Solar
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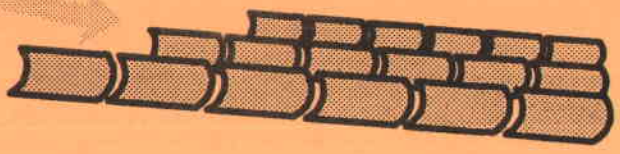

The DOE

Solar Thermal Electric Program

Quarterly Progress Report
Second Quarter, Fiscal Year 1992

Submitted by:

Sandia National Laboratories
Albuquerque, New Mexico

National Renewable Energy Laboratory
Golden, Colorado

April, 1992

Sandia
National
Laboratories

NREL

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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 National Renewable Energy Laboratory (NREL), and their contractors.

This quarterly progress report is written to the Solar Thermal Electric Technology Program's draft Annual Operating Plan (AOP) of January 21, 1992.

MANAGEMENT STATUS REPORT

Structure of the Solar Thermal Electric Technology Program

The Solar Thermal Electric Technology Program is a market-oriented, industry-driven set of cooperative activities with heavy private sector involvement in both planning and execution. It has taken this approach in order 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 determine the overall direction of the program. Technology Development efforts in the concentrator and power conversion tasks support the Commercial Applications task. This is the second fiscal year that the program has had this orientation. Relative to fiscal years prior to FY91, technology development milestones focus on nearer timeframes, and far-term research plays a reduced, but continuing, role. The FY92 structure of the program is outlined as follows:

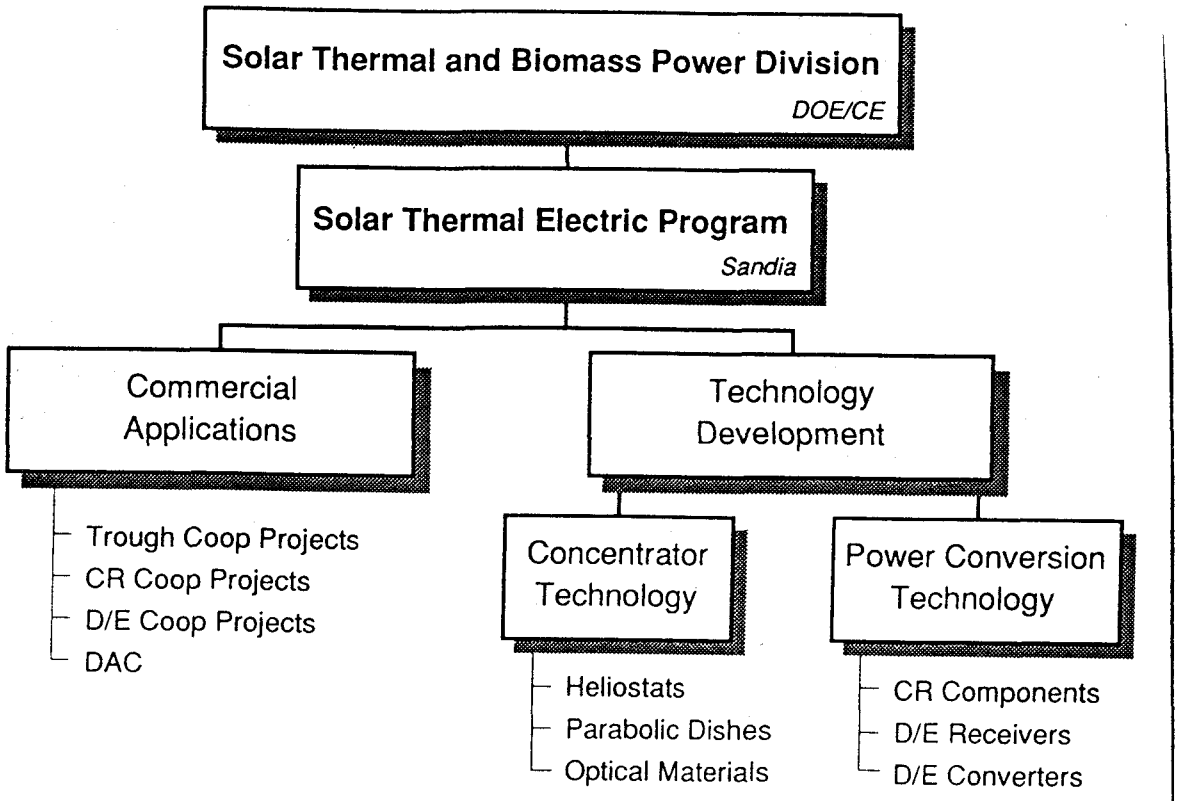
FY92 SOLAR THERMAL ELECTRIC PROGRAM

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. Concentrators
  1. Heliostats
  2. Parabolic Dishes
  3. Optical Materials
- B. Power Conversion
  1. Central Receivers
  2. Dish Receivers
  3. Dish Converter Solarization

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



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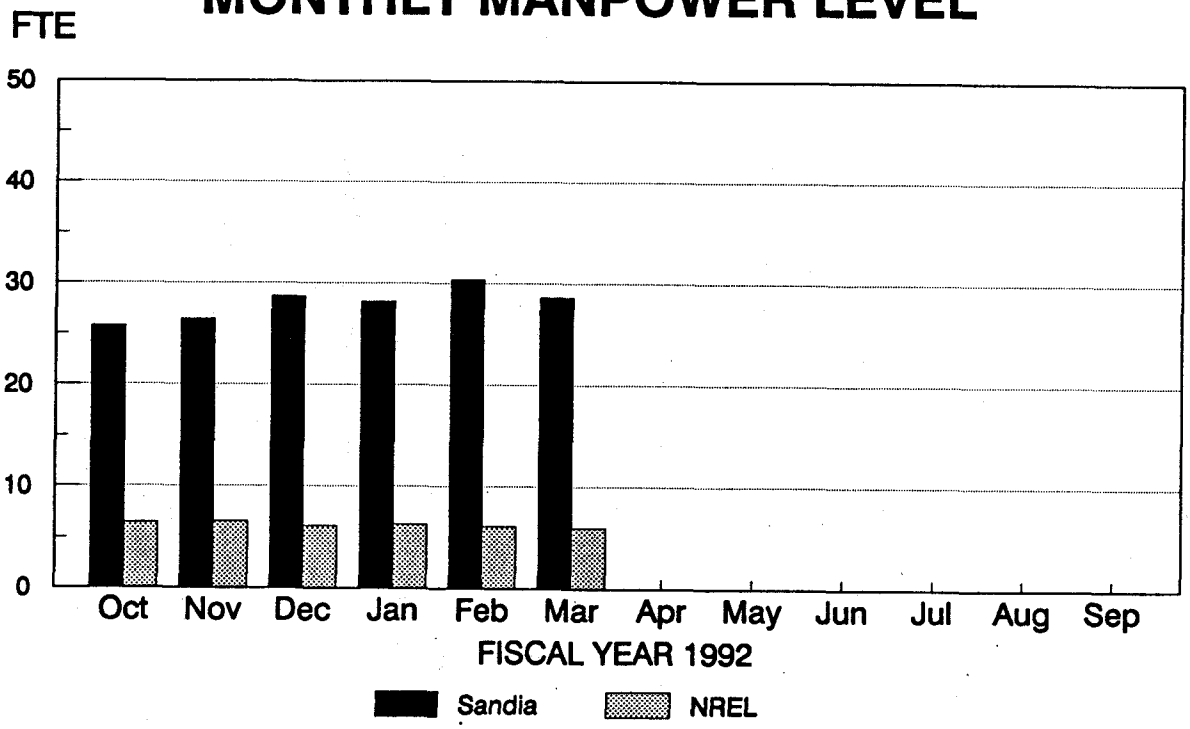
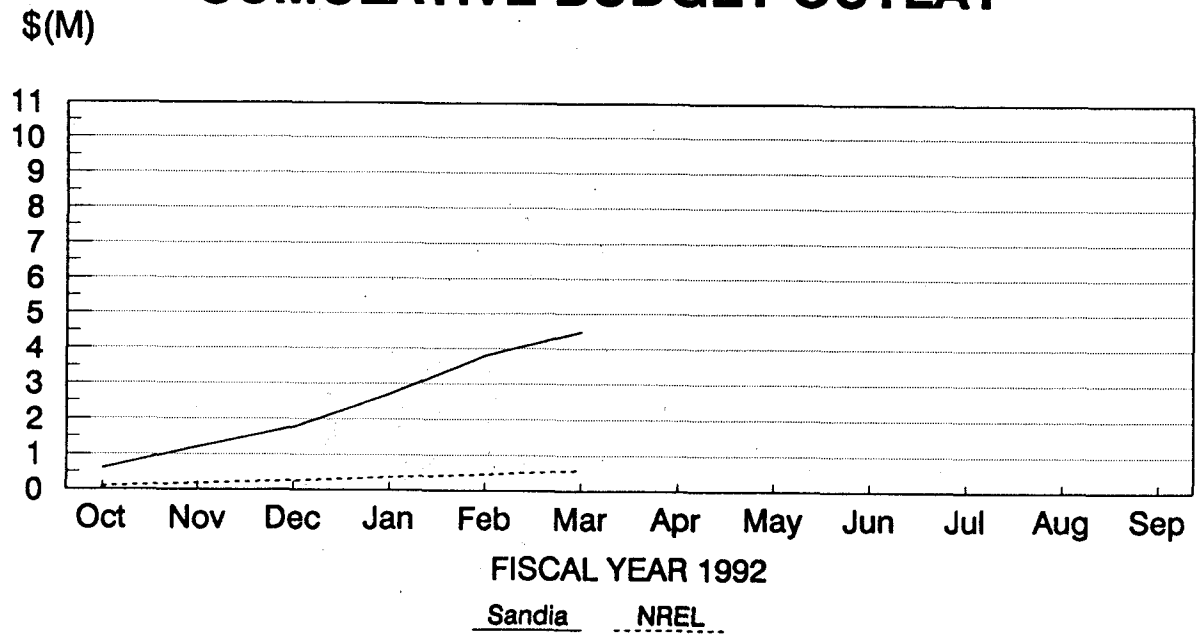
MONTHLY MANPOWER LEVEL



CUMULATIVE BUDGET OUTLAY



Procurement Summary

SOLAR THERMAL ELECTRIC SUBCONTRACTS

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1992 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IA	Molten Salt System Study	Bechtel	SNL87-5142	$217	0	0	01/92-06/92	Large	TBD	J. Chavez
IIA1	Replaceable Membrane	IST	SNL42-9690	$50	$50	--	11/89 - 2/91	Small	91-7006	D. Alpert
IIA1	Heliostat Integration	Solar Kinetics, Inc.	SNL42-9691	$100	$100	--	10/89 - 1/91	Small	90-7038	D. Alpert
IIA1	Heliostat Fabrication	SAIC	SNL54-5780	$540	$400	$140	01/90 - 4/91	--	None	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	88-7035	T. Mancini
IIB1	Volm.Rec. Furnace Test	NMSU	SNL66-9967	$45	$30	0	01/90-12/90 (Extended to 12/91) Contract completed 12/91	Univ. Paper	1992 ASME	J. Chavez
IIB1	Volm.Rec.	Bechtel	SNL96-0524	$23	0	0	0	Large	TBD	J. Chavez

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1992 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IIB2	Reflux Heat-Pipe Rec.	Stirling Ther. Motor	SNL33-3036	$245	$225	$20	04/87 - 7/91	Small	--	T. Moss
IIB3	2ndSTM4-120	Stirling Ther. Motor	SNL75-8851	$265	$265	--	04/89 - 06/90	Small	--	M. Powell
IIB3	ASCS Design	NASA LeRC	DOE Inter-agency	$6169	$1035	$1800	01/89 - 01/93	Govt--		M. Powell
IB	Dis JVP	Cummins	SNL69-7763	$7000	$1750	$1250	06/91-12/93	Large		R. Diver
IB	US-JVP	Competitive	SNLAB-8717	$10,000	0	$1258	12/92-12/97	Large	R. Diver	
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	--	K. Rawlinson
IIB2	Solar Rec. Heat Loss Testing	California Polytech	SNL02-5759	$105	$30		09/86 - 09/92	Univ.	ASME and ISES papers	A. Heckes
IIB2	Heat-Pipe	Cummins	NREL11160-01	$75			07/91	Large	--	M. Bohn
IIB3	Stirling Engine Solarization	Detroit Diesel Company	SNL67-9086	$211	$211	0	1/92-11/92	Large	TBD	M. Powell

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1992 Funds ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IC	O&M cost Reduction	LUZ Engineering Corp.	SNL12-3117	$234	234		05/91-06/92	Large	Three Reports	G. Kolb
IID	Tech Trans Documentation	Solar Energy Inds. Assoc.	SNL42-5186	$327	$187		03/90-02/92	Non-profit	Three TT Rpts.	D. Menicucci
IIA3	Direct	SAIC	NRELYF-2-11191-1	$130	-0-	$130	3/92-5/93	--	--	G. Jorgen

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

Major Milestone Schedule

For reference, milestones identified in the FY 1992 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 1992

Lab	Date	Activity-Task Reference	Descriptive Title
First Quarter, FY 1992			
SN	October 1991	IIA2	Place contracts for two facet sets for the Faceted Stretched Membrane Dish.
SN	November, 1991	IA	Complete summary of commercialization regulatory barriers.
SN	November, 1991	IB	Draft utility-scale dish/engine joint venture RFP.
SN	November 1991	IIB3	Support the DOE Modular Power Generation Workshop.
SN	December 1991	IC	SEGS O&M reduction R&D plan documented.
SN	December 1991	IIB2	Complete pool-boiler materials and methods bench tests.
SN	December 1991	IIB2	Test thermal imagery system for reflux receivers.
Second Quarter, FY 1992			
SN	January 1992	IA	Support utility consortium's development of a proposal to the California Energy Commission for Solar Two financial support.
SN	February 1992	ID	Participate in the SOLTECH 92 joint meeting.
RE	February 1992	IIA3	Contract award for alternative optical reflective material development.
RE	March 1992	IIB2	Define approach and roles for collaborative industry/laboratory investigation of non-reflux receiver development.
SN	March 1992	IIA2	Place pedestal fabrication contract for Faceted Stretched Membrane Dish.

