Ped. Fab	TIW Fab. & Mach.	SNL57-4436	$57	–	–	12/87 - 12/90	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 09/90)	Large	SAND87-2290	J. Chavez
Elec Tech	Volum. Rec. Furnace Test	NMSU	SNL66-9967	$30	-0-		01/90 - 12/90	Univ.	--	J. Chavez
Elec Tech	PRE Panel/ Manifold	Hufman, Inc.	SNL70-8957	$20	$20		Closed	Small	--	J. Chavez
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.
Elec Tech	Heater Heads	Stirling Therm Mtrs	SNL78-8095	$ 45	--		10/1 -12/31/90	Small	--	Kevin Linker

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	Evaluate responses to the Request for Information.
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 (April, 1991)	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	Decide on heat-pipe versus pool-boiler receivers for further development.
SN	May, 1990	3C	Initiate final design of ASCS
SN	June, 1990 (Nov., 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 July, 1990 on the molten salt pump and valve hot loop; complete 2000 hours of operation on the cold loop.
Fourth Quarter, FY 1990			
SN	July, 1990 (Dec., 1990)	2A	Complete fabrication of SAIC's prototype of 100-m^2 market-ready heliostat.
SN	July, 1990 (Dec., 1990)	2B	Reach decision point: Dish designs to fabricate and test.
SN	July, 1990 (Cancelled)	2C	Complete the Sol-Gel mirror production cost study.
SN	July, 1990 (Nov., 1990)	2C	Complete and document replaceable film study.
SN	July, 1990 (Dec., 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 (May, 1991)	3A	Complete testing of an optimized volumetric receiver absorber.
SN	September, 1990 (Cancelled)	2A	Initiate fabrication of first prototype of SKI's market-ready heliostat.
SN	September, 1990 (Sept., 1991)	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.

Lab	Date	Activity-Task Reference	Descriptive Title
SE	September, 1990	2C	Document studies of polymer film-to-silver adhesion.
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)	Write 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) (Nov., 1990)	Publish 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 membrane dish optical element for testing at the STTF.
		C2-3 (Cancelled)	Document cost potential of silvered metal structural mirrors.
		C2-2 (Sept., 1990	Reach 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	Complete 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.

Fiscal Year 1990 (Rescheduled to FY 1991)

	C3-3 (Sept., 1990)	Initiate on-sun testing of the STM4-120 Stirling engine.

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
• Complete computer model of the faceted dish support structure. SE	06/90	(Deleted)
• Complete validation of OPTDISH and ODMF optical codes using the data from SHOT. SE (2B)	08/90	08/90
• Complete and document preliminary evaluation of ultraviolet-enhanced mirrors for photochemical applications. SE (2C)	09/90	09/90
- A preliminary evaluation of ultraviolet-enhanced mirrors for photochemical applications has been completed and is being documented.		
• Document studies of polymer film-to-silver adhesion. SE (2C)	09/90	09/90
- Studies of polymer film-to-silver adhesion have been completed and documented.		

TASK 3. Electric Systems Development

• Initiate the salt flow testing on the PRE. SN(3A)	01/90	08/90
• Complete 2000 hours of operation on the molten salt pump and value cold loop. SN(3A)	06/90	07/90
• Release request for proposal for preliminary design of hybrid reflux receivers. SE	07/90 (12/90)	
• Complete testing of an optimized volumetric receiver absorber	08/90 (07/91)	
• Initiate on-sun testing of the STM4-120 Stirling. SN(3C)	09/90 (09/91)	
• Initiate final design of Advanced Stirling Conversion System. SN(3C)	02/90 (04/90)*	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	05/90
• Complete the comparative study of salt and air receivers. SN(3A)	5/90 (10/90)*	08/90
• Test and deliver the STM4-120 Kinematic Stirling Engine	06/90	09/90
- Stirling Thermal Motors (STM) operated Sandia's STM4-120 at their facility. The engine was thoroughly checked-out to assure reliable operation at higher pressure levels. The STM4-120 has been delivered to Sandia for continued testing.		
• Continue monthly meetings for final design of the Advanced Stirling Conversion Systems (ASCS)	Thru Qtr	Thru Qtr

- Monthly meetings for the ASCS final design have been held with Stirling Technology Company (STC) since the May kick-off meeting. Both Sandia and NASA/LeRC personnel have attended these scheduled meetings.

• Design review of Sandia's gas-fired Heat Pipe Evaporator	08/90	08/90

- An internal design review was held for a Sandia designed tubular gas-fired heat pipe evaporator for the STM4-120 Stirling engine. This design is intended to be an upgrade to the current finned gas-fired heat pipe evaporator.

• Decide 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

*** Rescheduled to this date.**

TECHNICAL STATUS REPORT

2. CONCENTRATOR DEVELOPMENT

TASK 2A. HELIOSTATS

- **Science Applications International Corp. began final assembly of its 100-m^2 market-ready stretched-membrane heliostat.**

  Science Applications International Corp. began the final assembly of its 100-m^2 market-ready heliostat at the NSTTF. SAIC's heliostat sports two 50-m^2 stretched-membrane mirror modules on a single pedestal. Because of other commitments to the multi-faceted dish program and delays in receiving materials from suppliers, the final assembly began several months later than originally planned.

  Though not necessarily the optimal heliostat for large power plants, the dual-module design was selected because it provides a near-term commercial product. Two key advantages are the use of an existing drive system (Peerless-Winsmith's unit for the Lugo PV field) and the ability to stow the mirror modules face down. In addition, very few modifications would be required to build a 50-m^2 single-module heliostat for use at smaller plants. The heliostat should be completed and installed for Sandia's testing early next quarter. (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. Because of other commitments to Sandia's point-focus dish program, the design will not be completed until early next quarter. (SNL)

- **Sandia delayed completing its testing of two large-area heliostats and the low-cost drive.**

  Because of other commitments to the point-focus dish program and reimbursable activities, evaluation of the optical performance of the two large-area glass-mirror heliostats and the low-cost drive was not completed as planned. Preliminary results for ATS's 150-m^2 heliostat showed very good optical performance; no evaluation has been performed on SPECO's 200-m^2 heliostat.

- **Alpha Solarco, EPRI, and Sandia met with Peerless-Winsmith to discuss further applications of the low-cost drive.**

  A meeting was held at Peerless-Winsmith with Alpha Solarco, EPRI, Scientific Analysis, and Sandia to discuss the status of the low-cost heliostat drives and future applications. Alpha Solarco has reported several problems with the elevation drive in the unit it has installed at Pahrupm, Nevada. It has had problems with the automatic grease dispenser on the elevation drive. The dispenser has plugged and the grease has separated. The elevation drive operated smoothly when first installed but has recently been plagued by blown fuses indicating increased friction in the unit. This problem is believed to be a result of the problems with the grease dispenser, but that cannot be confirmed until the drive is disassembled for inspection. In any event, Alpha Solarco is requesting that Winsmith collaborate on building a large drive unit within the next six weeks. Alpha Solarco and EPRI also discussed plans they both have to build larger arrays, which would require upscaled versions of the low-cost drive. Additionally, Alpha Solarco is considering some downscaled versions of the drive for smaller arrays it is developing.

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 continued.
- 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, and a design review meeting will be held.

TASK 2B. PARABOLIC DISHES

Accomplishments

- **A review of Solar Kinetics' Stretched-Membrane Dish Task 2 was conducted.**

  A design review was conducted at Sandia National Laboratories in Albuquerque, NM, on Thursday, August 30, 1990, to document the results of Task 2 of the Solar Kinetics Inc. (SKI) Single-Element Stretched Membrane Dish Development Project.

The purpose of Task 2 of the project was to design, fabricate, and test a 7-meter diameter stretched-membrane optical element. The design was completed in August of 1989. The 7-meter diameter optical element was fabricated and preliminary testing was conducted at SKI's facility in Dallas, Texas, from October 1989 through April 1990. The optical element was then disassembled, shipped to Sandia, and reassembled from May 21, 1990 through July 9, 1990. On-sun tests are currently being conducted at the NSTTF in Albuquerque.

SKI addressed a number of issues in the design review including: the structural design of the 7-meter diameter optical element, scaling of the water/vacuum forming process with the diameter of the optical element; the issues associated with the fabrication of a silver-acrylic polymer membrane and the selection of an aluminized membrane for the 7-meter optical element; the strength and optical performance of the metal and polymer membrane seams; and the tooling, fabrication, and installation on the optical element of the dish. SKI also established that the dish optical membrane could be rolled onto a contoured mandrel for transportation to the dish assembly site. This is important because it means that the dish can be fabricated in the shop and the components shipped to the site for assembly. Previously, we had thought it necessary to fabricate the optical membrane at the dish assembly site. This would require the shipment of heavy tooling to the site with the attendant costs and additional time for site fabrication.

SKI has been authorized to proceed with Task 3 conceptual design of a complete 75-kW_T dish. In this task, SKI will design a dish to be integrated with the STM kinematic Stirling engine and a heat-pipe receiver. A design review will be conducted at the conclusion of Task 3 conceptual design and, if appropriate, SKI will proceed with the detailed design of the full-scale dish in Task 4.

- **Sandia began on-sun testing of the 7-meter diameter optical element.**

Testing of the Solar Kinetics 7-meter diameter, stretched-membrane optical element started in July at the National Solar Thermal Test Facility (NSTTF). Figure 2.B.1 is a picture of the 7-meter optical element on test at the NSTTF in Albuquerque, New Mexico. Testing includes flux mapping of the receiver target plane, distant-observer evaluation of the dish contour, and cold-water-cavity calorimetery to measure the total power produced by the dish. These tests are directed at determining the effects of membrane stabilization pressure, gravity sag of the membrane, creep of the optical membrane, and dish orientation on the performance of the concentrator.

Preliminary results of the optical testing indicate that the 7-meter diameter optical element is capable of producing 21 kW of thermal power within a 15-cm diameter circle at a peak flux of about 5200 suns and insolation of 1 kW per square meter.

Figure 2.B.1 The 7-meter diameter stretched-membrane concentrator on test at Sandia's National Solar Thermal Test Facility in Albuquerque, NM.

- **SKI and SAIC fabricated second-generation facets for the faceted dish and delivered them to SERI for evaluation with SHOT.**

SKI and SAIC completed fabrication of second-generation facets for the faceted stretched-membrane dish and shipped them to SERI for optical evaluation.

SKI's fabrication technique involves plastically deforming a thin stainless steel membrane using a uniform load to achieve a nominally parabolic contour. The company forms the facets to correspond to the longest focal length on the dish (f/D of 3.0) and operates them at a slightly higher vacuum for the shorter focal length positions. Measurements made with SERI's Scanning Hartmann Optical Test (SHOT) instrument show SKI's first-generation facets to range from 2.05 to 2.35 mr 1σ slope error for the f/D range of the dish. SKI has modified its facet forming procedures slightly for ease of assembly and has installed a focus-control system designed for the faceted dish second-generation facet.

The facets fabricated by SAIC are not preformed but rather elastically shaped with a vacuum to the desired contour. That is, the facets are operated like the stretched-membrane heliostats except at a higher vacuum level so that the center displacement of the membrane is larger -- the facet has a shorter focal length. This requires that the stainless steel membranes be operated at high levels of stress. The results of measurements of first-generation facets showed SAIC's facets to range from 2.95 to 3.30 mr 1σ slope error for the focal length range of the dish. The errors are greatest near the edge of the facet. SAIC has modified the facet design to accommodate a higher level of pretension in the front membrane and installed a new vacuum and focusing valve for faster draw down of the facet.

An artist's concept of the faceted dish is shown in Figure 2.B.2.

- **SERI researchers completed preliminary measurement of the optical performance of the "second generation" (SM) dish facets received from SAIC and SKI.**

SERI researchers set up an optical testing facility capable of characterizing the prototype facets fabricated as part of the DOE Solar Thermal faceted membrane dish program. The Scanning Hartmann Optical Test instrument (SHOT) was installed and calibrated in a warehouse of sufficient size to allow testing of point focus concentrators with focal lengths as high as 12.0 meters.

