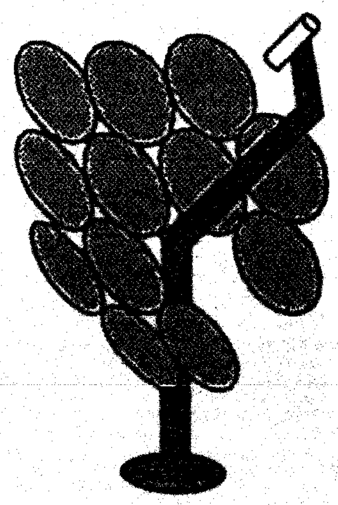
Solar
Thermal
Energy

The DOE

Solar Thermal Electric Program

Quarterly Progress Report
Second Quarter, Fiscal Year 1991



Submitted by:

Sandia National Laboratories
Albuquerque, New Mexico

Solar Energy Research Institute
Golden, Colorado

April, 1991

Sandia
National
Laboratories

SERI

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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 Electric 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.

This quarterly progress report is written to the Solar Thermal Electric Program's Annual Operating Plan (AOP) approved on March 19, 1991.

MANAGEMENT STATUS REPORT

Structure of the Solar Thermal Electric Technology Program

The Solar Thermal Electric Technology Program has shifted its emphasis from research and development to a commercial applications-driven set of cooperative activities with heavy industrial involvement in both planning and execution. The purpose of this shift is to accelerate the commercialization of solar thermal electric technology. By closely linking the program to private sector needs, specific activities support early market penetration of the technology, and program resources are more highly leveraged. Government/industry partnerships produce teams uniquely qualified to accomplish this. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of the laboratories.

Under this scenario, the program is divided into two main categories: Commercial Applications and Technology Development. Commercial Application activities will determine the overall direction of the program. Technology Development efforts in the concentrator and power conversion tasks will support the Commercial Applications task. Relative to earlier fiscal years, technology development milestones focus on nearer timeframes, and far-term research plays a reduced, but continuing, role. The FY91 structure of the program is outlined as follows:

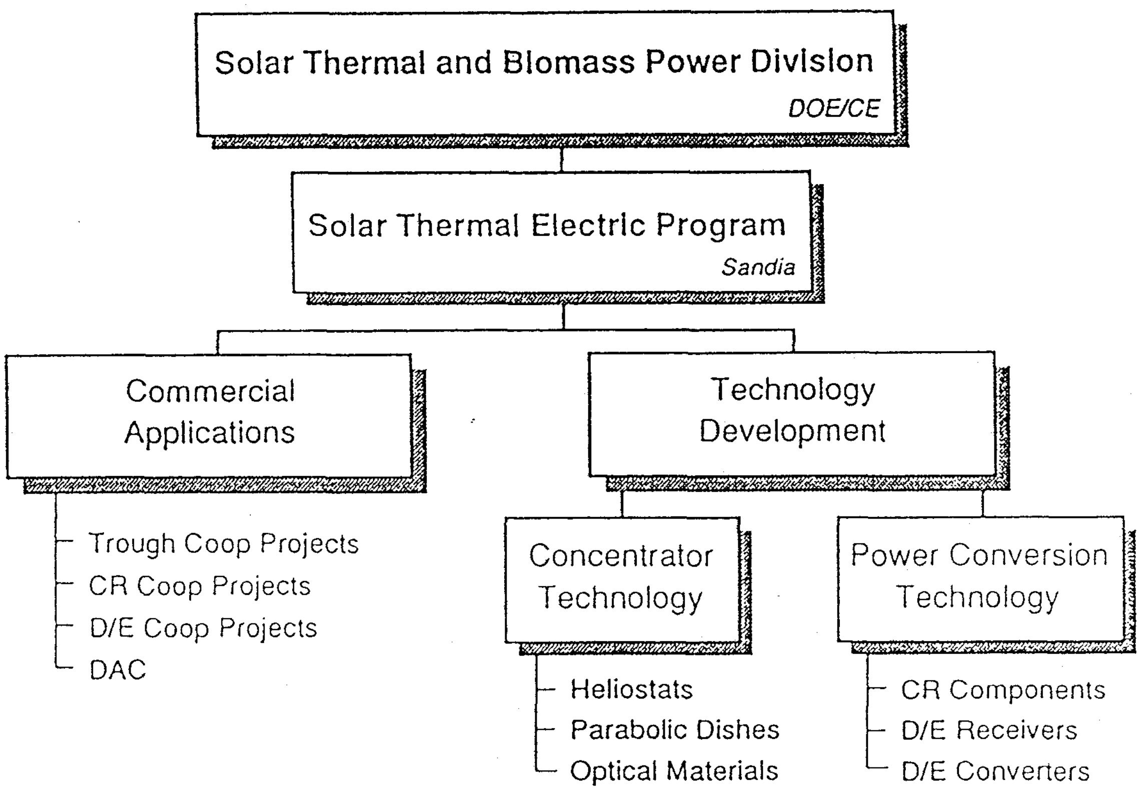
FY91 SOLAR THERMAL ELECTRIC PROGRAM

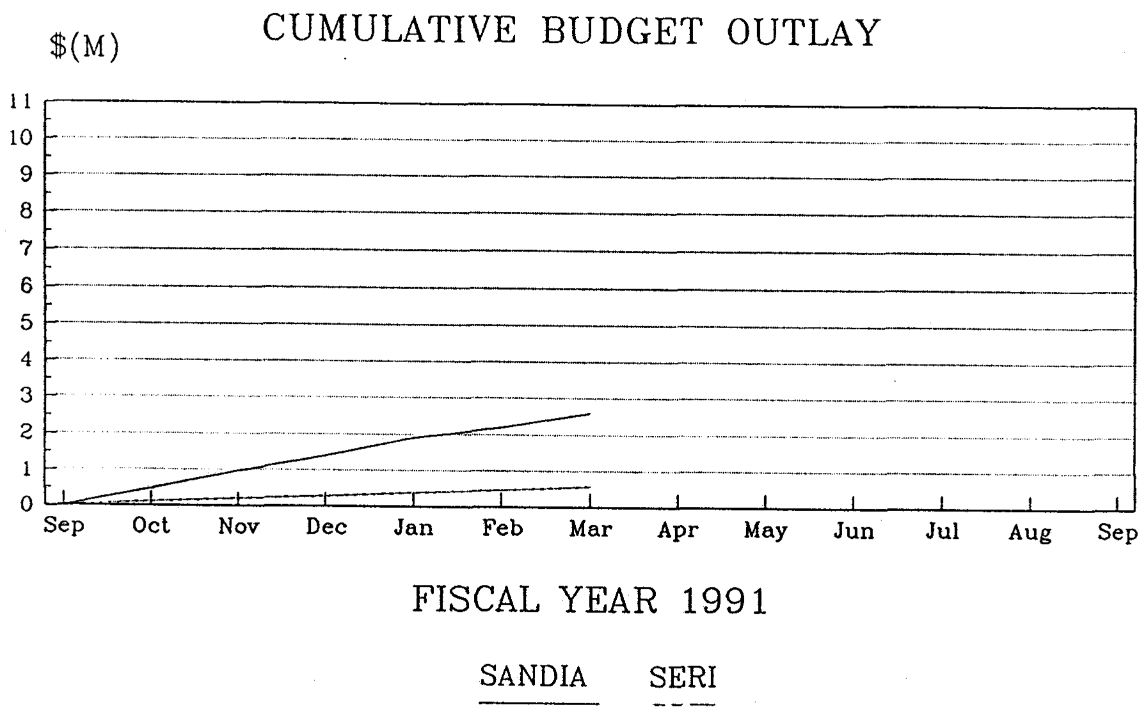
I COMMERCIAL APPLICATIONS
- A. Central Receiver Cooperative Projects
- B. Dish/Engine Cooperative Projects
- C. Parabolic Trough Cooperative Projects
- D. Design Assistance

II TECHNOLOGY DEVELOPMENT
- A. Concentrator Technology
  1. Heliostats
  2. Parabolic Dishes
  3. Optical Materials
- B. Power Conversion Technology
  1. Central Receiver Technology
  2. Dish Receiver Technology
  3. Dish Converter Solarization Technology

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. Sandia National Laboratories is the Program's lead laboratory.Together, these two field laboratories are responsible for implementation of the research and development plans that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts placed with private industry, other research organizations, and universities.





CUMULATIVE BUDGET OUTLAY
$(M)
11
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8
7
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0
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FISCAL YEAR 1991
SANDIA
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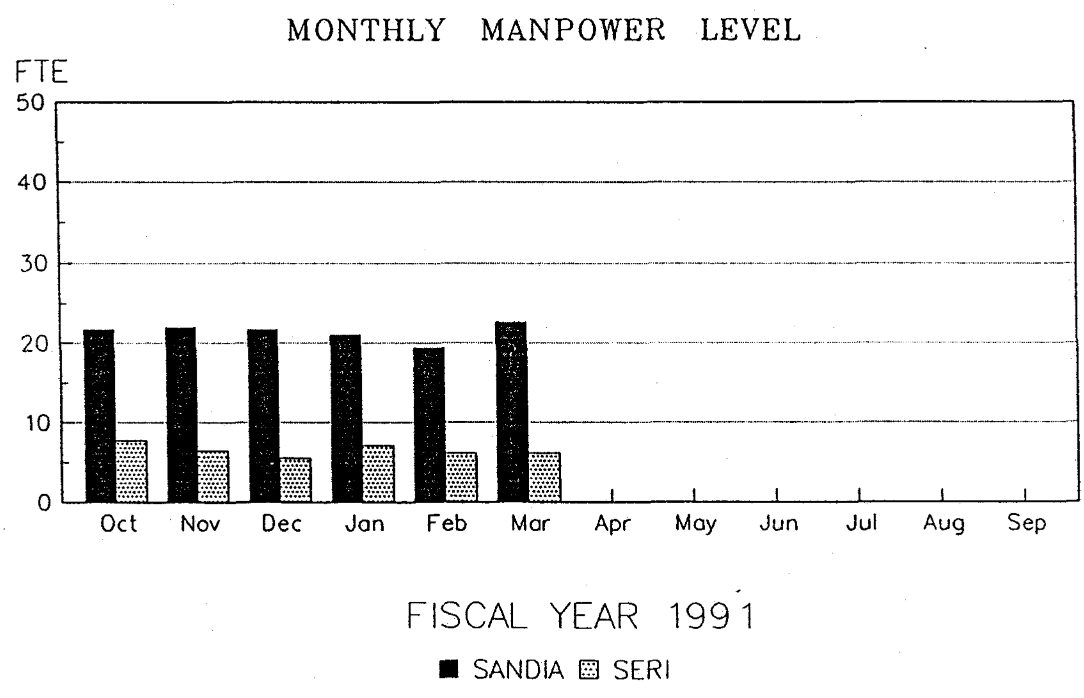

MONTHLY MANPOWER LEVEL
FTE
50
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FISCAL YEAR 1991
SANDIA
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Procurement Summary

SOLAR THERMAL ELECTRIC SUBCONTRACTS

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1991 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IIA1	Replaceable Membrane	IST	SNL42-9690	$50	$50	--	11/89 - 2/91	Small	TBD	D. Alpert
IIA1	Heliostat Integration	Solar Kinetics, Inc.	SNL42-9691	$100	$100	--	10/89 - 1/91	Small	TBD	D. Alpert
IIA1	Heliostat Fabrication	SAIC	SNL54-5780	$540	$400	$140	01/90 - 4/91	--	TBD	D. Alpert
IIA1	NSTTF Technician Services	Ewing Technical Design	SNL63-5487	$1,350	$450		04/89 - 04/92	--	TBD	E. Rush
IIA1	Coll. Supp. Struc.& Ped.	WGAssoc	SNL42-9815	$242 (est.)	--	$242	09/89 - 4/91	--	TBD	T. Mancini
IIA1	Faceted Dish Development	SKI SAIC	SNL42-9814B SNL42-9814A	$209 $238	-- --	$209 $238	09/89 - 4/91 (4/91)	Large	TBD	T. Mancini
IIA1	Stretched-Membrane Dish Dev.	Solar Kinetics, Inc.	SNL55-2495	$1,656	$500	--	04/88 - 12/91	Small	SAND88-7035	T. Mancini
IIB2	Reflux Heat-Pipe Rec.	Stirling Ther. Motor	SNL33-3036	$225	$101		04/87 - 6/90	Small	--	R. Diver
IIB1	Volm.Rec. Furnace Test	NMSU	SNL66-9967	$45	$30		01/90-12/90 (Extended to 5/91)	Univ.	--	J. Chavez
IIB3	2ndSTM4-120	Stirling Ther. Motor	SNL75-8851	$360	--	--	04/89 - 06/90	Small	--	K. Linker