RE	March 1992	IIA3	Second contract award for alternative optical reflective material development.
RE	March 1992	IIB2	Award contracts for hybrid receiver development.
SN	March 1992	IIB2	Complete testing and evaluation of the Dynatherm heat-pipe receiver.
RE	March 1992	IIB2	Complete Cummins/Thermacore heat-pipe fabrication and ground test of the durability receiver.

Third quarter, FY 1992

SN	April 1992	IA	Initiate Technical Advisory Committee activities to oversee the Solar Two.
SN	April 1992	IB	Release utility scale dish/engine joint venture RFP.
SN	April 1992	IC	Report issued that describes initial R&D work to reduce O&M costs.
RE	April 1992	IIA3	Select sites and document test plan for optical materials outdoor testing.
SN	June 1992	IIA2	Complete design of the 60 kW_t Single-Element, Stretched Membrane Dish.
SN	June 1992	IIB1	Complete the study of thermal storage and steam generator issues in support of Solar Two.
SN	June 1992	IC	Contract established with Kramer Jct. Company to implement full multi-year R&D plan.
SN	June 1992	IIA1	Document test results on the two large-area glass heliostats and the low-cost drive.
SN	June 1992	IIB1	Complete final report on the joint USA/German Second Generation central receiver status assessment.

Fourth Quarter, FY 1992

SN	July 1992	IB	Deliver a CPG dish/Stirling system to the Pennsylvania Energy office Thermacore test site.
SN	August 1992	IIA2	Place contracts for the fabrication of the 60 kW_t, Single-element, Stretched-Membrane Dish.
RE	August 1992	IIA3	Document alternative reflector materials R&D progress and suggested activity.
SN	August 1992	IIB1	Complete 1000-hour molten salt corrosion effects test.

SN	September 1992	IIA2	Install first set of facets on the drive pedestal at the NSTTF.
SN	September 1992	IIA2	Install drive pedestal for the Faceted Stretched-Membrane Dish at the NSTTF.
SN	September 1992	IB	Deliver a CPG dish/Stirling system to the SCAQMD test site.
SN	September 1992	IC	Issue report that describes interim R&D work to reduce O&M costs.
SN	September 1992	IIB1	Complete study of the internal film receiver concept.
SN	September 1992	IIB2	Complete validation of advanced molten salt instrumentation and salt freeze phenomena, testing.
SN	September 1992	IIB2	Complete setup and begin 10,000-hour pool-boiler bench test.
SN	September 1992	IIB2	Complete second generation on-sun pool-boiler receiver fabrication and begin testing.
SN	September 1992	IIB3	Complete Fabrication of the Detroit Diesel, 25kW power conversion system.
SN	September 1992	IIB3	Conclude test-cell evaluation of the STM4-120 engine.
SN	September 1992	IIB3	Complete final designs of ASCS selected to be commercialized.

SIGNIFICANT ACCOMPLISHMENTS SUMMARY

MAJOR MILESTONES	Planned	Actual
FY 1992		
TASK I		
• Complete summary of commercialization regulatory barriers.	11/91	11/91
• Draft utility-scale dish/engine joint venture RFP.	11/91	11/91
• SEGS O&M reduction R&D plan documented.	12/91	12/91
• Support utility consortium's development of a proposal to the California Energy Commission for Solar Two financial support.	01/92	12/91
• Participate in the SOLTECH'92 joint meeting.	02/92	02/92
• Contract award for development of alternative optical reflective material.	02/92	02/92
• Second contract award for development of alternative optical reflective material. Contractor selected and contract in DOE area office for final approval.	03/92	
• Complete CPG heat-pipe receiver fabrication/ground testing.	03/92	12/91
• Select sites and document test plan for optical materials outdoor testing.	04/92	
• Initiate detailed design efforts for the Solar Two project, pending an agreement between DOE and the utility consortium.	04/92	
• Release utility scale dish/engine joint venture RFP.	04/92	
• Report issued that describes initial R&D work to reduce O&M costs.	04/92	
• Contract established with Kramer Jct. Company to implement full multi-year R&D plan.	06/92	
• Deliver a CPG dish/Stirling system to the Pennsylvania Energy office Thermacore test site.	07/92	
• Document alternative reflector materials R&D progress and suggest future activity.	08/92	
• Deliver a CPG dish/Stirling system to the SCAQMD test site.	09/92	
• Issue report that describes interim R&D work to reduce O&M costs.	09/92	

TASK II

• Place contracts for two facet sets for the Faceted Stretched Membrane Dish.	10/91	10/91
• Support the DOE Modular Power Generation Workshop.	11/91	11/91
• Complete pool-boiler materials and methods bench tests.	12/91	12/91
• Test thermal imagery system for reflux receivers.	12/91	12/91
• Place pedestal fabrication contract for Faceted Stretched Membrane Dish.	03/92	03/92
• Contract award for alternative optical reflective material development.	02/92	02/92
• Define approach and roles for collaborative industry/laboratory investigation of non-reflux receiver development.	03/92	03/92
• Award contracts for hybrid receiver development.	03/92	03/92
• Complete testing and evaluation of the Dynatherm heat-pipe receiver.	03/92	01/92
• Complete Cummins/Thermacore heat-pipe fabrication and ground test of the durability receiver.	03/92	03/92
• Second contract award for alternative optical reflective material development.	03/92	
• Select sites and document test plan for optical materials outdoor testing.	04/92	
• Complete the study of thermal storage and steam generator issues in support of Solar Two.	06/92	
• Complete design of the 60 kW_t Single-Element, Stretched Membrane Dish.	06/92	
• Document test results on the two large-area glass heliostats and the low-cost drive.	06/92	
• Complete final report on the joint USA/German Second Generation central receiver status assessment.	06/92	
• Place contracts for the fabrication of the 60 kW_t, Single-element, Stretched-Membrane Dish.	08/92	
• Document alternative reflector materials R&D progress and suggested activity.	08/92	
• Install drive pedestal for the Faceted Stretched-Membrane Dish at the NSTTF.	09/92	
• Install first set of facets on the drive pedestal at the NSTTF.	09/92	
• Complete study of the internal film receiver concept.	09/92	

SIGNIFICANT ACCOMPLISHMENTS SUMMARY (cont'd)

MAJOR MILESTONES	Planned	Actual
FY 1992		
• Complete validation of advanced molten salt instrumentation and salt freeze phenomena, testing.	09/92 09/92	
• Complete setup and begin 10,000-hour pool-boiler bench test.	09/92	
• Complete second generation on-sun pool-boiler receiver fabrication and begin testing.	09/92	
• Complete Fabrication of the Detroit Diesel, 25kW power conversion system.	09/92	
• Conclude test-cell evaluation of the STM4-120 engine.	09/92	
• Complete final designs of ASCS selected to be commercialized.	09/92	

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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

Solar Two consortium.

Financial commitments for the Solar Two project grew closer to the $39 million goal. There are now nine utility participants: Southern California Edison, Los Angeles Department of Water and Power, Sacramento Municipal, Pacific Gas & Electric, Idaho Power, PacifiCorp (owner of Utah Power and Pacific Power), APS, SRP, and the Pasadena Water and Power Dept. The California Energy Commission will contribute $1 million to the project and California's South Coast Air Quality Management District will add $100,000. EPRI will also be a partner in Solar Two through its "tailored collaboration" program.

After a competitive procurement that included a commitment of financial support, Bechtel was selected as the project's architect/engineer. The value of Bechtel's contribution is about $1.7 million. Bechtel has extensive experience with solar power technology and is a valuable addition to the project.

Southern California Edison Co. hosted a workshop in Albuquerque on February 20 and 21 for possible industrial participants in Solar Two. The workshop was the first direct effort toward obtaining financial contributions for Solar Two from equipment suppliers. Sandia helped organize the workshop, provided briefings on DOE's R&D activities, and conducted a tour of the Central Receiver Test Facility. Over 70 individuals attended the workshop, including firms that could supply the plant's receiver, heliostats, heliostat drives, nitrate salt, pumps, valves, steam generator, controls, instrumentation, storage tanks, and operation staff. Representatives of many of the utilities that are currently members of the Solar Two consortium were present along with representatives of other utilities, DOE,

NREL, and EPRI. The goal of the workshop was to brief possible equipment suppliers on the project status and goals, the general equipment requirements and scopes of supply, and the options for financial participation in the Solar Two consortium. After the workshop, over a dozen offers of financial contributions and/or participation were provided by suppliers. Some offers were for up-front cost-sharing, while others were simply an expression of an intent to bid in any competitive procurement. The value of all the offers was about $2 million, although because of duplication and other issues, the actual value to the project is probably closer to $1 million. Evaluation of the offers for their technical merit and actual value to the project will be completed early next quarter. Additional commitments may also be obtained later in the project as part of formal requests for quotations on individual procurements.

Solar Two is currently about $2 to $3 million short of its $39 million goal.

System and receiver design workshop held.

On March 26 and 27 Sandia sponsored a workshop on plant design and receivers for solar power towers--both commercial plants and Solar Two were considered. Over 30 people attended the workshop including experts from Sandia, NREL, and industry, as well as representatives of each of the Solar Two consortium's utilities. The goal of the meeting was to identify and discuss any key issues related to the optimization of a commercial plant's design that should be addressed before a detailed design for Solar Two is initiated. The workshop was successful in raising many important issues, and the discussion among the experts was very valuable in helping to identify an approach to be taken to address each issue. Future workshops will deal with the design of the steam generator, thermal storage tanks, and salt transport system and with design standards for power towers.

The workshop also presented an an opportunity for the consortium's members to discuss the role and constitution of the Solar Two Technical Advisory Committee (TAC). TAC will serve as the Steering Committee's technical arm, and Sandia will take a lead role in coordinating TAC's activities.

Application to DOE for financial support for Solar Two consortium.

The utility members of the Solar Two consortium met in Los Angeles on March 12 to formalize the Associates Agreement, which establishes the single entity that will

enter into the cooperative agreement with DOE. A revised version of the Associate's application for financial support will be completed early next quarter.

Solar Two's heliostats.

Since Solar One was shutdown in September 1988, Sandia has monitored the status of the mirror field. In January 1990, our survey indicated that 1% of the reflective surface area of the field was lost due to failure of the epoxy bonds that attached the facets to the heliostat structure, as well as corrosion of the silvered surface of the mirrors. We noted that virtually all the facets with attachment failures had not been vented during a retrofit effort in 1984. A second survey in March 1991 indicated that the attachment failures were continuing to occur at a nearly linear rate and that lack of venting was closely linked to the failed facet attachment. In February 1992, a third survey was conducted. Results indicated that approximately 2.5% of the reflective area of the field is now lost, with about 2/3 caused by facet attachment failure and 1/3 by silver corrosion. Attachment failures were continuing to occur at a linear rate. The rate of corrosion loss, however, had increased by a factor of nine since the survey in January 1990, and corrosion was much worse on facets that were not vented.

Sandia took action to mitigate the loss of mirrors. Nearly 1/4 of the 1818 heliostats experiencing the highest loss rates were fitted with vents to allow moisture trapped inside to escape. We are also exploring the possibility of turning all the mirrors face up, which would prevent moisture inside the facet from standing on the mirror, as well as relieve the tensile stress on the epoxy bond.

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

- Continue support of SCE's efforts to form a Solar Two consortium of utilities, industry, and regulatory agencies and the preparation of an application to DOE for cost sharing the project.

- Continue technical support of SCE's efforts to define the design of Solar Two that best simulates a commercial plant and address the technical issues raised at the March 26-27 workshop. Additional workshops on other components will be planned.

SCE is planning a major press release and ribbon-cutting ceremony at Solar Two. The target date is late May.

B. Dish/Engine Cooperative Projects

Obejective: Form industry, user and government consortia which will field economically competitive prototype dish/engine solar electric systems for remote and grid-connected markets.

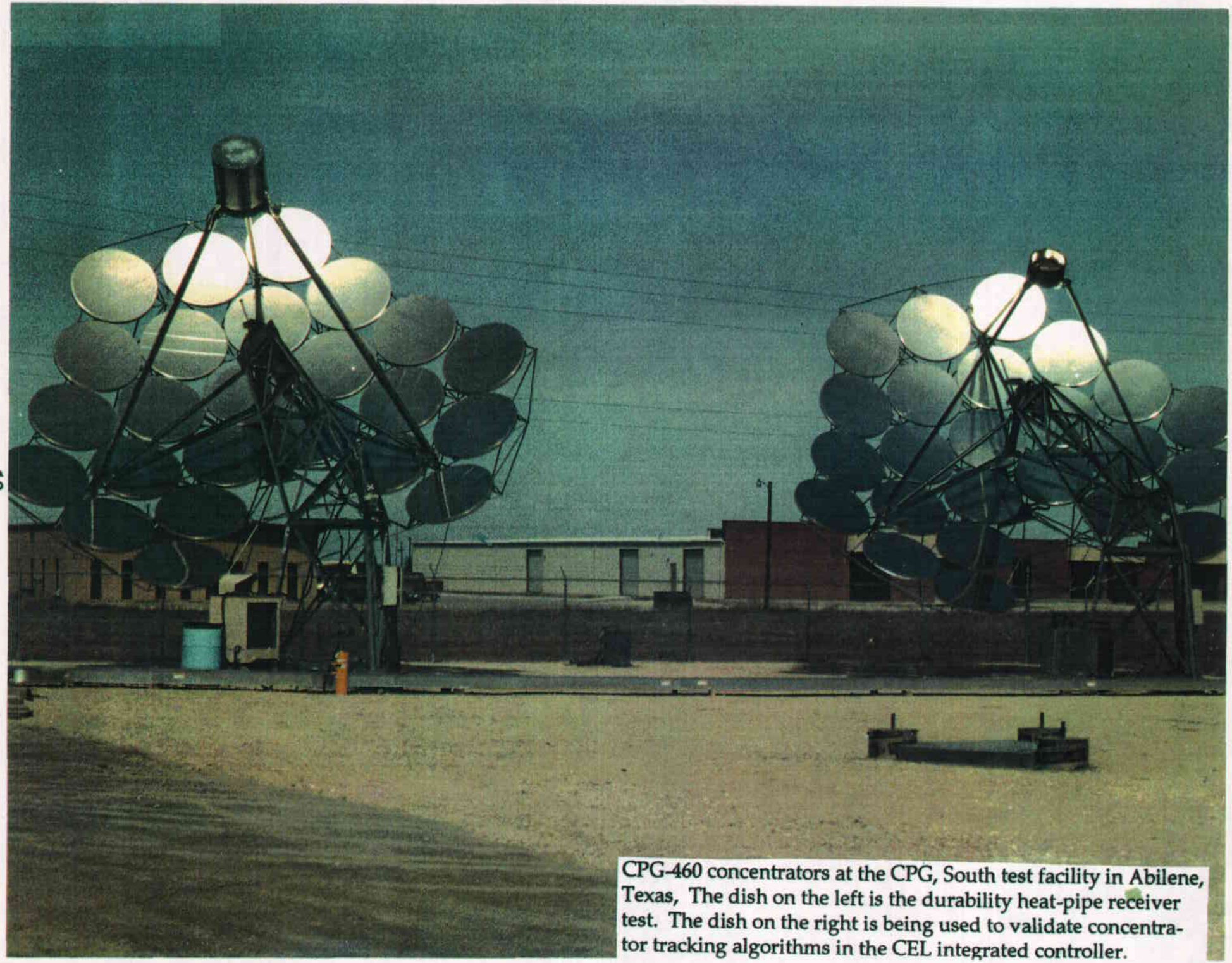
Accomplishments

Joint Venture Program Team Meeting #3 held in Abilene, Texas.