To date, two rounds of testing have been completed. In late May and early June, two facets were received (one each from Solar Kinetics, Inc. and Science Applications International Corp.) and tested for optical performance. The SKI dish

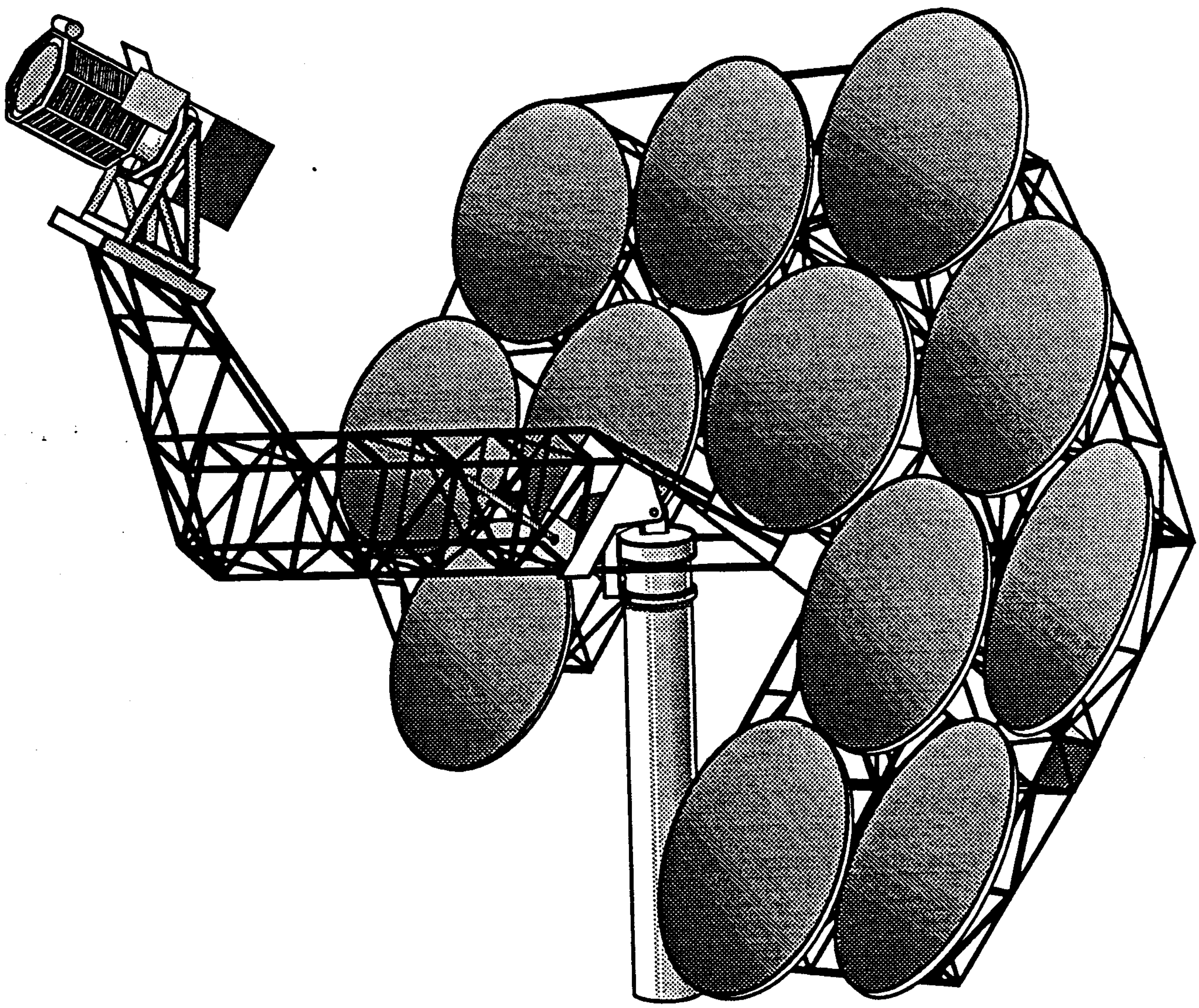


Figure 2.B.2 An artist's concept of the multi-faceted stretched-membrane solar concentrator.

performed well by utilizing plastic deformation forming to reduce the error associated with vacuum stabilization of membrane surfaces. The overall r.m.s. slope error was less than 2.4 milliradians over the range of desired focal lengths. The SAIC dish utilized elastic deformation to achieve the desired optical shape and thus exhibited slightly more error as a result (less than 3.3 milliradians r.m.s. over the desired focal length range). The information resulting from the testing of each facet was used to make improvements to their respective fabrication processes. Two more "second- generation facets" were constructed as a result of this feedback and are currently being tested at the SHOT optical testing facility. Preliminary results indicate that both facets have improved their overall slope error between 0.5 and 1.0 milliradians over the range of achievable focal lengths. Testing is not quite complete and is ongoing at this time.

- **Several dish concentrator optical performance simulation programs have been validated by comparing predicted results with measured data.**

Several optical design tools have been developed at SERI during the past two years. These have been used extensively both in-house and by industry to carry out analyses of dish concentrator systems and to optimize performance of such designs. The first program, OPTDISH, models dish concentrators consisting of a single optical element. The second code, ODMF, enables multi-facet dish arrays to be modeled. The performance simulations of these programs have been validated by comparing predicted results with measured on-sun data.

Since ODMF evolved from the solar furnace design tool (SOLFUR) and in fact is a special case of SOLFUR in which the primary facet array is "on sun," validation of SOLFUR would validate ODMF as well. Furthermore, since OPTDSH can be viewed as a single face case of ODMF, validation of SOLFUR/ODMF would also validate OPTDSH. Thus, the approach to validating all three codes was to compare flux patterns as predicted by SOLFUR with those actually measured at SERI's High Flux Facility.

Measured vs. calculated data have been compared on the basis of flux distribution (in terms of contour plots) and peak flux for both single-facet and multiple-facet cases. Agreement in measured vs. predicted peak flux values has been obtained within the uncertainty associated with the measurement/calibration process. Excellent agreement has also been demonstrated by comparing contour maps, (also known as "flux maps") of measured vs. computed flux levels.

- **Colorado State University (CSU) submitted the wind load design guide for review.**

Dr. J. Peterka submitted the first draft of the wind load design guide. The guide is being prepared using the wind load tunnel data for both heliostats and dishes that have been compiled by CSU over the past few years and is being done in response to comments from industry that such a document would be desirable. Copies have been distributed to SERI and industry for review. CSU is working on an addendum, which will include data on non-peak loads. Completion of this work is expected during the first quarter of FY91.

Planned Activities for Next Quarter

- Sandia will complete on-sun testing of the 7-meter diameter stretched-membrane optical element.
- SERI will complete SHOT evaluation of the second-generation facets for the faceted dish.
- Sandia will complete on-sun testing of the two second-generation facets for the faceted dish.
- Sandia will conduct a Design Review for Phase 1 of the Faceted Stretched-Membrane Dish Development Project.
- Sandia will collect comments on the wind load design guide and submit them to J. Peterka. Copies of the addendum will be distributed for review.

TASK 2C. OPTICAL MATERIALS

Accomplishments

- **Preliminary results are available from a tunneling experiment that was designed to investigate several approaches of mitigating the tendency of silver polymer reflectors to exhibit delamination failure during service conditions. While the tests are ongoing and major conclusions are not yet available, several pieces of useful information have been obtained.**

  Two sets of samples incorporate an edge joining structure in which a strip of PMMA is attached via either a solvent weld or a thermal weld to bridge an inner seam. A third sample set uses an innovative material construction developed at SERI in which an adhesion promoting inorganic interlayer is deposited between the PMMA film and the silver layer. The final sample set represents a field-replaceable reflector material candidate. These are samples of ECP-305 laminated to a polyester film. The polyester is subsequently mounted on aluminum substrates using a two-sided sheet adhesive. The adhesive on the aluminum side is low-tack.

  Ten replicates of each sample set were prepared. All outer edges were protected by an angle bracket/C-channel clamping arrangement around the perimeter. Samples have been cycled between a water bath and drying chamber (and back to the water bath) on a daily basis. Three half-samples (i.e., one side of a bridge-joined sample) failed due to tunneling after 1/2 cycle (water immersion). Two of these samples were solvent welded and one was heat welded. A fourth half sample (the other half side of one of the previously failed solvent weld samples) tunneled after the dry part of the first cycle. It is suspected that the sample was placed in the dry chamber such that water entrained in tunnels within the failed upper half propagated through the joining bridge and caused tunnels in the lower half of the sample. After three weeks of exposure (15 cycles), no additional tunnel failures have occurred.

  A video microscope system was to be used to provide a permanent record of the condition of the prepared samples. Samples were inspected with the system immediately after they were assembled and again after 1 hour of immersion in water to document any seam defects. The results of these examinations are summarized in Table 1.

Table 1. Results of Initial Inspection of Sample Seams

	# of Initial Defects for 20 Half Samples		% of Seam Length Initially Defective	
Sample Type	Total	Away from Edge Clamp	Total	Away from Edge Clamp
Solvent Weld	7	6	2.9	2.7
Heat Weld	17	12	10.2	8.0
Replaceable Laminate	18	1	8.0	0.5
SERI Construction	10	4	4.8	1.9

Two important points should be emphasized:

1. The edge clamp arrangement adversely affected the seams of all sample material types in the region where the interior seams meet the exterior edge bracket. The replaceable laminate was most susceptible to this effect; perhaps due to lateral movement associated with tightening the clamps too high for the low-tack adhesive layer to withstand. The solvent weld samples withstood the clamping process the best but were not problem free.

2. Numerous initial defects were evident in the heat-sealed and solvent-sealed seams, even away from the outer edge clamping regions. These flaws allowed water to penetrate the bridge seal from the outset of exposure testing. It is clear that the joining process must be optimized both in terms of solvent/heat application selection as well as operator technique.

   No correlation between occurrence of initial defects and tunnel failure was found. One solvent weld sample failure had the most number of defects (3); two others that tunneled had no apparent initial imperfections. The heat weld sample that failed had an intermediate number (2) of initial flaws; samples with a greater number as well as those with the same or fewer number of defects have not tunneled. Cyclic exposure of all samples is continuing.

- **Polymer film-to-silver adhesion research and related tunneling experiments carried out at SERI during FY90 were very successful and have been documented.**

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. SERI has developed two accelerated tests to aid in understanding the causes of tunneling and thereby in devising methods of mitigating delamination failures. These tests have indicated that a number of parameters contribute to the tunneling process. Such factors include sample size, substrate material, edge joining approach, edge cutting technique, edge sealing method, and reflector material construction. Given a large variation in tunneling test results, it is important to control sample parameters sufficiently well to assure success in discerning how best to deal with the tunneling problem.

Laboratory tests have identified several methods that can slow the initiation and propagation of tunnels. By increasing the adhesion of silver to the polymer film, tunneling can be controlled even when damage is experienced during service (as might be caused by hail or vandalism). Other means of resisting delamination have concentrated on edges formed when mirrors are fabricated, because tunneling virtually always begins at edges. The proper preparation and protection of edges can slow the initiation of tunneling. Reducing the number and types of flaws introduced when silvered polymer mirrors are cut to size can delay tunneling. Certain ways of protecting edges after they are formed (for example, the application of heat seals or silicone caulk) are also effective. Although none of these methods is 100% effective in preventing tunneling during accelerated laboratory tests, some (like increasing the adhesion between the silver and the polymer film) can substantially decrease this process.

- **Results of outdoor exposure testing of production ECP-305 reflector materials in Arizona and Florida are very encouraging.**

Such samples have maintained solar-weighted hemispherical reflectances between 92-93% after 9 months of weathering. The experimental precursor to ECP-305, termed 719-37-G, has maintained reflectance near 92% after 18 months exposure in Arizona. This result for the G material is a notable improvement over the prior production material EPC-300.

