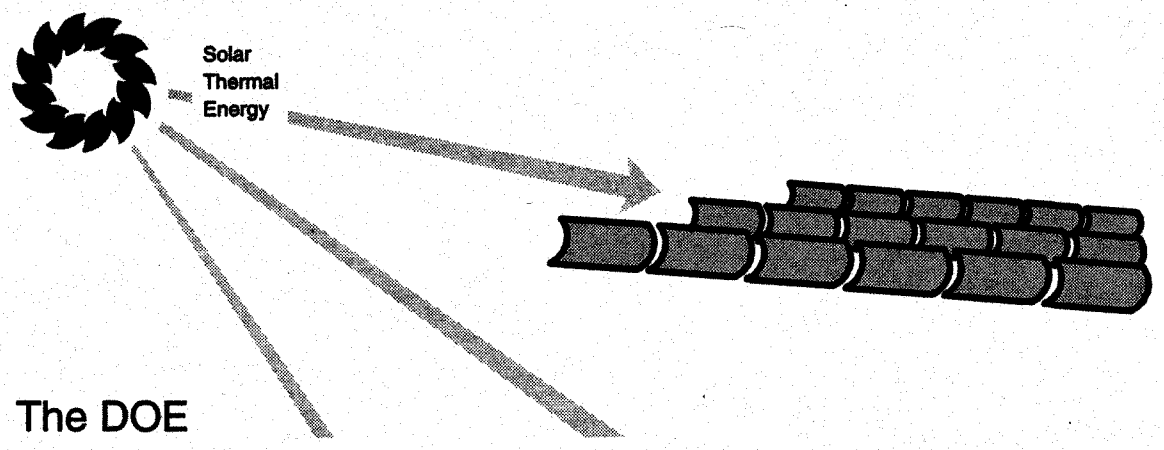
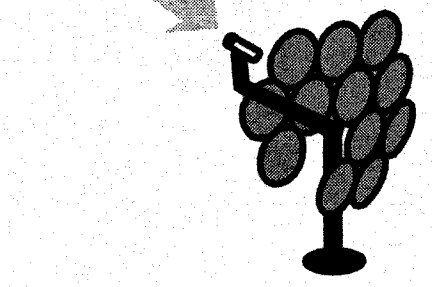
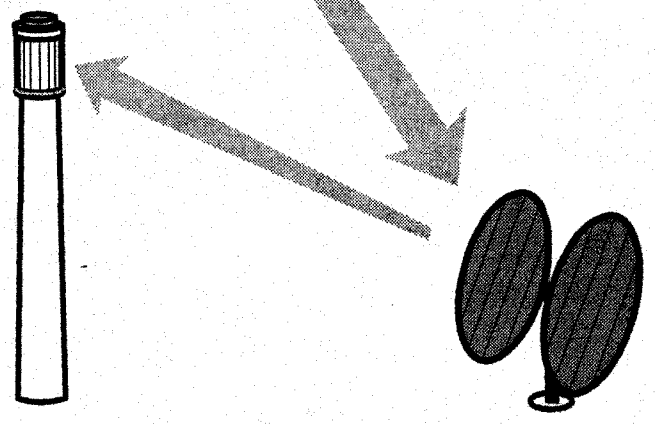


The DOE

Solar Thermal Electric Program

Quarterly Progress Report
First Quarter, Fiscal Year 1993





Submitted by:

Sandia National Laboratories
Albuquerque, New Mexico

National Renewable Energy Laboratory
Golden, Colorado

March, 1993

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 October 1992.

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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 three main categories: Commercial Applications, Technology Development, and the Reimbursables. 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. Reimbursables allow the unique capabilities of the program to be available to interested parties outside of the program and help support test facility operations and improvements. This is the third 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 FY93 structure of the program is outlined as follows:

FY93 SOLAR THERMAL ELECTRIC PROGRAM

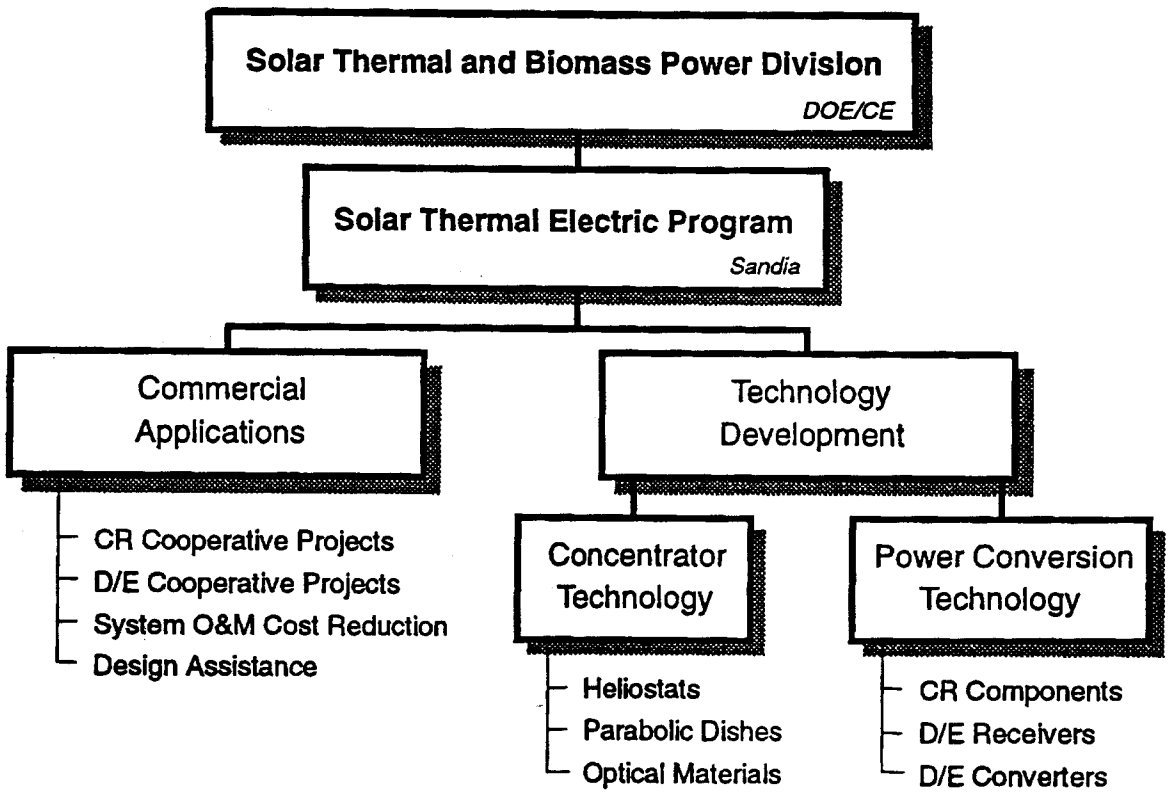
I COMMERCIAL APPLICATIONS
- A. Central Receiver Cooperative Projects
- B. Dish/Engine Cooperative Projects
- C. System Operations and Maintenance Cost Reduction
- D. Design Assistance

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

III REIMBURSABLES

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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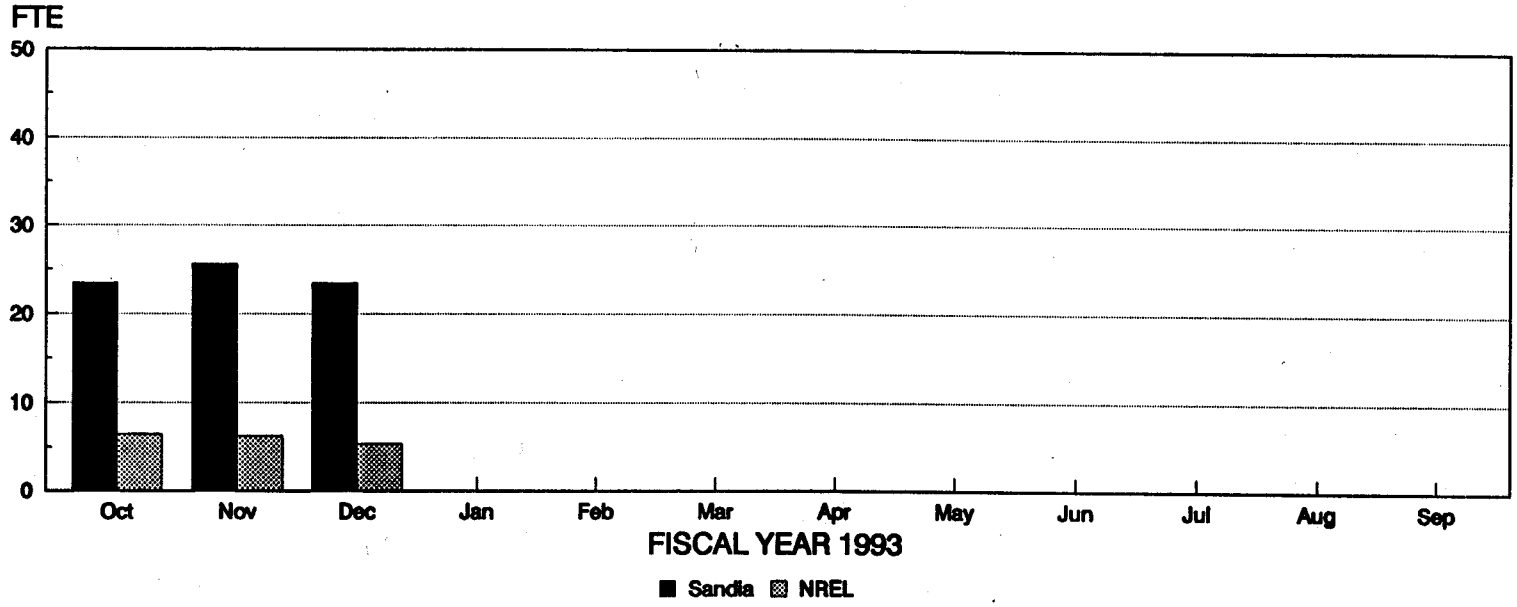
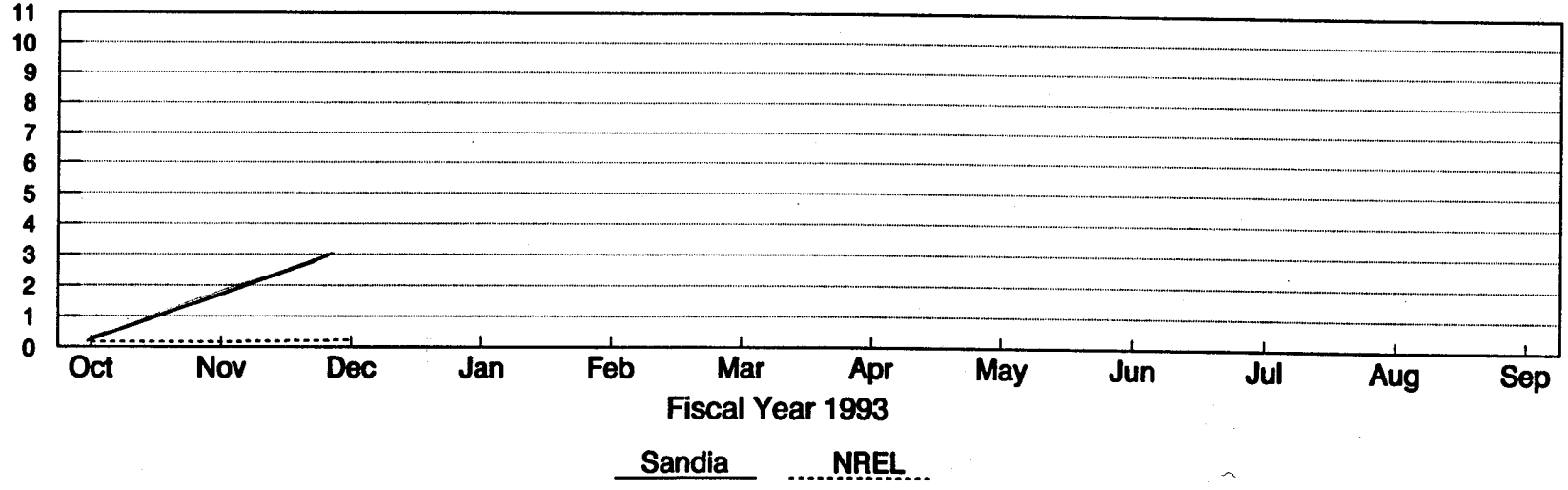