The JVP team meeting # 3 was held in Abilene, Texas on January 22, 1992. Concentrator and receiver subsystems were the focus of the meeting. Scientists and engineers from the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL) attended the meeting with the objectives of learning about the technical approach and status of the JVP and to identify areas in which the laboratories can contribute to the JVP. Wind loads on the solar concentrator and optical films development and testing are topics of vital importance to the JVP. SNL and NREL have expertise in these areas. Solar receiver development and evaluation, vibration modal analysis of the concentrator, optical evaluation of facets, and concentrator drives testing are other areas in which the laboratories can contribute to the commercialization effort.

Durability heat-pipe solar receiver accumulates hours in on-sun tests.

CPG, South continued on-sun durability heat-pipe receiver testing over the quarter. By the end of the quarter, the heat-pipe solar receiver had accumulated over 335 hours on-sun at temperature (675°C), and at full-power. Early morning on-sun startup, without the use of auxiliary electric heaters, has been demonstrated on more than 25 days. Absolutely no evidence of receiver degradation has been observed. A second CPG-460 solar concentrator was also erected and used for concentrator controls development testing. A photograph of the two CPG-460 concentrators at the Abilene, Texas test site is shown on the following page.



CPG-460 concentrators at the CPG, South test facility in Abilene, Texas, The dish on the left is the durability heat-pipe receiver test. The dish on the right is being used to validate concentrator tracking algorithms in the CEL integrated controller.

Sandia, NREL provide technical support for JVP.

Sandia and NREL continued to provide technical support for the JVP. Of note was a seminar by consultant Don Mattox which was held at the National Solar Thermal Test Facility and sponsored by NREL. Don is a former Sandian and is chairman of the Society of Vacuum Coaters. He was able to provide unique insights into the metalization industry as well as innovative approaches for the design of polymer film solar mirrors, which could be of critical benefit to the JVP as well as other solar thermal systems. Sandia is supporting the JVP in the form of equipment loans such as calibrated reflectometers, the video flux mapper system, and surplus computers to support testing. Sandia personnel and training are also being provided as necessary.

Commerce Business Daily announcement released for the utility-scale Joint Venture Program (US-JVP).

A Commerce Business Daily announcement for the Utility-Scale Joint Venture Program was released on March 26, 1992. The announcement solicits industry for potential bidders who are interested in entering into a joint venture with the objective of developing and commercializing distributed, point-focus, solar thermal systems which can be used by utilities.

Dish-Stirling Joint Venture Program reviewed by DOE Office of Program Assessment.

A DOE peer review of the Dish-Stirling Joint Venture Program was conducted in Albuquerque, New Mexico on March 10, 1992. This unplanned activity was not budgeted for in the JVP, but was graciously accommodated by CPG.

Joint Venture Programs highlighted at SOLTECH 92.

Presentations on the Cummins Dish-Stirling Development Programs and the DOE Joint Venture Programs were made by Jerome Davis, President of CPG, and Rich Diver, Technical Manager of Joint Venture Programs at Sandia, respectively, at SOLTECH 92 in Albuquerque, New Mexico, on February 19, 1992. The JVP was also mentioned by Sandia Vice President of Energy & Environmental Programs, Dan Hartley, and presented as an example of the new partnership approach

between government and industry. A kiosk describing the JVP was also displayed at SOLTECH and received a lot of attention.

Sunpower experiences setbacks and breakthroughs on the Joint Venture free-piston Stirling engine development.

In early January, 1992, the Sunpower, Inc. free-piston Stirling engine was shut down because of a heater-head stress (and safety) related problem. An approximately two-month shutdown of engine testing was needed to redesign and fabricate a new heater head and integrate it with an electric heat-pipe. Prior to the shutdown the maximum power output of the engine/alternator was 6.2 kW_e. Although this is adequate for the phase 1, 5-kW_e system, engine/alternator efficiency was a disappointing 20%. When engine testing resumed with the new heater head (partially redesigned to improve efficiency) and with a new cooler design, the engine was easily able to achieve 7 kW_e. More importantly the engine/alternator efficiency improved to 26% at 6.2 kW_e output at only 620°C. At this output, the engine stroke is a comfortable 13mm (maximum engine stroke is 14.5mm).

During the 2-month shutdown, Sunpower conducted resonance tests on the engine's power piston. The resonance test is a good simulation of loads on the bearings. After a total of 145 hours of testing, the engine was disassembled, and no evidence of distress to the bearings was observed.

After only 11 hours of testing with the new heater head, the electric heat pipe developed a leak. Investigation revealed that a small helium leak developed around one of the engine's heater tubes. Following an involved rebraze process the engine should be operational again by April 16, 1992.

Dish-Stirling Joint Venture Program Team Meeting #4 held at Sunpower.

The JVP team meeting #4 was held at the Sunpower, Inc. in Athens, Ohio on March 4, 1992. The meeting took place two weeks prior to the resumption of engine testing. Engineers from CPG, Cummins Electronics, Thermacore, McCord Heat Transfer, Sunpower, and Sandia attended the meeting. Objectives of the meeting were to review the engine and cooling system designs, and to address system integration issues. Design and materials issues related to the heater-head were also discussed.

Clever Fellows Innovation Consortium (CFIC) completed preliminary design of an alternative 5-kW$_e$ Stirling engine for the JVP.

Because of the importance of the Stirling engine to the Joint Venture Program, Clever Fellows Innovation Consortium (CFIC) was included as a parallel Stirling engine developer. In November, CPG and CFIC reached agreement on licensing and royalties for the CFIC engine. The CFIC engine technology, which utilizes flexures, virtually eliminates wear and makes possible extremely long-life engines. Cummins is paying 100% of the CFIC engine development cost. CPG will select either the Sunpower or CFIC engine for further development in Phase 2 of the JVP. The CFIC engine presented at the preliminary design review at CPG on February 4, 1992, incorporates a number of clever innovations, including an inherently low-stress heater head configuration, flexure bearings, and a low-cost electromagnet alternator.

Concentrator mirror development continued at the CPG-South.

CPG, South continued development of concentrator mirrors. The mirror rim design was finalized, and film and mirror rims were ordered. A membrane tensioning device was nearly completed at the end of the quarter. The mirror tensioning fixture uses a pneumaticaly actuated clamp to significantly speed up mirror production. The first new mirrors should be produced in early April 1992.

Cummins Power Generation finalizes drive design for the Dish-Stirling Joint Venture Program.

The diurnal drive for the Cummins 5-kW$_e$ system is based on the low-cost azimuth drive concept developed under the heliostat program at Sandia. The drive design for the CPG-460 concentrator designed by Winsmith is smaller than the original heliostat design and incorporates a 3-inch hole through the center to accommodate cables. Castings for the drive housing and finish machining of the drive components are the critical path activities for the first system delivery, currently scheduled for July, 1992. In order to support the tight schedule, Cummins and Winsmith have agreed to share the cost of expediting fees for the drives. Outside machine shops near Winsmith's facility will be used. Sandia plans to test one of the first drives to determine its ultimate strength. The declination drive design was also finalized during the quarter.

Sandia completes development of a "2f" Mirror Quality Assurance (QA) Technique to support mirror manufacturing QA by Cummins.

Development of a technique to evaluate the optical quality of stretched-membrane facets was completed by Sandia. The approach uses the same hardware and software used in the Sandia Beam Characterization System (BCS). In this technique, a specially designed target is placed at the radius of curvature of the mirror (two focal lengths). It is therefore called the "2f" technique and is capable of providing rapid measurement of mirror quality. The Beamcode software is capable of providing the necessary data reduction of the vast amount of video based data. Sandia's objective is to provide the equipment, techniques, and training to support mirror production at CPG, South scheduled for April 1992. A mirror facet developed under the DOE Innovative Concentrator Program is being used for the development process. The technique will also be provided to SKI and SAIC to support mirror development in the Sandia Faceted Dish Program.

Request for Proposal (RFP) package for a Utility-Scale Joint Venture Program completed.

The RFP for a utility-scale joint venture program (US-JVP) was completed, passed through Sandia management review, logged into the Sandia purchasing system, and delivered to Sandia's contracting representative for release. The RFP will be sent to respondents of the Remote Power JVP, responders to the recent Commerce Business Daily announcement, and other interested industrial concerns.

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

- The JVP team meeting # 5 will be held in Albuquerque, NM on April 23, 1992. Concentrator and receiver subsystems and system integration will be the focus of the meeting. Sandia will also demonstrate a reliability model developed by Sandia's probability risk assessment groups for potential application to the CPG 5-kW_e system.

- CPG, South will continue durability heat-pipe receiver testing. The second CPG-460 solar concentrator will be used for systems integration testing in Abilene, TX.

- Sandia will provide technical support to the JVP in the following areas: loan of additional calibrated reflectometers, loan of a video flux mapper system, loan of another surplus computer for engine data acquisition. Sandia personnel and training, will also be provided as necessary. Sandia also is working with CPG and Thermacore personnel on testing the durability heat-pipe receiver on test bed concentrator #1 with the infrared camera system. This facility provides the ideal tool for determining the limits of the receiver design.

- Sandia will begin transferring the 2f and flux mapper technology to CPG, South.

- Sunpower will demonstrate 100 hours at full power output on their prototype solar engine.

- The RFP for the utility-scale joint venture program (US-JVP) will be released.

C. Parabolic Trough Cooperative Projects

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

Accomplishments

Phase 1 contract completed.

The costs associated with O&M have a significant influence on the economic viability of the SEGS technology. Currently, O&M costs account for approximately 20% of the plant electricity costs. Reductions in O&M costs (expressed in cents/kW-hr) would enhance the profitability of the SEGS plants, as well as the marketability of other solar power technologies currently being developed by Sandia for the Department of Energy (DOE). An example of a DOE technology that would benefit is solar central receivers. Central receiver power plants have many of the same subsystems contained within a SEGS power plant and the O&M of these subsystems would be similar.

This work is being performed in two phases, each governed by a separate subcontract:

1. A study of the historical O&M costs at the LUZ plants is conducted and these costs are categorized. This information is used to develop a multi-year strategy to reduce the costs of the most costly O&M categories. Upon completion of the strategy, research and development (R&D) is begun to reduce the cost of one or more of the important O&M categories.

2. The full multi-year strategy developed in Phase 1 is implemented. Work will be performed to complete the R&D begun in Phase 1 and on the remaining important O&M categories.

The Phase 1 contract was completed during the present quarter. All agreed upon deliverables from Kramer Junction Company (formally LUZ Engineering Corporation) were received by Sandia. These are listed below:

a. A draft report describing the historical O&M costs at SEGS 'plants (4th quarter, FY91).

b. A draft report detailing the O&M cost reduction strategy to be implemented during Phase 2 (1st quarter, FY92).

c. A SEGS LS2 parabolic trough was installed at the NSTTF "(2nd quarter, FY92).

d. A progress report describing the installation of the LS2 trough at Sandia and work conducted at SEGS 6 and 7 to reduce O&M costs associated with valves (2nd quarter, FY92).

During the present quarter, an 8.3 meter section of a SEGS LS-2 parabolic trough was installed at the NSTTF. During the next several months, the optical efficiency of the trough will be determined, as well as the thermal losses from the heat collection elements. This information will be used to determine optimum replacement intervals for the heat collection elements given a variety of degraded conditions.

Also during the quarter, the turbine bypass valves at SEGS 6 and 7 were inspected. Historically, these valves have been leaking and causing a drop in Rankine cycle efficiency for these plants. A new operation and maintenance strategy is currently under evaluation to assure that these valves adequately perform their function. Since this was also a problem at the Solar One central receiver plant, the solution to this problem will also help central receiver technology.

Planned activities next quarter

- Sandia will begin testing the LS2 parabolic trough.
- Sandia will attempt to establish a new contract with Kramer Junction Company to perform Phase 2 work. The cost share between Kramer Junction Company and Sandia will be 50% by each organization.

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 system.

Support: The Design Assistance Center activities reported here are generally supported by (1) the Solar Thermal Electric Program, (2) the Solar Thermal Industrial Program, or (3) both programs. They are reported together for completeness and in recognition of the fact that boundaries are often not distinct within each activity.

Accomplishments

Talk presented on Sandia's Design Assistance Center at Colorado Springs.

C. P. Cameron presented a talk on Sandia's Design Assistance Center at a Solar Process Heat and Technology Workshop in Colorado Springs, Colorado.