Another experimental material that is similar to the polymer used in ECP-305 and 719-327-G (an improved PMMA compared to that used with ECP-300 in the sense that less sulfur- containing compounds are added) but that does not contain any UV stabilizers has also been tested. The reflectance of samples of this material

(719-37-F) after 18 months in Arizona is between 95-96%. These results generally confirm accelerated laboratory experiments. In particular, the durability exhibited by the type-F material points to the future potential for significantly improved mirrors. A slight cloudiness is evident with this material, which suggests that specular reflectance needs to be demonstrated.

Accelerated testing of reflector materials having low levels of UV absorbers but incorporating a back protection interlayer continue in SERI's solar simulator exposure chamber. After over 1000 hours for one sample set and nearly 500 hours for another, optical durability remains high (above 93% hemispherical reflectance). Some crazing occurs with these materials, which may be related to the elevated temperatures (80°C) they experience. Such micro-cracks can adversely affect specular reflectance.

- **An evaluation of mirror materials that exhibit enhanced reflectance in the ultraviolet spectrum (300-400 nm; intended for photochemical applications) has been completed and is being documented.**

For continuity and snyergism with the optical materials task in this program, this small task has been conducted and is being reporterd here. Organic waste detoxification requires cleavage of carbon bonds. Such reactions can be photo-driven by light that is energetic enough to disrupt such bonds. Typically, this requires photons below 400 nm. Because the terrestrial solar resource below 400 nm is so small (roughly 2.5% of the available spectrum), highly efficient optical concentrators are needed that can withstand real world outdoor service conditions. In the past, optical elements for solar application have gone to great lengths to avoid the ultraviolet bandwidth due to the harmful effects of such light on the collector materials themselves. For example, current generation silver polymer reflectors for solar thermal electric application incorporate 2% (by weight) UV absorber materials into the polymer film. This effectively forfeits the UV part of the spectrum in return for protection against optical degradation and longer lifetime. To optimize the cost/performance benefit of photochemical reaction systems, optical materials must be developed that not only exhibit high efficiency but are also inherently stable against the radiation they are designed to concentrate.

The requirements of UV optical elements (in terms of appropriate spectral bands and level of reflectance/transmittance) were established through interactions with other workers involved in photochemical applications. UV-enhanced reflector materials were emphasized. The issue of spectral splitting was also discussed. A literature search of UV reflector materials was completed and appropriate articles related to the state of the art were reviewed. This review, along with discussions with industrial contacts, allowed the establishment of a data base of currently available materials. Some candidate advanced materials were also identified.

Several interesting concepts have been suggested to achieve high reflectance of ultraviolet radiation. These include the use of non-periodic absorbing materials, gradient index rugate filters, and staggered multidielectric layers. The first approach makes use of the fact that in the UV spectral region, differences in refractive index are small but variations in absorption coefficient can be large. Such absorption differences may allow the placement of antinodes of the EM light field at the reflector surface to achieve high reflectance. By varying thin film deposition parameters and/or codepositing different materials, a design gradient index profile may be obtained which results in high UV reflectance. Finally, use of an arithmetic or geometric progression of layer thicknesses may also be feasible to increase reflectance.

- **Replaceable reflective film development continues at Industrial Solar Technology (IST).**

Under contract to Sandia, Industrial Solar Technology is developing a method for replacing the reflective film; the best polymer materials and adhesives have been evaluated. IST has selected 0.010-in polycarbonate for the polymer substrate and 3M's 9425 for the low-tack adhesive. The specularity of a number of candidate material constructions was measured by SERI using its Reflectometer II instrument. Measurements were carried out at 650 nm as a function of the two-dimensional detector acceptance angle. A circular normal beam profile was fit to the specular reflectance data to obtain the 1/2 cone angle specularity (σ). A clear distinction was evident between samples mounted directly on metal substrates (having σ <1 mrad) and several replaceable laminate constructions (having a σ of roughly 2-2.5 mrad). The selected method will likely also be appropriate for use on membrane dishes and troughs. Ken May of IST visited Sandia on August 9 to finalize plans for the installation of a replaceable reflective film on a membrane heliostat. The first demonstration of film replacement will take place at the National Solar Thermal Test Facility early next quarter. (SNL)

Planned Activities for Next Quarter

- Cyclic accelerated exposure of tunneling samples presently under test will continue.

- Plans will be formalized and an approach begun to investigate improved/alternate and replaceable reflector material constructions (as a cooperative effort with industry).

- IST will finalize its evaluation of alternative materials to be used in a replaceable reflective film for heliostats, dishes and troughs and install a replaceable reflector on a 50-m^2 membrane heliostat at the NSTTF.

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; the hot loop surpasses 6750 hours and cold loop surpasses 2400 hours.**

  Both the hot and cold molten salt pump and valve (P&V) loops are continuing to operate in the auto-sequence mode at the Solar Thermal Test Facility. The hot loop now has over 6750 hours of operation and the cold loop has over 2400 hours. 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 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 milestone 3A this past quarter on the P&V loops by operating the cold loop over 2000 hours.

  During near-continuous operation this past quarter, the hot loop operation of 550 hours brought its total to 6750 hours of operation since November 1987. The hot pump has 4350 hours of operation with the new pump shaft. The hot loop was shut down this quarter for inspection of the valves and packing materials. None of the valves shows any sign of excess wear. The valve packing, an Inconel wrapped fiberglas with Teflon spacing rings, appeared to be in good condition after 3000 hours of operation. The valves were re-installed with new shafts and new packing materials. The hot loop was re-started and continues to operate.

  The cold loop is continuing to operate and gained an additional 700 hours of operation this past quarter. Milestone 3A was achieved this past quarter by surpassing 2000 hours of operation. The loop is only operated 12 hrs/day. It is not operated during the day, 8:00 a.m. - 8:00 p.m., because of the high cost of energy (the cold motor utilizes 2 MW). The original packing material, a carbon fiber material with Teflon spacing rings, is working satisfactorily in the valves. The hot loop packing material was installed in one valve and survived 40 hours of operation. The cold motor failed after 2400 hours of operation. We suspect that the pump re-design, after the original problems with the pump, was not complete. Consequently, the motor bearings are experiencing excessive loads causing them to fail. The cold motor was repaired.

Both the hot and cold loops are to be shut down at the end of the quarter. An ASME paper on the P&V testing was written this quarter. The final report on the P&V is being prepared.

- **Molten salt flow testing on the DAR PRE was begun; this concludes Major Milestone 3A.**

The Panel Research Experiment (PRE) was operated with molten salt flow on the panel this past quarter. Conducting salt flow concludes a major milestone. The PRE is a 3-MW_t experiment designed to evaluate the technical feasibility of the direct absorption receiver concept.

After numerous checkout tests were completed, the testing of salt flow on the panel was initiated on August 15, 1990. The panel is tilted back 10° and there is no blackener in the salt. All results described are preliminary. Prior to salt flow, heliostats are used to preheat the panel up to 500°F. Preheating of the panel works satisfactorily; however, because of the non-uniformities in the heating, there is some deformation in the panel.

All the components on the PRE work satisfactorily. The pneumatic cylinders appear to be working as designed in accommodating the thermal growth in the panel and keeping the panel tensioned and flat while it is operating. The panel warps as it cools down after operation; however, it does not appear to be a significant problem. The inlet manifold works well in distributing the salt flow onto the panel; however, it cannot accommodate the higher flow rates of >9.5 kg/m.s (25 gpm/ft), that would allow operation in the film Reynolds number regime of 75,000. There are some minor leaks around the manifold. The edge containment pieces used to keep salt on the panel appear to work satisfactorily.

The inlet temperature of the salt on the panel is 330°C (625°F). The salt flow on the panel looks very much like water flow. With salt flow rates of up to 9.0 kg/m.s (22 gpm/ft), up to film Reynolds numbers of 38,000, there is light misting off the panel when there is no wind. The waves and misting increase with increasing flow rate. However, most of the droplets fall back to the panel. High-speed movies were used to characterize the flow. Testing with fans to simulate wind has shown that winds at 20 mph incident at 45° cause significantly more misting and droplet ejection from the panel. The droplet ejection occurs primarily below 4 m, where the heavy wave tips are blown off the panel.

Some heating of the salt has been accomplished by focusing as many as 12 heliostats onto the panel. A thermal loss analysis of the panel (with 330°C (625°F)) salt flowing at 9.0 kg/m.s (22 gpm/ft) has shown losses of 170 kW. When twelve heliostats are on the panel, they supply ~ 250 kW; however, there is only a temperature gain of 2 - 3°C. This test demonstrated the need to add the blackener to the fluid to increase the efficiency of the receiver.

The results from the salt flow testing are preliminary. However, this testing has shown the engineering feasibility of building a DAR panel. The method of resolving the fluid instabilities (waves and droplets) and adding the blackener still needs to be worked on.

A meeting of the DAR experts from industry and other national laboratories was held on September 24 to observe the PRE operation and discuss the DAR concept. Everyone was favorably impressed with the PRE construction and operation. The experts concluded that the panel warping was not a significant concern, that a method of retarding wind effects on the salt flow would be more beneficial than developing the intermediate manifold, and that the permissible levels of nitrate salt contamination into the environment should be investigated.

An ASME paper on the design, construction and testing of the PRE was also prepared this past quarter.

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

New Mexico State University (NMSU) is testing volumetric air receiver materials at its solar furnace. Sandia has 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.

The furnace testing has progressed steadily this past quarter. Testing of various densities, porosity and stacking of the materials is being conducted to evaluate heat transfer characteristics and thermal efficiencies. Over twenty different configurations of porous ceramic material and knit wire mesh have been tested.

The results have shown that the knit wire mesh, configured as a 5-cm thick rolled absorber, generally has high efficiencies, 92% at an air flow rate of .0036 kg/s (7 ft^3/min) and outlet temperature of 580°C, compared to two layers of porous ceramic material, 2 - 20 ppi, 20% dense 0.5 cm samples, which had efficiencies of

70% at .0036 kg/s (7 cfm) at 580°C outlet air temperature. The problem with the knit wire mesh is that it degrades (oxidizes) fairly quickly. The porous ceramic samples are much more robust.

All the results are preliminary and insufficient testing has been conducted to statistically prove the results. Neither of the absorber configurations for the wire mesh nor the porous ceramic has been optimized. It is obvious that the knit wire mesh has a higher efficiency than the porous ceramic; however, an absorber configuration utilizing both ceramic and wire mesh may be the best choice from the standpoint of efficiency and structural integrity.

The heat transfer coefficients for the porous ceramic materials have been calculated and appear to be very low. Further analysis of the heat transfer coefficients is being conducted. Testing and analysis are continuing.

- **Second Generation Central Receiver Study continues.**

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 is focusing on 30-MW and 100-MW plants with capacity factors in the 40 to 50% range.

During the present quarter, the draft results of the study were presented at the solar conference in Davos, Switzerland. The results indicate that molten salt power plants have a lower levelized energy cost than current generation volumetric air plants. This is because the thermal storage system for the air plant costs significantly more than the storage system for the salt plant: $88M vs. $22M. Also during the quarter a substantial portion of the draft report was written and a paper was submitted to the 1991 ASME conference that describes the reliability analysis conducted for the molten salt power plant.

- **Materials analysis of the tubes in the Themis central receiver begins.**

One element of the Second-Generation Study described above is to perform reliability analyses of competing concepts for central receiver power plants. One of the plants under study uses a molten salt receiver that has many design similarities to the Themis receiver that was shut down in 1986. For example, the tube material (316SS) and tube wall thickness (1.5 mm) are similar. Since this receiver was exposed to more solar hours (~3000 hrs) than any other salt receiver in the world, it is a valuable source of data regarding receiver reliability and expected lifetime. Even though the salt outlet temperature was approximately 100°C lower than we envision, salt temperatures in the highest solar flux region are comparable.

During the quarter, Sandia obtained several Themis tubes from engineers at the Centre National de la Recherche Scientifique. The tubes were exposed to a solar flux of approximately 0.5 MW/m^2. These tubes were submitted to Sandia's materials science laboratories for analysis.