Cumlative Budget Outlay



Procurement Summary

SOLAR THERMAL ELECTRIC SUBCONTRACTS

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1993 Funds ($K)	Total Costs to Date ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IA	Molten Salt System Study	Bechtel	SNL87-5142	$159	$1260	$33.1	$130	01/92-03/93	Large	TBD	J. Chavez
IB	Dis JVP	Cummins	SNL69-7763	$7000	$3500	$2300	$2682	06/91-03/94	Large	Phase Reports	R. Diver
IB	US-JVP	Competitive	SNLAB-8717	$10,000	-0-	$2458	-0-	05/93-05/98	Large	TBD	M. Powell
IB	Tech Trans Documentation	Solar Inds. Energy Assoc.	SNL42-5186	$175	$55	$90	$135	03/93-02/92	Non-profit TT Rpts.	Three	D. Menicucci
IC	O&M cost reduction	Kramer Junction Company	SNLAB-0227	$3162	$650	$400	$216	07/92-09/95	Large	TBD	G. Kolb
II	Solar Test Support	EG&G	SNL05-4912	$850	$190	$250	$583	12/88-10/93	Large	N/A	C. Cameron
II	Electrical Support Service	J & S Electric Co., Inc.	SNL75-7415	$351	$70	$82	$253	02/89-02/94	Serv. Support	N/A	L. Gillette
IIA1	NSTTF Technician Services	Ewing Technical Design	SNL63-5487	$1350	-0-	-0-	$250	04/89 - 04/93	Serv. Support	N/A	E. Rush
IIA1	Coll. Supp. Struc. & Ped.	WGAssoc	SNL62-0292	$390	-0-	$391	$256	09/89 - 12/92	Small	TBD	T. Mancini

Procurement Summary (continued)

Task	Specific Contract Subject	Contractor	Lab Contract Number	Present Contract Value ($K)	Prior Year Funds ($K)	FY 1993 Funds ($K)	Total Costs to Date ($K)	Period of Performance	Contractor Type	Major Reports	Project Monitor
IIA1	Faceted Dish Development	SKI SAIC	SNL67-0291B SNL67-0291A	$468 $409	$427 $409	-0- -0-	$427 $409	09/89- 09/92 04/91-09/92	Small Large	TBD TBD	T. Mancini T. Mancini
IIA1	Stretched-Membrane Dish Dev.	Solar Kinetics, Inc.	SNL55-2495	$1740	$500	-0-	$1740	04/88-12/92	Small	88-7035	T. Mancini
IIA3	Direct Optical Materials	SAIC	NREL YF-2-11191	$130	$130	-0-	$57	03/92-05/93	Large	TBD	G. Jorgenson
IIA3	Optical Materials	3M	NREL 2A-2-11031-1	$139	$139	-0-	$38	9/10/92-6/9/93	Large	Final Report	G. Jorgensen
IIA3	Optical	IST	NREL	$139	$1	-0-	$76	04/92-04/93	Small	TBD	G. Jorgensen
IIB2	Heat-pipe	Cummins	SNL AB3348	$145	$145	-0-	$10	08/92/04/93	Large	Monthly	C. Andraka
IIB3	2nd STM4-120 Ther. Motor		Stirling	SNL75-8851	$425	$80	-0-	$410	04/89 - 02/93	Small	M. Powell
IIB3	ASCS Design	NASA LeRC	DOE Inter-agency	$6169	$1035	-0-	$4800	01/89 - 01/93	Govt	--	M. Powell
IIB3	Stirling Engine Solarization	Detroit Diesel Company	SNL67-9086	$318	$211	$107	$190	01/92-02/93	Large	TBD	M. Powell
IIB3	Dish/ Stirling	Cal Poly Pamona	SNL67-3678	$88	$9	-0-	$85	11/91-05/93	Univ	One	P. Klimas

NOTE - This list contains subcontracts exceeding $50,000.

Major Milestone Schedule

For reference, milestones identified in the FY 1993 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 1993

Lab	Date	Activity-Task Reference	Descriptive Title
First Quarter, FY 1993			
SN	Nov 1992	IA	The Participants Agreement, E&C Agreement, and DOE Cooperation Agreement will be finalized so that the Solar Two project can be officially started.
SN	Jan 1993	IA	The Fourth Technical Advisory Committee meeting will be held. TAC meetings will be held quarterly thereafter.
SN	Apr 1993	IA	Authorization to proceed to final design and construction based on completed plant layout and cost estimate.
GFO	Jun 1993	IA	Solar One thermal storage tank removed.
SN	Aug 1993	IA	Replacement facets for Solar Two heliostat field selected.
SN	Nov 1992	IB	Conduct Phase 1 review of CPG joint venture program.
SN	Dec 1992	IB	Deliver CPG "prototype" water pumping dish/Stirling system to the California Polytechnic University test site.
SN	Dec 1992	IB	Demonstrate the remote village electrification application at the CPG Abilene, Texas facility.
SN	Jan 1993	IB	Complete evaluation of proposals for the utility-scale joint venture program.
SN	May 1993	IB	Demonstrate the utility grid-tie application at the CPG Abilene, Texas facility.
SN	Jul 1993	IB	Award contract(s) for the utility-scale joint venture program.

SN	Dec 1992	IC	Sandia will complete documentation of the testing of the SEGS heat collection elements.
SN	Jan 1993	IC	Survey of advanced selective surface coatings for SEGS plants and central receivers will be completed.
SN	Mar 1993	IC	Mid-term report that describes advancements in FY93 tasks 1-7 (described above).
SN	Jun 1993	IC	Data acquisition system to facilitate maintenance planning will be implemented.
SN	Jul 1993	IC	Evaluation of cyclic stresses in the power block will be completed.
SN	Sep 1993	IC	Final report that describes advancements in FY93 tasks 1-7.
SN	Apr 1993	ID	Participate in SOLTECH 93 meeting.
SN	Feb 1993	IIA1	Complete documentation of the test results on the two large-area glass-mirror heliostats and the low-cost drive.
SN	Aug 1993	IIA1	Completion of testing and documentation on the first prototype of 100-m^2 dual-module stretched-membrane heliostat.
SN	Nov 1992	IIA2	Complete installation of the Faceted Stretched-Membrane Dish at the NSTTF.
SN	Nov 1992	IIA2	Conduct Final Design Review for the Single-Element Stretched-Membrane Dish design.
SN	Mar 1993	IIA2	Place contract to fabricate a Single-Element Stretched-Membrane Dish.
SN	May 1993	IIA2	Complete testing of FSMD with the elastically-formed SAIC facets.
SN	Sep 1993	IIA2	Complete testing of the FSMD with plastically-formed SKI facets.
RE	Nov 1992	IIA3	Identify procurement process and technical approach for additional alternative reflector.
RE	Jan 1993	IIA3	(Key) Initiation of outdoor materials test at Arizona Public Service or alternate site.
RE	Feb 1993	IIA3	Installation of materials test racks at Sacramento Municipal Utility District or alternate site.
RE	Apr 1993	IIA3	Document status of outdoor testing activities.

RE	Aug 1993	IIA3	Document alternative reflector materials R&D progress.
SN	Jan 1993	IIB1	Complete the Bechtel study of 100 MW_e molten salt steam generators and thermal storage systems.
SN	Feb 1993	IIB1	Complete the 4000-hour molten salt corrosion and stability tests.
SN	Mar 1993	IIB1	Complete testing of wire mesh materials at New Mexico State University.
SN	Jun 1993	IIB1	Complete testing of the Bechtel volumetric air receiver at the Plataforma Solar (Subject to SolarPACES approval.)
SN	Sep 1993	IIB1	Publish the Second Generation Central Receiver report.
SN	Dec 1992	IIB2	Complete planned on-sun testing of Sandia 75kW_t heat-pipe receiver.
RE	Aug 1993	IIB2	Test 10kW_t hybrid receiver on sun.
SN	Sep 1993	IIB2	Complete fabrication and begin testing Sandia advanced-wick heat-pipe receiver.
SN	Sep 1993	IIB2	Complete fabrication and begin testing on-sun boiling stability advanced concepts receiver.
SN	Dec 1992	IIB3	Complete fabrication of the Detroit Diesel/STM PCS.
SN	Feb 1993	IIB3	Complete integration of the PCS with a test bed concentrator.
SN	May 1993	IIB3	Complete on-sun tests for the PCS with the directly illuminated receiver.
SN	Aug 1993	IIB3	Complete integration of the PCS with an alkali metal solar receiver. (Subject to DDC/STM contracting agreement.)

SIGNIFICANT ACCOMPLISHMENTS SUMMARY

MAJOR MILESTONES	Planned	Actual
FY 1993		
TASK I	**Planned**	**Actual**
• The Participants Agreement, E&C Agreement, and DOE Cooperation Agreement will be finalized so that the Solar Two project can be officially started.	Nov 1992	
• The Fourth Technical Advisory Committee meeting will be held. TAC meetings will be held quarterly thereafter.	Jan 1993	Jan 1993
• Authorization to proceed to final design and construction, based on completed plant layout and cost estimate.	Apr 1993	
• Solar One thermal storage tank removed.	Jun 1993	
• Replacement facets for Solar Two heliostat field selected.	Aug 1993	
• Conduct Phase 1 review of CPG joint venture program.	Nov 1992	Nov 1992
• Deliver CPG "prototype" water pumping dish/Stirling system to the California Polytechnic University test site.	Dec 1992	
• Demonstrate the remote village electrification application at the CPG Abilene, Texas facility.	Dec 1992	
• Complete evaluation of proposals for the utility scale joint venture program.	Jan 1993	Jan 1993
• Demonstrate the utility grid-tie application at the CPG Abilene, Texas facility.	May 1993	
• Award contract(s) for the utility-scale joint venture program.	Jul 1993	
• Sandia will complete documentation of the testing of the SEGS heat collection elements.	Dec 1992	Dec 1992
• Survey of advanced selective surface coatings for SEGS plants and central receivers will be completed.	Jan 1993	
• Mid-term report that describes advancements in FY93 SEGS tasks 1-7.	Mar 1993	

•	Data acquisition system to facilitate SEGS maintenance planning will be implemented.	Jun 1993	
•	Evaluation of cyclic stresses in the power block will be completed.	Jul 1993	
•	Final report that describes advancements in FY93 SEGS tasks 1-7.	Sep 1993	
•	Participate in SOLTECH 93 meeting.	Apr 1993	

TASK II

•	Complete documentation of the test results on the two large-area glass-mirror heliostats and the low-cost drive.	Feb 1993	
•	Completion of testing and documentation on the first prototype of 100-m^2 dual-module stretched-membrane heliostat.	Aug 1993	
•	Complete installation of the Faceted Stretched-Membrane Dish at the NSTTF.	Nov. 1992	Nov 1992
•	Conduct Final Design Review for the Single-Element Stretched-Membrane Dish design.	Nov 1992	Nov 1992
•	Place contract to fabricate a Single-Element Stretched-Membrane Dish.	Mar 1993	
•	Complete testing of FSMD with the elastically-formed SAIC facets.	May 1993	
•	Complete testing of the FSMD with plastically-formed SKI facets.	Sep 1993	
•	Identify procurement process and technical approach for additional alternative reflector.	Nov 1992	Nov 1992
•	(Key) Initiation of outdoor materials test at Arizona Public Service or alternate site.	Jan 1993	
•	Installation of materials test racks at Sacramento Municipal Utility District or alternate site.	Feb 1993	
•	Document status of outdoor testing activities.	Apr 1993	
•	Document alternative reflector materials R&D progress.	Aug 1993	

• Complete the Bechtel study of 100 MW_e molten salt steam generators and thermal storage systems.	Jan 1993
• Complete the 4000-hour molten salt corrosion and stability tests.	Feb 1993
• Complete testing of wire mesh materials at New Mexico State University.	Mar 1993
• Complete testing of the Bechtel volumetric air receiver at the Platforma Solar (Subject to SolarPACES approval.)	Jun 1993
• Publish the Second Generation Central Receiver report.	Sep 1993
• Complete planned on-sun testing of Sandia 7kW_t heat-pipe receiver.	Dec 1992
• Test 10kW_t hybrid receiver on sun.	Aug 1993
• Complete fabrication and begin testing Sandia advanced-wick heat-pipe receiver.	Sep 1993
• Complete fabrication and begin testing on-sun boiling stability advanced concepts receiver.	Sep 1993
• Complete fabrication of the Detroit Diesel/STM PCS.	Dec 1992
• Complete integration of the PCS with a test bed concentrator.	Feb 1993
• Complete on-sun tests for the PCS with the directly illuminated receiver.	May 1993
• Complete integration of the PCS withan alkali metal solar receiver. (Subject to DDC/STM contracting agreement.)	Aug 1993

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 solicitation efforts.