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1991 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IIB3	ASCS Design	NASA LeRC	DOE Inter-agency	$4369	1050	1035	01/89 - 01/93	Govt.	--	K. Linker
II	Solar Test Support	EG&G	SNL05-4912	$150	$150		12/88 - 10/93	Large	--	C. Cameron
II	Electrical Support Service	J & S Electric Co., Inc.	SNL75-7415	$120	$60		02/89 - 02/92	Serv. Support	--	J. Stomp, Jr.
IIB3	Heater Heads	Stirling Therm Mtrs	SNL78-8095	$ 46	46		10/1 -12/31/90	Small	--	Kevin Linker
IIB2	Solar Rec. Heat Loss Testing	California Polytech	SNL02-5759	$105	$30		09/86 - 09/91	Univ.	ASME and ISES papers	A. Heckes
IIB2	STEP Test Program	Georgia Power	SNL42-4859	$42	$42		06/89 - 03/90	Large	Final Test Report	A. Heckes
IIB2	Heat Pipe	Cummins	SE10137-01	$65	$65		10/90	Large	TBD	M. Bohn
IID	Tech Trans Documentation	Solar Energy Inds. Assoc.	SNL42-5186	$327K	$187K		3/90-2/92	Non-profit	Three TT Rpts.	D. Menicucci

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

SN	January, 1991	IIA2	Task 3 conceptual design review for the single-element SM dish project.
SN	February, 1991	IIB1	Complete final report on molten salt transport loop testing.
SN	March, 1991	IIB1	Complete volumetric receiver absorber material characterization testing.
SE	January, 1991	IIB2	Initiate Cummins/Thermacore heat-pipe receiver durability testing.
SN	February, 1991	IIB3	Complete evaluation of the Sandia tube/screen-wick gas-fired evaporator.
SN	March, 1991	IIB3	Complete final design of the Stirling Technology Company ASCS.

Third Quarter, FY 1991

SE	March, 1991	IIA3	Propose most promising solutions for delamination problem in film.
SE	July, 1991	IIA3	Document investigation of alternate reflector materials.
SN	April, 1991	IB	Award contract(s) for Dish/Stirling Joint Ventures.
SN	April, 1991	IIB1	Conclude coordination of the final report on USA/FRG second generation central receiver study.
SN	May, 1991	IIB1	Issue status report on PRE salt flow and low-level solar characterization testing.
SN	May, 1991	IIB2	Complete short-term, bench-scale, pool-boiler testing to finalize design parameters for second-generation full-scale pool boiler.
SN	May, 1991	IIB3	Complete preliminary design of the Cummins/Sunpower/Thermacore ASCS.

Fourth Quarter, FY 1991

SN	September, 1991	IA	Present a report to DOE summarizing the results of interactions with outside organizations.
SN	September, 1991	IC	Finalize operational maintenance cost reduction plan for commercial parabolic trough solar electric power plants.

Major Milestone Schedule

For reference, milestones identified in the FY 1991 Annual Operating Plan (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 1991

Lab	Date	Activity-Task Reference	Descriptive Title
First Quarter, FY 1991			
SN	December, 1990	IA	Make utility scale central receiver presentation to review committee.
SN	October, 1990	IB	Issue request for proposal for Dish/Stirling Joint Venture.
SN	November, 1990	IIA1	SAIC completes fabrication of a prototype of its 100-m^2 market-ready heliostat.
SN	November, 1990	IIA1	SKI completes a design for its market-ready heliostat.
SN	November, 1990	IIA2	Complete testing of the 7-meter diameter SM optical element.
SN	November, 1990	IIA2	Phase 1 design review for the faceted dish project.
Second Quarter, FY 1991			
SN	February 1991	IA	Initiate utility scale central receiver presentations to organizations interested in central receiver commercialization.
SN	January, 1991	IB	Complete technical evaluation of Dish/Stirling Joint Venture responses to request for proposal.
SN	January, 1991	IC	Begin identification of R&D necessary to reduce commercial parabolic trough solar electric plant operation and maintenance costs.
SN	March, 1991	ID	Participate in the SOLTECH 91 joint meeting.

SN	September, 1991	IIA1	Completion of testing and documentation of two large-area glass-mirror heliostats and low-cost drive.
SN	September, 1991	IIA3	Document field replaceable reflector material results.
SN	September, 1991	IIB2	Initiate long-term pool boiler bench testing to assess lifetime issues.
SN	September, 1991	IIB2	Complete installation and checkout and initiate on-sun testing of the next-generation pool-boiler receiver.

SIGNIFICANT ACCOMPLISHMENTS SUMMARY

MAJOR MILESTONES	Planned	Actual
FY 1991		
TASK I		
• Issue request for proposal for Dish/Stirling Joint Venture.	10/90	10/90
• Make utility scale central receiver presentation to review committee.	12/90	12/90
• Complete technical evaluation of *Dish/Stirling* Joint Venture responses to request for proposal.	01/91	01/91
• Begin identification of R&D necessary to reduce commercial parabolic trough solar electric plant operation and maintenance costs.	01/91	
• Initiate utility scale central receiver presentations to organizations interested in central receiver commercialization.	02/91	12/90
• Participate in the SOLTECH91 joint meeting.	03/91	03/91
• Award contract(s) for Dish/Stirling Joint Ventures.	04/91	
• Present a report to DOE summarizing the results of interactions with outside organizations.	09/91	
• Finalize operational maintenance cost reduction plan for commercial parabolic trough solar electric power plants.	09/91	
TASK II		
• Complete testing of the 7-meter diameter SM optical element.	11/90	
• Phase 1 design review for the faceted dish project.	11/90	11/90
• SAIC completes fabrication of a prototype of its 100-m^2 market-ready heliostat.	11/90	11/90
• SKI completes a design for its market-ready heliostat.	11/90	11/90

SIGNIFICANT ACCOMPLISHMENTS SUMMARY (cont'd)

MAJOR MILESTONES	Planned	Actual
FY 1991		
• Initiate Cummins/Thermacore heat-pipe receiver durability testing.	01/91	02/91
• Task 3 conceptual design review for the single-element SM dish project.	01/91	03/91
• Complete final report on molten salt transport loop testing.	02/91	03/91
• Complete evaluation of the Sandia tube/screen-wick gas-fired evaporator.	02/91	
• Propose most promising solutions for delamination problem in film.	03/91	03/91
• Complete volumetric receiver absorber material characterization testing.	03/91	
• Complete final design of the Stirling Technology Company ASCS. 03/92	03/91	
• Conclude coordination of the final report on USA/FRG second generation study.	04/91	
• Complete short-term, bench-scale, pool-boiler testing to finalize design parameters for second-generation full-scale pool boiler.	05/91	
• Issue status report on PRE salt flow and low-level solar characterization testing.	05/91	
• Complete preliminary design of the Cummins/Sunpower/Thermacore ASCS.	05/91	
• Document investigation of alternate reflector materials.	06/91	
• Completion of testing and documentation of two large-area glass-mirror heliostats and low-cost drive.	09/91	
• Complete installation and checkout and initiate on-sun testing of the next-generation pool-boiler receiver.	09/91	
• Initiate long-term pool boiler bench testing to assess lifetime issues.	09/91	
• Document field replaceable reflector material results.	09/91	

TECHNICAL STATUS REPORT

I COMMERCIAL APPLICATIONS

A. Central Receiver Cooperative Projects

Objective: Develop and support an implementation plan for a utility-scale solar central receiver electricity generating facility.

Accomplishments:

Central Receiver "Roadshow" presentations completed.

This quarter, an intensive effort was undertaken to increase awareness of DOE's solar central receiver technology. The key activity in this effort was direct presentations to utilities, QFs, IPPs, industry, state energy commissions, and state utility commissions. The presentations highlighted the progress the technology has made, particularly with a molten nitrate-salt heat-transfer fluid. Nearly 20 presentations were given to all major utilities and state agencies in the sunbelt; a list of the nearly 50 key organizations contacted is attached.

The presentations emphasized the point that central receivers meet utilities' needs today for clean, reliable, low cost power. The central message of the presentation is that the technological risk is low and that, with today's designs, central receivers are economic, reliable, and ready for commercialization. A summary of the extensive data base, which allows the cost, performance, and reliability of the plant to be confidently predicted, was presented. In addition, a key feature of central receivers--the availability of an economic energy storage system, which permits power to be dispatched, load following, and capacity factors up to 60%, without fossil fuel backup--was highlighted. A comparison of energy costs of central receivers with today's alternatives, and possible avenues for deploying commercial power plants were also presented. A copy of the presentation materials, and a companion color brochure, are available from Sandia or DOE.

In addition to utilities and IPPs, the education effort targeted state regulatory commissions and energy offices, because the regulatory climate around the utility sector will have a major impact on future demonstrations and commercial deployment.

Throughout the 3-month effort, key organizations were kept updated on on the progress of the presentations and the information being collected. These key organizations included the DOE, the California Energy Commission, Southern California Edison, PG&E, Bechtel, and Luz International. In addition, we frequently briefed key contacts in the solar thermal industry.

As a result of these efforts, utilities and state agencies are once again very interested in solar central receiver technology. In addition, our meeting directly with utilities, regulatory agencies, IPPs and QFs, provided us details on their needs and requirements and with key insights on the the best path to follow to achieve commercial deployment. We are now confident of the potential for significant application of this technology in the utility sector in the late 1990s, when substantial amounts of new generating capacity will be needed. However, even though a cost-competitive 100-MW central receiver power plant could be built right now with today's technology, such a plant is unlikely to be built because of the large capital investment ($300 million) and the associated perceived financial risks, combined with the current over capacity of the largest utilities in the Southwest. Therefore, to reduce the perceived risk, we are exploring an upgrade of the 10-MW Solar One Pilot Plant with a second-generation, molten-salt heat-transfer system, as a precursor to sizeable utility investment for large power plants in the 1995-2000 time frame. The project would provide the needed validation of an fully integrated molten-salt system. The estimated cost to upgrade the plant is $30 million. At the January 14, 1991, briefing, Southern California Edison personnel expressed renewed interest in central receivers, a strong desire to see Solar One in operation, and a willingness to commit financial support. The California Energy Commission, the Sacramento Municipal Utility, and the Los Angeles Department of Water and Power will all likely join with SCE. The upgrading of the Solar One Pilot Plant fits well with CE's mission of promoting the use of renewable energy in partnership with states and the utility sector. On March 15, 1991, SEC's top management authorized their staff to actively solicit financial support for the project from other utilities--a number of possible partners have been identified.

The restarting of Solar One with a molten salt system is attractive for a number of reasons:

- It has the lowest overall cost for a system validation experiment
- It requires a finite, short-term commitment from DOE
- It will lead to commercial deployment in the late 1990s.

Efforts are continuing at Sandia to develop the partnership between utilities, state agencies, and industry that will be essential to successful commercialization of this technology, and a detailed "Solar 2000" central receiver draft strategic plan has been prepared (copies available from Sandia). We firmly believe, and are supported by key members of the solar thermal industry, that required research on salt, i.e., tube central receivers is essentially completed and we are dedicating our efforts to achieving the large-scale demonstration needed to stimulate commercial deployment.

Planned activities next quarter

- Meetings are planned with staff of SCE and with representatives of key utility and industrial groups to discuss the possible cost-shared upgrade of Solar One.
- Investigate alternative designs and specifications for the plant so as to best meet the utilities' scale-up needs.
- Continue to explore the possibility of forming a utility steering committee to coordinate the deployment of the first commercial plants before the end of the decade.

Organizations That Attended Sandia's Presentations on Today's Central Receiver Power Plant Technology

Utilities

Southern California Edison
PG&E
L.A. Dept of Water and Power
San Diego Gas and Electric
Sacramento Municipal Utility District
Glendale (CA) Municipal
Pasadena (CA) Municipal
Burbank (CA) Municipal
Riverside (CA) Municipal
Salt River Project (AZ)
Tucson Electric
Arizona Public Service
Sierra Pacific Power Co. (NV)
Nevada Power Co.
Silver State Power Association (NV)
Overton Power District (NV)
Southwest Gas Co. (NV)
City Public Service (San Antonio, TX)
City of Austin (TX) Municipal
TU Electric (Dallas, TX)
Texas Electric Cooperatives
Central and Southwest Service (TX)
Public Service of Colorado

State and Federal Agencies

California Energy Commission
California Public Utilities Commission
California Air Resources Board
Southern California Public Power Authority
South Coast Air Quality Management District (L.A., CA)
Arizona Corporation Commission
Arizona Energy Office
Arizona Power Authority
Lower Colorado River Authority (TX)
Governor's Energy Management Center (TX)
Public Utility Commission of Texas
Bureau of Reclamation
EPRI
Colorado River Commission of Nevada
Nevada Public Service Commission
Nevada Conservation Commission
Nevada Energy Office
Nevada Dept. of Agriculture
Nevada Office of State Lands
Interstate Solar Coordination Council
WAPA
Electric Auto Association
Desert Research Institute (NV)

Industry

LUZ
Bechtel
Hadson

B. Dish/Engine Cooperative Projects

Objective: Form one or more industry, user and government consortia which will then begin efforts to field economically competitive prototype dish/Stirling solar electric systems for remote markets within the next three years.