- **National Energy Strategy for Solar Thermal Electric Technology is being developed.**

  In support of DOE's efforts to develop a National Energy Strategy (NES), Sandia performed analyses of solar thermal electric technology and wrote sections of a paper entitled "Solar Thermal Electric Technology Rationale." The paper was co-authored by EA Mueller Corporation, Sandia, and DOE. The paper reviews the basic principles of solar thermal electric technology and provides cost and performance projections. It also discusses the market status and identifies user requirements to help establish the future technology path.

<u>Planned Activities Next Quarter</u>

- Mothball the pump and valve loops, and prepare the final report on the pump and valve testing.
- Mothball the DAR PRE in place and prepare a summary report on the PRE testing.
- Complete the furnace testing and analysis of porous ceramic and wire mesh materials.
- Conclude coordination for the final report on the Second-Generation Central Receiver Study.
- Complete qualitative analysis of the Themis receiver tube for thermal fatigue.

TASK 3B. DISTRIBUTED RECEIVER TECHNOLOGY

Accomplishments

- **Pool boiler failure analysis was continued.**

Sandia metallurgists have sectioned and examined the absorber dome material around the area of the leak. Very localized melting was evident, with no heat affected areas seen away from the failure zone. Oxidation and sodium attack depths were limited to less than 1 mil. The failure did not occur at an artificial nucleation site. An investigation of seven spare absorber domes revealed several small surface flaws in addition to artificial nucleation sites, but none large enough to cause a high stress concentration.

Sandia scientists have reviewed and refined the stress analysis and materials studies used in the design of the receiver. While stresses were high compared to yield at operating temperatures, the number of cycles was not high enough to indicate fatigue. Fluctuating input flux due to incremental tracking of the dish was considered, but the cycles were still not high enough to cause fatigue failure. Temperature fluctuations due to bubble departure should not cause a large enough stress to cause fatigue damage.

The peak flux in the region of failure was measured by Sandia engineers with a single flux gage to be about 75 W/cm^2, which compares favorably with the CIRCE2 model used in the design process. The CIRCE2 model and the flux gage experiments indicate a peak in the flux in the vicinity of the point of failure.

Sandia engineers have identified a new possible failure mode that concerns a transition to film boiling and/or reaching the flooding limit during startup. The design should be suitable for boiling as low as 600°C, which is where boiling initiated in the bench tests. However, on-sun boiling typically initiated at about 480°C. A review of the data confirms that this start-up had a unique temperature history compared to usual starts due to a temporary shutdown for a failed thermocouple. Further analysis of the x-ray data is in progress to determine void fractions during start-up and operation. Infrared thermography films may also help characterize boiling patterns.

Further disassembly of the receiver is awaiting the completion of the x-ray analysis.

- **Reflux receiver technology was highlighted at 25th Intersociety Energy Conversion Engineering Conference (IECEC).**

  At the 25th IECEC held in Reno, Nevada, August 12-17, 1990, two sessions were devoted to solar applications of Stirling engines. Papers on reflux receiver development for dish-Stirling applications were presented by Sandia (2), Thermacore (1), and Stirling Technology Company (STC) (1). In addition, papers on the commercial development of dish-Stirling systems by Cummins, STC, and NASA included discussions of reflux receiver heat transport systems. Acknowledgement of Sandia's contributions to the technology was made in virtually every presentation in the two sessions. Sandia also presented preliminary findings concerning the pool boiler failure following the sessions. Each dish-Stirling session attendance exceeded attendance at any of the other Stirling sessions.

- **Sandia and SERI are working with Cummins to perform long-term durability testing of a Thermacore heat-pipe receiver.**

  Sandia and SERI are supporting Cummins Power Generation and its contractors to test the long-term durability of a heat pipe reflux receiver. In this cost-shared project, which is currently being negotiated, SERI would provide approximately one-third of the financial support, with Cummins providing the remainder. Sandia and SERI have also agreed to provide technical support. Sandia plans to support dish focusing, alignment, and characterization activities and will be lending to Cummins flux mapper and calorimetry hardware. SERI has offered the use of the SHOT system for characterizing the LaJet Energy Company LEC-460B facets. Potential benefits of this cooperative arrangement include definitive performance characterization of the LEC-460B concentrator and the Thermacore heat pipe receiver, long-term test data on a reflux receiver collector system, technical and financial support of Cummins, and transfer of technology from the government labs to industry. Figure 3.B.1 is a photograph of the Cummins 4-kW$_e$ dish-Stirling demonstration unit.

- **Stirling Thermal Motors begins fabrication of a heat-pipe receiver for on-sun testing at Sandia.**

  Stirling Thermal Motors has begun fabrication of a full-scale screen-wick heat-pipe solar receiver for on-sun testing. The design is based on the second bench-scale heat pipe receiver that was successfully tested at Sandia during the last quarter. The design uses fine mesh SS screens and features a pedestal type artery system on a thin (.5 mm) distribution wick. The distribution wick is formed by first sintering fine mesh screen to flat SS316L sheet stock and then hydroforming the assembly

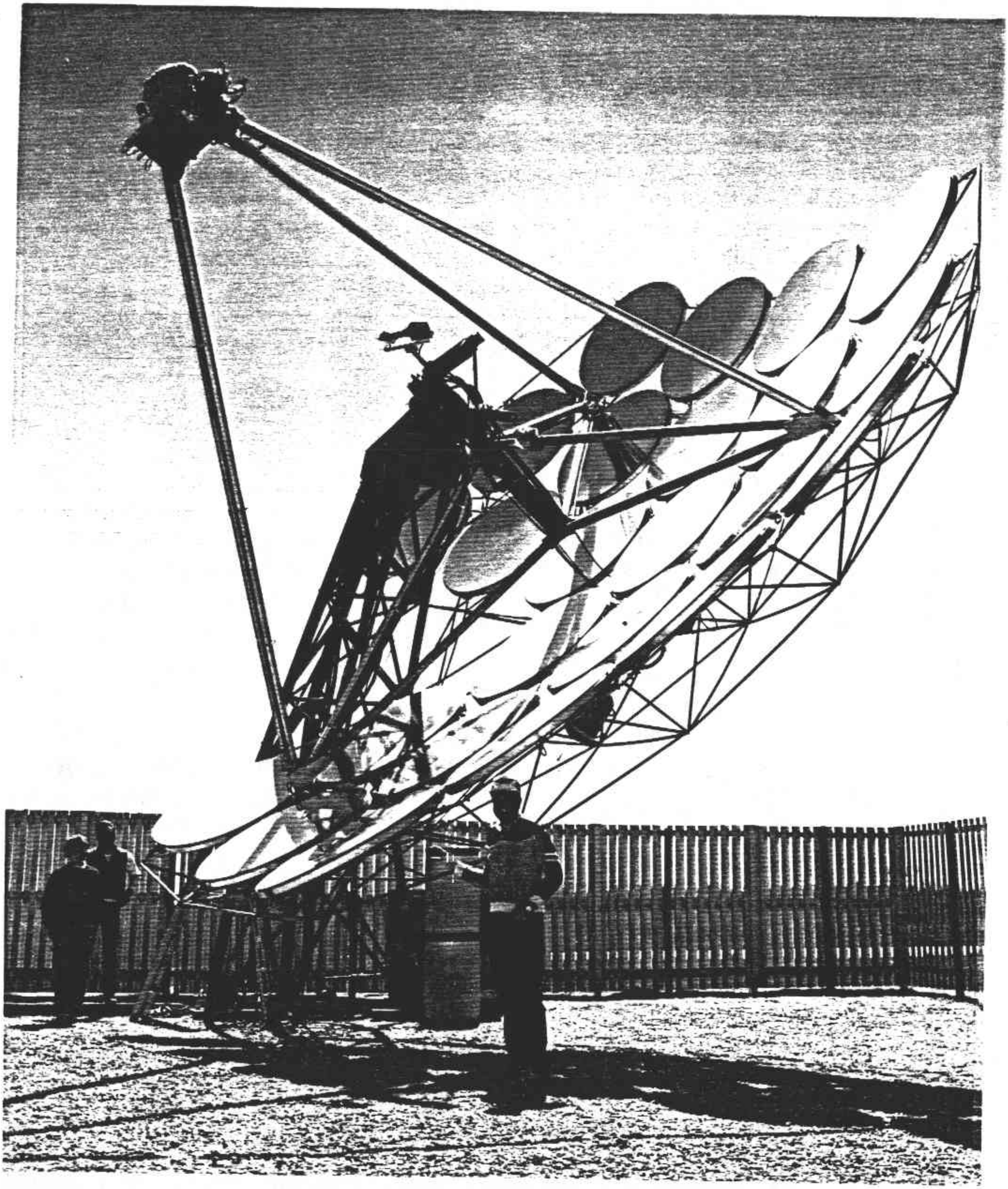


Figure 3.B.1 - Cummins 4-kW$_e$ dish-Stirling demonstration unit. Sandia engineer Chuck Andraka provides support to the LEC-460B.

into a spherical absorber. Although previous permeability measurements indicate inadequate flow capability of the distribution wick (the forming process tends to close the pores), a modified version of the Sandia heat-pipe receiver design code indicates acceptable performance if the number of arteries is increased from 8 to 16. At Sandia's request two of the sintered assemblies will be impregnated with wax before hydroforming in an attempt to maintain permeability. Sandia has transferred the artery fabrication technology to STM and STM has fabricated the tooling and developed the techniques to produce quality arteries. Figure 3.B.2 is a sketch of a Sandia proposed design which incorporates redundant and independent arteries.

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

Sandia has identified Haynes 230 alloy as the leading candidate for the structural material for the next- generation reflux receivers. Because it is a new alloy, primary concerns for its use are formability, weldability, and boiling surface enhancement. Its formability was demonstrated when Haynes 230 sheet stock was rolled into 1-3/4" tubes for pool boiler bench scale testing. The alloy was gas-tungsten-arc (GTA) welded to itself, 316 stainless steel, and Inconel 600. The welds were cross sectioned and found to be excellent and free of cracks.

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. From tests at Sandia, the parameters for achieving the required adherence of an Inconel 600 powder to Haynes 230 have been determined. This has been accomplished without plating the Haynes 230 prior to sintering.

- Sandia engineers have determined the parameters for sintering 304L stainless steel powdered metal to Haynes 230 with the required adherence after many tests. However, the Haynes 230 must be electroless Ni plated, 0.0002" thick, to achieve the required adhesion.

- Another method of boiling surface enhancement is to drill a hole in the wetted surface of the receiver/absorber. Using a YAG laser, holes 0.007" in diameter and 0.018" deep were made with a high degree of repeatability. A hole with these dimensions was drilled into the inside surface of the tube to be used for bench-scale testing.

- The fixtures needed to sinter the powdered metal to the inside surface of the Haynes 230 tubing have been completed, and all of the items required to complete the assembly of the bench test pool boilers have been acquired.