The workshop was organized by NREL and NMERI in conjunction with the Army Corps of Engineers. It was attended by personnel from military installations, primarily in Colorado. There was interest in solar systems, since federal facilities

are being required to reduce their use of conventional energy sources. While federal orders promote shared-savings arrangements, several attendees expressed concern about procurement problems associated with either third-party or shared-savings arrangements. The problems are associated with procurement regulations designed to prevent out-year obligations if, for example, a user facility were shut down with many years remaining on a third-party contract. The government might be expected to pay the system owner for out-year energy that would not be used.

Assistance to IST to prevent wind damage to solar field at Tehachapi.

Sandia has been assisting Industrial Solar Technology (IST) regarding the performance of the solar trough hot water system in Tehachapi, California. In late 1991, high winds have begun to create problems with the system. The 3/8" all-thread rod that connects one trough to the next is bending and breaking, and, troughs are bending along their leading edge. Although the damage is relatively minor at this time, left unaddressed, the problem could become significant and field performance would be reduced due to the reduction in operable troughs.

At IST's request, Sandia engineers are assisting in developing a strategy to assess the wind induced problems. Sandia's engineers began work by analyzing the strength of the 3/8" rod and recommending changes to the design. Sandia will also analyze the wind loads that are causing the trough edges to bend. Recommendations for correction will be provided to IST during the next quarter.

Sandia continues support to Gould Incorporated, Foil Division.

Gould is in the process of upgrading its 60,000 square foot solar system that is used to produce hot water for a copper foil manufacturing process. The upgrade should be completed within a year or two and, when completed, is expected to produce electricity savings of about $120,000 per year. In the last nine months of 1991, the solar system, operating with about 75% of the field, displaced over $60,000 of electricity. This included all of the refurbishment costs such as 16 new flexhoses, new control and logic boards, and some motors. The goal is to have over 90% of the system operating by the end of this year. Sandia will continue to provide technical consulting throughout the course of the project.

Technical consulting for the California Energy Commission (CEC).

Sandia engineers are involved in a number of CEC activities. The first involves the proposed solar project at the prison in San Luis Obispo. Sandia engineers are working with BESICO regarding the instrumentation for monitoring the solar system that will be installed. The second effort is to complete a boiler efficiency manual to assist the California officials to determine boiler efficiency for the plants where solar systems are to be installed. An accurate measure of the boiler efficiency is important because it is used to value the energy produced by the solar system. A third effort is to install a solar hot water performance monitoring system at Galt. This evacuated tube collector system was purchased the State of California and they are interested in having a neutral third-party measure its performance.

Sandia agrees to consult to SMUD on new solar initiative.

Sandia is consulting with SMUD on the technical details of a new initiative to encourage the use of solar systems in their utility district. The effort includes a rebate program for installing new systems. SMUD is writing specifications for selecting systems and contractors. Sandia is helping with this effort.

Technical support given to the New Mexico State Energy and Minerals Department (NMEMD).

Sandia is continuing to work with the NMEMD to provide technical assistance and consulting regarding the use of solar thermal technology in the state of New Mexico. Sandia is currently providing technical consulting regarding the implementation of the State's comprehensive energy policy.

An effort is also underway in which Sandia engineers will help train State of New Mexico engineers on the methodology to identify and refurbish non-operating solar thermal systems within state institutions. The first refurbishment project involves a community college in northern New Mexico. Sandia will assist the State on the techniques to bring the existing non-operational system into production.

Support given to City of Albuquerque.

Sandia engineers are consulting with Albuquerque officials in an effort to reduce the city's energy use through conservation and renewable technology. Sandia representatives are serving on an advisory committee that is forming recommendations to the city council. After the council acts, the committee will discuss how to implement the final decisions.

Support provided for Sandia's Technology Transfer Programs.

The solar thermal programs are consulting to Sandia's Technology Transfer Program about the application of solar thermal technology. Currently, engineering support is provided on several projects: a) The development, test, and evaluation of a solar powered ice melting system for cow-watering troughs, b) helping initiate minority owned businesses in the solar field, and c) advising various interested organizations on the benefits of solar energy technology. These efforts are funded outside of the solar thermal programs.

Technical assistance provided to State of Arizona.

Sandia has been asked to provide engineering consulting to the Arizona Department of Commerce concerning the refurbishment of an existing, non-operational solar trough system at a school. The system was built in the early 80's and was never used. It is currently being considered for heating the building space and indoor pool. The proposed refurbishment would involve simplifying the system to heat water. Solar program engineers along with a local A&E firm have examined the solar system and estimate that the conversion will cost about $20,000 to $30,000, and that there is a high probability of success. It is proposed that the cost of the refurbishment will be shared between the State of Arizona, APS, and the DOE.

Training provided for Albuquerque public schools personnel.

Sandia engineers will be assisting the Albuquerque Public School (APS) system to upgrade some solar systems that are currently not operating. The assistance will include direct technical consulting on specific systems as well as conducting a workshop for APS engineering and maintenance personnel. The purpose of the

effort is to help APS personnel to repower existing non-operating systems and to install new ones.

Solar thermal technology applied at Kirtland Air Force Base.

Sandia is continuing to work with Kirtland AFB officials regarding a third-party financed solar system. The purpose of the effort is to help prepare a RFP that the Air Force is planning to release that will request proposals for a third-party financed solar powered steam generation system to augment an existing boiler at the Kirtland AFB East Officer's Club. This effort is a follow up to meetings that were held last year to discuss the potential of solar thermal technology on the base. It is expected that the RFP will be released next quarter and that the selection of a contractor could be made in late summer.

Refurbishment underway of Solar System at VA Hospital.

We are assisting engineers at the Veterans Administration Hospital in Albuquerque, NM to renovate and to return an existing solar system into service. This system, which was installed in 1985, has been shut down since around 1986 because it produced excessively hot water and caused pressure/temperature relief valves to open. Last year, Sandia began working with VA engineers to restart the system. One-half of the system operated manually last quarter and is now under automatic operation. VA engineers are now consulting with Sandia about modifying the hot water system to use the remainder of the solar system. After it is 100% operational, the system could save about $12,000 per year in gas usage.

Consulting given to the Government of Mexico.

Sandia's Photovoltaic Design Assistance Center is coordinating a technical consulting effort to help the Mexican government apply renewable technologies in Mexico. As part of the effort, the solar thermal program is providing consulting about solar thermal technologies. Currently, we are assisting in the design of a walk-in, fish storage bin that will be cooled with ice from Energy Concepts ice maker. Another effort involves the development of a 50kW solar thermal electric project in Puertos Lobos. A used ORC engine coupled with IST troughs is being considered for this demonstration project. There are also two smaller efforts: 1) outlining case studies of successful solar thermal projects involving industrial

applications, and 2) preparing an outline of suggestions for solar thermal technology briefings that can be presented by program personnel.

Testing of the Energy Concepts ice maker continues.

The DOE, as represented by Sandia engineers, is continuing to work with Energy Concepts to test the Mini- and Full-Isaac solar ice makers. The testing has followed a plan that was jointly developed by DOE and Energy Concepts. The results of the tests are being used by Energy Concepts to improve the design of the system. Additional tests may be conducted on the Double-Isaac, a larger version of the Full-Isaac, six of which are scheduled to be sold to the Mexican government.

Testing of the BSAR solar distiller.

Sandia has been testing the residential solar distiller developed by BSAR. The testing has is based on a plan that was jointly developed by DOE and BSAR. The test results will be used by BSAR to improve the design of the system. Tests of the first BSAR model are complete and suggested design changes have been implemented by the manufacturer. A new model is currently being assembled for testing next quarter.

SOLTECH 92 Meeting

Sandia and NREL, co-sponsors for the SOLTECH 92 meeting held on February 17 - 20, 1992, in Albuquerque and was responsible for organizing two solar thermal electric symposia and in designing and constructing an exhibit on solar electric technology.

The solar thermal electric sessions focused on central and distributed generation and 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.

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 program documents were distributed.

Solar educational modules developed.

The STDAC, working in cooperation with Sandia's educational outreach project, is developing a set of classroom modules designed to educate students about the fundamentals of solar energy. Three modules are being prepared for various grade levels including 4-5, 7-9, and high school. Each module contains a video tape that explains about solar energy collection fundamentals, an outline of classroom activities and experiments, and a description of how to build some simple solar collectors models. The 4-5 grade module was completed last year. The 7-9 grade module was recently completed and will be ready for the 1992/93 school year. The high school package will be completed next year. Copies of these educational modules will be available through Sandia's Teacher's Resource Center. The solar collector models associated with each module will be available for loan to teachers in the Albuquerque.

Miscellaneous Consulting Efforts

Other on-going technical assistance projects include:

-- New Mexico Solar Energy Industries Assoc.
-- Solar Weatherization Assistance Program
-- U.S. Army

On-going test and evaluation projects include:

-- Pegasus
-- IST
-- Aquavit Foundation

Any significant progress on these activities will be reported next quarter.

Planned activities for next quarter

Current plans are 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.

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

Procurement Summary: The DOE, through Sandia, is continuing to work with the Solar Energy Industries Association to develop documentation materials such as films, brochures, and poster materials that show the potential for solar thermal technologies. To date, work on this one-year effort is complete. A one-year extension to this contract was completed last August.

STDAC CONTACTS THIS QUARTER:

Technology/Subj	Requester	Affiliation
Central Receiver	Robin Grewall	Solar India Group
	Craig Simpson	Ontario Hydro, Canada
	Jeff Antisdel	Nevada Energy Commission
	Dr. B. S. Negi	Indian Institute of Technology
	Dr. A. K. Maitra	Nat'l Thermal Power Corp., India
	Heinz Schreiber	Fed Ministry for Environ.-Austria
	Wolfgang Struwe	Dir-Fed Environ. Agency-Austria
	Ingrid Tomasitz	Fed Ministry for Environ.-Austria
	Rosy Weiss	Fed Ministry for Environ.-Austria
	Robin Grewall	Solar India Group
	Jeff Antisdel	Nevada Energy Commission
	Ken Hoogakker	Individual
	Christine Susany	University Texas at El Paso
	P. H. Vaidya	Industrial Credit & Invest. of India
Dish	Dough Wood	Solar Steam
	Dr. Conrad Heins	Jordon College Energy Institute
	Bob Rogers	PKI
	John Johnson	Photon Energy
	Ron Tafoya	State of New Mexico
	Mark Steele	Individual
	Robert J. Radway	Radway & Associates
Dish/Engine	Claudio Estrada-Gasca	Laboratorio de Nacionale Solar
	Rob Songster	Individual
Dish/Stirling	Bob Shaubach	Thermacore, Inc.
	Harry Braun	Hydrogen Energy Associates
	Dr. Walter Bienert	Dynatherm
	J. W. Holliday	Information Technology Solutions
	Paul Hesse	Individual
	Brad Johnson	PEPCO
	Bob Lettin	Stirling Thermal Motors
	Andreka Geffroy	University of Mexico
	Mark Steele	Individual
	Burton Krakow	NYSERDA
	Scott Lush	The Appleby Group
	Brad Johnson	PEPCO
	Jack Noble	Stirling Thermal Company
	Alec Jenkins	California Energy Commission
Education	Rachel Skolneck	Futures
Flat Plate	Brian K. Johnson	State of New Mexico
	Bernard Steierman	Nippon Electric Glass
	Allen Carroezza	Schofield Solar
	Joe Allegro	InterSol Systems
	Ron Sopher	Virginia Dept. of Agriculture

General Information	Bill Wahl	Rockwell International
	Cathryn Lenkiewicz	High School Student
	Kathleen Gibson	High School Student
	Adriana Campillo	High School Student
	Walter Bienert	Dynatherm
	Mark Bel	Union Electronics
	Bob Turner	University of Nevada
	Robert Alei	Individual
	Bob Shaubach	Thermacore, Inc.
	Doug Wood	Solar Steam
	Hugh Edmonds	Individual
	Scott Markman	Individual
	Sammy Moran	Moran Electric
	Matthew Baca	State of New Mexico
	Dave Lillard	Solar Engineering Energy Report
	Ann Polansky	SEIA
	Andy Walker	Individual
	Chuck Whitaker	Individual
	Larry Krom	Energy Study Group of Spring Green
	Kirk Collier	Individual
	Thor Stronsted	Individual
	Robert Radway	Consultant
	Bob Alei	Consultant
	Scott Lush	The Appleby Group
	Ruth Feldgrill-Zankel	Fed Ministry for Environ.-Austria
	Gerhard Reiweger	Austrian Embassy, Washington, DC
	Mike Minten	City of Albuquerque
	Bob Rogers	PKI
	Bob Bird	Individual
	Don Cavenar	Individual
	Floyd Gallagher	Hanford
	Tim Modidine	Individual
	Jeff Webb	New Mexico Land Office
	Joel Goodman	Individual
	Randy Gee	IST
	John Stroyls	Georgia Southwestern College
	David Malina	Individual
	Glen Sawyer	Individual
	Seung Kim	Student
	Paul Sharp	Individual
	Wendy L. Miller	Southern Cal Edison
	Ian Andrews	Pacific Corp.
	Jorge M. Huacuz Villamar	Inst. de Investigaciones Electricas
	John Stroyls	Georgia Southwestern College
Heat Pipe Receivers	Anthony J. Mulac	Individual
	Dipl-Ing. O. Goebel	DLR Inst. for Technische Thermodynamik
	David Wolf	Dynatherm
High Performance Wick Structures	Bob Burns	Astronaut
	Bryan Layda	ERB
	Ray Bennett	Hogan Industries