Accomplishments

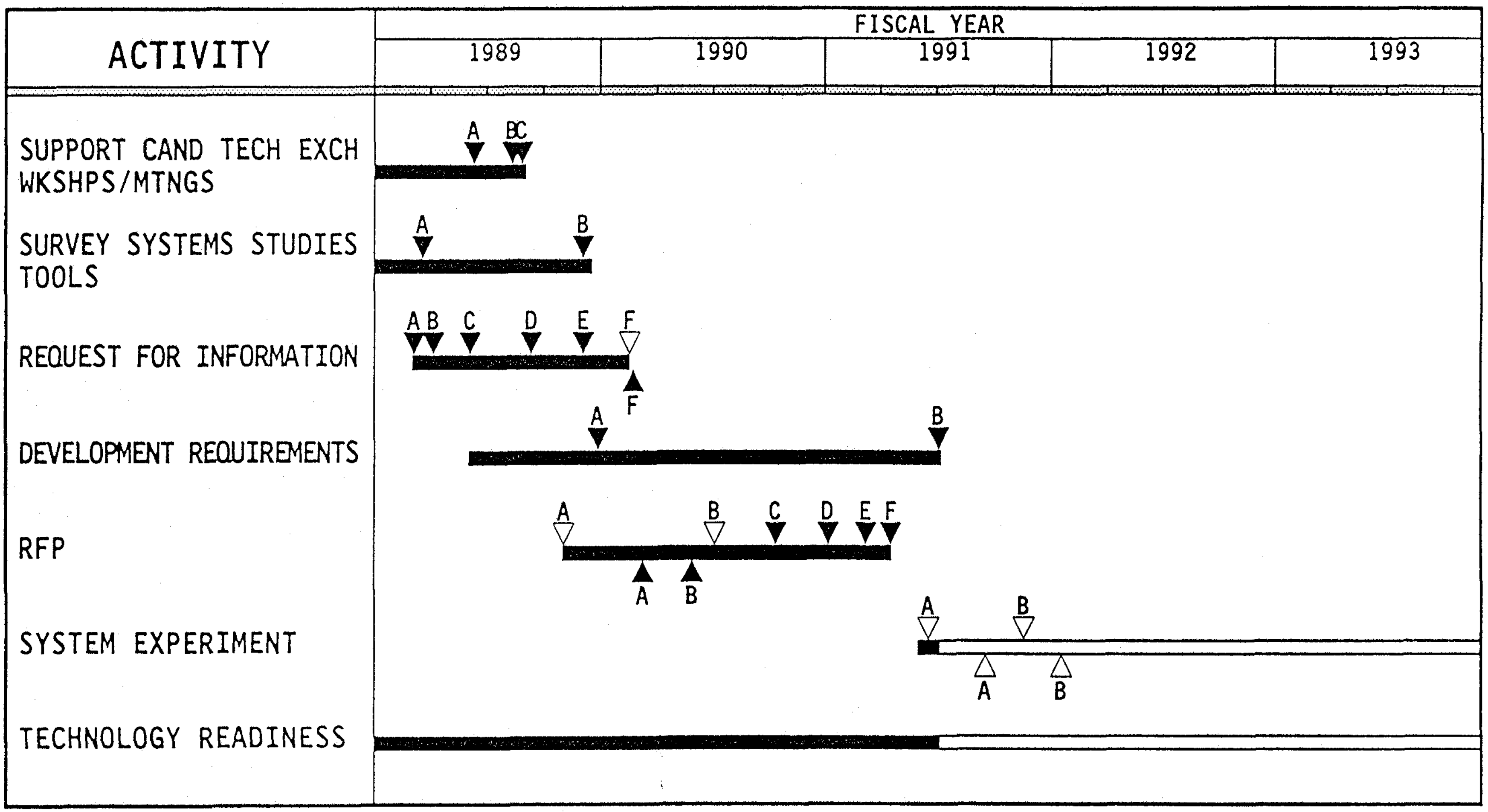
Dish-Stirling Joint Venture proposals evaluated.

Six proposals for the DOE dish-Stirling joint venture were evaluated by a technical team consisting of staff members from Sandia, SERI, and NASA. Based on the technical and cost evaluations, final recommendations for awards were presented to DOE/HQ. Sandia contracting personnel have notified the leading contender(s).

Planned activities for next quarter

- The Sandia dish-Stirling joint venture industrial partner(s) will be audited and the contract(s) negotiated. Sandia's objective is to complete negotiations and to place the contract(s) by the end of June, 1991.

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=EVALUATION COMPLETE

SYSTEM EXPERIMENT
- A=AWARD
- B=FIRST UNIT FIELDED

m30491 4-04-91

C. Parabolic Trough Cooperative Projects

Objective: Work closely with industry to reduce the costs associated with operating and maintaining parabolic trough based solar electric generating plants through research and development based on the extensive operating experience of LUZ Engineering Corporation.

Background:
The Solar Electric Generating System (SEGS) power plants located in Southern California generate 95% of the world's solar electricity, with an existing capacity of 354 MW at the end of 1990. These plants are operated and maintained by a U.S. subsidiary of LUZ International known as LUZ Engineering Corporation. LUZ has contracts to build another 300 MW by 1994, and projects an additional 1000 MW during the balance of the 1990s. The ability to implement these plans rests solely on the economic viability of the SEGS technology.

The costs associated with operating and maintaining (O&M) the SEGS plants have significant influence on the economic viability of the technology. Currently, O&M costs account for approximately 15-20% of the plant electricity costs. Reductions in O&M costs coupled with further reductions in capital costs and increases in conversion efficiency, would significantly enhance the marketability, further development, and widespread use of SEGS technology, as well as other solar power technologies currently being developed by the program.

Accomplishments:

Response to request for quotation received by Sandia National Laboratories.

Last quarter a statement of work was negotiated with LUZ Engineering as a first step in a multi-year cost-shared effort involving LUZ and the program. A request for quotation (RFQ) was issued to establish the costs and schedules for completing the three tasks in the statement of work. These tasks are:

- Identification of R&D necessary to reduce O&M costs
- Development of O&M cost reduction plan
- Test of plan adequacy

A response to the RFQ was received nearly halfway through the quarter. Contract negotiations have continued since the response was received. The focus of these negotiations has been on intellectual property rights and the desire by LUZ to protect certain information relating to the operation of its power plants. There does not appear to be any fundamental conflict between LUZ and Program interests, and negotiations should reach a successful conclusion.

Planned activities next quarter

- Conclude negotiations with LUZ and begin work.

D. Design Assistance

Objective: Accelerate the use of solar thermal systems through cooperative efforts with private industry, by assisting and educating potential users, and by supporting industry and users in the selection, design, characterization, and demonstration of promising solar thermal systems.

Accomplishments

United Solar Technologies/Industrial Solar Technology Process Heat System producing heat for the correctional facility in Tehachapi, California.

Industrial Solar Technology and United Solar Technologies (UST) are operating a solar thermal industrial process heat system at the state correctional facility at Tehachapi, California. The STDAC-designed and installed performance monitoring system has also begun operation, and the data is now being used to verify the energy produced by the system. UST/IST use a separate monitoring system to measure the energy, which is used in calculating the energy bill that is submitted to the prison.

Solar Process Water System installation schedule accelerated at LBJ Hospital, American Samoa.

Sandia personnel are working with DOE/PSO regarding the design and construction of a solar process water (SPW) 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.

AET, a flat-plate manufacturer, was selected to provide the collectors for the project. Delivery took place in March. Also, based on Sandia's recommendation, the hospital project management has decided to hire a professional contractor to prepare the site and build the collector support system. Work has begun. Hospital officials are now considering a Sandia recommendation to hire a professional mechanical contractor to install the plumbing system.

Sandia continues support in upgrading Gould IPH System in Chandler, Arizona.

Sandia personnel are working with Gould engineers to solve some O&M problems with the IPH system located at their plant in Chandler, Arizona. Subjects of cooperation have been flexhose difficulties, delamination of the collector's aluminized reflective surface, and the design of a performance monitoring system.

In July, Sandia supplied, from salvage, some advanced generation flexhoses for performance and reliability testing at Gould. In January, Gould officials concluded that these hoses were superior to the existing hoses and should be used in the future. Also, based on data from the newly installed BTU meter, Gould estimated that the plant could save over $120,000 worth electricity per year. As a result, Gould has asked for Sandia's assistance in planning and developing a second phase of system evaluation that will determine if a full plant upgrade is warranted.

Assistance continues to California Energy Commission for solar thermal water heating at the correctional facility in San Luis Obispo.

Solar Thermal Design Assistance Center (STDAC) engineers participated in a "preproposal walk-through" of a California state prison in San Luis Obispo. This event is part of a recently issued Request for Proposal (RFP) soliciting a third-party financed solar thermal system. The RFP focuses on systems that produce heat that can be used to supplement the existing gas-fired district steam system. However, solar systems that produce electricity as a by-product will also be considered. The procurement of this system is being managed by the California Department of Corrections and the California Energy Commission. Sandia is providing technical consulting regarding the solar energy portion of the project.

Approximately ten solar energy organizations participated in the walk-through, including Cummins Power Generation. They represented most of the major solar thermal technologies including trough, dish, flat-plate, and linear Fresnel lens.

Consultation provided to Plains Electric.

Sandia engineers are consulting with Plains Electric, an electric utility cooperative in New Mexico, regarding the application of solar thermal electric technology. Plains is projecting a demand growth of about 3% per year in the 1990s and is considering solar thermal electric as a possible option for providing this capacity.

Plains officials envision that solar steam generators will be used to produce steam to augment that produced by gas/oil in their Algodones facility when it is operating. The Algodones power plant is currently in an operational stand-by status. The advanced generation PKI square dish, along with IST, SKI, Sunsteam, and LUZ troughs, are all candidates for producing the solar heated system.

Kirtland Air Force Base civil engineers considering solar.

Members of Sandia's STDAC met with officials of the USAF 1606 Civil Engineering Squadron at Kirtland AFB in New Mexico.

This squadron is responsible for all of Kirtland's energy consumption, and the discussion focused on how solar thermal technology can be used to reduce fossil energy usage on Kirtland AFB. Kirtland officials are interested in reducing fossil energy by about 2% per year to save money and to meet the intent of a congressional mandate. They are considering solar electric technologies as candidates for replacing some of the fossil fuel and have asked for technical assistance in evaluating the potential of solar technology.

Tonto National Forest officials request STDAC support.

Tonto National Forest officials are in the process of adding solar energy systems at a number of the user facilities within their territory. Sandia was asked to review proposals for the solar water heating systems. After review, Sandia forwarded some technical comments to Tonto officials and their contractors. There are a number of these projects planned for the next several years, and Sandia has been asked to provide technical consulting for them.

Central Receiver feasibility study for Ft. St. Vrain.

Public Service Company of Colorado (PSC) is performing a study to determine if it is feasible to repower a portion of the Ft. St. Vrain nuclear plant with solar energy. SERI is coordinating program contributions to a study which is considering both photovoltaic and solar thermal systems. PSC has placed a subcontract with Black and Veatch (B&V) to perform the work and a final report is due in May or June 1991. Sandia is supporting B&V be performing design and annual performance calculations. During the quarter, Sandia and SERI personnel attended the kickoff meeting at PSC in Denver and performed DELSOL and SOLERGY calculations according to specifications outlined by B&V. These calculations were forwarded to B&V.

Solar energy training for Armenian engineers planned.

The USAID is supporting an effort to help rebuild the earthquake devastated areas of Armenia. As part of the effort, they are planning to integrate renewable energy into the electric/steam generation mix to be developed for this republic of the USSR. The local USAID representative on this project has asked for the STDAC and PVDAC to provide training for Armenian engineers in the use of solar technologies. The goal in the 3-5 day ST training course is to provide an understanding about the potential for solar thermal, some theory about solar energy systems, and some practical understanding about how they are designed, built, and maintained. A proposal detailing the contents of the course is in progress.