The Solar Two consortium has secured the $19.5 million needed for their half of the Solar Two project. SCE's commitment is now $11.5 million since they have agreed to backstop the project. However, the consortium is continuing to seek additional financial support from other utilities and agencies (these additional funds will first go to returning SCE's commitment to their original intention). Since SCE will be rejoining EPRI, EPRI will be a participant in the project (this is the $1.0 million contribution). A meeting with Senator Bryan of Nevada, was held in October to brief him on the benefits of central receiver power plants. Sandia provided technical support for the briefing. There is a good chance of further discussion with the Nevada state officials and its utilities. Sandia is also working with the Indians to participate in the Solar Two project.

Solar Two participants' completed and cooperative agreements pending.

The Solar Two Participants Agreement was finalized in November and has been signed by all the participants who will join this Agreement (including SCE, SMUD, Pacificorp, Idaho Power, APS, and SRP). All the other participants and contributors will sign side agreements to the Participants Agreement. Now that the agreement is completed, SCE, acting on behalf of all the participants, can enter into a Cooperative Agreement with DOE. SCE has been working with DOE/GFO to finalize the Statement of Work for the Cooperative Agreement (Sandia is providing DOE/GFO with input on the SOW and schedule). Once the Cooperative

Agreement is signed, early next quarter, the Solar Two project will be officially underway.

SCE has authorized Bechtel, as the Constructor and Engineer, to begin work on the first phase of the Solar Two project.

Solar Two technical support.

Sandia has been working with SCE and industry to address the technical issues related to Solar Two. Listed below are some of the technical support accomplishments during the past quarter. Due to the delay in the signing of the Participants Agreement, the TAC meeting for this quarter was canceled.

- As Chair of the Solar Two Technical Advisory Committee, Sandia has prepared a draft Policies and Procedures document to govern the operation of the TAC. This document delineates the purpose, membership guidelines, structure, review process, and review documents for the TAC. The Solar Two project manager and the Steering Committee will have to approve this document.

- The magnitude 7.5 earthquake on June 28 damaged about 4% of Solar One's 22,000 mirrors; the damage resulted from the failure of the glue bonds between a mirror and its three support plates. To prevent further loss of mirrors, the field has been stabilized by riveting all the remaining mirrors to their support plates. Sandia issued a competitive RFP, and the riveting of the mirrors was completed this past quarter. In addition, under the same contract, Sandia will add vents to the last 5000 mirrors which have not already been vented. This venting will eliminate water accumulation inside the mirrors.

- Sandia is preparing an RFQ to assess options for replacing the mirrors damaged in the earthquake and lost to corrosion. The RFQ will go to a number of different vendors to evaluate the performance and cost of the various options. The best candidates will be tested at the NSTTF. To balance the flux on the receiver, the Solar Two project will add about 100 new heliostats to the south portion of the field. One option for these heliostats is to buy the flat glass mirrors and trackers from the defunct Carrisa Plains PV plant. To assess this option, Sandia is helping to evaluate the quality of these heliostats.

- Because of the environmental liabilities, the disposition of Solar One's oil and gravel thermal storage system is a key issue in the signing of the Participants Agreement. Sandia has been working with DOE/GFO to assess the various options of disposing of the thermal storage system. A meeting was held at Solar One on November 12, with DOE/GFO, SCE, and Dames and Moore, to discuss the options. Dames and Moore, contracted by DOE/GFO, will prepare an RFQ for the removal of the thermal storage system. Oil samples were taken in early December to evaluate the make up of the oil and determine if there are any hazardous materials. Dames and Moore expects to have an RFQ prepared by early next quarter. Sandia will provide input to the RFQ and help evaluate the proposals.

Planned activities for next quarter

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

- The next Solar Two Steering Committee Meeting will be held on January 26, 1993. The next Technical Advisory Committee meeting will be on January 27, 1993 in Salt Lake City, Utah.

- Continue technical support of SCE's efforts to define the design of Solar Two that best simulates a commercial plant and addresses the technical issues of central receivers.

B. Dish/Engine Cooperative projects

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

Accomplishments

Cummins 7-kW_e Dish-Stirling system integration testing progresses.

Operation of the Cummins Power Generation, Inc. (CPG) dish-Stirling system continued throughout the quarter at the CPG facility in Abilene, Texas. In late October, the system was briefly shut down by a heat pipe leak. During the shut-down, the engine was completely disassembled and inspected. After approximately 250 hours of operation (119 hours on-sun), no distress to the engine's wear surfaces was detected.

A vibration isolator and a modified aperture plate and ceramic receiver cone were installed on the system during the down time and the stainless-steel heater head was replaced with a new Haynes 230 heater head and heat-pipe receiver. During the first 135 hours of system operation (119 were prior to the retrofit), 145 incidents were recorded in the Standard Engine Reliability Tracking System (SERTS) used by Cummins. Most of the incidents are related to over-temperature of the aperture plate thermocouples and excessive vibration due to unbalanced free-piston Stirling engine. Implementation of a vibration isolator was very successful. An estimated 96% of the vibration transmitted to the concentrator structure has been eliminated. Following implementation of the vibration isolators, vibration induced incidents have been reduced dramatically. As of December 15, a total of 163 operational hours have been logged on the system.

Sandia holds Phase 1 Review of the Cummins Dish-Stirling Joint Venture Program.

The phase 1 design review of the dish-Stirling Joint Venture Program (JVP) was held at the Cummins Power Generation, Inc. (CPG) headquarters in Columbus, Indiana on November 19-20, 1992. Rich Diver, Craig Tyner, Tom Mancini, and Mark Powell from Sandia and professor Bill Stine of California Polytechnic University (Cal Poly) attended the review. In the two-day review meeting, CPG and their subcontractors made detailed presentations on work preformed in phase 1 of the JVP. Rich Diver from Sandia presented preliminary results from the systems optimization analysis. The status of the overall system and major components, as well as phase 2 plans were also discussed. Overall progress has been outstanding. Systems have been installed and operated in Abilene, Texas and Lancaster, Pennsylvania and more than 160 hours of on-sun operation have been accumulated. A third system is scheduled for delivery to the Cal Poly site in

Pomona, California in the 2nd quarter of FY93. Good technical progress has also been made on all of the major components. Sandia is in agreement with CPG's recommendations to proceed to phase 2 beginning January 1, 1993, and to extend the phase 2 period of performance to 15 months (at no additional cost).

Dish/Stirling Joint Venture Program passes Cummins "M-2" review.

The dish-Stirling Joint Venture Program (JVP) passed Cummins Engine Company's management review # 2 on December 15, 1992. Passing the M-2 review represents a significant milestone in the commercialization of the CPG dish-Stirling technology and reaffirms Cummins top management's commitment to this program. The management "M" review is a key element of Cummins Total Quality System. In the M-2 review, the CPG dish-Stirling system was assessed to confirm that expected operating parameters can be met. Data from the Abilene, Texas and Lancaster, Pennsylvania prototypes, along with data from the various component tests, were used to evaluate the technical potential of the CPG technology. An independent evaluation (and subsequent strong recommendation) of the technical aspects of the program by a committee of Cummins technical experts provided some of the technical input that Cummins top management used to decide to proceed into the next phase of commercialization. In addition to the technical evaluation, marketing and financial plans for the program were re-evaluated and the program was assessed in the context of Cummins long-term objectives. A most significant aspect of this decision is Cummins financial commitment to dish-Stirling technology (including utility-scale as well as remote-power applications) during a period in which Cummins is focusing on near-term profitability. Based on technical information presented at the phase 1 design review in Columbus, Indiana last month, Sandia is in agreement with CPG's recommendations to proceed to phase 2 beginning January 1, 1993, and to extend the phase 2 period of performance to 15 months.

Three Phase-1, CPG-Specified engines assembled and displacer gas bearings implemented.

Assembly of all three of the phase 1 free-piston Stirling engine/alternators were essentially completed during the quarter. Shakedown testing of two of the "concept validation" engines, CV-1 and CV-2, was conducted throughout the the

last quarter of FY92. The CV engines were specified and built according to Cummins' procedures. The original Sunpower prototype engine, P-1, is currently installed in Abilene, Texas. CV testing indicated less than expected power and efficiency compared to the P-1 engine. Diagnosing the problem has been a difficult and time consuming exercise. In October 1992, excessive friction on the displacer bearing was determined to be the cause of the performance short fall and a decision was made to implement gas bearings on the displacer. By the end of the quarter, displacer gas bearings had been implemented and engine/alternator performance was up to expectations. Around the clock durability testing of CV-1 should be initiated in early January 1993. Automation of the Sunpower test cell for durability testing of the engine has been completed.

Sandia performs optimization analysis of the CPG dish-Stirling system.

An optimization analysis of the CPG dish-Stirling system was performed by Sandia during the quarter. A system performance and cost model of the CPG phase 1 system developed by Sandia and transferred to CPG, was used to perform sensitivity studies of various design parameters. Based on the phase 1 system design and Cummins cost estimates (in quantities of 10,000 units/year) levelized energy cost is projected at $0.27/kWh -- a very competitive energy cost for the remote power applications for which it is intended. Improvements in system performance and cost of electricity are expected in phases 2 and 3 of the Joint Venture Program. The systems analysis results approach provides CPG and their subcontractors important insights as to the priorities for improving the economic competitiveness of their system. The system analysis model and results were presented at the 6th International Symposium on Solar Thermal Concentrating Technologies in Mojacar, Spain. The Sandia optimization study results were presented at the phase 1 design review in Columbus, Indiana.

Cummins Power Generation completes installation of CPG Dish-Stirling System at the Thermacore Test Site in Lancaster, Pennsylvania.

CPG installed a CPG-460 solar concentrator at the Thermacore, Inc. test site in Lancaster, Pennsylvania during the week of August 3-7, 1992. Cold-water calorimetry with the Durability heat-pipe receiver indicated improved concentrator optical quality compared to the first system installed in Abilene, Texas. The

improved performance is assumed to be a result of higher-quality facets on the Lancaster concentrator. Following limit testing on the Durability heat-pipe receiver at Sandia in May, the receiver was returned to Thermacore, where on-sun testing has continued. A total of approximately 600 hours were accumulated on the receiver prior to its removal and dissection. The CV-2 receiver/engine/alternator assembly was subsequently installed in Lancaster in early November 1992.

Sandia, NREL provide technical support for the JVP.

Sandia and NREL continued to provide technical support for the JVP. A "round robin" characterization of two Cummins facets has been nearly completed. The "round robin" evaluation involves characterizing two CPG facets with the optical evaluation tools developed by Sandia and NREL. In addition to providing important information on the Cummins facets, this process is expected to provide insights into the relative strengths and weaknesses of the various tools developed in the Solar Thermal Program. NREL is coordinating the "round robin" evaluation and has performed Scanning Hartmann Optical Testing (SHOT) of the two Cummins facets. The NREL SHOT results are in excellent agreement with the Sandia "2f" technique. Both techniques measure a slope error of approximately 1.3 mrd for the "good" facet and 2.3 mrd for the "bad" facet.

NREL also continued weathering tests and consulting on optical films. Some of the CPG mirror candidates have shown very promising results after several months on the NREL weatherometer. Sandia loaned to California Polytechnic University a calibrated Device & Services portable reflectometer. Sandia has also provided to CPG a system performance and economic analysis model which will guide system optimization.

Interim Design Review held for the Clever Fellows Innovation Consortium (CFIC) Alternative 7-kW$_e$ Stirling Engine/Linear Alternator.