Irrigation Systems	Rex Martin	Nebraska Technical Assistance Center
Receiver Testing	Bob Curcio	BDM International, Inc.
	John Mall	Northrop Corporation
	Rob Newman	Applied Physics Laboratory
	Thomas Pylkanen	Atlantis Energy, Ltd.
	Tom Salas	BDM International, Inc.
	Deanne Iwan	Mitre Corporation
	Vernon Goldberg	WGA
	David Gorman	ATS
Solar Absorp. Cooling	Mecos Faberson	California Energy Commission
	Brian Schepers	Barns & McDonald Engineering
	Tim Lam	Individual
Solar Collectors	Joel Goodman	Individual
Solar IPH	Ed Ney	Jones, Lall and Davis
Solar Therm Systems	Abricas Aqoi	University of Mexico
	Claudio Estrada	Individual, Mexico
	Jack F. Stuart	Individual
	Peter Hines	Chums Research
	George Dey	Iowa State University
	Robert Salerno	Ethicon
	Jim Kramer	Ethicon
	Bruce Curry	Ethicon
	Russell Sheward	Ethicon
	Martin Plugge	Ethicon
	Joe Miller	Ethicon
	Kathleen Dolan	Ethicon
	Martha Buddecke	Johnson & Johnson
Troughs	Britt Reed	Utah, Division of Environment
	Ron Richmond	Individual
	Steve Hester	PG&E
	Jack Stewart	Jamaica West
	Carlo LaPorta	UST
	Frank Mancini	Arizona Energy Commission
	David Hodgsen	Individual
	P. H. Vaidya	Invest. Corp. of India
	Dave Kearney	Kearney & Associates
	Hank Price	LUZ Engineering Corp.
	Brian Schepers	Burns & Mc Donnell Engineering
Wind & Solar Energy	Yacob Mulugetta	Individual/Student

Industrial Contacts

Optical Materials Industrial Contact List for 2nd Quarter FY92

CONTACT	ORGANIZATION	COMMENTS
D. Mattox	IP Industries	Mirror materials
K. May and R. Gee	IST	Alternate reflector materials
K. Beninga	SAIC	Alternate reflector materials
B. Klein	Business Factors, Inc.	Alternate reflector materials
M. McGlaun	CPG	Mirror materials
D. Wood		Mirror coatings
M. Taylor	CPG	Mirror materials
T. Evans	Dow Chemical	Alternate reflector materials
R. Aresti	Solar Energy Corp.	Emittance measurements

II TECHNOLOGY DEVELOPMENT

A. Concentrator Technology

1. Heliostats

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

Accomplishments

There were no significant accomplishements in the area of heliostat development this quarter.

Planned activities next quarter

- Testing and evaluation of SPECO's 200 m^2 heliostat, STS's 150-m^2 heliostat, and Winsmith's low-cost heliostat drive will continue.
- Testing and evaluation of SAIC's 100-m^2 stretched-membrane heliostat will continue.

2. Parabolic Dishes

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

Accomplishments

Placed contract for fabrication of the drive pedestal and support structure for the Faceted Stretched-Membrane Dish.

A contract was placed with WGAssociates of Dallas, Texas, on March 24, 1992, for Phase 2 fabrication and installation of the drive pedestal and facet support structure for the Faceted Stretched-Membrane Dish. The Phase 1 detailed design, which was completed in December, comprises the pedestal, azimuth and elevation drives, tracking controls, facet support structure, and the power-conversion-

assembly support structure. The design balances the weight of the receiver/engine with that of the facet support structure to reduce loading on the azimuth and elevation axes of the drive.

The Faceted Stretched-Membrane Dish drive pedestal will be installed for testing at the NSTTF in Albuquerque, New Mexico. Twelve facets each from Solar Kinetics, Inc. (SKI) of Dallas, Texas, and Science Applications International Corp. (SAIC) of San Diego, California, will be installed on the pedestal at different times for test and evaluation.

The structure is scheduled for installation, check out, and final acceptance in Albuquerque in late September. SAIC will complete the delivery of their twelve facets to Sandia in late June 1992, and SKI will deliver their twelve facets in late July 1992. Facets will be tested at Sandia for compliance with specifications before they are installed on the dish.

Reviewed replacement of the optical film on the 7-meter diameter optical element.

The optical film that was used on the 7-meter diameter, Single-Element Stretched-Membrane Dish was an aluminized polyester that had no protective overcoat. It was not intended to be a long-term optical surface but merely a short-term demonstration of the technology. The film actually lasted about a year and one half, exceeding our expectations.

The long-term film, which we have anticipated using on the full-scale dish, is an aluminized polyester film with a protective polyester overcoat made by Dunmore. Unfortunately, during the last year, Dunmore has stopped making the film. Rumors indicate that the reason Dunmore suspended manufacture of the film was that it had performed poorly in the field due to failures of the protective overcoat. Whatever the reason, the loss of the Dunmore film leaves us without a viable optical film for the Single-Element Stretched-Membrane Dish.

By way of background, one should note that ECP 305 is not a viable film for use on the Single-Element Stretched-Membrane Dish because it is a brittle, acrylic film. The optical surface of the single-element dish must be elastic so that it can be drawn down by vacuum until it rests on the surface of the contoured, stainless steel membrane. During an earlier phase of the project, we investigated using a

compound membrane made of ECP 305 laminated to polyester but rejected this approach because of the difficulty of transferring the loads and strain across the seams. Even if the load transfer problem could be solved, this approach would require a very large vacuum to draw the heavy, compound optical membrane down into contact with the pre-formed stainless steel membrane.

A possible solution to the problem of finding an elastic optical film for the single-element dish has been suggested by Solar Kinetics. SKI proposes to use the unprotected aluminized polyester as the optical film with a second, overlaying fluorocarbon film to protect it. The primary question about this approach is whether or not the fluorocarbon film can be *welded* together to form a membrane. SKI is currently investigating this and, if it appears to work, we propose to make replacement membranes for the 7-meter diameter optical element using this approach. If this approach is successful at the 7-meter scale, then it could also be used on the full-scale prototype dish. In addition to testing the two-membrane approach on the dish, we will send samples of the membrane system to NREL for evaluation in Weather-O-Meter and QUV tests. It should be noted that this approach could also accommodate other optical films such as 3M's SA 95 (silver) or SA 85 (aluminum) films, which are not rated for outdoor application. The true long-term solution to the optical film issue may involve one of several alternative film approaches currently being investigated by NREL.

Modified the NASA tracking structure to accommodate testing of facets for the Faceted Stretched-Membrane Dish.

The redesign of the NASA tracking structure for on-sun testing of facets for the Faceted Stretched-Membrane dish has been completed. It will be implemented during the next quarter and testing of the SAIC facets will be initiated.

2-f look-back technique demonstrated.

A simple 2-f look-back technique has been demonstrated at the NSTTF for quantitative evaluation of near-spherical facets. The technique involves using a video camera to record the image of a target located at a two-focal-length distance along the axis of the facet. The target is made of a number of circumferential rings representing discrete ranges of facet slope error. The camera views the image of the target in the facet through a hole in the target's center.

The technique has the advantage of providing a quantitative measure of the facet's slope error without going through an extensive ray-trace mapping of the facet. Results are quickly and readily available without extensive manipulation of the data. The technique could prove to be an important tool for assure the quality of facets during the manufacturing process.

Planned activities for the next quarter

- Complete modifications to the test structure for on-sun testing of facets for the Faceted Stretched-Membrane Dish.
- Delivery by SAIC of six facets for the Faceted Stretched-Membrane Dish.
- Begin testing of SAIC facets for the Faceted Stretched-Membrane Dish.
- Make decision on the replacement of the optical film for the 7-meter diameter stretched-membrane dish.
- Conduct Final Design Review for the Single-Element Stretched-Membrane Dish.

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

Several subcontract awards were made to industrial partners for cost shared, collaborative alternate reflector materials R&D.

A subcontract has been awarded to Science Applications International Corporation (SAIC) for a project entitled "Directly Deposited Reflective Surface Development". The proposed approach will use a commercial coating material, which has demonstrated outdoor weatherability, as a levelizing undercoat and a protective top layer. This coating will be applied to thin metal substrates suitable as structural membranes for solar concentrators. A reflective metal layer will be applied prior to

the final top protective coating. SAIC has had good initial experience with similar constructions which have been developed for NASA applications. Other companies that have teamed with SAIC for the present effort include Allegheny Ludlum Steel Corp., SDC Coatings, Inc., and Sheldahl Corp.

A second subcontract has been awarded to Industrial Solar Technology Inc. (IST) for "Reflective Materials Research to Develop Teflon Films for Solar Applications". Their approach is a metallized polymer whereby an alternative polymer film, Teflon , is used as the front surface material. Like the current polymer film of choice (acrylic), Teflon is an inherently weatherable material. Unlike acrylic, however, it is nonhygroscopic and does not expand under highly humid conditions. This should provide greater resistance to delamination failure. In addition, Teflon has good barrier properties and (because it is an inherently low surface energy film) may be less susceptible to soiling problems compared to other polymer films. IST is teaming with DuPont and Sheldahl Corp. for this project.

A third concept has also been recommended for funding. This proposal was submitted by Dow Chemical Company of Midland, Michigan and uses alternating coextruded layers of low-cost, commercially available transparent thermoplastics to produce all- polymeric reflector materials. Reflection occurs because of constructive interference of light incident on the polymer stack. High specular reflectance across the solar spectrum can be obtained by tuning the refractive indices and number of layers of materials. A major advantage of the concept is that degradation of optical performance due to corrosion is eliminated. Another attractive feature of this approach is that such reflector materials can be directly thermoformed into usable structures, thereby reducing costs associated with support elements. Efficient broadband solar reflectors are envisioned that are fabricated from a high-speed, low-cost technique that has been commercially demonstrated. Dow has elected to pursue an advance patent waiver prior to initiation of the proposed work. They are presently interacting with DOE/Chicago to obtain the waiver.

An analysis of material and processing costs of metallized polymer reflectors was completed by Business Factors Inc.

A presentation was made at NREL on January 9 by a consultant firm, Business Factors Inc. (BFI), engaged in a subcontracted analysis of material and processing costs of metallized polymer reflectors. NREL and Sandia staff were in attendance.

A final report was delivered to NREL in March, 1992. Major conclusions and recommendations by BFI included:

- Costs of silvered PMMA reflectors comparable to such present state-of-the-art materials (whose cost in low volume production is roughly $2.25/ft2) is projected to be in the range of $1.40-$1.60 per square foot for reasonable production volumes and market competition.

- Based upon both technical and economic considerations, a top metallized PET film having a protective overcoat may provide a promising alternative to second surface silvered PMMA reflectors. Several vendors who were interviewed were optimistic that such a construction could ultimately achieve the optical durability requirements.

- Several suggestions with regard to metallized film specifications were provided. By using specifications which are already familiar to metallizers, laminators, and film suppliers, additional costs can be avoided.

NREL staff have provided support for the Dish/Stirling Joint Venture Project (JVP) in a number or areas.

Staff attended a Dish/Stirling Joint Venture Program (JVP) Team Meeting at Cummins Power Generation (CPG) South in Abilene, Texas in January 1992. Discussions of interest were held with regard to proposed reflector materials intended for use with CPG's concentrator subsystem. The intended material construction is an aluminized 7-mil thick polyethylene terephthalate (PET) substrate film with an UV cured top hard coat.

Subsequent to the meeting, additional recommendations and documentation of material options and test results were provided to CPG. Optical characterizations were carried out at NREL on unweathered reflector materials provided by CPG. These samples were 7-mil thick polyethylene terephthalate (PET, a thermoplastic co-polyester) substrates having a thin reflective layer of sputtered aluminum and a .1-mil thick protective hard overcoat. Solar weighted hemispherical reflectance values of 87-88% were found. Specular reflectance at 650 nm was measured to be about 81-82% for full collection angles of 4-12 mrad. Hemispherical transmittance through the multi-layer material was also measured. Roughly 1% of the light at UV wavelengths (350-400 nm) is transmitted by the stack. Such transmittance may be

detrimental to the performance of the polyester substrate material during service conditions. These results have been conveyed to CPG. Candidate samples have been subjected to accelerated weathering to allow evaluation of optical durability.

In an additional support effort for the JVP, NREL sponsored a seminar held in Albuquerque, New Mexico on March 9, 1992. Don Mattox, technical director of the Society of Vacuum Coaters, provided an overview of the state-of-the-art in the polymer film, metallization, and protective coating industries. Each of these areas were reviewed in terms of how they apply to potential solar reflector applications. A summary was also provided of industrial expertise in terms of who is doing what, how they are doing it, and what relevant R&D is being carried out. Problem areas as they relate to each aspect of reflective film construction were identified. Staff from NREL, SNL and CPG were in attendance. The main points of interest resulting from this seminar include:

- Abrasion-resistant, optical quality, hard top coating candidates should include inorganic coatings (such as SiO, MgF2, SiO1.8, and Al2O3) as well as organic coatings (for example, organosilicone and acrylic). Organic/inorganic composite coatings were also suggested.

- Most hard top coatings have relatively high surface energies which gives rise to soiling of the surface and makes cleaning difficult. Outdoor weathering (oxidation and UV surface exposure) will exacerbate this problem. An innovative potential solution to this problem would be to incorporate a renewable low surface energy coating to help protect the hard coat. Several commercial products were identified for consideration.

Candidate advanced reflector material samples have been fabricated in-house at NREL, optically characterized, and subjected to accelerated exposure testing.

These samples consist of polyethylene terephthalate (PET, a thermoplastic co-polyester) substrates (Hostaphan 4660 from Hoechst-Celanese) having a 1000Å reflective layer of sputtered silver. A protective back coating is also sputter deposited between the silver and the PET. Several sources (BFI and Don Mattox) have suggested SiO2 as a protective top coating for solar reflector application. In addition, it is believed that samples provided by LUZ, which have exhibited excellent optical durability in accelerated tests at NREL, incorporate SiO2 as a top

layer. Consequently, top protective hard coats of SiO2 of various thicknesses (100Å, 250Å, 500Å, 1000Å and 4000Å) were sputter deposited over the silver layers discussed above. Solar weighted hemispherical reflectance values ranged between 65-69% (for 4000Å SiO2) to 95 % (for 100Å SiO2). Thicker coats are expected to provide greater optical durability; thickness must obviously be traded off against initial reflectance. Specular reflectance measurements indicate very good specularity, independent of the thickness of the SiO2 layer. Candidate samples are being subjected to accelerated weathering in both the Weather-Ometer and Solar Simulator exposure chambers to allow evaluation of optical durability.