SOLTECH 91 co-sponsored by Solar Thermal Electric Program.

Sandia and SERI were co-sponsors for the SOLTECH 91 meeting held on March 26-29, 1991, in San Francisco. This included organizing the symposia and designing and constructing an exhibit on solar electric technology.

The solar thermal electric session contained a variety of speakers who discussed the three major technologies, market factors and opportunities, and state and federal regulations pertaining to solar generated electricity. Of particular interest were talks by representatives of the California Energy Commission and the Nevada Public Service Commission (NPSC) in addressing the societal costs of pollution. The Chairperson of the NPSC showed that when these societal costs are applied to new electric generating plants, solar central receivers were among the least expensive.

The solar electric exhibit was the result of a collaboration with Sandia's photovoltaic system research division. The exhibit featured small and medium sized photovoltaic systems along with large scale solar thermal electric systems. The exhibit was very well attended and thousands of documents were distributed.

Planned activities for next quarter

- Sandia is planning to continue to provide direct technical support to those organizations with which they are currently working. Accelerated efforts are planned to identify other opportunities to provide this service and other technology transfer and outreach activities. One of the potential areas is the DOD, which has significant potential for use of solar thermal electric technology. The STDAC has begun to collaborate with a researcher from the University of New Mexico to identify opportunities within the DOD. SERI will also have substantial involvement with this effort.

- Sandia will attend an interim review meeting at PSC in April and will refine the central receiver calculations based upon comments received at the meeting.

- STDAC CONTACTS THIS QUARTER

Technology/subject	Requester	Affiliation
Central Receiver	T. Laing	N. Carolina Elec Coop.
Central Receiver	P. Schmidt	Consultant
Central Receiver	S. Boyer	Ariz. Pub. Service
Central Receiver	M. Staackmann	U. of Hawaii
Central Receiver	J. Crawford	SunPower
Dish Development	B. Church	Britannia Metals Ltd.
Dish Development	J. Galluscio	Consultant
Dish Development	E. Ansbro	Malahide Centre, Ireland
Dish Development	A. Majeed	B.N.R. Inc
Dish Development	A. Leland	Lucifer Fireworks Co.
Dish Development	H. Edmonds	Consultant
Dish Development	B. Negi	Indian Inst. of Tech.
Dish Development	P. Sherts	SKI
Dish Development	M. Mogus	E. Stroudsburg Univ.
Dish Development	R. Kelly	United Solar
Dish Development	G. Hagerman	SeaSun Power
Dish Stirling	J. Kalinowski	Westinghouse
Dish Stirling	J. Dudenhoefer	NASA
Dish Stirling	J. Fields	Yosemite Systems
Dish Stirling	T. Godett	STM
Dish Stirling	P. Mahrle	STM
Dish Stirling	V. Galindo	CIEDAC/Mexico
Dish Stirling	C. Bunas	Consultant
Dish Stirling	L. Johansson	STM
Dish/Stirling	B. Reed	State of Utah
Dish/Stirling	C. Bunas	Humboldt State University
Distributed Receiver	W. Akbari	Consultant
Distributed Receiver	B. Stine	Cal Poly
General Info	A. Jacquinot	Technocomp
General ST Elec	B. Reed	Utah Energy Office
IPH	R. Mason	Delphi Int'l
IPH	G. Coffer	Coffer Garden Prod.
IPH	D. Vincent	U. of Redlands
IPH	C. Wood	State of NM
IPH	B. Thoren	Lund Institute
IPH	K. Balkwill	Rockwell/ETAC
IPH	H. Franey	Calif. Dep. Correct.
IPH	C. Bensinger	PKI
IPH	C. Dallas	Sage Advance Corp.
IPH	R. Bahm	Bahm and Assoc.
IPH	D. Bailet	Plains Electric
IPH	B. Rogers	PKI
PV Central Rec.	D. Swanson	Stanford U.
PV Central Receiver	C. McGowin	EPRI
PVCR	R. Swanson	SunPower
Solar Air Condit.	C. Kripper	Mission Energy

Solar Air Condit.	F. Wilkinson	Integrity Systems
Solar Controls	R. Nelson	Georgia Power
Solar Controls	D. Gorman	Consultant
Solar Cooling	E. Jabre	Consultant
Solar Desalinization	J. Augustine	Consultant
Solar Electric	E. Perez	Solar Uno
Solar Res. Asses.	K. Kerschen	Black & Veatch
Solar Resource	I. Kubo	Cummins Power Generation
Solar Resource Asses.	E. Sheftelman	Consultant
Solar Testing	C. Edwards	Northrup
Solar Testing	K. Shaw	PDA
Solar Testing	S. Loo	Northrup
Solar Testing	J. Moll	Northrup
Solar Testing	R. Oeding	PDA
ST Concentrators	J. Andersen	Andersen Mfg.
ST Concentrators	T. Stockelrand	LGK Corp.
ST Concentrators	S. Baer	Zomeworks
ST Concentrators	P. Erskine	Consultant
ST Economic Info	B. Markback	State of Nevada
ST Electric	S. Bacilieri	Precision Solar Control
ST Electric	B. Goodrich	N.E. Utility Council
ST Electric	D. Eisemann	Skyline Govt. Services
ST Electric Devel.	T. Kay	Solar Util. Network
ST General Info	A. Almakalek	U. of Colorado
ST General Info	G. Hagerman	Seasun Power Systems
ST General Info	N. Nguyen	Consultant
ST General Info	A. Cummings	Caribbean Assemblies
ST General Info	M. Polonara	Gov. of Italy
ST General Info	H. Schaller	State of Nevada
ST General Info	J. Anderson	Anderson Manuf.
ST General Info	P. Stevens	U. S. Senate Staff
ST General Info	G. Ratliff	Consultant
ST General Info	M. Ajmal	Pakistan Gov.
ST General Info	P. Geerdts	U. of Cape Town
ST General Info	T. Marqueen	Ebasco Services
ST General Info	C. Louie	Consultant
ST General Info	R. Gallagher	Consultant
ST General Info	S. Kaneff	Austrialian Nat. U.
ST General Info	R. Albers	Consultant
ST General Info	R. Boyles	Rensselaer PI
ST General Info	J. Kouroupis	APL
ST General Info	R. Cartade	Consultant
ST General Info	R. James	Nevada PUC
ST General Info	R. Grewal	Solar India Ltd.
ST General Info	J. Zini	Consultant
ST Program Info	D. Neil	HNEI
ST Program Info	M. Kaya	State of Hawaii
ST Program Info	D. Kearney	LUZ
ST Program Info	K. Beninga	SAIC

ST Program Info	T. Kay	Consultant
ST Program Info	B. Howley	Seimons Solar
ST Program Info	T. Volek	NM SEIA
ST Testing	F. Weiskoff	APL
ST Testing	J. Kouroupis	Johns Hopkins Univ.
ST Testing	G. Curry	Northrup
ST Testing	J. Kime	APL

SERI industrial contacts during the quarter included:

Technology	Contact	Affiliation
Alternate Reflectors	Joe Fossen	Scharr Industries
Heat Pipe Receiver	Pete Dussinger	Thermacore
Heat Pipe Receiver	Ted Godett/ Lennart Johansson	STM
Optical Testing of Concentrator Facets	MonteMcGlaun	La Jet
Receiver Durability Testing	John Bean	Cummins Eng. Co
Replaceable/Alternate Reflectors	Kelly Beninga	SAIC
Replaceable Reflector Meeting	Russ Chikoski	SPECO
Replaceable Reflector Meeting	Randy Gee	IST Corp.
Replaceable Reflector Meeting	Dave Gorman	ATS Inc.
Replaceable Reflector Meeting	Gus Hutchinson	SKI
Replaceable Reflector Meeting	Ken May	IST
Replaceable Reflector Meeting	Dan Sallis	Dan-Ka Products
Resource Assessment Trough Sys.	Dave Kearney	LUZ International
Trough Systems	Don Erickson	Energy Concepts Co.

II TECHNOLOGY DEVELOPMENT

A. Concentrator Development

1. Heliostats

Objective: Establish commercial readiness of the heliostat for central receiver solar thermal electric applications.

There were no activities this quarter.

Planned activities next quarter

- Testing and evaluation of SPECO's 200-m^2 heliostat, ATS's 150-m^2 heliostat, and Winsmith's low-cost heliostat drive will continue.
- Sandia will begin the testing and evaluation of SAIC's 100-m^2 stretched-membrane heliostat.
- A report describing SKI's design for a market-ready heliostat will be published.

2. Parabolic Dishes

Objective: To bring parabolic dish concentrator technology to technical readiness for use in dish/Stirling electric.

Accomplishments:

Sandia reviewed changes to the faceted dish structural design with SKI and SAIC.

Changes to the structural design of the faceted stretched-membrane dish were much less than we originally thought they would be. Therefore, a meeting of the project participants was not required. The changes in the structural design were discussed with SKI and SAIC and no problems were identified.

Sandia has completed on-sun testing of facets for the faceted stretched-membrane dish facets.

The Solar Kinetics and Science Applications International facets for the faceted stretched-membrane dish were tested on sun at the National Solar Thermal Test Facility in Albuquerque, New Mexico. The data are currently being evaluated and the evaluation should be completed during April. Preliminary data are consistent with the trends shown in SERI's SHOT tests of the facets.

SKI's and SAIC's facets were placed on sun and the flux-density distributions produced by the facets at their respective focal planes measured using Sandia's video flux mapping system. The Solar Kinetics' facet, measured by SERI to have slope errors ranging from 1.15 to 1.45 milliradians over the facet f/D range of 2.7 to 3.0, had peak fluxes of from 798 to 1163 suns. The SAIC facet's peak fluxes were from 359 to 425 suns over the same f/D range, corresponding to slope errors of 2.55 to 2.65 milliradians as measured at SERI.

Draft Phase 1 reports for the Faceted Dish Development Project submitted to Sandia.

Draft Phase 1 reports for the Faceted Stretched-Membrane Dish Development Project have been submitted to Sandia by WGAssociates and Solar Kinetics. SAIC's report will be submitted to Sandia by the middle of April.

Conceptual design review held at Sandia for the SKI Single-Element Stretched-Membrane Dish Project.

The conceptual design review for the Solar Kinetics' Single-Element, Stretched-Membrane Dish Development project was held at Sandia on March 13, 1991. Staff members from Sandia and SERI participated in the review of the conceptual design of a 75 kW_T dish.

The 75 kW_T dish is 11.7 meters in diameter and, therefore, material selections will change to accommodate the increased weight and wind loads over the 7-meter diameter prototype. Provisions have been made in the full-scale design to reduce the relative sizes of the hub and spokes in order to reduce shadowing and blockage. Overall, the optical element design is substantially the same as the 7-meter diameter optical element installed at Sandia.

The support and drive system for the dish is a king-post design with an elevation-over-azimuth drive configuration. We are attempting to use the Winsmith, low-cost drive concept for the azimuth drive but there may be problems because of the large over-turning moments. This will be evaluated further and the drive selected during the detailed design phase of the project. Solar Kinetics has started on the detailed design, which is scheduled for completion by December 1991.

Planned Activities:

- Sandia will release Phase 2 Requests for Proposal for the fabrication of the faceted stretched-membrane dish.
- Sandia will complete the reduction of the data for the faceted stretched-membrane dish facets.
- SAIC's Draft Phase 1 report for the Faceted Dish Development Project will be submitted to Sandia.
- Sandia will evaluate the proposals for Phase 2 of the Faceted Stretched-Membrane Dish Project, the projected performance of the dish with SKI and SAIC facets, and make recommendations to DOE on how to proceed with the project.
- The drive configuration for the SKI Single-Element Stretched-Membrane Dish will be finalized.

3. Optical Materials

Objective: Perform appropriate R&D to obtain materials for concentrators which have improved durability and performance, increased service lifetimes, and decreased cost.

Accomplishments

Results from a series of cyclic exposure tunneling experiments have identified two approaches which offer increased resistance to delamination in silver polymer reflector materials.

One procedure uses an elevated temperature pre-bake (prior to cycling) of samples laminated to their substrate material. The second method substitutes an alternate edge tape (Tedlar) for the standard ECP-244.

Samples (9" x 24") with and without the standard ECP-244 edge tape were prepared to allow comparison on the basis of whether or not a pre-cycling heat treatment of 80°C for 2½ days was applied. Based upon encouraging static soak test results, sample with an alternate edge seal tape (Tedlar) were also included (non pre-baked only). Eight replicates of each sample set were prepared. All outer edges were protected by an angle bracket/C-channel clamping arrangement around the perimeter. Samples are cycled between a water bath (27°C) and a drying chamber (2 hours at 50°C) and back to the water bath three times per week.