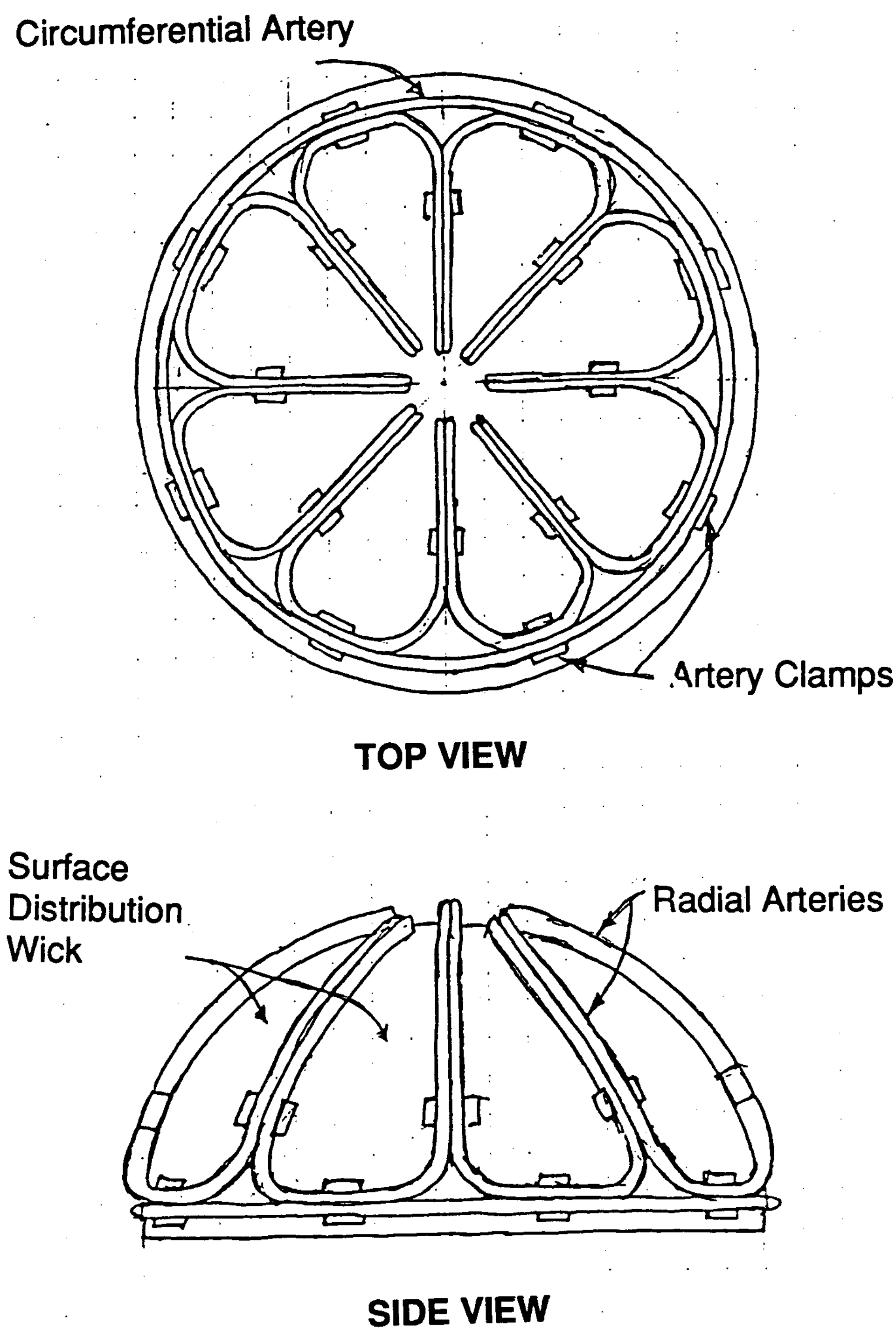


Figure 3.B.2 - Sketch of the artery design proposed by Sandia. The wick features an artery structure that is mounted on top of a thin surface distribution wick. Connections between arteries are made by clamping artery segments together. Independent and redundant arteries are made feasible with this approach.

- **X-ray diagnostics of reflux pool-boiler receiver are being continued.**

  Analysis of x-ray data taken during full-power operation of the pool boiler receiver has progressed. These data contain information on the void fraction at various locations in the receiver during boiling. Additional data have been taken with the receiver drained of sodium in order to establish baseline x-ray attenuation and the scattering-in or background signal. A computer model has been constructed to calculate void fractions based on x-ray detector signals and the detailed geometry.

- **Design of next-generation on-sun pool-boiler receiver has begun.**

  The pool-boiler receiver rim weld is being re-designed to be more commercializable. The new design will be more inspectable and will use mass-production techniques. A seam weld is being considered. Trial welds have been made both on a spare set of the old stainless steel domes and on flat pieces of the next material (Haynes 230). Ultrasonic and metallographic inspections have begun. Stress analysis on the new design is underway.

- **Lifetime issues studies are underway.**

  Haynes 230 material samples are undergoing short-term creep and creep-fatigue interaction tests. Preliminary results indicate low-cycle fatigue performance moderately better than type 316L stainless steel at 800°C. Stress analysis indicates that stresses will be lower than in the stainless steel receiver, while the yield strength will be about three times higher.

<u>Planned Activities for Next Quarter</u>

- Analysis of the on-sun x-ray data will be completed.

- Design of the next-generation pool-boiler receiver will be finalized.

- Sandia engineers will construct bench-scale pool boilers 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 will continue to dismantle the on-sun pool-boiler receiver. Other areas of concern, including the edge weld and the boiling initiation cavities will be metallurgically studied.

- Stirling Thermal Motors will complete fabrication of a full-scale reflux heat-pipe wick assembly. If permeability and pore radius measurements are acceptable, final fabrication for on-sun testing at Sandia will be completed.

- Sandia engineers plan to participate at the 2nd Annual ASCS Heat Transport System Workshop in Lancaster, PA. Presentations covering some of the technical results from the Sandia pool-boiler reflux receiver programs are scheduled.

TASK 3C CONVERSION DEVICES

Accomplishments:

- **The STM4-120 Kinematic Stirling Engine has been tested.**

  Stirling Thermal Motors (STM) has completed check-out of Sandia's STM4-120 Stirling engine at its facility in Ann Arbor. The engine operated at a power level of 20 kW. In addition, the engine's cold end components were subjected to 3.3 million fatigue cycles during cold motoring. Theoretically, 3.3 million cycles is equivalent to an infinite life. Based on this information and the results, the engine was returned to Sandia and reinstalled on its test stand where testing will continue. In addition, a set of heater heads for the engine have been up-graded at STM with new bellows and evaporators. These new components are intended to improve the reliability of the engine.

- **Monthly meetings continue for the final design of the Advanced Stirling Conversion System (ASCS).**

  Stirling Technology Company (STC) has held monthly review meetings of its ASCS through the quarter. Both Sandia and NASA/Lewis Research personnel have attended the meetings. STC has continued with the reoptimization of the engine and heat transport system. The final engine design is near completion. See Figure 3C-1. Table I presents STC's best design estimate of the engine and its performance for a finalized design. NASA/LeRC personnel have reviewed the reoptimized engine design and agree that this final design could meet the goals.

RESULTS

	CURRENT DESIGN TARGET	ASCS PRELIMINARY DESIGN
OPERATING PRESSURE (BAR)	150	183
SPEED (Hz)	35	50
RECEIVER HEAT INPUT (kW)	86.8 kW	86.8 kW
ENGINE HEAT INPUT (kW)	80.2 kW	80.2 kW
ENGINE PV POWER OUTLET (kW)	33.5	33.46
HYDRAULIC MOTOR INPUT (kW)	31.3	31.28
GROSS ELECTRICAL POWER (kW)	28.1	27.9
NET ELECTRICAL POWER (kW)	26.1	25.9
SYSTEM EFFICIENCY NET ELECTRIC/RECEIVER INPUT	30.0	29.8

Table I Engine Final Design Parameters

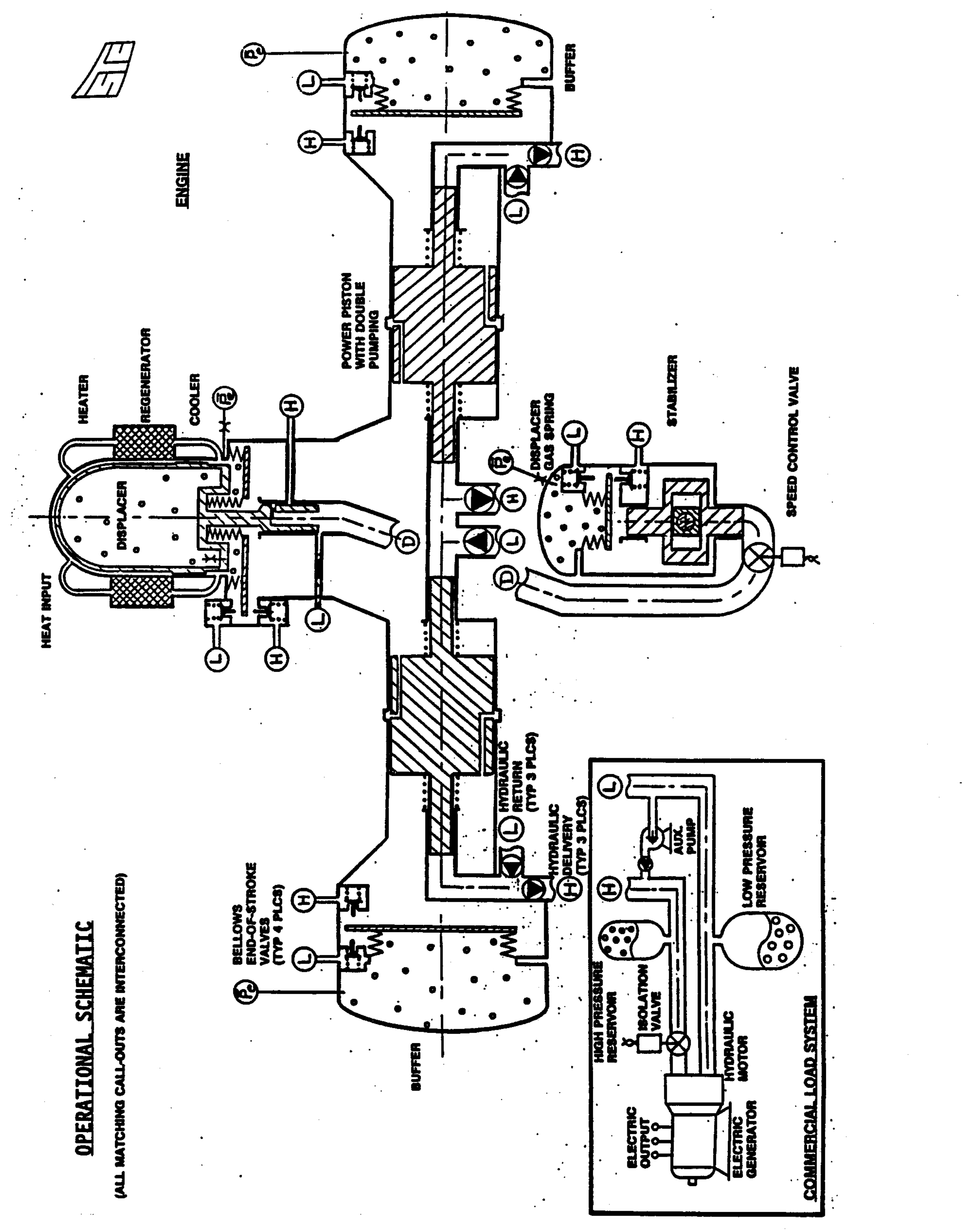


Fig. 3C-1 STC Engine Operational Schematic

Development of the heat transport system was continued by both STC and Thermacore, a subcontractor to STC. STC has been conducting long-term tests of the heater head braze material while Thermacore is operating a subscale pool boiler. Both institutions have been successful in their testing to date. A heat transport meeting is scheduled during the next quarter where results from these ongoing experiments will be reviewed.

- **Design review of Sandia's gas-fired heat pipe evaporator continues.**

  An internal design review of the Sandia designed gas-fired heat pipe evaporator was held during the quarter. Sandia is considering an alternate design to the current finned heat pipe evaporators on the Stirling Thermal Motors STM4-120 kinematic Stirling engine. The Sandia design is intended to improve the reliability of the current method of heat input to the engine.

  The key component of the heat pipe system is the evaporator section that removes heat from the combustion gases. The evaporator is made up of a series of tubes that are similar to those in a tube-in-shell heat exchanger; see Figure 3C-2. Screens inside the tubes of the evaporator section distribute the heat pipe working fluid, sodium in this case, across the heated tube walls by capillary pumping. As the fluid in the screens evaporates, energy is removed from the combustion gas stream. Vapor is collected in the top manifold and transferred to the engine heater head.