A new cyclic tunnel test has been initiated to investigate concerns with ECP-305 laminated to curved substrates.

Previously, eleven samples of ECP-305 were mounted without edge tape on flat aluminum (18"x24"), thermally treated at 80°C for 65 hours, and then bent to a 70" radius of curvature. The samples were immersed in water for 152 days and they had not tunneled after that time. Upon removal from the water one sample quickly delaminated over a large area and after drying for one day two additional samples also delaminated over large areas. Other samples had minor delaminations mostly from interior points of imperfections that had developed during initial immersion in water. None of the samples developed the finger-like tunnels that are representative of earlier types of failures.

Based upon the findings discussed above, a new delamination experiment has been initiated. Five curved (70" radius of curvature) samples each of the following constructions were prepared (all samples are ECP-305 on bare aluminum substrates, 18"x24", razor cut):

- No heat treatment, no edge tape 80°C heat treatment (65 hr.) after bending, no edge tape
- 80°C heat treatment (65 hr.) before bending, no edge tape
- 80°C heat treatment (65 hr.) before bending, ECP-244 edge tape
- 80°C heat treatment (65 hr.) before bending, Tedlar edge tape

All samples are being cycled between 27° water and a 50° drying chamber three times per week. After one cycle, all five curved samples having no heat treatment and no edge tape had experienced delamination failure. After three additional cycles, no other failures have occurred.

Outdoor testing of optical materials.

NREL researchers have developed an outdoor testing site selection strategy and have documented it in a draft report and a conference paper. The report describes the outdoor testing program, the site selection criteria, the site selection process and a test plan of materials targeted for initial exposure testing.

Through preliminary phone discussions, several utility companies have expressed their willingness to take part in this program by providing site locations and personnel to maintain sites. These companies include the Los Angeles Department of Water and Power, the Sacramento Municipal Utility District, Utah Power, and Idaho Power. Several new contacts in addition to some follow up contacts are currently being made. Once all the data is collected concerning utility interest, site characteristics and cost, a prioritized selection of outdoor testing locations will be made and site activation initiated.

Site activation will require installation of the test racks and any necessary site preparation, the installation of any needed phone or power lines, and the installation of any needed meteorological data acquisition equipment. Once the sites are in place and active, NREL researchers will begin an outdoor exposure testing program of materials outlined in the test plan. This program will provide much useful data on the "real-world" durability and performance of advanced optical materials for solar thermal electric applications. It will also contribute much needed information correlating real-world outdoor exposure data with accelerated weathering data.

Planned activities for next quarter

- Subcontracted alternate reflector R&D initiatives will continue.
- Parallel/complementary in-house efforts on alternate reflector materials will continue; candidate constructions will be prepared, optically characterized, and subjected to accelerated and real-time durability testing.
- Milestone IIA3, "Select sites and document test plan for optical materials outdoor testing," will be completed.

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 published.

The molten salt pump and valve final test report was published last quarter.

Bechtel begins work on the Thermal Storage and Steam Generator Study contract.

A kick-off meeting was held at Bechtel last quarter to initiate the Thermal Storage and Steam Generator Study. Sandia contracted with Bechtel to evaluate design, cost, and warranty issues associated with molten salt thermal storage and steam generator designs. Information on these issues is necessary to define the optimal design for a 100 MW_e plant. The Utility Studies, completed in 1988, proposed a baseline design for all the major subsystems in a central receiver power plant. However, the thermal storage and steam generator are two subsystems in which a number of design issues have been raised.

This past quarter Bechtel began placing contracts with the subcontractors (vendors) who will provide input on the designs for hot tanks and the steam generators. There has been a delay in Bechtel placing contracts with the vendors because of the terms and conditions passed down for Sandia/DOE. The problems are with the conflict of interest terms. It appears the through discussions with DOE that the problems have been resolved. The study has been delayed approximately two months.

Design specifications for central receiver power plants addressed.

Southern California Edison (SCE) has established a contract with Solar Power Engineering Company (SPECO) to prepare design standard for central receiver power plants. The document and its contents will be the basis for the design of the

Solar Two plant and to future molten salt central receiver systems and component design.

A meeting to kick off the work was held at Sandia last quarter. Representatives from SPECO, SCE, Sandia, and SAIC attended the meeting. SPECO will prepare an outline for design standards for the entire central receiver molten salt plant. The current scope of work calls for detailed design standards to be established for molten salt components only (e.g., pumps, valves, heat trace, etc.), other systems will be detailed later.

Sandia is supporting SCE in their contract with SPECO, and Sandia will provide review and input to the standards. The detailed design standards on the molten salt components are to be completed in six months, in time to support the initial design of Solar Two.

Fabrication of the molten salt corrosion tests begins.

Sandia, at the request of SCE, will be conducting experiments to determine the suitability of molten nitrate salts, with chloride levels between 0.2% and 0.7% by weight, for use in central receiver power plants. The motivation for these experiments is the interest in Chilean nitrate salts, which may be significantly cheaper (as much as 40% cheaper) than the current salt source, but have relatively high levels of chlorides. Experimental results will show effects on material corrosion and the long-term stability of the salt.

Last quarter a test plan was prepared and sent out for review. In addition, the fabrication of the "pots" which will contain the molten salt and material coupons was initiated. The testing will be conducted at the National Solar Thermal Test Facility. There will be two vessels with ten kilograms of salt for each of six different salts. Each salt will be tested in a carbon steel vessel at 400 ^{o}C and a 304 stainless steel vessel at 600^{o}C. The vessels will contain metal coupons which will be analyzed periodically to determine corrosion effects during the 4000 hour test period. The salt to be used in the testing was provided by the Chilean Nitrate Salt company.

The experiment assembly is currently being completed.

Second Generation Central Receiver Study reporting still under discussion.

The second generation central receiver study as been reviewed by experts in the US and Europe. The Sandia and DLR study participants are currently determining how to best resolve the reviewer comments.

A presentation on this study was given at the DOE peer assessment.

Fabrication of Bechtel's volumetric air receiver begins.

The contract with Bechtel to design and fabricate a volumetric receiver absorber, to be tested at the Plataforma Solar, was placed last quarter. This contract calls for Bechtel to fabricate a nichrome knit wire mesh volumetric receiver (they have already designed it) to be tested on the test bed at the Plataforma Solar de Almeria. However, the scheduled testing of this receiver is on hold pending US approval for involvement in the IEA and the IEA's agreement to test the absorber. No work has been initiated on the modeling of volumetric receivers because of the uncertain US involvement in the IEA.

A presentation on the volumetric air receiver program was given at the DOE peer assessment.

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

- A meeting will be held to review the progress on the thermal storage and steam generator study.
- A review of the volumetric receiver design and test program will be held next quarter.
- A meeting to refine the molten salt system standards will be held next quarter.
- The molten salt corrosion testing will begin next quarter.

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/Thermacore durability heat pipe testing continued

The Thermacore heat-pipe receiver is a key element in the Cummins 5-kW dish-Stirling system. Previous receivers have shown significant progress, but continued difficulties have centered around the absorber wall-wick bond. Thermacore appears to have solved the problem, and Cummins began testing the second Durability Heat Pipe last quarter. Cummins has a very aggressive schedule to deliver complete systems this summer.

Due to excellent weather and all-day operation including some weekends, Cummins South is ahead of schedule on testing the Durability Heat Pipe. As of March 31, the heat pipe had been subjected to over 335 hours on sun at vapor temperatures greater than 670°C. All of this time is with all 24 mirrors focused on the receiver. No indications of hotspots, dryouts, or other damage have occurred. Prior receivers showed damage in the first 20 hours, and were run at reduced power. The present receiver is started cold (no preheating) when the sky is clear in the early morning. The receiver has survived more than 25 such startups. The 500 hour test goal should be reached in mid May, depending on weather.

Dynatherm heat-pipe receiver tested.

The Dynatherm receiver testing at Sandia has been completed.

The Dynatherm heat-pipe receiver was funded by Cummins for possible application to the 5 kW dish-Stirling system. The receiver uses Sandia-provided 316L stainless steel domes and a screen wick assembly. Cummins specification was for 30kW throughput, and the Dynatherm design point is nearly 40 kW throughput.

The receiver testing began last quarter, and was performed on the Sandia 60kW$_t$ solar furnace facility. The receiver was demonstrated for representatives of Dynatherm, Thermacore, and DOE in January. The receiver exhibited dryout tendencies in some startup sequences, apparently due to the low elevation (horizontal) of the dish in the furnace mode. A re-priming technique was developed and demonstrated. The receiver developed a leak during the sixth startup, due to dryout and over temperature. Evaluation of the receiver after testing indicated that the receiver design is credible. Several assembly changes were suggested to improve performance during startup and at the very low elevation angles required by furnace operation. Dynatherm is currently evaluating the design for extension to 75 kW$_t$ power throughput levels. The test results are being documented in a paper for the IECEC conference in San Diego, in August.

Completed construction and began testing four new bench-scale NaK boilers.

Four additional bench-scale pool boilers have been constructed and testing is well underway at Sandia. This is an extension of the work completed in the last quarter. The tests are part of an effort to evaluate materials and methods for the next-generation liquid-metal reflux-pool-boiler receiver. The materials and methods that are under consideration have been selected based on their potential for long life and economical operation. The selected materials are Haynes Alloy 230 for the vacuum envelope and NaK-78 for the heat-transfer fluid. The methods under consideration are various surface modifications and added gases to stabilize boiling and control hot-restart behavior. In the last quarter, laser-drilled holes and 1/4"-diameter sintered-powder-metal coatings were tested; none met the requirements for stable boiling at any temperature, and inert-gas addition and test-vessel tilting reduced but did not eliminate boiling instability.

The new bench-scale boilers include electric-discharge-machined cavities, a Thermacore-fabricated sintered-powder surface, three Friction-Coating sintered-powder surfaces, and a screen overlay of one of the previously-tested powder coatings. So far, only the sintered-powder surfaces have been tested. Excellent boiling stability was obtained with all of them at 750 and 700°C. No clear effect of tilt was seen. With added gas, stable boiling was achieved in some cases at temperatures below 600°C. Hot-restart tests on the sintered-powder coatings have just begun, with no satisfactory results to report yet.

Development of a 75-kW heat-pipe solar receiver continues.

Because of the current thrust to have an on-sun test of the STM4-120 engine by the end of this calender year, Sandia has accelerated its internal efforts to develop a 75-kW heat-pipe solar receiver. Over the past quarter, two approaches for constructing a reliable 75-kW receiver have been devised, and a program is now under way to fully develop the receiver systems. The major difference between the approaches is the manner in which the arteries for the receiver's wick system are constructed. Figure 1** shows the construction of the artery options. The open artery system is capable of transporting large quantities of the liquid metal working fluid with relatively low pressure drops and it is easy to construct. The packed artery system is more difficult to construct, however, the packed artery will reprime itself if a void ever develops in the artery structure.

Figure 2** illustrates how the two artery options will be used in a 75-kW solar receiver system. With an open-artery network, separate artery branches will be linked to a common central manifold that allows liquid to pass from one artery to the next. The screen wick tab on the artery is used to attach the artery system to a distribution wick on the receiver's evaporator surface. A similar approach will be used to attach the packed artery network to a receiver's evaporator surface.

Techniques for constructing an open artery system have been developed and successfully demonstrated. Screen covered evaporator domes that were developed under an earlier contract with Stirling Thermal Motors will be used in constructing a full-scale heat-pipe solar receiver. Fabrication of a full-scale, 75-kW_t receiver is now under way, and a receiver for calorimetry testing is scheduled to be completed near the end of the summer quarter FY92.

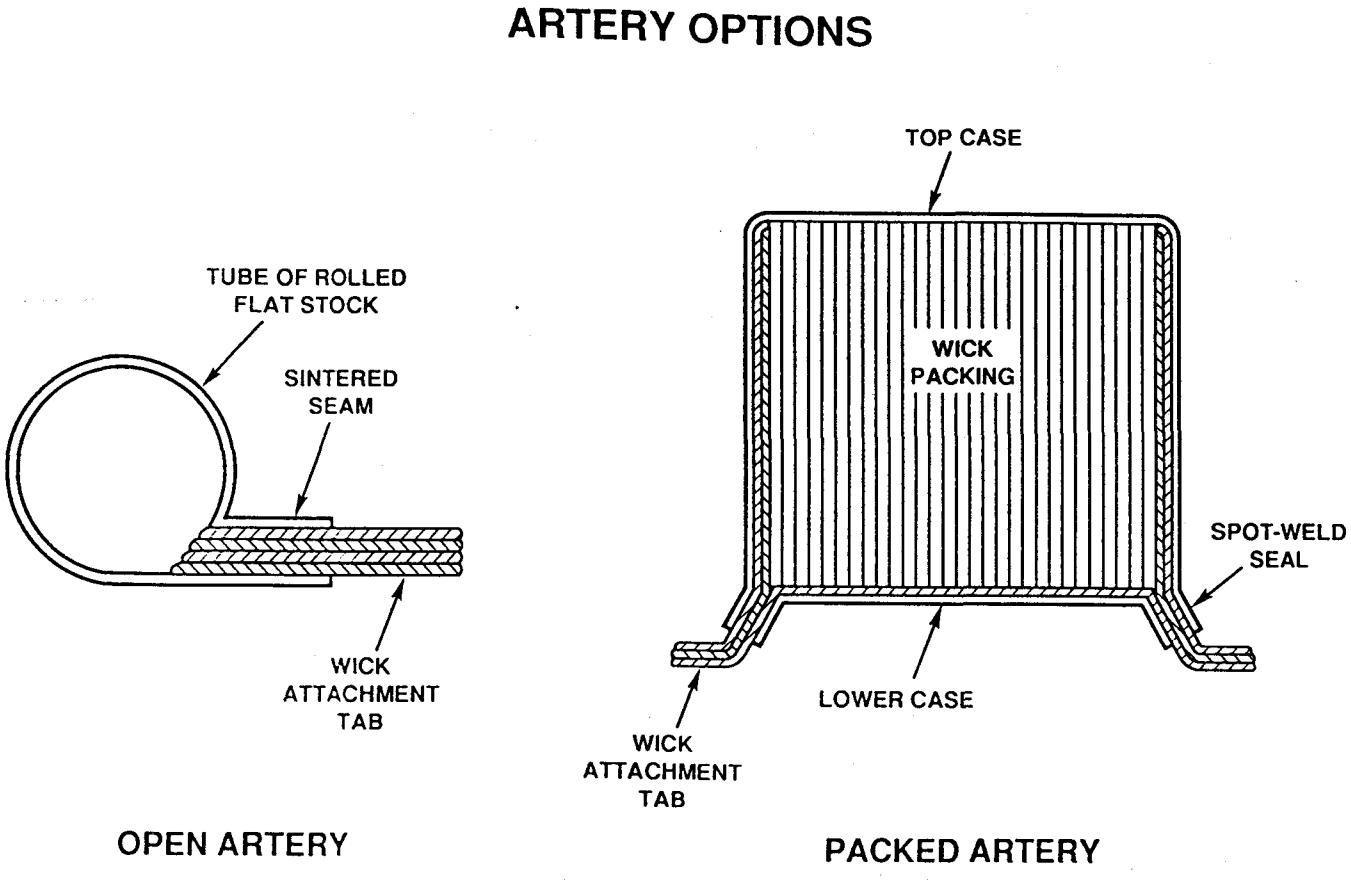


Figure 1. Cross-sectional view of two options for creating an artery structure in a heat-pipe solar receiver.