After 70 days of testing (28 cycles) none of the sixteen pre-baked samples (8 with and 8 without ECP-244 edge tape) failed. In addition, none of the Tedlar edge-taped (non pre-baked) samples exhibited tunneling. In contrast, seven of out of eight samples without edge tape which were not pre-baked had tunnelled after 14 days (5 cycles). In the same time, five out of eight of the non pre-baked samples with ECP-244 edge tape had failed.

> **Static soak testing of pre-baked vs. non pre-baked samples have exhibited results similar to the cyclic experiments.**

Five samples each of 22" x 22" pieces of ECP-305 mounted on aluminum substrates were prepared. All edges were cut with a razor blade (the harshest cutting method) and no edge protection (tape, clamps, etc.) was provided. Samples were subjected to a 2½ day pre-exposure baking at 80°C. After over 100 days of exposure, none of these samples have exhibited any tunnel propagation. Some damage along exposed edges occurs and grows very slowly (≈¼" per month of immersion) but catastrophic failure is never experienced. For an identical sample set (except no pre-bake treatment was applied) previously tested, five out of five samples had tunneled within several weeks. A total of 31 pre-baked (at 80°C) samples having a minimum of 50 days submersion in water are presently under test. No tunnel failures have occurred, resulting in a reliability of 91% at a confidence level of 95%. At this level of confidence, the reliability of these samples is over 100 times greater than for identical samples (razor cut, non-protected edges) without the thermal pre-bake treatment.

> **To explore whether pre-baking provides tunnel resistance over the full mirror surface, several pre-baked samples which have demonstrated resistance to tunneling were purposely damaged and returned to cyclic testing.**

Such damage is intended to simulate hail/vandalism expected to be experienced during real world service conditions Six pre-baked samples which had not failed after 37 days (15 cycles) of testing were subjected to drill holes, knife cuts, and hammer blows and returned to cyclic testing. After an additional 60 days (26 cycles) of exposure, no tunnel propagation failures have occurred.

> **To further examine the benefits of thermal treatment of silvered polymer reflector materials, a new screening experiment, designed to investigate the time/temperature tradeoffs associated with this procedure, has begun.**

Samples (24" x 24" of ECP-305 were laminated to aluminum substrates and thermally treated at 60°, 70° and 80°C for 4, 22, and 40 hours prior to initiation of testing. Samples will be evaluated in terms of tunnel initiation and propagation as a function of time samples are submerged in water. In addition, SERI is considering several approaches to quantifying the effect of thermal treatment by means of standard peel adhesion tests.

A new cyclic tunneling experiment which is designed to investigate several alternate approaches of mitigating delamination failure during service conditions has been initiated.

Improved edge-joining processes are being evaluated. A new solvent roller applicator was fabricated and was used to weld a bridge strip between adjoining edges of ECP-305. Several candidate solvents were considered including acetone, methyl ethyl ketone, amyl acetate, toluene, and methylene chloride. Acetone was selected on the basis of availability, ease of use, and environmental safety. A number of approaches to heat welding were attempted. These included the use of 1" wide tacking iron, a hot air welding tool, and soldering irons with various size tips. A soldering iron with a 5/16" wide tip gave the best results in terms of reproducibility and bond reliability.

Based upon promising results from previous water soak screening tests, samples whose edges were heat-sealed (using a soldering iron and no bridge strip) and whose edges were cut and sealed by a laser cutting process were included in the present set of samples. The replaceable reflector laminate recommended and installed by IST is also being tested. These are samples of ECP-305 laminated to a 10 mil thick polycarbonate film. The polycarbonate is subsequently mounted on aluminum substrates using a two-sided sheet adhesive (3M 9425). The adhesive on the aluminum side is low-tack.

Several innovative SERI sputtered constructions were included n the present set of samples. Sputtered silver samples are being tested for comparison with evaporated silver (the standard ECP-305 configuration). Another set of samples incorporates edge masking during silver deposition to produce a 1/4" wide unsilvered edge to isolate the silver layer from possible edge flaws. Reflector stacks having an adhesion promoting interlayer between the silver and the front surface polymer film are also being tested.

Eight replicates of each sample set were prepared (except for the adhesion promoting interlayer type for which only four samples were made due to safety related priorities). All outer edges were protected by an angle bracket/C-channel clamping arrangement around the perimeter. Samples will be cycled between a water bath (27°C) and a drying chamber (2 hours at 50°) and back to the water bath three times per week. All samples will be inspected using the video system each time they are cycled to provide a permanent record of tunnel initiation and propagation.

A meeting on replaceable reflector materials was hosted by SERI. Interested parties from industry, Sandia and SERI were in attendance.

An historical review of replaceable/removable reflector materials was provided and results of replaceable reflector R&D during FY90 was presented. Based upon these experiences, a work plan for FY91 was devised. Emphasis was placed on the development of a marketable product which exhibits reliable construction and ease of installation in the field and which is environmentally acceptable and economically feasible.

Several approaches were identified which could result in a near-term market usable product. The time requirements for replaceable reflector materials as a function of technology type was felt to be one year for troughs, three years for heliostats and five years for dishes. Trough needs could be addressed by modified designs which incorporate throw-away substrate replacement or by optimizing the replaceable laminate concept initiated by IST in FY90. A higher risk (longer term) approach would be to pursue the development of a less aggressive adhesive in place of the adhesive currently used in silver polymer reflectors.

Alternate application techniques may benefit all technologies. Use of wax, grease, and other innovative mounting methods were suggested. The elimination of adhesives may address the replacement issued for heliostats and dishes. Dish designs already incorporated reflector replacement and stretched heliostat designs could be altered to allow clamping rather than welding to the structural ring. Alternate substrate materials (such as polyester and perhaps fluorocarbon films) for no-tack applications should be evaluated in terms of mechanical durability.

A Commerce Business Daily announcement was prepared and released which solicits industrial interest in collaborative R&D of alternate reflector material constructions which achieve the long-term goals of the solar thermal program.

The stated goals include maintenance of 90% specular reflectance (into a half acceptance angle of 4 mrad) for ten years under real-world service conditions and an initial cost of ≤ $1.00 per square foot. Material systems such as protected front surface reflectors, improved metallized polymer films, and thin glass mirrors were cited as possible approaches of interest.

Delaminations appearing in the replaceable reflective film.

After three months of outdoor exposure, the first replaceable reflective film installed on a stretched-membrane heliostat began to delaminate. The separations are, as generally seen with silvered-acrylic films, at the interface between the silver and the acrylic. The replaceable reflective film was installed by Industrial Solar Technology and consists of 3M's ECP-305 film laminated to a 10 mil polycarbonate substrate. The laminated film is held onto the heliostat with a low-tack adhesive. There does not appear to be any separation of the low-tack adhesive. All of the delaminations appear to have started at the edges of the reflective film and extend inward--water droplets are evident between the silver and the acrylic layers. There are about 20 individual delaminations, generally 3 to 10 inches in length and about 1 inch across. The total affected area is well less than 1% of the reflector's total area. There have been no delaminations in the replaceable film laminated to one glass facet on a Test Bed Concentrator. A presentation on the status of development and evaluation of the replaceable film was made at SERI's February 20 planning meeting by Industrial Solar Technology and Sandia.

Planned activities for next quarter

- Static and cyclic accelerated exposure of tunneling samples presently under way will continue.
- A request for proposal will be issued to industrial companies who respond to the CBD solicitation of interest in alternate reflector materials.

B. Power Conversion

1. Central Receiver Technology

Objective: Develop central receiver technology in direct support of the central receiver commercial applications programs.

Accomplishments

Molten Salt Pump and Valve Test final report nearing completion.

The main section of the final report on the molten salt pump and valve test was completed this past quarter. However, the appendices, which support much of the data in the main section of the report, have not been completed. We expect the report to be completed and ready for management approval by mid May.

The final report on the design and construction of the molten salt pump and valve loop test, which was completed last quarter, is still in the management review process. The report was written by Babcock & Wilcox and will be published as a Sandia contractor report.

A paper was written for the 1991 ASME Solar Conference on the results from the pump and valve experiment. The paper was given at the conference in Reno, Nevada on March 18.

Panel research experiment final report in preparation.

A draft of the summary report on the design and construction of the Panel Research Experiment, which includes preliminary test results, was started this past quarter. The panel research experiment was mothballed last quarter after the preliminary salt flow testing of the experiment was conducted. Data from the experiment was analyzed this quarter for input into the final report.

Volumetric Air Receiver absorber material testing.

New Mexico state University (NMSU) is testing volumetric air receiver materials at its solar furnace. The test results will be used to characterize materials (e.g., ceramic foam, knit wire mesh, etc.) and to validate computer models for future tests.

This past quarter, most of the solar furnace testing that has been conducted has been on various configurations of the porous ceramic foam. The thermal efficiencies of the ceramic foam have been as high as 77% at 775°C with a sample of 15 ppi, 15% dense, 0.75 inch thick material. Because of uncertainties in some of the earlier data, some of the sample configurations are being retested.

In order to evaluate the heat transfer coefficient the surface area of the ceramic material is needed. Nitrogen deposition measurements were made on three of the Pyromark coated samples that were furnace tested, to determine the area per gram of material. The values ranged from 0.71 m^2/g for 20 ppi, 20% dense to 1.24 m^2/g for 5 ppi, 15% dense. These values are used in calculating the heat transfer coefficients.

Based on the test results to date, it appears that the porous ceramic foam will not achieve the high thermal efficiencies required for a volumetric receiver. The material is robust and can handle high temperatures; however, at the temperatures required for electricity production (1050°F) the porous ceramic foam is not the optimal material. We will continue the furnace testing to evaluate the knit wire mesh material.

Second Generation Central Receiver Study.

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

The study is basically completed and we are currently preparing a draft to the report. This past quarter we received portions of five of the seven sections the Germans were to prepare. We are reviewing the German input and will continue to work on the report.

Planned activities next quarter

- The final report on the pump and valve loop experiment will be completed.
- We will continue to work on the summary report of the design, construction, and testing of the panel research experiment.
- Testing and analysis of the volumetric air receiver absorber materials will be completed and a report will be drafted.
- We will continue to work on the draft of the Second Generation Study report.

2. Dish Receiver Technology

Objective: Develop liquid metal reflux receiver technology in direct support of industry-led commercial programs and investigate advanced concepts for long-term reliable and low-cost receivers.

Accomplishments

Cummins/SERI/Sandia Heat Pipe Receiver Durability Test initiated on-Sun.

During the second quarter the durability heat pipe receiver was fabricated, acceptance tests were completed, and on-sun testing started.

Thermacore completed fabrication of the receiver. Performance of both (circumferential) arteries was tested in methanol and found to provide factors of safety of 1.8 for one artery and 2.6 for the other. The heat pipe was charged with 1800 gm sodium and processing of the heat pipe was started followed by the 40-hour acceptance test. In this acceptance test, the receiver was operated at full power (approximately 21kW) at 675°C and at several orientations. These orientations were meant to test the performance of the arteries over the range of motion of the LaJet concentrator expected during the durability test. In addition, a number of warm restarts was successfully completed from temperatures of 650, 600, 550 and 500°C. Thermacore also completed fabrication of the gas-gap calorimeter needed for the on-sun durability test. This work completed Task 1 of the subcontracted effort.

During the 40-hour acceptance test, a number of the quartz lamps used to provide heat to the receiver failed. SERI supplied replacement lamps to Thermacore by overnight mail and avoided delay in the project.

LaJet performed extensive cold-water calorimetry on the concentrator in order to determine the optimum receiver aperture. From these tests, it was determined that a 7" aperture was optimum and that the concentrator would be able to supply sufficient power to the receiver with 19 of its 24 facets in operation. LaJet implemented the SNL CIRCE2 code and used the code to determine maximum flux levels delivered to the receiver absorber dome. Calculations showed that 33 W/cm^2 would be the maximum during normal, full insolation, operation and that this value would rise to 40 W/cm^2 during concentrator defocussing. Both of these flux levels appeared to be acceptable. In addition, detailed performance and sensitivity analyses of the Thermacore heat-pipe receiver were provided to Cummins by Sandia. Figure 1 shows the Thermacore receiver design-point performance and temperature distribution predicted by the newly developed Sandia reflux-receiver thermal-performance model. This work completed Task 2 of the subcontracted effort.