Because of the importance of the free-piston Stirling engine/linear alternator to the Joint Venture Program, Clever Fellows Innovation Consortium (CFIC) was included as a parallel Stirling engine developer. 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 plans to select either the Sunpower or CFIC engine for further development in the August 1993 time frame in phase 2 of the JVP. The CFIC engine/alternator incorporates a number of clever innovations, including a relatively low-stress heater-head configuration, flexure bearings, and a low-cost alternator. Design and fabrication of the CFIC engine/alternator is approximately two months behind schedule. The delay has been caused by vendor errors in critical parts. The current CFIC schedule calls for engine performance testing in March 1993.

Concentrator mirror manufacturing progresses at the CPG,South facility.

CPG, South continued development of their stretched-membrane facets technology. In the CPG facets, membrane tensioning is provided by a mirror tensioning fixture that uses a pneumatically actuated clamp and tensioning mechanisms. For all of the mirrors manufactured thus far, a 4-mil Dunmore aluminized film has been used. A CPG specified 7-mil film was coated with a protective acrylic coating in July, but unfortunately the coating shop cut the 65-inch wide film to 60-inch width, making it unusable. A new film was ordered and shipped to the metalizer. However, contamination on the film made it unusable as well. A third roll of film was aluminized and sent to the coater in December. Assuming no other mistakes, the film should be available for making mirror facets in early January. The mirror's rim design has also been modified, and extrusions have been made and rolled. The exceptional quality for the rims suggest possible improvement relative to the 1.3 mrd mirrors produced in the first batch. NREL and Sandia plan to perform another "round robin" evaluation of two mirrors from the next batch of mirrors when these become available.

Three qualifying proposals received for the Utility-Scale Joint Venture Program.

Four responses to the request for proposal (RFP) for the Utility-Scale Joint Venture Program (US-JVP) were received on October 23. The RFP solicits industry for proposals to enter into a joint venture with Sandia with the objective of developing and commercializing distributed, point-focus, solar thermal systems which can be used by utilities. Three of the proposals are considered technically responsive and meet the spirit of the proposal. All three of the technically-responsive proposals employ dish/Stirling systems of approximately 25 kW_e output. The technical

scores and costs for the top two proposals suggest that the quality of their proposals is essentially identical. Either two or perhaps three contracts (depending on resources) will have to be placed due to the similar quality of the proposals when compared to the evaluation criteria.

Planned activities for next quarter

- CPG will field a prototype water pumping system at the California Polytechnic University site in Pomona, California.

- CPG will continue system integration testing in Abilene, Texas and Lancaster, Pennsylvania.

- Sandia and NREL will continue to provide technical support to the JVP. CPG plans to initiate testing of an artery-free heat-pipe receiver in Abilene, Texas in February 1993. Financial support for Durability heat-pipe receiver #3 is being provided by NREL. CPG and Thermacore would like to perform limit testing on a test bed concentrator with the Sandia infrared camera system when schedules permit.

- Sunpower will initiate durability testing on CV-1 in January. Planar springs testing for the "design validation" (DV) engines to be built in phase 2 may interfere with the long-term CV engine durability tests. Engine durability tests are planned to continue in the Abilene engine test facility, which is currently under construction, in March 1993.

- Recommendations regarding the US-JVP contracts will be submitted to DOE.

- Laboratory testing of the CFIC free-piston Stirling engine/linear alternator is expected to start in March 1993.

- Sandia plans to provide flux mapping of the upgraded CPG-460 concentrator in Abilene, Texas by early February.

C. Operation and Maintenance of Utility-scale Solar Thermal Power Plants 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 operating experience of LUZ Engineering Corporation and its derivatives, e.g., Kramer Junction Company.

Accomplishments

Development of low-cost method of applying cermet selective surface.

The demise of LUZ has removed the source for commercial-grade cermet selective surfaces for solar field receiver tubes. KJC and Sandia are working with Vapor Technology of Boulder, Colorado, to develop a lower cost method for applying cermet coatings. This company was chosen because key individuals now working there developed the cermet machine for LUZ. The machine built for LUZ cost $3.5M. The cost estimate for a new machine proposed by Vapor Technology is $750K. In the new machine, a batch rather than continuous process method is proposed. This lowers costs because the number of vacuum chambers is reduced along with several other simplifications in the design.

During the quarter, Sandia visited Vapor Technology to gain a better understanding of the process and to discuss the possibility of demonstrating cermet-coated tubes at the Solar Two central receiver. Currently, central receiver tubes use Pyromark which is a non-selective coating. If cermet could be successfully implemented in a central receiver, radiation losses would be reduced by a factor of five and cause a significant improvement in the thermal performance. Vapor Technology currently has the capability of coating 2-foot lengths of tubing. Perhaps the cermet coating could be tested at Solar Two by welding one or more 2-foot sections within an existing panel.

Next quarter, KJC will visit Vapor Technology, create new cermet samples, and try to replicate the optical properties achieved by LUZ in Israel. KJC has access to the final optimized parameters for the process. Sandia and NREL will be given the samples for in-depth optical testing.

Testing of heat collection elements at Sandia.

Sandia completed efficiency testing of heat collection elements (HCEs) employing a black chrome coating. Last quarter, tests of the cermet tubes were completed. The HCE test program at Sandia is now completed. These tests produced data to help KJC determine the optimum replacement intervals for the HCEs given a variety of degraded conditions. Two series of tests were completed: 1) as new HCE and 2) degraded HCE with vacuum broken. Test results indicate that loss of vacuum causes about a 9% reduction in heat collection efficiency and that wind has little

effect on performance. (Evaluated at average temperature condition in solar field.) The Kramer Junction plant employs 80% black chrome and 20% cermet tubes.

Initial comparisons of test data with analytical models of heat loss indicate that the model accurately predicts heat loss for the case involving a loss of vacuum in the annulus. However, for the case involving an intact vacuum, the model significantly underpredicts losses. We suspect the underprediction is due to either 1) the level of vacuum in the tested tubes was degraded, or 2) inadequacy of the analytical model. During the next quarter, we will investigate this apparent discrepancy and write a draft report that summarizes the test results.

Collector tests at Kramer Junction.

LS-3 test loops were placed in operation at SEGS VII last quarter to test the effects of counter weights, sun sensor alignment, truss alignment and HCE alignment. Initial improvements due to these test loop modifications are 2%, 12%, 10%, 15%, respectively. Final testing, using more accurate instrumentation, were slowed considerably during the present quarter due to difficulties of winter period testing and delays associated with receiving materials. New flow meters were delivered late in the quarter. It is planned to complete and fully check out all elements of the installation in early January and initiate testing. Good test data may not be possible until March. Documentation of the testing is underway.

Testing of advanced flow meters.

The selection of reliable and accurate flow meters has been a problem that has plagued central receiver and parabolic trough power plants for many years. Last quarter, two new types (vortex shedding and acoustic) were investigated to determine if testing of them at Kramer Junction should be pursued. The company Sontek visited the KJ site to discuss the acoustical device. The preliminary conclusion is that the Sontek concept is not mature enough for installation at KJC, but may be promising for further R&D for both troughs and central receiver plants.

Study initiated that will examine the historical causes of plant outages.

KJC supplied Sandia detailed records that can be used to estimate the frequency and causes of plant outages at Kramer Junction from 1989 to the present. Sandia is examining these records to glean important insights that will improve the design and operation of future trough and central receiver power plants. During the quarter, seven plant-years of data were reviewed and it was found that most of the outages that have occurred at KJC would also be applicable to commercial central receivers. The insights will be documented in a SAND report which should be available toward the end of the year.

Development of advanced HTF pump seals.

HTF pump seal failures are a major cause of outages and maintenance expenses at Kramer Junction. During the quarter, a new method of sealing, using graphite fiber packing, was tried on an HTF pump at KJC. This approach did not prove to be successful. A double-seal arrangement is now the leading candidate. This approach will be more closely examined next quarter.

Revision of project budget.

DOE informed Sandia that the budget for FY93 could be reduced from $902K to $400K. This will have a major impact on the expected deliverables for this project. A revised set of deliverables, at the $400K funding level, will be developed next quarter.

Sandia advises Indian government regarding the proposed project to build a SEGS plant in India.

At the request of the United Nation Development Program (UNDP), Sandia's Greg Kolb advised the Indian government regarding the proposed project to build a 30 MW solar parabolic trough power plant near Jodhpur, India. The responsible government organization is the Solar Energy Center, which is a branch of the Department of Non-Conventional Energy Sources. Meetings were held in New Delhi from December 7 - 18. Mr. Kolb related the experience gained from operating similar power plants at Kramer Junction, USA, and Indian engineers provided site-specific data. It was concluded that the relatively successful operation of parabolic trough technology in the USA does not guarantee that it will be successful at Jodhpur. The uncertainty is the result of differences between the Jodhpur site and the USA site, as well as significant infrastructure differences. Considering these uncertain ties, the financial risk of the project could be significantly lessened by downsizing the project to a 10 to 15 MW size. The experience gained from operating this smaller plant should be adequate to decide whether much larger solar thermal power plants should be introduced within the near term in India. The Indian government is considering involving Kramer Junction Company and/or other U.S. companies in the project. The UNDP paid for all travel expenses associated with this trip.

Planned activities next quarter

- Write a draft report summarizing HCE testing at Sandia
- Prepare cermet samples and deliver to Sandia and NREL for testing
- Continue study of historical causes of plant outages

D. Design Assistance

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

Support: The Solar Thermal Design Assistance Center activities reported here are 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

Assistance to SEGS.

The STDAC has agreed to assist the Daggett Leasing Corporation (DLC) and the Kramer Junction Company (KJC). The areas of assistance are outlined below:

1. The SEGS 1 & 2 facilities sustained significant damage due to a recent earthquake. Sandia is currently performing a finite element analysis of these systems to help recommend some corrective measures. Most of the damage involved loss of reflective surface, but the original equipment manufacturer will not provide replacements and SEGS is looking for help from domestic sources. Industrial Solar Technology (IST) was contacted for help in constructing aluminum plates laminated with reflective film. Sandia agreed to help IST in developing the replacement mirrors.

2. Kramer Junction Company has requested technical consulting about the design and installation of a new quality-assured solar monitoring system for their SEGS plants. Work on this project will begin in the second quarter.

3. The Mt. Pinatubo volcanic eruption has apparently caused a significant reduction in the direct normal radiation that has reduced revenue about 20%. The SEGS owners want some explanations about the problem. Sandia has begun analyzing existing solar radiation data to explain the apparent reduction in insolation due to the volcano.

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 began to create problems with the system. At IST's request, Sandia engineers assisted in developing a set of suggested structural changes to the field to prevent further damage. The structural changes were implemented last quarter. More analysis is planned using a finite element model that is currently being developed. IST has conducted some destructive static load tests on some existing modules to provide calibration data for the finite element model. Work on this project will continue through this FY.

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. Sandia has issued a contract to Gould to provide records of the economic and energy performance of the systems in 1992 and 1993. These records will be assembled into a report about the performance of the Gould system.

Technical consulting for the California Energy Commission (CEC).

Sandia engineers are involved in a number of CEC activities. The first involves the 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. BESICO and CDC will meet late in this quarter to sign the contract to install the system. A STDAC engineer will attend the meeting to discuss technical details for the monitoring system. A second effort is to assist CEC and CDC officials in developing RFPs for third-party financed solar systems in other prisons. Work on these RFP began in September. A third effort is to install a solar hot water performance monitoring system at Galt. This evacuated tube collector system was purchased by the State of California and they are interested in having a neutral third-party measure its performance. Sandia has received a formal request from the State of California to begin monitoring the system and work on the project began in September. Sandia has developed a design of the monitoring system. Installation will occur in the second quarter.

Refurbishment of a Solar System at a New Mexico College.

The State of New Mexico Energy and Minerals Department has asked for Sandia's assistance in refurbishing a solar system at the Northern New Mexico Community College. Sandia and the State have agreed on a cost-shared project that will include the New Mexico Solar Energy Industries Association. Work on the project will continue through this FY.

Support for Sandia's Technology Transfer Programs.

Sandia's Solar Thermal Program is consulting to Sandia's Technology Transfer Program about the application of solar thermal technology. Currently, engineering support consists of advising various interested organizations on the benefits of solar energy technology. Support for this effort is provided through Sandia's Technology Transfer Programs.

SNL sponsored project to commercialize Solar Thermal Technology.