  Sandia has completed the paper design and has begun the hardware fabrication. The initial test evaporator will be constructed of SS321. This evaporator will be used only as a proof-of-concept vehicle. Any subsequent evaporators would be constructed of Inconel 617. A successful test will lead to installation of these evaporators on the heater heads of the Stirling Thermal Motors Stirling engine.

Planned Activities for Next Quarter

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

- Monthly reviews of the ASCS final design and heat transport meeting with Sandia, STC and NASA/LeRC are scheduled.

- Testing of the Sandia tubular-designed gas-fired heat pipe evaporator will begin, including tests of performance and reliability.

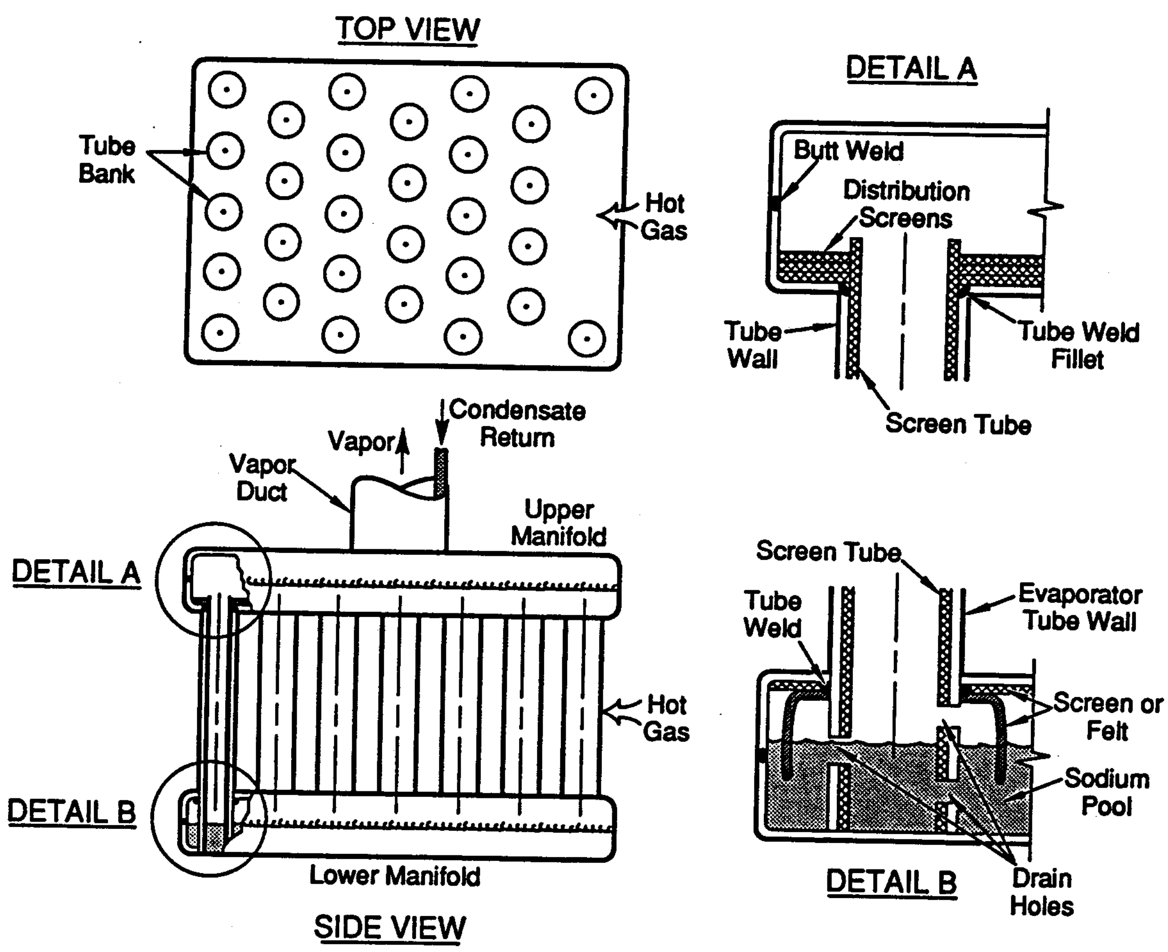


Fig. 3C-2 Tube Heat Pipe Evaporator

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

Approximately 150 members of the Society of American Military Engineers attended their regional meeting in Flagstaff, Arizona, August 16-17. Ron Pate (SNL, 6223) and Paul Klimas were invited to address interested attendees on the present status of photovoltaics/wind energy and solar thermal technology for Department of Defense applications. Approximately 30 persons heard the solar thermal presentation and participated in the panel discussion that followed. During that discussion a consensus was reached that recognized the importance of renewables to both energy independence and environmental responsibility. This particular group of military engineers appeared to favor co-generation as the preferred approach for attacking their energy problems and recognized that solar thermal technology could play a part.

Subtask 4A.3. Design Assistance and CORECT Support

- **Sandia provides design assistance for the Cummins 5-kW$_e$ dish-Stirling system.**

Cummins Power Generation Company and its contractors continue toward their goal of commercializing a 5-kW$_e$ dish-Stirling solar electric system. Cummins recently successfully demonstrated its prototype 4-kW$_e$ system to industrial, utility, and government representatives. The system combines a Sunpower free-piston Stirling engine, a Thermacore reflux heat-pipe receiver, and a LaJet Energy Company stretched-membrane dish concentrator and was used to pump water during the demonstration. Sandia engineers have been actively involved with the design and development of the heat-pipe receiver that transforms concentrated sunlight into usable heat for the engine. Sandia support has included metallurgical analysis of a failed Thermacore receiver, identification of appropriate materials for the next-generation receiver, thermal flux and heat pipe performance modeling, and heat pipe test support. During this quarter, Sandia engineers provided gas-gap calorimeters and installation support and presented results of receiver thermal analyses and flux distribution studies that will be used in Cummins system models and receiver design studies. Sandia also helped to develop a plan for performance and durability testing of the next-generation Thermacore receiver. Cummins is prepared to fund two-thirds of the cost of the receiver test, which will provide important endurance and performance data for this new class of receiver. Cummins has internally funded 100% of the system development costs to this point. Two 5-kW_e prototype systems are scheduled for delivery to the Southern California Air Quality Management District (SCAQMD) in July 1991. System life and reliability goals are to demonstrate 1000 hours of life and 160 hours mean time between failures with these units. Cummins recently reported plans that include commissioning a full-scale 5-kW_e system manufacturing plant as early as 1996.

- **An agreement was signed by industry to install an industrial process heat system.**

Industrial Solar Technology and United Solar Technologies have signed an agreement to install a solar thermal industrial process heat system at the state correctional facility at Tehachapi, California. The Solar Thermal Design Assistance Center (STDAC) is completing the design and installation of a performance monitoring system for the new plant. Sandia staff have also consulted on other aspects of the plant's engineering design, including the electrical control system, a wind loading assessment, and a 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 the next quarter.

- **Sandia and DOE/Pacific Site Operation are working on a solar absorption cooling system in American Samoa.**

Sandia personnel are working with the DOE/Pacific Site Operation regarding the design and construction of a solar water heating system located at the LBJ Hospital in American Samoa. 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, in cooperation with personnel from Rockwell's Energy Technology Engineering Center (ETEC), have agreed on a system design, and components are currently being procured for the project. Sandia will lead the effort to design the hospital's service hot water system and will oversee its construction. ETEC will act as a technical advisor. ETEC will lead in the development of an Operation and Maintenance manual for the system and in the system acceptance testing. ETEC's involvement, as described above, has been approved by DOE/SAN. In a related development, LBJ hospital officials have negotiated an insurance claim regarding hurricane damage to the existing solar system collectors, which were planned to be used for the system. As a result, new collectors can be purchased. Construction is expected to begin in late 1990 and should be completed by the spring of 1991.

- **Dominican Republic solar industry representative visits National Solar Thermal Test Facility.**

  Ellis Perez, vice-president of Solar Uno, visited Sandia to discuss the potential of solar thermal technology to help alleviate severe electrical energy shortages in Santo Domingo, Dominican Republic. A tour of the NSTTF was held and after it discussions centered on which solar thermal technologies could be applied on the island. Mr. Perez was most interested in applying central receiver (CR) technology. He asked if the DOE would be interested in cost-sharing the construction of a 100-MW CR in Santo Domingo. He was also interested in purchasing the equipment at Solar One for use in Santo Domingo. We suggested that he formulate a proposal for possible presentation to DOE/HQ. He was also interested in some large-scale solar IPH projects (e.g., food drying, fish canning, etc.). He asked for STDAC technical help in developing these projects. He is planning a follow-up with STDAC regarding these ideas.

- **Sandia and the California Energy Commission (CEC) have concluded an agreement to cooperate in development and commercialization of solar thermal energy technology.**

  Sandia and the California Energy Commission (CEC) have recently concluded an agreement to cooperate in the development and commercialization of solar thermal energy technology. The agreement is the result of long-standing discussions between STDAC personnel and the CEC staff regarding possible joint efforts.

  The first cooperative effort will involve the development of solar thermal plants at two state prisons in California. In both applications, solar thermal technology is being proposed to displace fossil fuel that is currently used to heat water. The California Department of Correctional Services (CDC) has asked the CEC to lead the effort to solicit third-party financed projects. In turn, the CEC has asked for STDAC technical support in identifying technology options and determining the criteria for selecting an appropriate technology for the prisons' purpose. The STDAC will also provide technical consulting regarding the final selection of the project developers and in monitoring the performance of the installed systems. Work with the CEC is expected to continue through FY91.

- **The DOE, in conjunction with the California Energy Commission, sponsored a National Energy Program Managers Conference in Newport Beach, California, on September 17-21, 1990.**

The objective of the annual conference was to discuss the critical environmental and energy issues facing state and territorial energy officials. Within the session entitled "Renewables: New Technologies and Applications," Sandia was asked to present information about the potential for solar thermal energy including IPH, hot water, and electricity.

Sandia personnel presented a 25-minute overview at the session and solar thermal technology was very well received. There was curiosity about the cost and operation of the LUZ plants and the plans for the Cummins dish-Stirling system development. However, the major interest centered on solar hot water and steam, especially with respect to state facilities. There was particular interest in the prison projects at Brighton, Colorado, and Tehachapi, California. Several state energy officials asked for specific technical assistance in applying solar technology to some of the prisons and other state institutions in their state. However, because of funding and operational uncertainties, the STDAC was not discussed, and it was suggested that they document their request in writing and submit it to Sandia for possible assistance as a technology transfer activity.

- **STDAC personnel are consulting with Gould engineers to solve some O&M problems with the IPH system located at their plant in Chandler, Arizona.**

Early this quarter Sandia personnel travelled to the Gould plant to consult with Gould engineers regarding some O&M problems with the solar IPH system located nearby. Gould officials asked for Sandia's help in addressing problems including flexhose failures, reflective film delamination, and installing a performance monitoring system.

To help reduce flexhose failures, Sandia recommended an advanced-generation flexhose, and provided several for testing at Gould. The installation of these hoses was reviewed, and some simple changes to their support configuration were recommended to maximize hose life. A plan for evaluating the performance of the new hoses was also discussed; it included regular inspections and documentation. Finally, the Gould staff was shown how to modify the field concentrator controls to minimize unnecessary hose flexing and extend hose life.

Another problem at the plant is that about 3 to 4% of the aluminized reflective surface is delaminated. Large areas of delamination can be repaired by removing the delaminated sections of the film and covering them with new, adhesive backed film. For smaller areas, the delamination can be arrested by cutting the film above the delamination path and sealing the ends with tape or edge sealer. Both techniques were demonstrated to the Gould staff.

The remainder of the effort was spent on the design of a performance monitoring system, which is needed to quantify the economic benefit of the solar heat. To most accurately measure the solar heat's actual benefit to the plant, Sandia has recommended the installation of an integrating BTU meter at the point where the solar-heated water enters the plant's boiler. Specific suggestions were forwarded to Gould personnel regarding the type of equipment to purchase and where the components should be installed. They are in the process of purchasing and installing the equipment.