On-sun testing of the receiver began on February 14 and as of April 5, 111 hours of operation at 675°C were completed. The durability test is planned for a total of 500 hours operation at 675°C. SERI and SNL personnel visited the Abilene test site to observe on-sun testing and measure absorber temperatures using

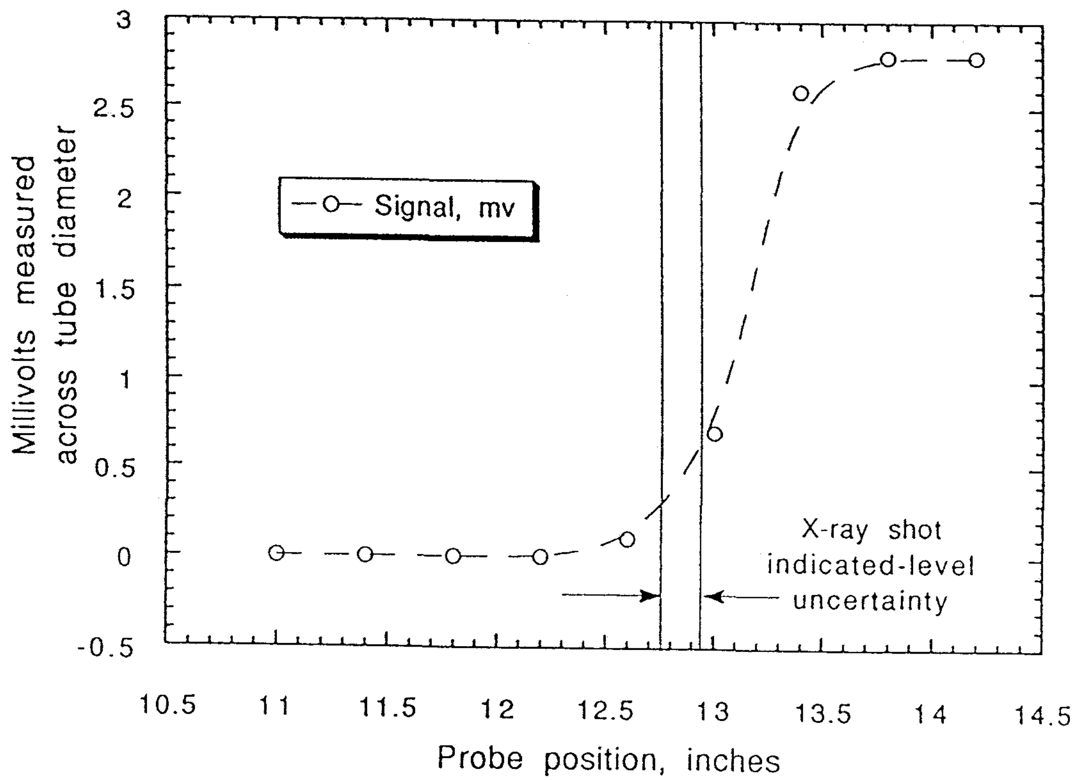


Figure 1. NaK-level data taken using a 5-amp, 4-wire resistance probe, oriented transverse to 1.75" tube axis

the Sandia infrared camera. Although inclement weather precluded tests we took the opportunity to review the test data taken to date in detail and to discuss future plans. SNL personnel installed the gas-gap calorimeter automatic control system and checked its operation.

The only anomalous behavior seen during the testing to date has been the development of two hot spots on the receiver absorber dome. One of the hot spots has been stabilized by removing the concentrator facets focused on that area. Nothing has been done to stabilize the other hot spot and it is slowly degrading in the sense of gradual increase in temperature. At this time, it is operating between 770 and 800°C. If it goes beyond 840°C, more facets will be defocussed to stabilize the hot spot. To maintain full power operation, additional facets aimed at other areas of the absorber dome can be brought into focus. At the present time, 16 facets are focused delivering 15 kW_{th} which is still sufficient to operate the 5 kW_e engine. Without disassembling the receiver it is difficult to say what is causing the problem but models indicate that lower-than expected wick permeability may be leading to localized wick damage.

Fabrication of four bench-test pool boilers completed.

Fabrication of the second two bench-test pool boilers has been completed at Sandia. Among the total of four pool boilers, one is a baseline version having no surface enhancement for stabilization of boiling. The remaining three each have one of the following surface enhancements: a laser-drilled cavity, a sintered IN-600 powder coating, and a sintered type 304 stainless steel powder coating.

NaK transfer to bench-test pool boilers completed.

Transfer of NaK from a shipping container into the four Sandia bench-test pool boilers has been successfully completed. Until now, a defined-volume technique has been used at Sandia for all alkali-metal transfers in the reflux receiver program. In the present case, an electrical-resistance technique for liquid-metal level measurement was developed at Sandia and verified radiometrically (see Figure 2). This technique was used for final level adjustments in the pool boilers, and will be used in lieu of defined volumes in future filling operations.

Documentation of pool-boiler receiver X-ray diagnostics underway.

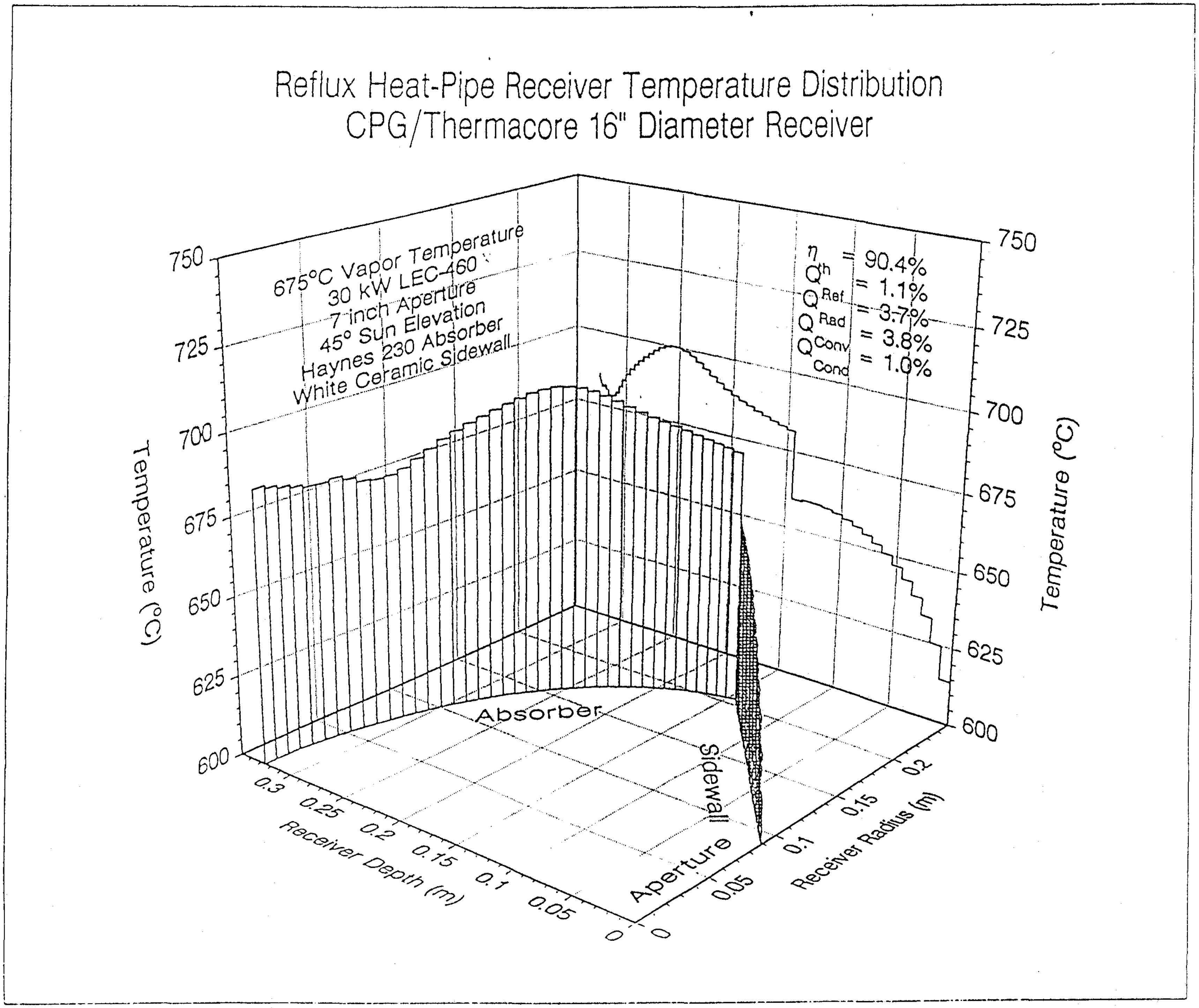
Documentation of the Sandia on-sun pool-boiler receiver X-ray diagnostics is approximately 60% complete.

Metallurgical examination of the on-sun pool boiler elbow-to- condenser weldment completed.

Dye-penetrant tests of the elbow-to-condenser weldment of the Sandia On-Sun Pool-Boiler Receiver have been completed. This joint, above the sodium free surface, is subjected to the passage of a thermal front on each startup. No evidence of cracks in the weldment was found. Other parts cut from the on-sun pool boiler have finally reached the front of the queue at the Sandia metallurgical laboratory, and examination has begun.

Design of next-generation on-sun pool-boiler receiver completed.

Sandia engineers met with Ultimate Hydroforming to finalize forming and joining details of the next-generation pool-boiler receiver design. All of the features of the strawman design described in the last quarterly report have been incorporated into the final design. Ultimate, the supplier for the first-generation receiver domes, offered this design critique in order to assure that we develop a manufacturable design.


Reflux Heat-Pipe Receiver Temperature Distribution
CPG/Thermacore 16" Diameter Receiver
675°C Vapor Temperature
30 kW LEC-460
7 inch Aperture
45° Sun Elevation
Haynes 230 Absorber
White Ceramic Sidewall
η = 90.4%
Q Ref = 1.1%
Q Rad = 3.7%
Q Conv = 3.8%
Q Cond = 1.0%
Temperature (°C)
750
725
700
675
650
625
600
Absorber
Sidewall
Aperture
Receiver Depth (m)
0.3
0.25
0.2
0.15
0.1
0.05
0
Receiver Radius (m)
0.05
0.1
0.15
0.2

Ultimate also invited a welding expert from Saffron Engineering, a metallurgist from Haynes International, and a coatings expert from Friction Coating Corporation. Industry involvement during Sandia's design phases will help assure a quality product.

Hybrid receiver solicitation prepared.

SERI researchers have prepared a solicitation package for the Hybrid Receiver subcontract. The package includes the Statement of Work for design, fabrication, and testing of a 10 kW_{th} heat pipe or pool boiler receiver capable of operating on solar energy or with natural gas combustion.

Lifetime issues studies are being continued.

Strain-range calculations are underway at Sandia to enable lifetime estimates for the next-generation pool-boiler receiver. This effort will utilize data developed by Sandia metallurgists for Haynes alloy 230 behavior, including short-term creep, stress relaxation, isothermal low-cycle fatigue, and thermomechanical fatigue.

Safety and environmental documentation developed.

Sandia engineers have developed documentation of receiver activities in order to assure compliance with applicable Sandia, DOE, NEPA, and OSHA requirements. New safety and operating procedures have been developed for all receiver activities. Hazard assessments and inspections led to significant facilities modifications. Training for operations with NaK is being developed, and is awaiting proper NEPA approvals. NaK waste disposal has been arranged for, allowing continued use of NaK at the facility.

Overhaul of test cell for pool-boiler bench tests underway.

Extensive revisions to Test Cell 2 of Sandia's Engine Test Facility are 70% complete. This overhaul makes Test Cell 2 more convenient and safer for the variety of alkali-metal operations that it hosts. Included in the overhaul: safer and more flexible layout of utilities, including water, compressed air and other gases, high voltage, and data lines; and removal of many stored items, including sodium and NaK, to a new storage shed. Additional electrical work and documentation is required before operations are resumed.

Stirling Thermal Motors continues fabrication of a screen-wick heat-pipe receiver for on-sun testing at Sandia.

Stirling Thermal Motors continues fabrication of a full-scale screen-wick heat-pipe solar receiver for on-sun testing at Sandia. The receiver is based on a Sandia design that was successfully tested at Sandia in a bench scale test. The design uses fine mesh SS screens and features a pedestal type artery system on a thin (0.5 mm) distribution wick. The distribution wick is formed by first sintering 10 layers of 325 mesh screen to flat SS316L sheet stock and then hydroforming the assembly into a spherical absorber. At Sandia's request two of the sintered assemblies were impregnated with wax before hydroforming in an attempt to maintain permeability. The resulting wick structure, after removing the wax, was thicker than attempts without wax. Permeability measurements performed at STM indicate significantly improved permeability. Artery fabrication is currently the primary technical concern.