A new nine-month project has begun to commercialize a single solar thermal technology. This three-phase project, which is funded through Sandia's Technology Transfer Programs, has begun by identifying minority-owned companies who have the capability to commercialize a small-scale solar thermal technology. After these companies have been identified, each will be asked to select a solar thermal technology to commercialize. Each company will then compete for involvement in a technology transfer activity designed to assist the company in developing a complete business plan to manufacture and market the solar product. The Solar Thermal Design Assistance Center is providing the management and technical direction for the project.

Solar Thermal Technology applied at military installations.

Sandia engineers are directing the evaluation of potential solar systems at March AFB, California and Kirtland AFB, New Mexico. The proposed solar systems at these bases will be used for water heating and, possibly, absorption air conditioning.

Sandia is also assisting the US Army to assess the potential of solar energy systems at Dugway Proving Grounds, Utah. A site survey was conducted in this quarter and it was determined that solar systems have wide-spread opportunities on this Army post. DOE may cost share some of these projects.

Sandia to provide solar analysis consulting services to Ft. Huachuca.

Ft. Huachuca has requested consulting services involving an analysis of the potential for installing solar thermal systems at Ft. Huachuca, a U.S. Department of the Army facility. The need for the analysis is based on a recent Congressional action that makes $10M available for renewable energy projects within Department of Defense organizations. The federal project through which the money is being made available is called the Energy Conservation Investment Program. However, to qualify for some of the congressional money, a detailed proposal must be prepared that identifies each potential renewable energy project on the DoD installation and assesses its potential energy and cost performance. The proposals must be prepared in a specific format and the analysis must be performed

according to a specific computerized program that has been adopted by the Army. Engineers at Ft. Huachuca are purchasing technical assistance from Sandia National Labs to analyze the potential application of solar thermal technology on their facilities and to prepare proposals for the ECIP program. Ft. Huachuca has transferred money to Sandia to cover the costs of the analysis. A Work for Others Agreement to formalize the effort is being prepared.

Technical support provided to Luke AFB.

STDAC engineers are working with officials of Luke AFB near Phoenix, Arizona to refurbish a 12,000 ft^2 solar thermal trough system that was intended to heat water for three airmen dormitories. This solar system has been shut down since early 1980 due to drive mechanism problems.

After studying the system, STDAC engineers concluded that based on refurbishment costs plus a two-year O&M and training contract, the energy cost savings would pay for the refurbishment costs in about three to four years. Luke officials have authorized the project. Sandia has contracted to Luke AFB for a report on the refurbishment effort and the performance of the system for the first year of operation.

Consulting 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. Sandia assisted in the design of a walk-in, fish storage bin that will be cooled with an Energy Concepts ice maker. Sandia is also contracting with Energy Concepts to report on the installation and operation of other solar ice makers.

Another effort involves the development of a 30kW solar thermal electric project in Puerto Lobos. A used ORC engine coupled with IST troughs are being considered for this demonstration project. The Mexican Government has recently contracted to Industrial Solar Technology to design and install the system. The Mexicans have asked for Sandia consulting regarding the design review and monitoring of the system. Work on the project will begin in the next quarter and continue through this FY.

Participation in State of New Mexico Energy Task Force.

Dave Menicucci (6216) is participating in a State of New Mexico Energy Conservation and Renewable Energy Task Force. The task force's purpose is to develop recommendations for implementing the state's energy policy. Dave was

invited to serve on the task force by the governor of New Mexico; he was one of 18 individuals who were selected from over 200 candidates for the task force.

Technical Assistance to State of Arkansas.

STDAC engineers met with Arkansas State officials to discuss refurbishing an inoperative 30,000 ft^2 solar trough system at the Mississippi County Community College (MCCC) Blythsville, Arkansas. The experimental system was built in the early 1980s and was shut down around 1985. Chris Benson of the Arkansas Energy Department contacted the solar thermal program requesting technical advice about relocating the IPH system to a state prison. STDAC engineers inspected the system and concluded that it will require some major renovation to make it operational. Arkansas officials agreed to obtain some information about the current hot water loads at the prisons, the associated costs for producing the hot water, and the disposition of the prison officials about a solar addition to the facilities. Sandia agreed to assess the costs to move and refurbish the MCCC system. After all this information is obtained, Sandia will help the State estimate the potential cost effectiveness of relocating the solar system. Work on this project will continue through this FY.

Solar repowering study for Energy Foundation and State of New Mexico.

The Energy Foundation has recommended that the state of New Mexico consider repowering some existing electric power plants in New Mexico with solar energy systems. The State has accepted the recommendation but has asked Sandia to perform a cost/performance analysis of the option. The State has asked for analysis of two 45MW plants near Albuquerque. Work on the project has begun and the results will be reported next quarter.

Monitoring support for Hawaiian utilities.

The State of Hawaii, in cooperation with several electric utilities, has requested technical support from Sandia in designing, developing and installing a solar monitoring system on the islands to assess the impact of solar hot water heating on electric utility loads. Sandia will work with the Solar Energy Industries Association to provide the training and technology transfer assistance to the utility engineers who will implement the monitoring program.

Planning for SOLAR 93 Meeting.

Dave Menicucci (6216) was invited to participate in the planning of the SOLAR 93 meeting as a representative of the solar thermal electric community. Dave attended a planning meeting in November that involved the selection of those ASES papers for the technical sessions for the SOLAR 93 meeting. The ASES papers were

integrated with those from ASME in order to develop joint ASES/ASME sessions for the April joint meeting to be held in Washington, DC. Dave will chair one of the ASME/ASES Solar Thermal Electric sessions.

Testing of small scale solar thermal products.

Sandia engineers are 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.

Sandia is testing a new model of a residential solar distiller developed by BSAR. This testing follows Sandia tests of a previous version of the distiller, which produced information to improve its design. Many of these suggestions have been incorporated into the new model. Tests of the new model are based on a plan that was jointly developed by DOE and BSAR.

Testing has begun on a solar concentrating oven developed by Burns Milwaukee. The purpose of the tests is to quantify the oven's performance for use in the company's commercialization activities.

Testing will begin next quarter on an IST concentrating module. IST asked for the evaluation using Sandia's rotating platform to quantify the optical and thermal performance of the module.

Solar Thermal Electric technology brochures are being updated.

Work has begun to update existing brochures about solar thermal electric technology. These new brochures will feature the recent progress on all of the major solar thermal electric technologies with special emphasis on the cost shared development efforts involving Solar Two and the dish/Stirling systems.

Miscellaneous consulting efforts

Other on-going technical assistance projects include:

- New Mexico Solar Energy Industries Assoc.
- Solar Weatherization Assistance Program

On-going test and evaluation projects include:

- Pegasus

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.

STDAC CONTACTS THIS QUARTER:

Technology/Subj	Requester	Affiliation
Central Receiver	Vicente Estrada	Mexico
	Robert Field	Schafer Associates
	Don Desmond	Pennsylvania Energy Ofc.
	Daniel Krehling	Pennsylvania Energy Ofc.
	Don Desmond	Pennsylvania Energy Ofc.
	Paul Smith	Arizona Public Service
	Jessie O'Deck	Oakland
	Dr. A. P. Jain	NPL, New Delhi, INDIA
	Ken Hughes	Sierra Club
	Skip Carlson	Turbulence Tubes
	Linda DeWitt	National Geographic
	Michael Joseph	OCA Applied Optics
Ceramic Absorbers		
Dish/Stirling	Lloyd Hoffstatter	NY State Energy Office
	Ted Godett	STM
	J. Rein/T. Goen	Motorola
	Lee Fellows	Thermomotor Corp.
		IIE UIT/Mexico
	Bob Field	Shaefer Associates
	Scott McClug	State of Oregon
	John Spacer	Individual
	Burton Krakow	University of Florida
	Anthony San Severion	Individual
	Ted Godett	STM
	Ed Miniett	STM
	Tim Pearson	Advanced Components Sys.
	Ed Roatery	Solar Power Intl.
	Bob Ford	Tucson NOAA
Education	Karen Sullivan	Washington
	David Devlin	NM J. Academy of Science
	Jeff Hilderbrandt	Science TV

	Sylvia Hammond	Tech Communications
	Donna L. Needham	Miami College
	Donna L. Needham	Miami Dade County
	Marie Tolmeck	State of California
	Mariane Pasqualy	EDC
	Bob Donohue	Individual
General Info	Russ Burkhardt	Real Goods
	Sam Black	SEIA
	Taylor Moore	Individual
	Frank Leslie	Harris Corp.
	Frank Field	Schater Assoc.
	Greg Curry	Northrop
	Kelly Frazier	Applied Physics Lab.
	Jim Kime	Applied Physics Lab.
	C. Hill	Nigera
	Laura Finaccio	Italy
	Losario Pappa	Italy
	John Halmer	Individual
	Byron Knight	Harris Corp.
	Kent Wells	Individual
	Jim Swanson	Individual
	John Ford	WGA
	A. Kunnereth	WTNN Erdman
	Rodem Musr	WTNN Erdman
	Kavia Junes	WTNN Erdman
	Peter Heller	DLR
	Jim Huggins	FSEC
	Alec Jenkins	Individual
	Arlon Shertok	Shertok Corp.
	Sergio Lopez	National Tech Transfer
	Bob Grossberger	NMSU
	Jackie Rein	Motorola Inc.
	Tony Goen	Motorola Inc.
	William Stephensen	State of Hawaii
	Nick Devereux	NMSU
	Tim Lambarski	BDM
	Scott McCLarigon	Peletech International
	Rudi Shoenmackees	NMSU
	Anne Polanski	SEIA
	Marie Pollech	State of California
	Arlee Williams	State of New Mexico
	Andrew Wolf	University of New Mexico
	Donna McDelashon	State of NM/Technology Enterprises
	Eileen Yoshinaka	USDOE/Honolulu, HI
	J. Kern	Schlaich Bergermann und Partner
	Dr. Anibal B.Nordelo	Ministerio de Educacion Superior, CUBA
	Byron F. Knight	Harris Corp.,Melbourne, Fl.
	Marc Bullard	Consultant
	Sergio Lopes	Wheeling Jesuit College

	Mark Massen	Individual
	Thomas McWaters	Individual
	Joshua Davis	Student
	Charles Nichols	Texas Dept. of Commerce
	Ed Schrieber	Individual
	Bob Ford	Individual
	Doug Otis	Orange County California
	Jim Brown	Reno, Nevada
	Sam Black	Individual
	Stephen Dixon	Consultant
	Nan Green	NMSU
	Mark Luz	Individual
	Earl Greving	UC Operating Service
	Albert Hernandez	American Primose
	David W. Riggins	Texas Dept of Commerce
	Calixte Immanuel	Tropical Energy Consultants
	John Mall	Northrop
	Eliz Brady	Individual
	Vern Goldberg	WGA
	Joe Stehlik	Northrop
	Dean Leiby	Individual
	Maria Vargiello	Individual
	Juan Andrade	Individual (Chile)
	Donald Hendricks	Phillips Lab
	Greg Andersen	Individual
	Tracey Ray	Individual
	Neorla Higgins	Individual
	Janice Holt	Individual
	John Rusianovich	Individual
	Frank Barreras	Individual
	Jake Jakubazak	Individual
	Donald Dalton	United Technologies
	Greg Curry	Northrop Corp
	Bod Odeing	PDA
	Will Dumas	Individual
	Herbert Cohen	Individual
	Harvey Stephens	Individual
	Mike Lucid	Individual
	Dick Carr	Individual
	Tom Paul	Individual
	Janice Owen	Individual
	Arthur Chen	Individual
	Bob Bradshaw	Individual
	Steve Gooda	Individual
	Vi Pawlowska	Individual
	Linc Little	Individual
	Susie Thomas	Virginia Dept. of Energy
	Joe Allegro	Individual
	Jeff Mather	US Army Corps of Engineers/Albuquerque
Industrial Process Heat	Ken May	IST

	Rogelio Velasco	C.I.E.D.A.C, Mexico
	Arturo Solano	E.S.TEL., El Salvador
	Mike Minturn	City of Albuquerque
	David Bloom	State of New Mexico
	Caroline Shoun	Hawaai Dept. of Energy
	Sam Black	Individual
	Tom Young	Individual
	Clifton Toney	Tinker AFB
	Bill Stine	Ft. Huachaca
	Chris Benson	Akansas Energy Office
	Jeff Mather	US Army Corps of Engineers/Santa Rosa
	David Knipfer	Gould
	Cliff Toney	Tinker AFB
	Alan Chertok	Certek Corp
	Dr. J. Huacuz	Mexico
	K. Jarschke-Schultze	Individual
Insolation	Richard Perez	SUNY
	Hank Price	Individual
	Warren Gonder	Oregon Solar
	Al Makada	University of Colorado
	Ron Richmond	HISEIA
	Ray Bahm	Ray Bahm Associates
	James R. Smith	Kramer Junction Company
	Ray Bahm	Individual
	Mark Bullard	Resource Inc.
Heat Storage	Michael Brimmer	Santa Fe
Modelling	Teresa Ranger	Individual
	Peter Hines	Chums Research
	Dr. C. Voight	DLR
	Dave Kearney	Kearney Associates
Solar Absorption Air Cond.	Pramod Kulkarni	CA Energy Commission
	George Foruguram	Fourtech Systems
	Lou Matson	Consultant
Solar Thermal Testing	Tom Petersick	DOE/HQ

NREL Industrial Contact List for 1st Quarter FY93

Optical Materials Industrial Contact List for 1st Quarter FY93

CONTACT	ORGANIZATION	COMMENTS
J. Affinito	PNL	Alternate Reflectors
K. Beninga	SAIC	" "
R. Dahlen	3M	" "
T. Evans	Dow Chemical	" "
M. Featherby	SAIC	" "
R. Gee	IST	" "

D. Kearney	K & A	SEGS plants
C. LaPorta	United Solar	Alternate Reflectors
K. May	IST	" "
M. McGlaun	Cummins Power Gen.	" "
W. Schrenk	Dow Chemical	" "
P. Soliday	Cummins Power Gen.	" "

II TECHNOLOGY DEVELOPMENT

A. Concentrator Technology

1. Heliostats

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

Accomplishments

Completed a report documenting Sandia's BC System.