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

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 personal computer (PC).

Work in this quarter centered on the verification of the SOLIPH computer model developed at SERI. A mainframe version of this model was converted to run on an IBM/PC. Several errors were identified and corrected. The result is a working laboratory version of the code that is operational on a PC. Work on this program will continue as resources become available.

- **A special assistant to the Governor of Saipan visited Sandia.**

Mike Kenney, special assistant to the Governor of Saipan, visited Sandia. His purpose was to identify potential joint efforts with the STDAC to encourage the use of solar thermal technology in Saipan. The visit included a tour of the NSTTF followed by discussions. The conclusion was that solar thermal DHW/IPH technology could make a significant immediate impact in Saipan because most of the hot water and steam is created with electricity, which is in short supply. Mr. Kenney is planning to create some demonstration projects on the island and would like STDAC technical consulting in planning and building the projects. All STDAC efforts will be coordinated through DOE/PSO and DOE/SAN.

- **A government official from Ghana visited Sandia.**

  Joe Essondu of Ghana visited Sandia to tour the solar facilities and to discuss how solar thermal technology can be implemented in his country. As a representative of the government, he can recommend policy changes regarding energy use. Mr. Essondu was most interested in applying solar hot water and IPH technology and asked for several names of manufacturers. He also asked for technical assistance from the STDAC in developing an RFP for purchasing solar energy equipment for use in some government funded demonstration projects.

- Written and verbal requests for information are listed with the following Section.

- **STDAC CONTACTS THIS QUARTER:**

Technology/Subject	Requester	Affiliation
Central Receiver	R. Handis	Consultant
Central Receiver	O. McCullar	Consultant
Central Receiver	D. Gorman	ATS
Central Receiver	C. Chaza	Plataforma Solar
Central Receiver	J. Morris	Hitech Ceramics
Central Receiver	H. Wroten	SPECO
Central Receiver	S. Wu	Foster Wheeler
Central Receiver	T. Narayanan	Foster Wheeler
Central Receiver	L. Matthews	NMSU
Central Receiver	P. Bator	Babcock & Wilcox
Central Receiver	G. Tsiklauri	USSR
Central Receiver	C. Philibert	France
Central Receiver	G. Simonont	France
Central Receiver	W. Meineke	DLR
Central Receiver	P. D'Laquil	Bechtel
Central Receiver	E. Gray	E A Mueller
Central Receiver	T. Hillesland	PGE
Central Receiver	M. Hannan	Bechtel
Central Receiver	E. Perez	Dominican Republic
Concentrators	D. Konnereth	Solar Kinetics
CR Simulation Tools	J. Kern	FDR
CR/IPH Applications	M. Kaya	State of Hawaii
Dark Gas Receiver	E. Boer	Indiana University
Dish Concentrator	M. McGlaun	LaJet
Dish/Brayton	J. Kesseli	Northern Res.
Dish/Brayton	T. Slater	Consultant
Dish/Electric	S. John	CERI, India
Dish/Stirling	B. Bennett	Stirling Tech
Dish/Stirling	R. Lessley	Bechtel
Dish/Stirling	M. Jain	India
Dish/Stirling	J. Fannucci	PG&E
Dish/Stirling	J. Spacer	Consultant
Dish/Stirling	W. King	Georgia Power
Dish/Stirling	J. Sanzi	Thermacore
Dish/Stirling Receiver	M. Dustin	NASA
Distributed Receiver	W. Stine	Cal Poly Univ.
Distributed Receiver	W. King	Georgia Power Co.
Distributed Receiver	R. Nelson	Georgia Power Co.
Distributed Receiver	S. Rosner	Consultant
FP/Samoa Project	J. Shupe	DOE/PSO
General Info	A. Jones	Consultant
General Info	R. Handis	Consultant
General Info	J. King	NPPC

STDAC CONTACTS THIS QUARTER (continued)

Technology/Subject	Requester	Affiliation
General Info	S. John	India
General Info	A. Gates	Bell Labs
General Info	T. Tracey	Consultant
General Info	G. Everett	NATAS
General Info	M. Wilde	LBL
General Info	F. Childs	INEL
General Info	O. Popel	USSR
General Info	F. Pharabod	France
General Info	R. Niebo	NERC
General Info	B. Rivoire	CNRS
General Info	B. Negi	India Inst of Tech
General Info	B. Billak	DOD
General Info	P. Patwardhan	India
General Info	S. Fleishmann	World AgriPower
General Info	S. Clark	Citizen/Clean Enrg
General Info	J. Karis	State of Georgia
General Info	B. Billak	DOD/Pentagon
Heliostats	M. Sutton	Sutton & Assoc.
Heliostats	D. Gorman	ATS
Heliostats	M. Geyer	Flachglass
Heliostats	D. Smith	SAIC
Hybrid Receivers	R. Lessley	Bechtel
Hydroforming	M. Graham	Ultimet
IPH	J. Downey	Consultant
IPH	M. Epstein	Weizmann Inst.
IPH	B. Walters	Entech
IPH	K. Langer	India
IPH	A. Bronstein	Sunsteam
IPH	E. Sanders	APS
IPH	W. Helford	USAF
IPH	A. Jenkins	CEC
IPH	A. Abraham	ICF
IPH	R. Kelly	UST
IPH	B. Negi	India
IPH	K. May/R. Gee	Indus Solar Tech
IPH	B. Walters	Entech
IPH	P. Jaster	3M
IPH	P. Kulkarni	CEC
IPH	R. Kelly	UST
IPH	P. Patel	N Trans Rail Oper.
IPH	W. Prokop	Prokop Envir. Cons
IPH	G. Jones	Consultant
IPH	F. Scribner	TRW

STDAC CONTACTS THIS QUARTER (continued)

Technology/Subject	Requester	Affiliation
IPH	M. Jackson	Entech
IPH	P. Spearing	Thermomax
IPH	G. Robertson	ATT
IPH	P. Spearing	Thermomax
IPH	G. Robertson	ATT
IPH for Prisons	C. Wood	State of NM
IPH for Prisons	H. Franey	Cal. Dept Correct
IPH for Schools	E. Gard	Phoenix Pub School
IPH for State Facilities	D. Wickert	State of WI
IPH/CR	P. Erskine	Consultant
IPH/Solar Absorb. Refrig	A. Bronstein	Sunsteam
Low-cost Drives	E. Schmidt	Alpha Solarco
Material Processing	G. Alback	VORTEK
Material Processing	M. McGlaun	LaJet Energy
ORC	N. Gernert	Thermacore
Reflective Film	J. Anderson	Idaho Falls
Reflective Technology	D. Logan	LUZ
Reflux Receiver	B. Bennet	Stirling
Solar Deslinization	J. Jorgensen	Nat Wat Supl Assn
Solar Hydrogen	E. Bair	Indiana University
Solar Hydrogen	R. Parker	Solar Reactor Tech
Solar Resource Monitoring	J. Michalsky	SUNY
Solar Resource Monitoring	C. Barnaby	Barnaby Assoc
Solar Resource Monitoring	E. Gray	E. A. Mueller
Solar Resource Monitoring	R. Stewart	SUNY
Solar Themal Export	D. Kumar	Meridian
Solar Thermal Prog Info	C. LaPorta	UST
Solar Thermal Absor Cool.	P. Mismer	CEC
Solar Thermal Absor. Cooling	P. Mismer	CEC
Solar Thermal Export	D. Kumar	Meridian
Solar Thermal Modeling	E. Gray	E. A. Mueller
Solar Thermal Modeling	A. Bronstein	Sunsteam, Inc.
Solar Thermal Modeling	K. Hain	U.S./DOE
Solar Thermal Prog Info	S. John	Cent Elec/Chem
Solar Thermal Prog Info	K. Benninga	SAIC
Solar Thermal Prog Info	C. Williams	LaJet
Solar Thermal Prog Info	C. LaPorta	UST
Solar UV Monitoring	A. Eager	City of Alb.
STDAC Consulting	G. Leigh	NMERI
STDAC Consulting	A. Roy	Ben-Guron Univ
STDAC Contacts this Quarter (cont'd)		
Trough	D. Jaffe	LUZ
Trough	V. Goldberg	W G Associates
Utility Power	T. Trulove	NW Pow. Plan. Coun

Planned Activities for Next Quarter

- Paul Jaster of 3M is planning a program to develop a cost-competitive solar IPH system based on 3M's 11X refractive concentrator and Entech's housing and drive system. He has asked for Sandia's involvement as a technical consultant on the project. Sandia's work on this project, which is pending approval from DOE/HQ, is expected to begin in early October 1990.

- John Shupe, of DOE/PSO, is coordinating a four-day workshop and trade show on energy to be held on the U.S. island of Guam on May 15-18, 1991. John has asked for Sandia's assistance in formulating and conducting a four-hour workshop on solar thermal concentrator technology. Commitment to this request is pending approval by DOE/HQ.

- During the next quarter, planning will begin for SOLTECH 91 to be held in Sacramento during February of 1991. It is expected that the solar thermal portion of this year's meeting will closely follow last year's, with sessions covering the DOE research program, near-term industrial applications, solar detoxification of water, and solar thermal electric systems.

- STDAC personnel are planning increased involvement in Sandia's educational outreach activities. The STDAC is coordinating a team of staff members, each of whom will represent a specific renewable technology, to provide direct technical assistance to local schools regarding renewable energy education. Work will begin in October 1990 and will continue through the FY. These efforts are financially supported by SNL's education outreach budget.

Major Milestone Schedule

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

Procurement Summary

Sandia awarded a contract to the Solar Energy Industries Association to develop documentation materials such as films, brochures, and post 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 has been completed and it requests SEIA's assistance in expanding the STDAC's capabilities.

STDAC personnel are also monitoring a 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.

TASK 4C. ADVANCED ELECTRIC TECHNOLOGY

Objective

This program will establish cooperative consortia, that will assess and field a next-generation solar thermal electric system experiment within the next three years. The system is intended to be economically competitive in the electricity market place. This program will thus establish the manufacturing infrastructure and accelerate the cost and reliability learning curves for the unique solar thermal components critical to achieving the long-term performance and economic goals set for solar thermal systems.

Accomplishments

The original plan for this activity centered on a broad technological approach in which all next-generation solar thermal systems could compete for joint-venture development funding. Based on this approach, 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 responses to this RFI included a variety of technological approaches including refractive concentrators and Brayton cycle converters. Based on these responses, an RFQ was written and was submitted to DOE/HQ for approval.