Seven Sandia engineers and one SERI researcher attended the final design review of the Stirling Thermal Motors (STM) screen-wick heat-pipe solar receiver in Ann Arbor, Michigan on March 21, 1991. STM presented several artery design options based on arteries developed at Sandia and at STM. All of the approaches they suggested utilized circumferential and radial arteries. During the design summary discussions at the end of the meeting, Sandia and STM engineers developed a radically new artery structure concept, the Dual New Artery (DNA). The new artery concept uses a double helical configuration and is made possible by a new low-resistance artery developed by STM. The proposed artery structure offers good sodium distribution, ease of fabrication, simplicity, redundancy, and should be relatively easy to prime with sodium. STM anticipates delivery of the prototype receiver to Sandia in May.

<u>Planned activities for next quarter</u>

- Sandia test cell and documentation modifications will be completed.
- Testing will begin on the Sandia bench test pool boilers.
- Metallurgical analysis of the first on-sun pool boiler will be completed.
- Documentation of the on-sun x-ray tests will be completed.
- Contracts will be placed to fabricate the major components of the next-generation pool-boiler receiver.
- Stirling Thermal Motors will complete fabrication of a full-scale reflux heat-pipe wick assembly.

3. Dish Converter Solarization

Objective: In cooperation with industry, test and evaluate conversion devices applicable to solar thermal electric technology and respond to solar-specific issues. In particular, Stirling cycle heat engines are to be considered. These include a Stirling Thermal Motors kinematic Stirling engine and free-piston Stirling engines under final design by Stirling Technology Company and under preliminary design by Cummins Engine Company.

<u>Accomplishments</u>

Final design review held for the Stirling Technology Company (STC) Advanced Stirling Conversion System (ASCS).

The final design of the STC's prototype ASCS was presented on February 20-22, 1991, at the Lewis Research Center, Cleveland, Ohio, and reviewed with representatives from DOE, Sandia and NASA. The initial technical evaluation is now complete, however, a number of questions still remain. Until the "draft" final design report with supporting technical information is received, a final technical determination cannot be completed.

STC, based on knowledge gained in a separate, parallel activity, based its final design on a larger bellows than was specified in the preliminary design. This change has apparently led to reduced design margins. Further examination will be required to fully assess the effects of switching to larger bellows operating at lower frequencies.

Evaluation of the receiver, heat transport system and cooling system indicates that no additional work is required in the design of these components/subsystems.

Remediation of the Cummins Advanced Stirling Conversion System (ASCS) preliminary design continues.

This activity addresses the deficiencies identified during the preliminary design review held in early FY90. These include the DOE long-term cost goals and a number of technical issues with the free-piston/linear alternator conversion system design. Work accomplished to date indicates that progress has been made in successfully addressing these deficiencies. A review of the remediated preliminary design has been scheduled for April, 1991.

Tests on first Sandia-designed, gas-fired, heat-pipe evaporator completed.

The system for testing the gas-fired sodium evaporator is illustrated in Figure 3. In this system, hot gases from a propane burner are forced to flow between the 40 evaporator tubes. Liquid sodium that is on the inner surface of the evaporator tubes vaporizes and removes heat from the tube walls. The sodium vapor then travels to the condenser end of the heat pipe where heat is removed and measured using a gas-gap calorimeter. Under the influence of gravity, the condensed sodium flows down the condenser walls and into a gutter at the bottom of the condenser tube. A drain in the gutter directs the condensed sodium into the upper manifold on the evaporator. After the liquid sodium enters the upper manifold, it is allowed to flow along the manifold and spill into the evaporator tubes. Sodium that spills down the evaporator tubes either evaporates from the tube walls or is collected in the bottom manifold. A wick structure on the inner walls of the evaporator tubes distributes the liquid sodium over the evaporator tube walls.

The construction of the evaporator section of the gas-fired heat pipe is illustrated in Figure 4. Nine layers of 200-mesh screen are sintered to the inner surface of each evaporator tube to form a wick structure. There is also a spring inside of each evaporator tube that was used to hold the screens in place during the sintering operation. (These springs are not shown in Figure 4). The evaporator tube extends about 3-mm into the top manifold and about 18-mm into the bottom manifold. Two 1/4-inch diameter holes were drilled near the bottom of each evaporator tube to allow liquid sodium to flow in and out of the evaporator tube. Twelve tubes also had small holes drilled slightly above the 1/4" holes to prevent vapor from accumulating in the lower manifold. A 2-mm wide notch was cut at the top of each evaporator tube to reduce pooling in the top manifold.

Our first attempt to run the gas-fired sodium evaporator was on December 11, 1990. When the system was started, two tubes on the front row and one tube on the second row overheated. X-rays of the evaporator indicated that there was an insufficient supply of sodium in the lower manifold. After the system was visually inspected for damage and leak tested, a second charge of sodium was added to the system on January 21, 1991.

The system was started for a second time on January 28. During these tests, severe temperature cycles were observed on several evaporator tubes. Overheat conditions on two evaporator tubes were visually observed through a window in the combustion chamber. Similar events were measured on a few of the instrumented tubes. The temperature excursions were worse near the front of the evaporator and the cycling was almost negligible in the back tubes. In the worst of the instrumented tubes, the temperature fluctuated over 60°C in a period of about 15-20 seconds. These results are shown in Figure 5.

This testing and some innovative diagnostics involving resistance measurements to dynamically indicate the presence of sodium liquid coupled with first-order calculations suggest that the problems were caused by liquid entrainment. When the system operates at temperatures below 650°C, the liquid sodium appears

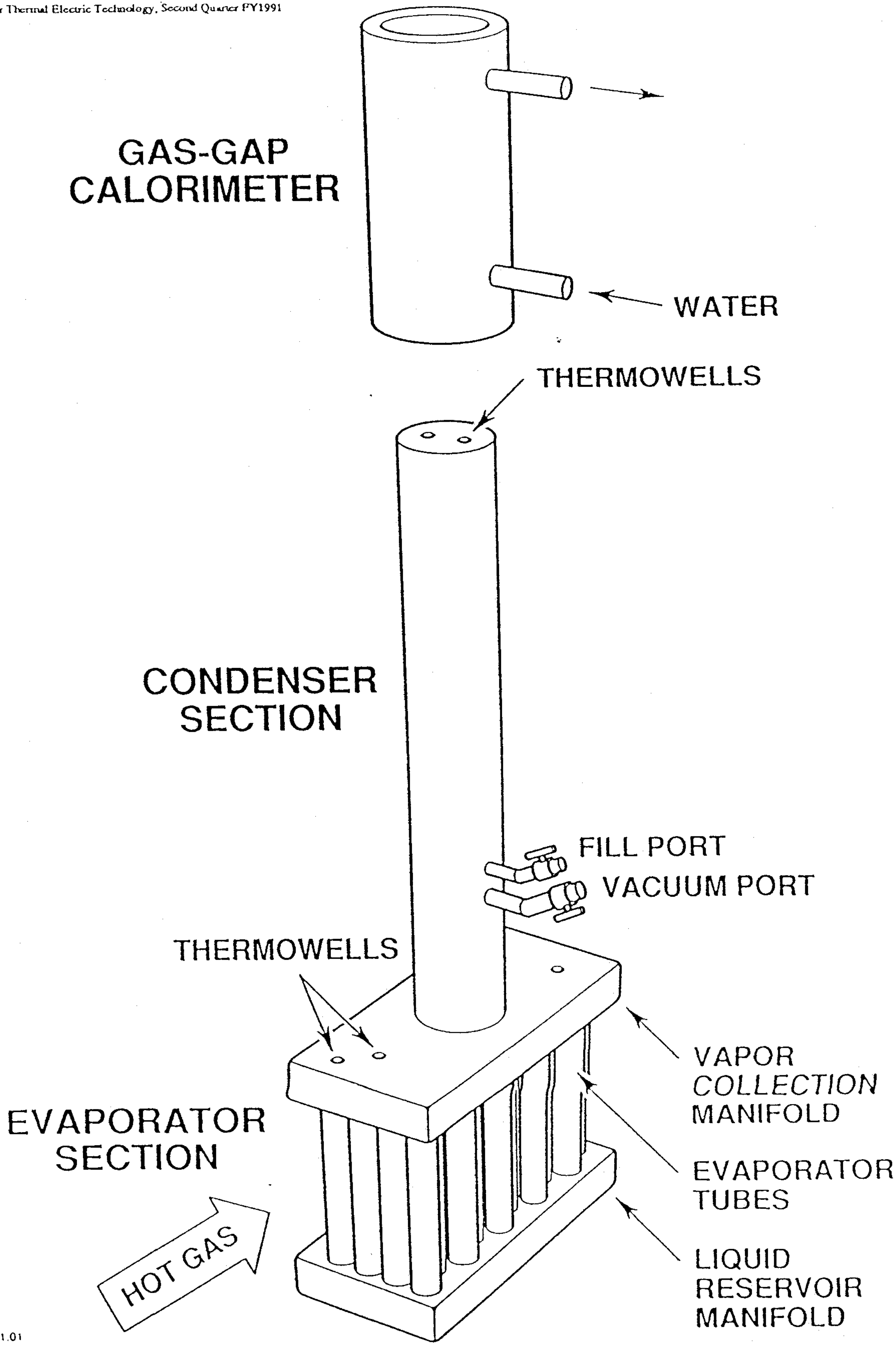


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Figure 3. Gas-fired Sodium Evaporator Test Configuration

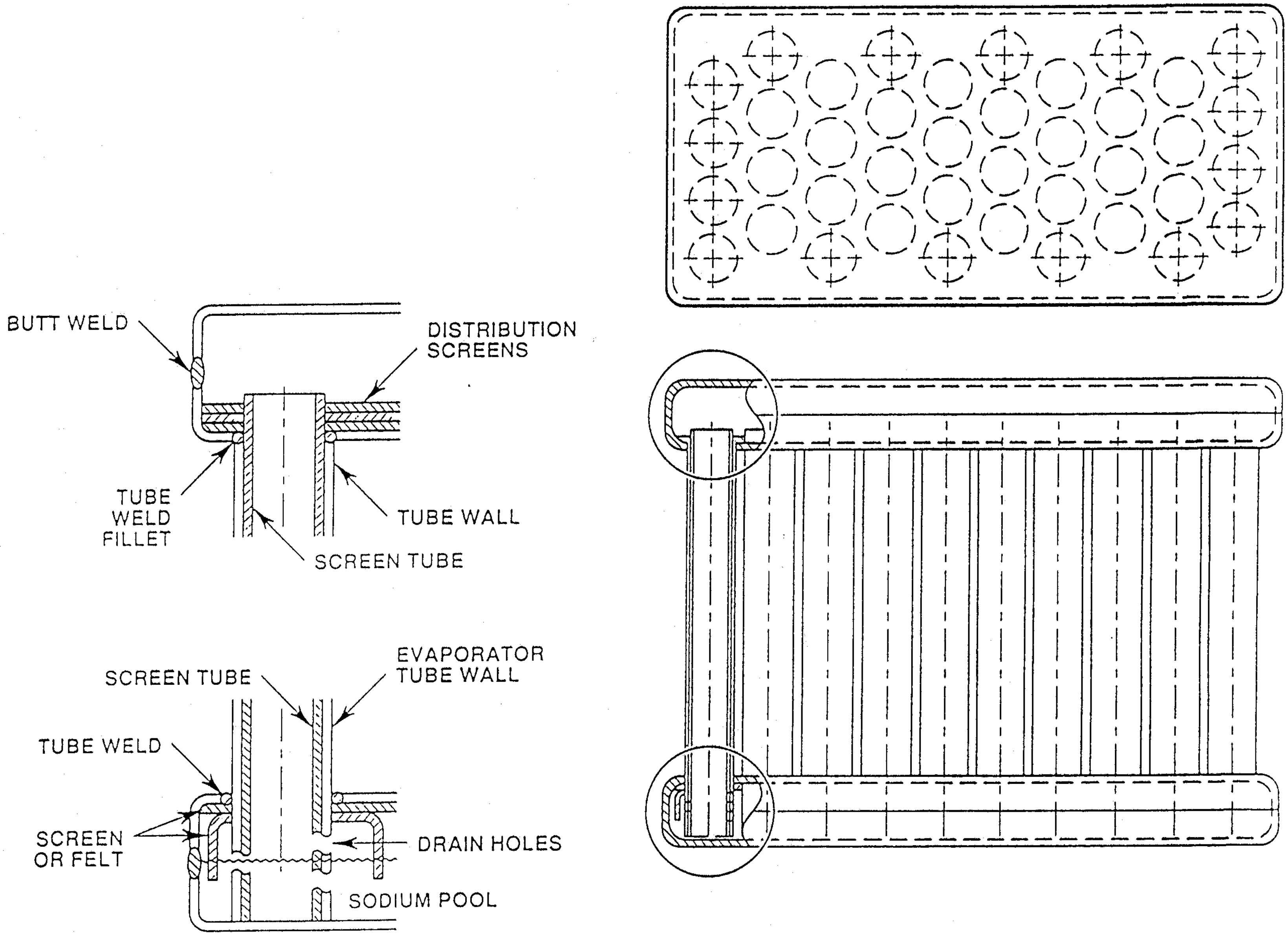

Figure 4. Sodium Evaporator -- Internal Construction

to become entrained in the high velocity vapor flow. The entrained liquid sodium becomes suspended at the top of the evaporator tubes and is prevented from reaching the heated tube surfaces.