A report was prepared documenting the Sandia's Beam Characterization System (BCS). The report contains the following information: descriptions of the components that the BCS comprises; the system's use in evaluating heliostats and dishes; and an uncertainty analysis of the system.

Planned activities for next quarter

- To reduce the data collected in testing of the SAIC Dual-Module Heliostat.
- This activity was delayed from the previous Quarter.
- Publication of a report documenting the test results of the two large-area heliostats and the low-cost heliostat drive.

Review of Wind-Tunnel test report.

Sandia received a copy of a report entitled, ***Wind Study of the Carissa Plain Photovoltaic Power Plant, Phase 1B Solar Trackers, Carissa Plain, California ARCO Solar Power Production, Inc.,"*** with the purchase of other data from ARCO Solar. This report was made available to J. Peterka at Colorado State University during the preparation of the wind load design guide. The text of his comments is included as a caution when applying this data.

"There is a well established methodology for modeling the atmospheric boundary layer in a wind tunnel, with published papers appearing in the literature in the 1960's. 1970's and continuing through the 1980's. The techniques are sufficiently well established that an American Society of Civil Engineers Manual of Practice on Wind Tunnel Testing of Buildings and Structures (No. 67) was published in 1986. The wind tunnel test report cited above violated many of the well-published criteria for simulation of the atmospheric boundary layer and for modeling wind loads on structures in such a boundary layer. These features include the proper simulation of turbulence. Figure III-8 of the report shows a very poor simulation of turbulence. The test section length of the wind tunnel used was quite short and does not permit proper simulation of wind loads. A second test was performed to define dynamic loads in a uniform flow wind tunnel with no attempt to simulate <u>any</u> properties of the atmospheric winds.

The methods for measuring pressures and moments on the collector under study were highly non-standard and probably cannot be shown to provide accurate results. This is the only laboratory I know of which uses portable pressure taps taped to the model surface. It was not clear that pressures were even measured on both front and back of the collector. The logic used to calculate moments has never appeared in the literature to my knowledge and is likely incorrect. The method used to measure moments relied on just two pressure taps, presumably because the laboratory does not have a balance. The results from these measurements must be considered suspect until the measurement methods are shown to be valid. The dynamic test was limited by assumption to only two modes. Other modes may be important, but were assumed to be unimportant. The lack of an atmospheric boundary layer in this test cannot be supported. Conclusions drawn from these tests must be considered suspect.

Discussion of the design wind speeds is confusing at best. It was not possible to determine exactly what wind speed was used and the supporting logic. Incorrect statements were made: for example on the page with equation 4.1 that there is a 19 percent probability of a 50-year wind occurring in 50 years (the real value is closer to 64 percent.)

There are more difficulties with the report, but the examples cited above are sufficiently severe that a list of detailed problem does not seem warranted."

2. Parabolic Dishes

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

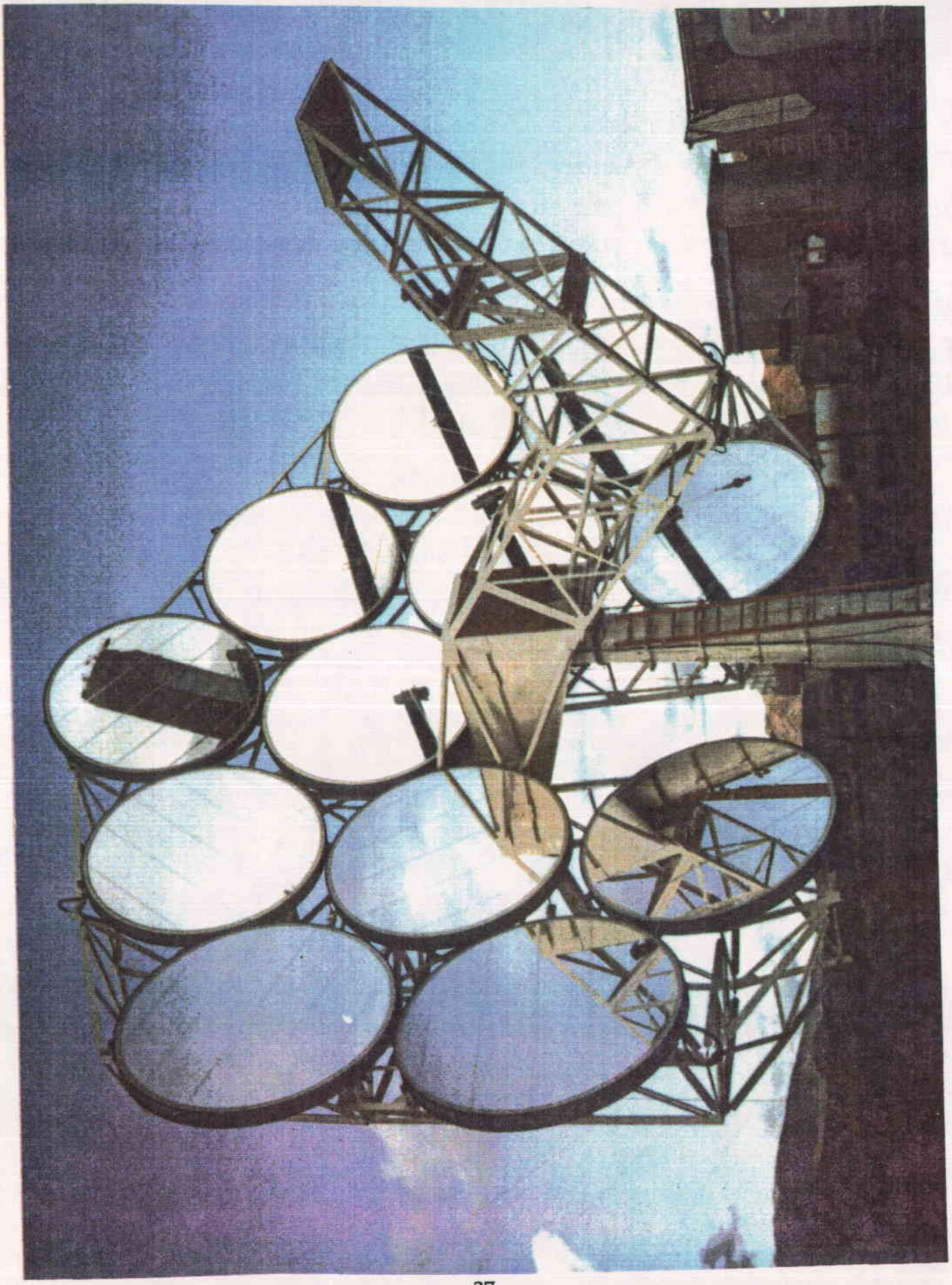
Accomplishments

Completed tests of faceted dish facets.

2-f testing of the SAIC and SKI facets for the Faceted Stretched-Membrane (FSM) Dish facets was completed. On-sun testing of the SAIC facets was also completed. The SKI facets will be evaluated in on-sun testing at a later date, nearer to when they will be installed on the dish.

Completed factory testing of the control system for the Faceted Stretched-Membrane Dish.

The control system for the FSM Dish was factory tested per the testing/acceptance criteria established in the WGA design. It passed the factory tests, was packaged, and shipped to Sandia's National Solar Thermal Test Facility (NSTTF) for installation on the dish.



Built a BC System for dish testing.

A BC System was configured for use in the testing of dishes. This system will be used to measure the flux-density distributions produced by the Test Bed Concentrators in preparation for receiver and receiver/engine tests. It will also be used to measure the beam profile produced by the FSM Dish.

Completed installation of the FSM dish.

The FSM Dish was installed and tested for acceptance at the NSTTF during the First Quarter of FY93.

Conducted the Final Design Review for Phase II of the Single-Element Stretched Membrane Dish Project.

The Final Design Review for the Single-Element Stretched Membrane Dish Project was conducted on November 4, 1992, at the NSTTF in Albuquerque, New Mexico. A recommendation to DOE on for how to proceed with this project is being prepared.

Planned activities for the next quarter

- Install the new membrane on the 7-meter diameter stretched-membrane dish
- Begin Testing of the Faceted Stretched-Membrane Dish
- Make a recommendation to DOE regarding the follow-on activity to the Single-Element Stretched Membrane Dish.
- If appropriate, start procurement of a full-scale SE 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

An organizational kick-off meeting held with 3M.

An organizational kick-off meeting was held with a key industrial partner who has recently initiated subcontracted development of advanced alternative reflector materials.

The meeting was held at NREL on October 5 with representatives from the 3M Company regarding their subcontract to develop a "Weatherable Silver Polymer Reflective Film." The purpose of this meeting was to review the background and objectives of each of the proposed tasks, to agree on an initial technical approach to achieving these goals, and to identify and coordinate the roles and responsibilities of the collaborative team (3M and NREL).

Previous work at NREL in collaboration with 3M had developed ECP-305, a commercial product which represents the state of the art in polymer reflective materials. The present effort is intended to incorporate recent NREL innovations in terms of corrosion preventing back protection and adhesion-promoting interlayers into a pilot-plant version of the commercial 3M material. The contract plan also includes the incorporation of the best properties of 3M's ECP-305 product with one of their other less expensive reflector materials (Silverlux) to produce a lower cost material that maintains the excellent performance of ECP-305. 3M will also pursue a releasable adhesive system to facilitate product replacement after long-term use and will explore options for further cost reduction in the manufacturing process.

Progress has been made in other collaborative efforts with industrial partners to develop alternate reflector materials.

A report titled "Reflection Loss from Silvered FEP through Surface Scattering from Interfacial Roughness" has been written by Industrial Solar Technology (IST) to identify a direction for improving the specular reflectance of silvered fluorinated ethylene propylene (FEP) films. IST is presently involved in a subcontracted, collaborative project with NREL to develop silvered Teflon reflective films for solar applications. Such materials have the potential for improved optical durability and lower cost compared to present commercial products.

A major concern at the outset of this work was the poor specular reflectance exhibited by metallized fluoropolymer films in general. Screening experiments performed during the early stages of this activity required additional emphasis to

be placed on the improvement in specular reflectance. The success of this aspect of the subcontract is critical to the overall project.

Electron microscopy has shown that the surface of FEP is considerably rougher than that of polymethylmethacrylate (PMMA, the material used in present state-of-the-art silvered polymers for solar applications) films. The theoretical modeling documented in the report is aimed at providing a better understanding of the important mechanisms that give rise to wide angle scattering losses in silvered FEP films. Based upon the results of the model, DuPont has agreed to develop an improved CFEP extrusion technique that will reduce the roughness of the FEP film and hopefully lead to improved optical performance.