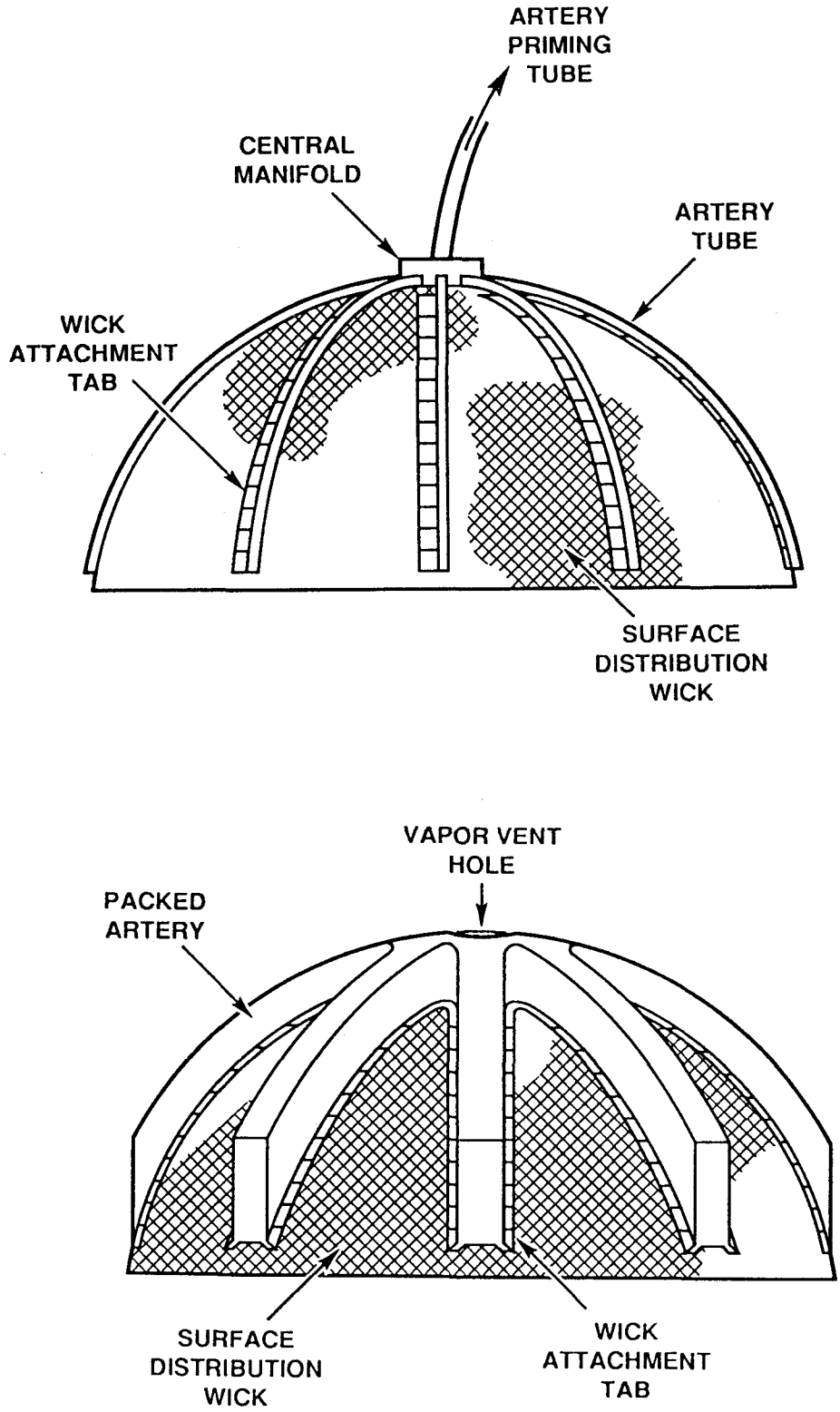


Figure 2. Side views of receiver wick structures that use an open artery design (top) and a self-priming packed artery design (bottom).

Construction of a bench-scale heat-pipe receiver.

Construction of a bench-scale receiver for testing the open and packed artery options is nearly completed. Results from the test will be used to determine the best approach for constructing an artery network on a full-scale receiver.

Components of the bench-scale system are illustrated in Figure 3**. The system was made by slitting a 1-3/4 stainless tube in half, and then sintering four layers of screen on the inside surface of each half of the split tube. An open artery structure is spot welded to one half of the split tube and a packed artery is attached to the other half. A liquid collection system in the top part of the heat pipe prevents condensed liquid from flowing directly onto the screen covered surfaces. The two sections are then welded together and a charge of sodium is added to the system after thermocouples are brazed to the outer surface.

Once fabrication on the bench-scale pipe is completed, the system will be subjected to a series of tests to determine the operating limits of the open-artery and packed-artery wick designs. Quartz halogen lamps will be used to put roughly 1800 watts of energy on a 3-cm by 10-cm patch of the heat-pipe. Liquid sodium must flow up the artery and across the screen covered surface to cool the heated patch. These tests will model the most severe operating conditions that a full-scale receiver system will encounter. Following these tests, a decision will be made about the best option for constructing a wick structure in a full-scale, 75-kW heat-pipe receiver system.

BENCH - SCALE ARTERY TESTS

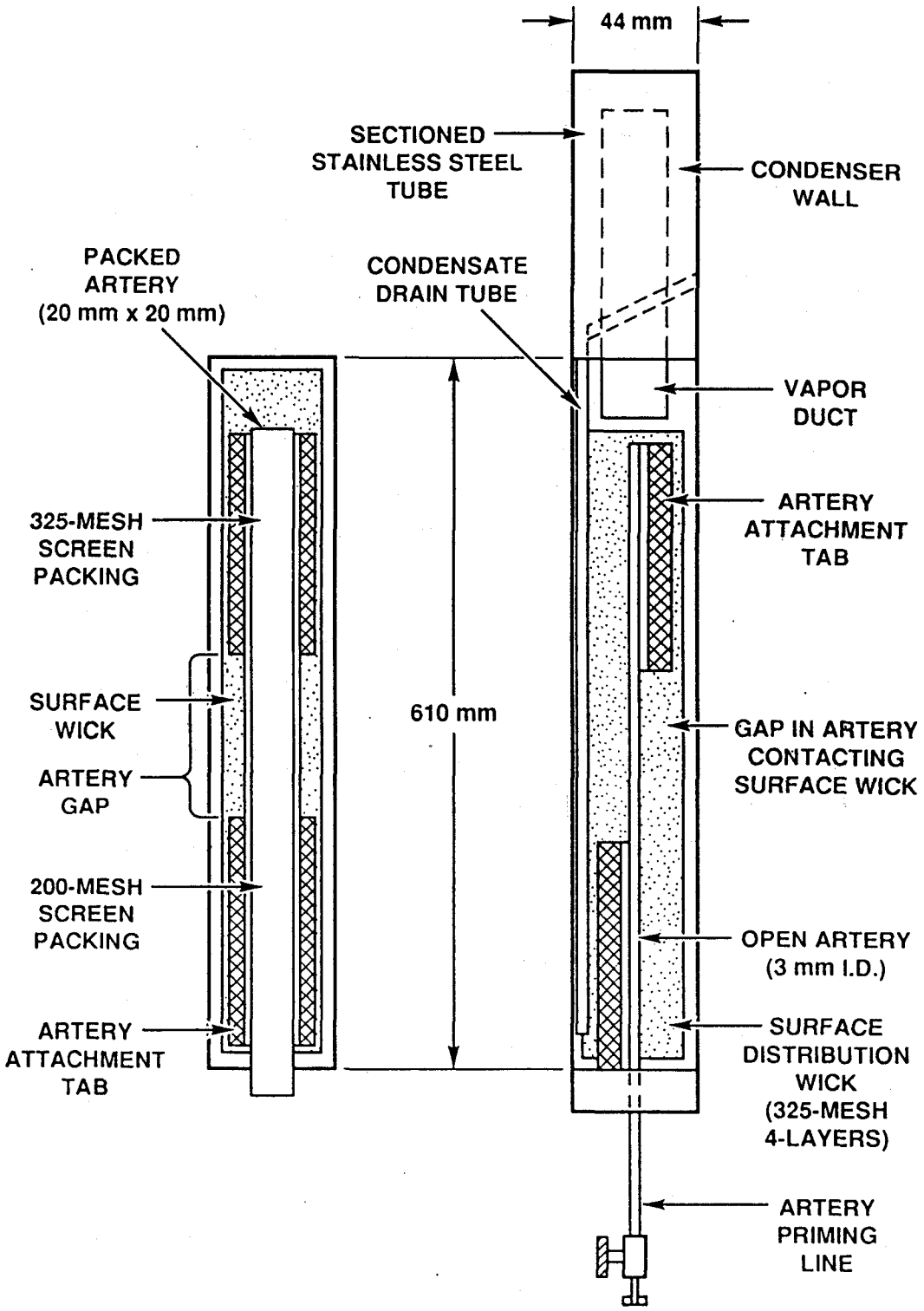


Figure 3. Construction of the bench-scale heat-pipe that will be used to test the performance of open and packed artery designs.

Requests for quotes for 75kW$_t$ heat-pipe receivers released.

Requests for quotes for a current technology 75kW$_t$ heat pipe receiver were submitted to Thermacore. This receiver will use the technology developed for the 5 kW$_e$ (30 kW$_t$) system, and extend it to operate the STM engine on Sandia's TBC and solar furnace. NREL will contract bench-scale development, while Sandia will contract for two on-sun receivers, one with a calorimeter, and one for the STM integrated package. The Thermacore receiver was selected as the concept with the greatest probability of success in providing a receiver for the STM engine integration system in this FY.

The requests have been considered by Thermacore, and a response is expected in the first week of the next quarter. Thermacore now has a business agreement with Cummins, requiring the contract for solar-related hardware to come through Cummins. The details of this agreement delayed the responses.

Completed design of 2nd-generation NaK steam-cleaning system.

Based on the successful demonstration of a prototype system for the reactive steam cleaning of NaK-contaminated hardware, design of a 2nd-generation system has been completed. This system is being designed as a permanent installation that will be safer and much more convenient to use than was the prototype. With most of the parts now on hand, assembly will begin as soon as the final long-lead items are delivered.

Stirling Thermal Motors receiver development program continues.

Stirling Thermal Motors (STM) is continuing to develop a heat-pipe solar receiver with their own internal funds, and, to encourage this mutually beneficial program, Sandia is providing limited assistance to STM's effort.

Sandia engineers visited STM and evaluated their current receiver approach. Sandia also provided a modified copy of their wick evaluation program to STM for application to their current receiver configuration. The code was modified to evaluate the self-priming artery currently under consideration. STM was unable to deliver a bench-scale heat pipe for testing at Sandia this quarter.

Joint work statement prepares for advanced receiver development with Cummins Power Generation.

Researchers have prepared a draft Joint Work Statement (JWS) for the Solid Receiver Task. The JWS has been submitted to CPG for their comments and revisions. In this task, NREL will collaborate via a cost-shared project with Cummins Power Generation (CPG) to develop a non-reflux receiver for dish/Stirling applications. The idea was originally submitted to NREL by CPG as an unsolicited proposal with the intent of developing an alternative to the heat pipe receiver concept. Since the work plan involved a number of elements to which NREL could directly contribute, CPG and NREL agreed that a collaboration was a good approach. A three-phase plan is envisioned. In the first phase, NREL will investigate several potential approaches. This investigation will involve literature searches, discussions with material suppliers, and thermal analyses. For the most promising candidates, materials testing will be performed in the laboratory and at the High Flux Solar Furnace to determine expected lifetime of the proposed materials of construction. If satisfactory, a preliminary technology assessment will be performed so that a fair comparison can be made with the heat pipe concept. Assuming a decision is made to proceed to Phase II, NREL will fund CPG to design, fabricate and ground test a full-scale receiver based on the concept. CPG will then perform on-sun testing at their facility to provide performance and durability data. Based on these data, NREL will update the technology assessment to allow CPG to decide if the concept should be dropped, tested further, or if it is ready to be commercialized. Phase III would see CPG carrying out the steps necessary to place the concept in the field in commercial applications. During the quarter, we investigated alternative contracting mechanisms for pursuing this activity, including a cost-shared research project and a Cooperative Research and Development Agreement (CRADA). Based on the scope of the study, the relative contributions of each organization, and a number of other factors, it was decided to pursue the project as a cost- shared research activity.

Winning proposals selected for hybrid receiver solicitation.