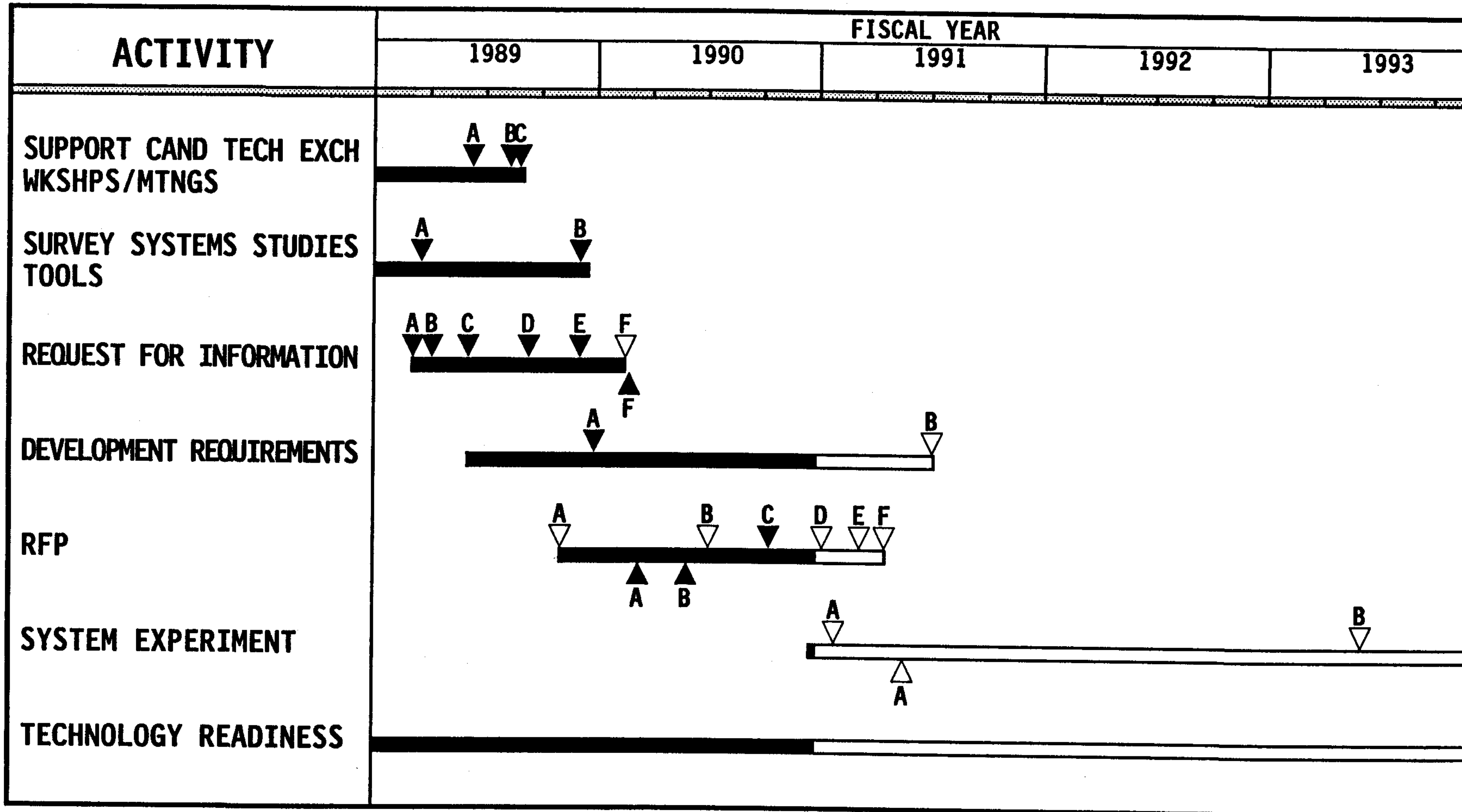
After due consideration, and in consultation with industry representatives, DOE/HQ, late in the third quarter, decided to restrict this joint-venture development effort to dish-Stirling systems only. The program was then renamed the Dish/Stirling Joint Venture Program and a new RFQ was drafted to reflect this approach. Late in this quarter, an Expression of Interest (EOI) was issued to the public seeking those companies who have an interest in competing for participation in this Dish/Stirling Program. Approximately 15 companies responded with an expression of interest in this program and requested an RFQ.

Planned Activities for Next Quarter

The RFQ has been undergoing final revisions and is currently in the process of final approval for release to the public. It is anticipated that the RFQ will be released to the responders of the EOI in early FY91.

Major Milestone Schedule: Due to DOE/HQ reorganization and program redirection, the project is approximately three months behind the original schedule. The accompanying milestone chart reflects this slippage.

DISH/STIRLING JOINT PROGRAM



SUPPORT CAND TECH EXCH WKSHPS/MTNGS
A=SOLTECH
B=DOE/HQ TECH BRIEFINGS
C=DISH/STIRLING WKSHP

SURVEY SYSTEMS STUDIES TOOLS
A=SURVEY COMPLETE
B=ENHANCEMENT COMPLETE

REQUEST FOR INFORMATION
A=BEGIN DRAFT
B=FIRST DRAFT
C=FINAL DRAFT
D=RELEASE
E=RESPONSE
F=COMPLETE EVALUATION

DEVELOPMENT REQUIREMENTS
A=INITIAL IDENTIFICATION
B=FINAL IDENTIFICATION

RFP
A=BEGIN PREPARATION
B=RFP COMPLETE
C=DOE APPROVAL
D=RELEASE
E=RESPONSE
F=SELECTION

SYSTEM EXPERIMENT
A=AWARD
B=EXPERIMENT FIELDED

M30990 9-25-90

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 has been using its windowed wind tunnel to expose military aircraft material samples to simulated nuclear thermal flash under simulated flight conditions. The final test series for this program was completed in early July.

- **Sandia completed development of pulses for nuclear hardness evaluation of a British aircraft canopy/cockpit at the National Solar Thermal Test Facility.**

  Funding has been received from the Defense Nuclear Agency for 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. For this test series the National Solar Thermal Test Facility will provide thermal transients that simulate the thermal output of a nuclear weapon. Previously, seven-second shaped pulses were simulated. This test series requires two-second pulses to simulate a weapon of much lower yield. This capability has been demonstrated as shown in Figure 5.1. The line indicates the customer's desired pulse shape. The data are from a flux gauge used to measure the simulated pulse.

  The canopy and cockpit have been received and a fixture assembled to hold them in the test configuration. The test series is expected to be completed in November.

- **A NASA STAR Facet and Panel Testing Project has been planned.**

  Sandia has been asked by NASA to test the STAR facets and panels for the space station on sun. 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 five facets and two fully-populated panels at three locations each.

The test fixture for the facet tests has been designed and is currently being fabricated at the NSTTF. We expect to begin facet tests in late November 1990 and panel tests in February or March 1991.

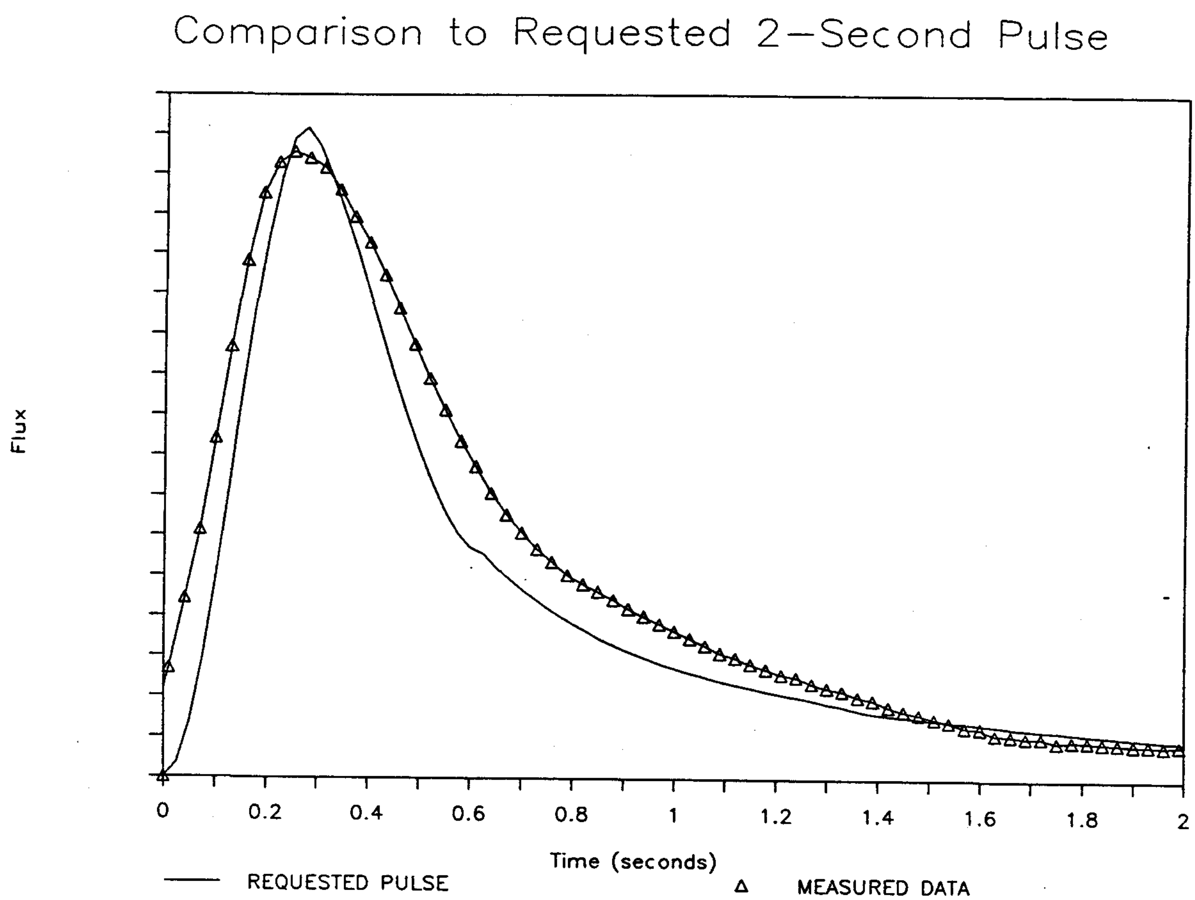


Figure 5.1 - Comparison to Requested 2-Second Pulse

Planned Activities for Next Quarter

- **Industry-funded thermochemical receiver development and test are planned.**

  DOE/AL is completing negotiations for development and test of proprietary thermochemical receivers using two novel, wide-spectrum, photochemical processes for private industry. Development of these systems is being done as a commercial venture by a company that needs to use the unique research and test capabilities at Sandia's National Solar Thermal Test Facility to demonstrate actual solar operation. Previous research was performed at a small-scale in university laboratories sponsored by this company. Although the company is small, it has made established contacts with major commercial industries and utilities regarding commercialization of these processes. These programs will begin as soon as formal contracting arrangements are completed.

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., J.B. Moreno, R.B. Diver, W.C. Ginn, V. Dudley, and K.S. Rawlinson, "Reflux Pool-Boiler as a Heat Transport Device for Stirling Engines: On-Sun Test Program Results," for publication in the Proceedings of the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV., Sandia National Laboratories, August 12-17, 1990.

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

Bohn, M.S. and H.J. Green, "Heat Transfer in Molten Salt Direct Absorption Receivers," Solar Energy (42:1), pp. 57-66, 1989, ACCNR: 11325.

Bohn, M.S. and M.S. Mehos, "Radiative Transport Models for Solar Thermal Receiver/Reactors," SERI/TP-253-3614, prepared for the ASME Solar Energy Conference, Miami, Florida, April 1-4, 1990, 8 pp., December 1989. [Available NTIS: Order No. DE90000303. ACCNR: 11466].

Chaza, C., and J. M. Chavez, "The Ceramic Foam Volumetric Receiver," presented at the 5th International Symposium on Solar High Temperature Technologies, Davos, Switzerland, Sandia National Laboratories, August 27-31, 1990.

Diver, R.B., C.E. Andraka, J.B. Moreno, D.R. Adkins, and T. A. Moss, "Trends in Dish-Stirling Solar Receiver Designs," for publication in the proceedings of the 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, Sandia National Laboratories, August 12-17, 1990.

Klimas, P.C., "United States Department of Energy Solar Receiver Technology Development," publication in Proceedings 5th Symposium in Solar High Temperature Technologies, Davos, Switzerland, Sandia National Laboratories, August 27-31, 1990.

Klimas, P.C., M. Becker, Second Generation Central Receiver Technology Comparison, SAND90-0947A, presented to the 5th International Symposium on Solar High Temperature Technologies, Davos, Switzerland, Sandia National Laboratories, August 27-31, 1990.

Publications Completed in FY 1990 (continued)

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, Miami, FL, Sandia National Laboratories, April 1-4, 1990.

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

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Scientific Meetings and Presentations

Second Quarter FY 1990

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

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

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

The Solar Thermal Design Assistance Center (STDAC) has initiated a semi-annual 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 features 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, Sandia National Laboratories, Miami, Fl, April 1-4, 1990.

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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, Sandia National Laboratories, Miami, FL, April 1-4, 1990.

Fourth Quarter FY 1990

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Chavez, J.M., "A Summary of the Design, Analysis, and Testing of Volumetric Air Receivers for Use in Central Receiver Power Plants," presented at the 25th Intersociety Energy Conversion Engineering Conference, Sandia National Laboratories, Reno, NV, August 12-17, 1990.

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