It is believed that these problems can be avoided if the sodium is forced to enter the wick structure at the top of the evaporator tube. This can be accomplished by extending the wick structure into the top manifold as illustrated in Figure 6. The tube inside the wick extension will help force the sodium to enter the wick and not simply run into the vapor space. With this new wick structure, overflow drains should be provided in some of the evaporator tubes to allow the excess sodium to pass to the bottom manifold (see Figure 6).

The tests indicated that the wick structure at the bottom of the evaporator tube operated properly, as long as liquid sodium was available in the lower manifold. On the second evaporator, however, the hole that allows vapor to flow out of the lower manifold should probably be made larger. The hole should also be placed closer to the top plate of the lower manifold to reduce the accumulation of vapor.

All the parts for a second gas-fired evaporator are available and partially assembled. Some questions remain however, about the best method to construct the evaporator wick and the overflow drain in the top manifold. These questions should be resolved shortly and the second gas-fired heat-pipe evaporator will be assembled and tested.

Planned activities for next quarter

- Complete fabrication of second evaporator with modifications to prevent sodium entrainment and resume testing.
- Conclude Cummins ASCS preliminary design remediation.
- Resolve STC ASCS final design issues.

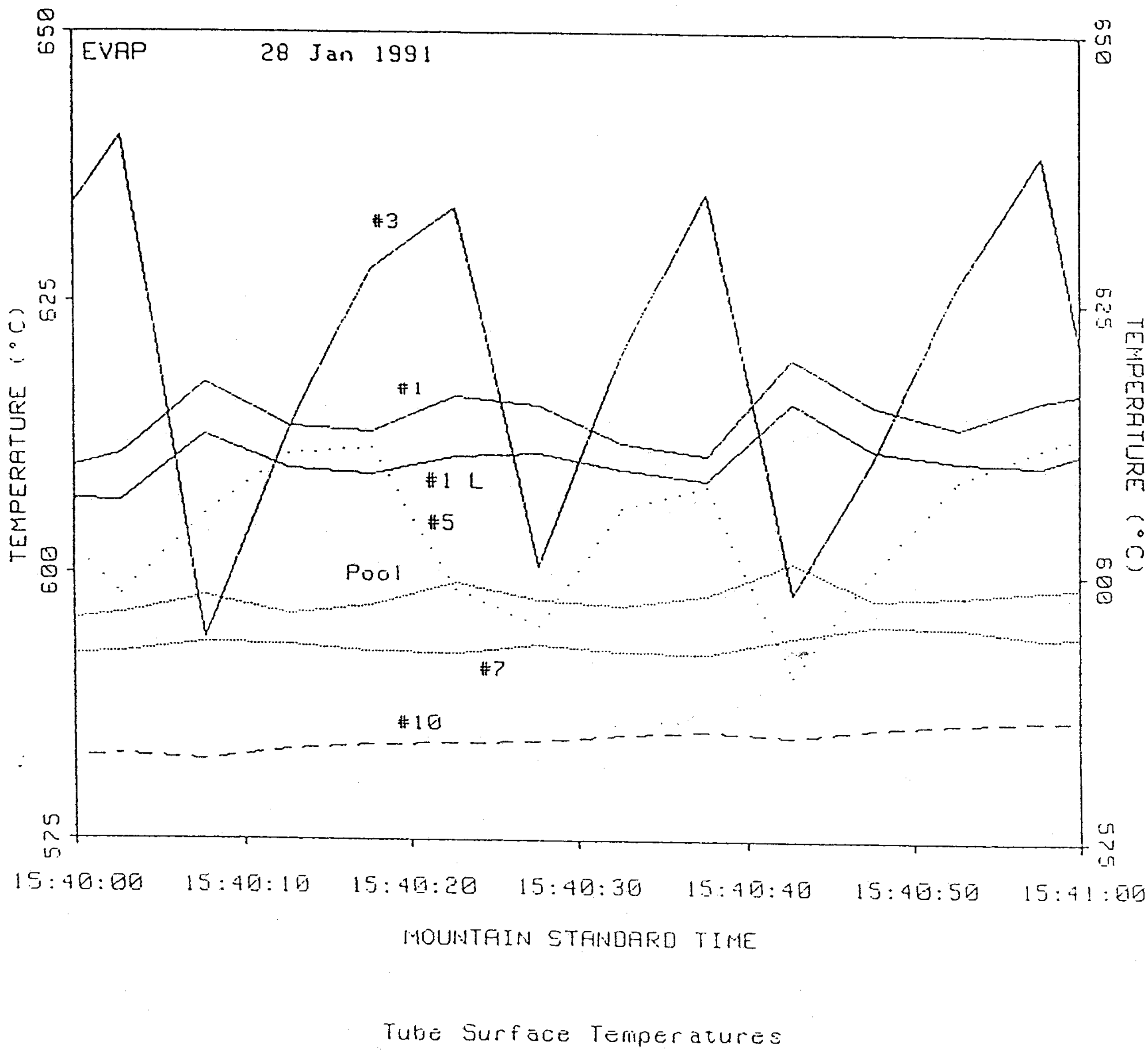

Figure 5. Evaporator Temperatures During a Period of Unstable Operation

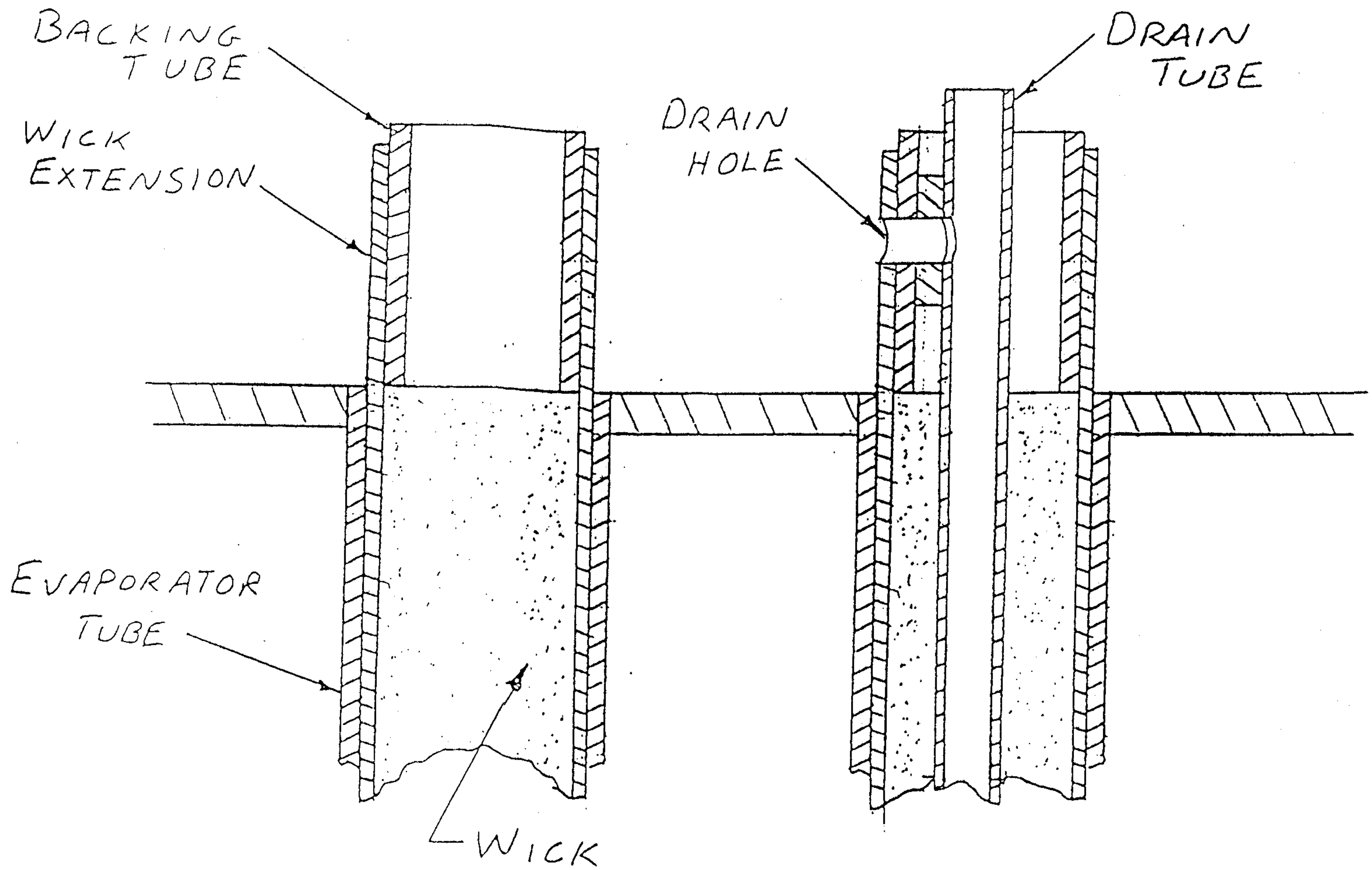

Figure 6. Proposed Modifications of the Wick in the Upper Portion of the Evaporator Tubes

III REIMBRUSABLE PROGRAMS

NATIONAL SOLAR THERMAL TEST FACILITY

Accomplishments

Applied Physics Laboratory completed a series of hot boresight error measurements at the National Solar Thermal Test Facility.

For several years, Johns Hopkins University Applied Physical Laboratory has been evaluating radar system while the radome is being exposed to simulated aerodynamic heating at Sandia's Solar Thermal Test Facility. A water-cooled radome mount with rotational and slew capability is installed in the upper test bay of the solar power tower. An antenna with rotational and translational capability is installed in a heliostat pedestal in the heliostat field. This system is used to measure hot boresight error over a range of antenna to redome angles while the flux from the heliostat field is dynamically changed to maintain constant heating. These tests are conducted for the U.S. Navy. The latest test program was completed in early February.

Testing of NASA facets completed.

Sandia has been asked by NASA to perform on-sun testing of the STAR facets and panels for the space station. The facets are triangular in shape 1 meter on-a-side and have spherical or torroidal curvature. The panels are populated with 24 facets and weighs about 80 pounds. Initial plans are to test five of the NASA facets on sun at the test facility.

The five test facets have been tested on sun and data are currently being reduced. A test report is under preparation for submission to NASA.

Planned activities for next quarter

- Evaluation of the nuclear hardness of a U.S. Air Force canopy is scheduled to begin in May.
- A third series of military aircraft material hardness test for Northrop/U.S. Air Force is scheduled to begin in June.

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Hogan, R. E., "Numerical Modeling of Dish/Stirling Reflux Solar Receivers," Second ASME-JSES-JSME International Solar Energy Conference, Reno, Nevada, March 1991. (Proceedings pp 215-222)

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Menicucci, D. F., Kolb, G. J., Albert, D. J., Chavez, J. M., "Consider a Solar Electric Power Plant," Sandia special publication, SAND91-0235, March 1991.

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Diver, R.B., "Solar Thermal Electric Program Power Conversion Technology Development," SOLTECH '91, San Francisco, California, March 1991.

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Klimas, P. C., "Solar Thermal Electric Program Cooperative Projects," SOLTECH '91, San Francisco, California, March 1991.

Konnerth, A., "Design and Cost of the First Commercial Stretched-Membrane Heliostats," Sandia National Laboratories, SAND90-7038, to be published.

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Mancini, T. R., "Analysis and Design of Two Stretched-Membrane Parabolic Dish Concentrators," accepted for publication in the August issue of the ASME Journal of Solar Energy Engineering.

Mancini, T. R., and K. R. Boldt, "The LaJet Innovative Concentrator: Design and Performance." Sandia Technical Report.

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Menicucci, D. F., "Solar Energy - A Viable Technology for Today and Tomorrow," presentation to the Albuquerque Science Teachers Association, March 1991.