During this quarter, the selection of two winning proposals was made. The first team consists of Cummins Power Generation (CPG) and their subcontractors Thermacore and Cornell University. The CPG team will pursue a heat pipe receiver design. The second team selected is Stirling Technology Company (STC) and subcontractor Kessli Associates. The STC team will investigate hybridization

of a pool boiler receiver. During the quarter, subcontracting has reached a resolution on several contractual issues that needed to be resolved prior to contract award. Subcontracting completed the work necessary to make the two awards and the package has been submitted for legal and DOE approvals. Work under this subcontract will be executed in two phases. In the first phase, to be completed in FY92, both firms will complete the design of their respective receiver concepts. In the second phase, to be started in early FY93, the firms will fabricate their receivers and participate in receiver testing to be performed at the NREL High Flux Solar Furnace. Southern California Gas Company has committed to a 20% cost-share contribution to the Hybrid Receiver Programs via direct participation with the two awardees.

DOE peer review diverts program resources.

A significant effort was expended on preparation and presentation of the receiver projects for the DOE peer review in March.

Planned Activities for Next Quarter

- **Continue Cummins durability heat-pipe receiver testing.**

  Cummins will continue to test the new durability heat pipe in Abilene. After at least 100 hours at the 675°C operating temperature, Thermacore will begin fabrication of receivers for the first delivery systems. This should occur during the second quarter. The testing goal is 500 hours at 675°C, which is expected to be reached during the third quarter. The receiver testing is supported through the Sandia joint venture program.

- **Pool Boiler Bench Testing**

  Testing of the four new bench-scale boilers will be completed. The most important remaining objective is to determine the added-gas composition to control hot-restart behavior.

  Design of the 10,000 hour (lifetime) bench-scale test will be completed and assembly of parts will begin.

- **Complete design and order next-generation pool-boiler receiver parts.**

A design review of the next-generation Sandia pool-boiler receiver will be completed, and a contract will be let for parts fabrication.

- **Sandia heat-pipe receiver.**

  Construction of a full-scale receiver will continue in anticipation of on-sun calorimetry testing by the end of FY92.

  The Sandia bench-scale heat pipe receiver is scheduled to be tested in early April.

- Award contracts for hybrid receivers.

  The contracts will be placed and design and fabrication efforts will begin. A kickoff meeting is planned as soon as the contracts are placed. Bench-scale testing and on-sun receiver design should be completed in this next quarter.

- **Steam cleaning.**

  The next-generation steam cleaner design will be implemented. Hardware fabrication will be completed and testing will begin.

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.

Accomplishments

Detroit Diesel Corporation awarded contract for solarization and packaging of STM engine.

A contract to package a STM4-120 kinematic Stirling engine for on-sun testing with the SNL Test Bed Concentrator (TBC) was placed with Detroit Diesel Corporation on January 28, 1992. The total contract cost is $265,000 with 24% of the cost shared by DDC. The power conversion system package includes a solar receiver, Stirling

cycle heat engine, electrical generator, mechanical and electrical interfaces, cooling system, and control system.

The contract statement of work includes design, fabrication, and assembly of all parasitics, interfaces, and components required for use in an on-sun test program. The package will be tested using a direct-flame heat input system and a quartz lamp array prior to delivery at SNL. The contract calls for delivery of the power conversion system, spare parts, and operations manual to SNL nine months from the contract initiation date. Installation and testing at SNL is not included in the current statement of work.

Kickoff Meeting for engine solarization contract held at SNL.

A meeting was held to discuss the technical requirements for the Detroit Diesel Corporation power conversion system (PCS). A draft Interface Control Document (ICD) was issued that specifies the mechanical and electrical interfaces between the PCS and TBC. The document was discussed in an effort to eliminate vague, ambiguous, or undefined requirements. The document will be reviewed and revised periodically as the PCS design evolves and will be used to guide the design effort.

Fabrication of 40-tube sodium evaporators for STM4-120 kinematic Stirling engine testing begins.

Fabrication of two sets of sodium evaporators for STM4-120 engine testing was initiated in January. The evaporators will be integrated into the STM engine located in the SNL engine test facility. The evaporators are sodium heat pipes which will simulate the heat transfer conditions between heat pipe solar receivers and a heat engine. Combustion of natural gas will provide the thermal energy for the system. The engine-evaporator test setup will be used to test the condenser section of the engine, the vapor ducts, and the liquid return system.

Compatibility tests complete at Stirling Technology Company.

Stirling Technology Company has completed a 10,000 hr. NaK compatibility test on six test capsules. The capsules have been shipped to NASA, Lewis Research Center for evaluation.

Contract to revise preliminary design placed with Cummins Power Generation.

A contract to revise the Cummins Power Generation preliminary design for a 25 KWe advanced solar conversion system was placed in February by NASA, LeRC. The contract calls for Cummins to revise the design to meet the cost and performance requirements for the ASCS. The design is scheduled to be completed and reviewed in September, 1992.

Planned activities next quarter

Complete evaluation of material compatibility test capsules.

Proceed with the Cummins preliminary design revision.

Conduct design review of DDC power conversion system package.

Begin fabrication of power conversion system components.

Complete ICD for power conversion system.

Plan PCS on-sun testing and TBC installation activities.

Complete evaporator fabrication, begin engine integration.

III REIMBURSABLE PROGRAMS

National Solar Thermal Test Facility / NSTTF

Accomplishments

BDM International Radome Test.

A fiber glass radome was exposed to several fluence levels simulating nuclear thermal pulses. Radar was transmitted through the radome before, during, and after the test.

A fifth series of military aircraft material hardness tests for Northrop/U.S. Air Force were conducted.

Aircraft materials were installed in the windowed wind tunnel behind the high-speed shutter in the center test bay of the solar tower. Test samples were exposed to simulated nuclear thermal pulses. The testing was completed in March.

A Reimbursable customer satisfaction survey was completed.

A Customer Satisfaction Survey was sent to all of our most recent reimbursable customers. We received seven responses to the 20 surveys mailed. Most surveys gave an Excellent or Good rating in almost all categories. These categories included: cooperation and responsiveness of staff, quality of data report and over-all test, quality of facility, safety and environmental protection, cost or value of service, and schedule. All those who responded said they would return to do additional testing (if they had appropriate tests), and all said they would recommend our services to others. The two areas identified by the survey that are most in need of improvement are: time required to process proposals, and the format that the data is presented in.

We have reduced the time required to process proposals through Sandia. Nyles Lackey, DOE/AL has been helping us to manage the time for processing proposals through DOE. This process is still very time consuming and prevents us from responding in a timely fashion to our customers.

We are developing standardize documentation of the data and error analysis of the data. The survey process will continue while we work to improve in areas identified by the survey.

Planned activities for next quarter

- **Atlantis Energy will return in April for a second test series on their Volumetric Air Receiver.**

The NSTTF will perform test on a prototype, volumetric air-cooled central receiver in the 220 test bay of the solar tower under contract to private industry. The first test series was completed in May of 1990.

- **A sixth series of military aircraft material hardness tests for Northrop/U.S. Air Force is scheduled to start in June.**

These tests will be similar to the testing completed in March, but with new test samples.

- **The Applied Physics Laboratory/U.S. Navy will conduct Hot Boresight Error Measurements at the NSTTF in July.**

The Johns Hopkins University Applied Physics Laboratory will be evaluating a Nitroxyceramic Radome for the U.S. Navy, while the radome is being exposed to simulated aerodynamic heating at the NSTTF. The tests are scheduled to start in July.

TECHNOLOGY TRANSFER

Publications in Progress:

Andraka, C.E. et. al., "Sodium Reflux Pool-Boiler On-Sun Test Results," SAND89-2773.

Andraka, C.E., Moreno, J.B. and Moss, T.A.; Boiling Behavior of Sodium-Potassium Alloy in a Bench-Scale Solar Receiver, SAND91-2801A, to be presented at the 27th IECEC, August 1992, San Diego California.

Andraka, C.E. et. al., "Sodium Reflux Pool-Boiler On-Sun Test Results," SAND89-2773. Passed peer review, ready for management review.

Andraka, C.E., D.A. Wolf, R.B. Diver, "Design, Fabrication, and Testing of a 30 kW_t Screen-Wick Heat-Pipe Solar Receiver," SAND92-0795C, to be presented at the 27th IECEC, August 1992, San Diego California.

Bean, J.R., and R.B. Diver, "The Cummins 5-kW_e Dish-Stirling Development Program," to be presented at the 27th Intersociety Energy Conversion Engineering Conference, August 3-7, 1992, San Diego, California.

Bohn, M. "Solar Energy Concentrating Systems: Technologies and Application." SERI/TP-254-4505. Golden, Colorado: National Renewable Energy Laboratory.

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

Diver, R.B., "Mirror Alignment Techniques for Point Focus Solar Concentrators," SAND92-0668, currently in review.

Grossman, J.R., Houser, R.M., Erdman, W.W. and Mancini, T. R."Summary of the Design and Testing of the Solar Kinetics 7-Meter Diameter Stretched-Membrane Optical Element."

Grossman, J.R., Houser, R.M., and Erdman, W.W.,"On-Sun Testing of the SKI and SAIC Stretched-Membrane Facets."

Grossman, J.R., Houser, R. M., Erdman, W.W., "Prototype Dish Testing and Analysis at Sandia National Laboratories."

Grossman, J. W., "Static Load testing of a Heliostat Drive," SAND 90-2624, Sandia National Laboratories, Albuquerque, New Mexico, December 1991.

Grossman, J. W., R. M. Houser, and W. W. Erdman, "Testing of the Prototype Facets for the Stretched-Membrane Faceted Dish," SAND 91-2202, to be published.

Grossman, J. W., R. M. Houser, and W. W. Erdman, "Testing of the Single-Element Stretched-Membrane Dish," SAND 91-22032, to be published.

Jorgensen, G., P. Schissel, C. Kennedy, "Advanced Reactor Material for Solar Thermal Concentrator Applications." SERI/TP- ; 257-4627. Golden, Colorado: National Renewable Energy Laboratory.

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Lotker, Michael, "Barriers to Commercializtion of Large-Scale Solar Electricity: Lessons Learned from the Luz Experience," SAND91-7014, November 1991.

Mancini, T. R., and K. R. Boldt, "The LaJet Innovative Concentrator: Design and Performance," Sandia National Laboratories, to be published.

Moreno, J.B., C.E. Andraka, and T.A. Moss, "Boiling Behavior of Sodium-Potassium Alloy in a Bench-Scale Solar Receiver", SAND91-2801A, to be presented at the 27th IECEC, August 1992, San Diego California.

Romero, V.J., "CIRCE2/DEKGEN2: A Software Package for Facilitated Optical Analysis of 3-D Distributed Solar Energy Concentrators - Theory and User Manual," SAND91-2238

"Today's Solar Power Towers," SAND91-2018, December 1991.

Publications completed in FY 1992

Alpert, D. J., et al., "Today's Solar Power Towers," SAND91-2018, December 1991.

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Grossman, J. W., R. M. Houser, and W. W. Erdman, "Testing of the Single-Element Stretched-Membrane Dish," SAND 91-2203, to be published.

Grossman, J. W., "Static Load Testing of a Heliostat Drive," SAND90-2624, Sandia National Laboratories, Albuquerque, New Mexico, December 1991.

Jorgensen, G., "Comparison of Predicted Optical Performance with Measured Results for Dish Concentrators." SERI/TP-255-4045 . Golden, Colorado: National Renewable Energy Laboratory.

Jorgensen, G., P. Schissel, C. Kennedy, Y. Shinton, D. Powell, and J. Siebarth, "Improved Tunnel Resistance of Silvered-Polymer Mirrors," NREL/TP-257-4419. Golden, Colorado: National Renewable Energy Laboratory.

Jorgensen, G., T. Wendelin, and M. Carasso, "Determination of Accuracy of Measurements by SERI's Scanning Hartmann Optical Test Instrument," SERI/TP-257-4190. Golden, Colorado: National Renewable Energy Laboratory.

Lotker, Michael, "Barriers to Commercialization of Large-scale Solar Electricity: Lessons Learned from the LUZ Experience, SAND91-7014, December 1991.

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.

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"Facet Development for a Faceted Stretched-Membrane Dish by SKI," SAND Contractor Rpt. 91-7009, Solar Kinetics Inc., Dallas, Texas, 1991.

"Design of a Solar Concentrator Support Structure, Pedestal, and Controls," SAND Contractor Rpt. 91-7007, WGAssociates, Dallas, Texas, 1991.

Scientific Meetings and Presentations:

Diver, R.B., "Reflux Solar Receiver Design Considerations," SAND91-1267C for the 1992 ASME International Solar Energy Conference, Maui, Hawaii, April 2-4, 1992.

Hogan, R.E., "AEETES - A Solar Reflux Receiver Thermal Performance Numerical Model," SAND91-1279C for the 1992 ASME International Solar Energy Conference, Maui, Hawaii, April 2-4, 1992.

Hoffman, E. L. and C.M. Stone, "Coupled Thermal-Structured Analyses of a Reflux Pool-Boiler Solar Receiver," SAND91-132C, Sandia National Laboratories, Albuquerque, to be presented at the ASME-JSES International Solar Energy Conference, Maui, Hawaii, April 4-8, 1992.

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Mancini, T.R., "The DOE Solar Concentrator Project," presented at SOLTECH'91, San Francisco, California, March 28, 1991.

Romero, V.J., "CIRCE2/DEKGEN2: A Software Package for Facilitated Optical Analysis of 3-D Distributed Solar Energy Concentrators," SAND91-1439C for the 1992 ASME International Solar Energy Conference, Maui, Hawaii, April 2-4, 1992.

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Solar Thermal Electric Power, ASME Winter Annual Meeting, panel session Chaired by T. R. Mancini, Sandia National Laboratories. Presentations by I. Kubo of Cummins Power Generation Co., Chuck Lopez of Southern California Edison, and Greg Kolb of Sandia (for David Kearney of Luz Energy Company).

Patents

J. P. Abbin, C. E. Andraka, L. L. Lukens, and J. B. Moreno; "Liquid Metal Electric Pump," Patent No. 5,080,559, granted January 1992.

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