Accelerated and real-time weathering results are available for a baseline construction which will serve as a benchmark comparison for exposure testing of IST's candidate alternate reflector materials . As part of their effort, a number of candidate samples designed to have improved corrosion resistance (due to protective interlayers and alternate back protection layers) have recently been delivered to NREL for initial (unweathered) optical characterization and are presently under accelerated exposure testing. Optical durability results will be compared with those for the following standard construction which has been under test at NREL for three months:

Teflon™FEP / Ag / Inconel / Adhesive / Al Substrate.

Roughly a 1% loss in solar weighted hemispherical reflectance $D(H_s)$ occurred between one and three months exposure in an Atlas Weather-Ometer (WOM), although H_s remained very high (9 6%). The length of outdoor exposure is still too early to provide meaningful results. Testing of these baseline samples is continuing.

Science Applications International Corp. (SAIC) has a subcontract with NREL on "Directly Deposited Reflective Surface Development." Based upon a series of screening tests, the most promising sample constructions have been selected for further evaluation. These constructions are:

1) Silvue 201 / SiO_x / Ag / Silvue 201 / 668 6 primer / SS

2) Silvue 201 / 6686 primer / Ag / Cr / Silvue 201 / 6686 primer/SS
3) Silvue XF057 / Al / Silvue 201 / 6686 primer / SS

where SS is a thin stainless steel substrate. Previous screening tests indicated that each layer has adequate bond strength except for silver deposited onto Silvue 201. This particular combination has been included in the selected constructions based upon other factors such as cost and performance. These sample sets will be delivered to NREL within the next month for initial optical characterization and initiation of durability testing.

Progress made toward activation of two outdoor exposure test sites.

NREL researchers have been working with the Sacramento Municipal Utility District (SMUD) and Arizona Public Service (APS) to activate the outdoor exposure test sites. SMUD has received, signed, and returned a loan agreement for the outdoor test site equipment. APS has received the loan agreement documentation and is presently reviewing its content. CRADAs are being considered as a means of formalizing the roles and responsibilities of NREL and the various utilities who have offered sites and assistance in operating and maintaining the outdoor exposure test facilities.

Exposure test racks have been received by both APS and SMUD. The meteorological instrumentation for both sites has been ordered and is due within the next month. Once this equipment is received, it will be set up and tested at NREL prior to being shipped to and installed at the test sites.

Support given to Dish/Stirling Joint Venture Program.

In support of the Dish/Stirling Joint Venture Program (JVP), optical characterizations have been carried out at NREL on candidate reflector materials provided by Cummins Power Generation (CPG) that have been subjected to accelerated weathering at NREL in an Atlas Weather-Ometer (WOM) and a Solar Simulator (SS) chamber.

The first set of samples are 7-mil thick polyethylene terephthalate (PET) substrates having a thin reflective layer of sputtered aluminum and a .1-mil thick protective

hard overcoat. These materials have experienced 5-6 months exposure in the WOM. Little degradation of solar weighted hemispherical reflectance $F(H_s)$ for three replicate samples has occurred. However, specular reflectance has severely dropped. Table 1 shows the measured specular reflectance at 650 nm for several acceptance angles as a function of exposure time in the WOM. The column labeled "1000 _" is the hemispherical reflectance at 650 nm.

Hemispherical transmittance through the multi-layer material was also measured. The amount of terrestrial aim-mass 1.5 solar radiation transmitted in the bandwidth 300-400 nm has increased from .50% to .62% after six months exposure in NREL's WOM. Such transmittance may be detrimental to the performance of the polyester substrate material during service conditions.

Five additional candidate materials provided by CPG have also been under test. These are all 7-mil PET (ICI-453) having a sputter-coated aluminum reflective layer. The five protective top coatings are SCR-M, a UV-acrylic, a low emissivity coating, a thermal cured organosilicone (General Electric AS4000, 3.6-7.1μ thick, coated by Vacumet, Inc.) and a UV cured organosilicone (General Electric 494-4029(10), 3μ thick, coated by General Electric).

Two samples of each of the five candidate materials have been exposed in NREL's WOM for three months. Samples were "free standing" (i.e., not laminated to any substrate) but untensioned; the back side was shielded by black-painted aluminum to prevent stray reflected light within the WOM from directly reaching the PET substrate. Both hemispherical reflectance and hemispherical transmittance have been measured. As with the solar simulator exposure results, the organosilicone coated materials have maintained their initial H_s values. In addition, no change in solar CUV-weighted (300-400 nm) hemispherical transmittance (T_{uv}) has occurred. The same is true for the SCR-M overcoated samples. Both the UV acrylic and the low emissivity overcoated materials, however, have exhibited a loss in H_s and an increase in T_{uv}. After 3 months exposure, all five materials exhibit a hazy (i.e., non-specular) appearance. Weathering of these materials is continuing.

Table 1. Specular reflectance at 650 nm as a function of acceptance angle (_) and exposure time (months) in the Weather-Ometer (one sample).

	Acceptance Angle (mrad)			
Time (months)	4	8	12	1000 _
0	81	81	82	87
1	72	74	75	87
5	52 -	61	64	87

Milestone Completed

A DOE Solar Thermal Electric Program milestone titled ***Identify Procurement Process and Technical Approach for Collaborative Alternative Reflector R&D at NREL during FY93*** was successfully completed. The objective of this activity was to identify a concrete plan, early in the fiscal year, that would guide NREL's approach to sponsorship of industrial research in optical materials.

Documentation of the milestone is contained in a letter report to DOE titled ***Procurement Process and Technical Approach for Additional Alternative Reflector R&D Sponsored by NREL during FY93.*** The recommended plan calls for industry funding in five separate areas of research. A synopsis of planned activities in order of priority is as follows:

1) Fund a revised version of a proposal for Polymer Multilayer (PML) reflective materials that was received in a previous competitive procurement issued by NREL for alternate reflector material R&D.

2) Perform a feasibility assessment of promising samples identified by industry experts.

3) Fund an unsolicited proposal for development of a front surface mirror.

4) Reserve minimal funding for follow-on development of concepts being developed by SAIC and/or IST.

5) Establish a steering committee to provide a mechanism for better communication and collaboration among the National Laboratories, solar industry, and optical materials industries.

These efforts will expand the number of advanced optical materials under investigation, will promote interest and involvement of the materials industry in solar thermal applications, and will broaden industry participation in the program.

Planned activities for next quarter

- Collaborative efforts with industrial partners to develop advanced alternate reflector materials will continue.
- Fabrication and characterization of promising candidate reflector materials will be carried out in parallel at NREL.
- Efforts at outdoor exposure test site activation will continue.

B. Power Conversion

1. Central Receiver Technology

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

Accomplishments

Work on the Thermal Storage and Steam Generator Study Contract continues.

Sandia issued a contract with Bechtel for a study to evaluate design, cost, and warranty issues associated with molten salt thermal storage and steam generator designs. Information on these issues, provided by the vendors, is necessary to define the optimal design for a 100 MWe 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 which need to be resolved. This study is a $125K effort, with approximately $90K going to the vendors under subcontracts.

This past quarter, Bechtel awarded the contracts to the vendors. These vendors include: Chicago Bridge & Iron, Pitt-Des Moines, Technigaz, Foster Wheeler, ABB Lummus Heat Transfer, Struthers Wells, and SAIC. The vendors will provide information on the design, cost, performance, and potential problems with the thermal storage system and steam generator system. The technical reports from all the vendors were due to Bechtel on December 15, 1992. Bechtel will evaluate all the information and recommend designs for the 100 MW plant.

Molten Salt Corrosion and Materials Test operates for over 2500 hours.

Testing of the molten salt and materials corrosion completed over 2500 hours of operation. Sandia, at the request of SCE and Bechtel, is conducting experiments to determine the suitability of molten nitrate salts, with chloride levels greater than the 0.3 %, by weight, specification, for use in central receiver power plants. The motivation for these experiments is the interest in less refined 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 salts.

Seven different salts are being tested, each at two different temperatures, 580°C and 315°C. Consequently, there are a total of fourteen vessels, "salt pots," each of which contain approximately nine kilograms of salt. The seven different salts, provided by Coastal Chemical and the Chilean Nitrate Salt Corp., are different grades (e.g., industrial, agricultural, etc.) of sodium and potassium nitrate and contain different levels of impurities. The corrosion rates of stainless steel materials are being tested in the hot salt pots, and corrosion rates of mild steels are being evaluated in the cold pots.

Salt samples were taken at 800 and 1600 hours this past quarter. The analysis of the salt chemistry data, material weight measurements, and oxide analysis allow several tentative conclusions to be made. First, 316 stainless steel is more corrosion-resistant than 304 SS regardless of the composition of the salt mixture. This result is consistent with the typical high-temperature oxidation behavior of these alloys. At 1600 hours the 316 SS had weight losses of 0.8 to 3 mg/cm2, while the 304 SS had weight losses of 0.8 to 6 mg/cm2. Second, a minor constituent of the Chilean KNO_3 causes more rapid (but a more adherent) corrosion than those

present in the other salt mixtures. Based on the chemical analysis, the only unique constituent in the Chilean KNO_3 appears to be sulfate. Salt mixtures formulated with Cedar Chemical's KNO_3 appear to represent a good choice for compatibility with both stainless steel and carbon steel. Third, carbon steel does not appear to be adversely affected by any of the salt mixtures at 320°C. The corrosion rates appear to be quite acceptable for commercial systems.

This test will continue for at least another 1500 hours. Coastal Chemical, the Chilean Nitrate Corp., Bechtel, SPECO, and SCE are very interested in the results of these tests.

Second Generation Central Receiver Study continues.

Work on the final report continued the past quarter on the Second Generation study. The Second Generation Central Receiver Study is comparing the cost and performance of molten salt and volumetric-air central receiver power plants. The study is a joint US/Germany effort and was initiated in the fall of 1989.

All the corrections to the report, including all the reviewer comments, have been made. A final review of the report by both the German and US authors is needed, then the report will be sent out for printing.

Fabrication of the Bechtel Volumetric Air Receiver nears completion.

Fabrication of the wire mesh volumetric air receiver absorber was brought to 90% completion this past quarter. Bechtel designed the volumetric receiver absorber and fabricated it under contract to Sandia. The absorber will be tested at the Plataforma Solar, hopefully as part of the IEA/SolarPACES Task III.

The Bechtel designed receiver is made up of individual screens of a nichrome (80-20 nickel chrome resistance wire) knit wire mesh. The receiver uses fifteen screens, with the screens made up of various layers and wire diameters. There will be a total of 41 layers of wire mesh in the receiver. The intent of the design is to make this receiver as "volumetric" as possible. This is accomplished by making the receiver less dense in the front where the flux is incident and more dense in the

back. Bechtel expects this receiver to have a thermal efficiency of approximately 90% at 600°C.

In fabricating the receiver, all of the materials have been procured and all of the receiver pieces have been machined. All that remains is the assembly of the receiver. However, the scheduled testing of this receiver is on hold pending U.S. approval for involvement in the IEA and the IEA's agreement to test the absorber. In addition, the Plataforma Solar is asking for 100 thousand DM for testing the receiver. Bechtel is working to secure funds to share the cost of testing the receiver. Once all the agreements have been signed and the funds for testing the receiver secured, the receiver will be shipped to Spain for testing.

Testing initiated of volumetric receiver material at New Mexico State University.

This past quarter, New Mexico State University (NMSU) began testing the absorber design and materials to be used in the test of the Bechtel absorber design at the Plataforma Solar de Almeria. NMSU used their solar furnace to test the knit wire mesh material for transmissivity and extinction coefficients. A large number of tests were conducted to provide statistical data. The measured extinction coefficients are very close to those used in analytically designing the receiver. The receiver may have a 1% higher transmission than the design value. This will negatively affect its performance by 1%.

NMSU is now preparing to conduct solar testing of the nichrome knit wire mesh materials to be used in the absorber. The knit wire mesh is 0.114 and 0.204 mm diameter wire (provided by Bechtel). NMSU is fabricating wire mesh layers identical to the Bechtel design. Because of the limitations of the test apparatus, numerous tests will be required with various wire mesh layer configurations to provide sufficient data to characterize the Bechtel absorber design. NMSU is currently planning the tests.

Test plan for molten salt components experiments formulated and tests coordinated.

The purpose of the molten salt experiments is to verify the use, operation, and reliability of components, instrumentation, and procedures proposed for implementation in the Solar Two project. Many of the components have been

proven in a molten salt environment but additional information is required. Other components have not been tested sufficiently in molten salt. The results from these experiments will aid in the design of the molten salt systems and reduce uncertainties of the performance of untested components and operating procedures.

This past quarter, a test plan was written to evaluate the components to be used in the molten salt loops at Solar Two. Sandia will conduct these tests to address concerns by the utilities, industry, and the Solar Two Technical Advisory Committee. The technical needs and concerns were prioritized and a test program that fits within our budget and schedule was developed. Consequently, some issues such as thermal cycling of full- scale valves cannot be implemented. Although the system cannot simulate all the operating conditions expected to be encountered with Solar Two, this test plan does address all the high priority issues. A select group of utilities and industry were invited to review the test plan and make recommendations.

The experiments will be conducted with the existing panel research experiment (PRE) molten salt loop at the NSTTF, but it will be modified to accommodate two wing panels from the Category B receiver (tested in 1987-88) to test a cold receiver startup procedure and conduct freeze/thaw experiments to assess any damage that might occur to the panels. This arrangement also allows for testing of other receiver panels at a later date. We will also add check valves, flanges, flow meters, and pressure transducers to test their performance. Although we cannot operate the salt loop at the pressures expected to be encountered in the Solar Two system, we can simulate operational and thermal cycling expected on the cold side of the system where the thermal ramp rates and stresses are not as severe as the hot side. The ramp rates on the hot side (down stream from the receiver) are very difficult to simulate with the existing loop and may require a separate test setup.

The major components are under procurement. The modifications and construction of the molten salt component loop will be carried out next quarter.

Analysis of Solar Two instrumentation for measuring flux and temperature conducted.

This past quarter, an analysis was conducted of the proposed suite of instrumentation needed to measure flux and temperature for Solar Two. Flux measurements are needed to control the receiver and provide performance data. Temperature measurements are required for receiver control and for performance measurement. Both measurements can be used for warranty purposes. The suite of diagnostics was proposed to measure: a) flux on the target, b) low resolution temperature measurement during warm-up phase, c) high resolution temperature across individual receiver tubes, and d) global radiation losses. Calculations were

done to determine signal strength, uncertainties, and feasibility of hardware using solar spectral irradiance data from NASA report R-351, atmospheric transmission calculations using LOWTRAN-5, and Planckian blackbody emission formulations. From these calculations, the following instrumentation was proposed for each of the measurements: a) six ground-mounted, silicon video cameras with a highly reflective target to measure total incident flux at 680 nm, b) a ground based IR imaging camera system with bandpass and attenuating filters operating at 10.6 or 9.7μm to measure low spatial resolution temperatures of the receiver, c) the same IR imaging system as b) but mounted near the receiver with a 10 cm lens, and d) combined data from a) and b).

System a) was chosen to operate at 680nm because at this wavelength, changes in atmospheric conditions, visibility, and sun position affect the full spectrum at the same rate as at 680nm. With a well-characterized reflective target, measurements of the incident flux levels to within 3% are possible. The low-spatial-resolution temperature measuring system at 10.6μm can conceptually measure temperature in the range 200-500°C with a resolution of 0.5-1.0 m. Solar pollution could result in an uncertainty of as much as 21°C, well within our needs. Commercially available IR cameras and electronics (e.g., Inframetrics) could be used for this system. A ground based, portable, CO_2 laser system may be required to characterize the emissivity of the heated receiver. The high resolution temperature measuring system is similar to b), but would be mounted near the receiver - possibly on the Beam Characterization deck and would use a 10 cm lens.

Plans for developing and testing these systems will be firmed up next quarter.

Planned activities for next quarter

- Bechtel will review all the subcontract reports and make recommendations on the steam generator and thermal storage systems to be used in a 100 MW plant.

- Testing of the molten salt corrosion will continue. The 2800-hour sample time will be reached on January 3, 1993. A decision will be made on how to proceed with these tests, i.e., whether to end them at 4000 hours or continue.

- The Bechtel volumetric receiver will be assembled.

- Begin construction of the molten salt test loop. Order equipment and begin construction.

- Continue performance testing knit wire mesh materials at the New Mexico State University solar furnace.

- Flux and temperature measurement plans will be finalized 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, low-cost receivers.

Accomplishments

Completed scheduled tests of Sandia's 75 kW Heat-Pipe Solar Receiver. (Dec. milestone)

The Sandia wicked heat-pipe test bed receiver has been tested on Test Bed Concentrator #1 (TBC-1) in both the furnace and tracking modes. The receiver uses an STM-supplied wick structure with a Sandia-developed artery system. The STM wick is a sintered multi-layer screen wick that is formed to shape with the domes. The artery structure consists of open 1/8" diameter tubes connected to the surface wick with screen tabs.

During fabrication, tests showed that the surface wick had significantly poorer performance than that specified by STM. Therefore, two layers of 200 mesh screen were spot-welded over the surface structure to enhance performance. Calculations show that the two layers of screen improve the permeability of the surface wick by an order of magnitude. Due to the poor performance of the surface wick, a complex structure of radial arteries was added to the wick. A redundant system of 20 radial arteries each provides sodium to sufficient points to overcome the surface wick deficiencies.

In spite of unusually harsh weather conditions, the scheduled testing of Sandia's 75 kW heat-pipe solar receiver was completed this quarter. The tests were conducted over the course of two days in both the solar tracking and solar furnace operating modes. At an operating temperature of 700°C, the temperature drop between the receiver's absorber surface and the condenser section was on the order of 20°C. The operating power levels that were achieved during this testing, however, were lower than expected. Where the system was designed to handle a power throughput of 65 kW, the maximum throughput that was observed during the tests was 14 kW. This throughput power (i.e., the power extracted by the calorimeter) corresponded to power input of approximately 27 kW. The large difference between the input power and the extracted power is a result of the tests being run with the aperture completely open. It is necessary to test with an open aperture so surface temperatures can be monitored with an infrared camera.

At input power levels above 27 kW, the IR camera showed that the upper edge of the absorber surface became hotter than the rest of the surface. This condition is consistent with the loss of liquid from the wick structure on the back side of the absorber surface. The cause of the dryout is still being studied, but it appears that the artery structure on the receiver wick may not have filled with sodium. If the artery structure was not completely full of sodium, only the thin wick over the evaporator surface would be available to distribute the liquid. A computer model of the wick structure showed that nonfunctioning arteries is a reasonable explanation of the overheat problem. Methods of repriming and sweeping gas out of the artery structure will be pursued at Sandia. If the artery is successfully reprimed, additional testing may be performed as TBC availability permits. In addition, work will continue on improved surface wicks (to reduce the artery requirements) and on development of a self-priming artery structure with sufficient permeability.

Advanced evaporator wick samples received from Friction Coatings Inc.

Sandia has contracted with Friction Coatings Inc. to develop potential heat-pipe wick structures applicable to reflux receivers. Preliminary tests showed that a porous metal structure developed by Friction Coatings in Detroit has flow capabilities an order of magnitude higher than the sintered and hydroformed screen wicks developed by STM. These coatings have the potential to reduce the requirements of the artery structure by improving the performance of the surface wick. The process used by Friction Coatings lends itself to manufacture on a spherical dome, and provides a cost-effective, robust wick structure.

A contract was placed with Friction Coatings to cover sections of tubes with their porous metal product for high-flux bench-scale receiver tests. Friction Coatings recently returned two of these tube sections to Sandia for inspection. Visually, the wick coating appears to be uniform in structure and thickness. Tests will be conducted before the end of December to determine the wicking properties of Friction Coatings' latest samples. Bench-scale tests of a heat pipe with a Friction Coatings' wick structure are scheduled for February 1993. If these tests are successful, the Friction Coatings' wick structure will be considered for application to a full-scale 75-kW receiver.

Thermacore 75 kWt Heat-Pipe Receiver fabrication continues.

Thermacore, Inc., sub-contracted to Cummins Power Generation, is developing a 75 kWt heat-pipe receiver for potential application to Sandia's STM/Detroit Diesel Stirling Power Conversion Unit. This receiver is based on the successful 30 kWt receiver supplied to the dish-Stirling joint venture program. The first receiver fabricated will be tested at Sandia on the Test Bed Concentrator (TBC) with power extraction by a gas-gap calorimeter.

A bench-scale test simulating the flux profile of the proposed receiver was operated successfully. The test demonstrated the use of a 0.3" thick powder wick with passive refluxing to the wick midpoint. The bench-scale test was funded through NREL. Based on the successful test, Thermacore sintered the wick structure on the demonstration heat pipe. Further analysis of the 75 kWt heat pipe shows that it should meet all design criteria. A previous analysis indicated insufficient pumping capability, but it was discovered that the model did not converge. A modified model that converges shows sufficient pumping capability. Thermacore will complete assembly and processing as well as bench-testing of the full-scale receiver in December. Delivery of the receiver is expected the first week in January, with on-sun testing beginning two weeks later.

Follow-up bench-scale NaK boiler tests started.

As part of the effort to improve the design tools for pool-boiler receivers, bench-scale NaK boiler tests will be continued as time and resources allow. The main objective will be to develop a more complete model of boiling instability. In this past quarter, Sandia has been assessing the usefulness of flash radiography as a diagnostic. Potentially, this technique could be used to determine nucleation sites, bubble departure sizes, and whether boiling on one heated surface suppresses boiling on an adjacent surface (a possible problem in hybrid receivers). Tentative results are encouraging: bubble images have been obtained over a range of temperatures, and appear to be consistent with the only other known measurements. Documentation of the previous bench-scale tests is progressing.

Bare-wall pool-boiler-receiver construction started.

Construction has begun on the duplicate of the first pool-boiler receiver, but without any surface modification to stabilize boiling. This receiver will be built from spare parts left over from the first pool-boiler receiver. It will be tested on-sun with a minimum of instrumentation to inexpensively address a hypothesis that has evolved out of previous studies. The tests will be short, for proof-of-concept only. The hypothesis is a result of the following observations: (1) the first pool-boiler receiver had 35 artificial cavities electric-discharge machined into the wetted side of its heated surface to stabilize boiling, (2) sodium always boiled stablly in the first pool boiler, (3) neither NaK nor sodium boiled stablly in bench-scale tests that used two artificial cavities, and (4) bench-scale tests show that boiling stability is favorably affected by heated-surface tilt out of the vertical and by increases in heated surface area. These observations suggest that stable boiling in the first pool-boiler receiver may have been a result of surface area and/or orientation alone. Alternatively, stability may have been a consequence of the large number of artificial cavities, which would tell us something about the statistical nature of boiling stability. The on-sun test of a bare-wall receiver will tell us which

explanation is correct, thus improving our tools for design of a stable pool-boiler receiver.

Next-generation pool-boiler-receiver construction underway.

The next-generation pool-boiler receiver is under construction at Ultimate Hydroforming Inc., of Sterling Hts, Michigan. This receiver will boil NaK in an envelope made from Haynes alloy 230, with a Friction Coatings Corporation's heated-surface modification to promote stable boiling. Delivery, initially scheduled for September 1992, is now projected for early January.

10,000-hour Pool Boiler Bench-Scale Test awaits documentation approval.

Additional attended shakedown testing of the durability bench-test pool boiler has been performed. Unattended continuous operation awaits DOE-mandated ES&H review of safety documentation. The review is well overdue, and a successful resolution is expected in December. Continuous operation will proceed immediately after approval is received, but will be paused during the holiday shutdown.

The Durability Pool Boiler Bench Test is designed to operate unattended for 10,000 hours in order to prove methods and materials used on the full-scale on-sun pool-boiler solar receivers. The selection of materials and boiling stabilization methods was based on successful short-term bench-scale testing performed at Sandia. The test vessel has a Friction Coatings Inc. boiling stabilization surface and a small amount of Xenon gas. The vessel is constructed entirely from Haynes-230 alloy. The test vessel will be subjected to fluxes similar to on-sun conditions. The power will be removed for 1/2 hour at 8-hour intervals to simulate diurnal cycles.

Steam cleaner fabrication.

Assembly and documentation for the next-generation NaK steam cleaning system has been completed. The electronics and controls systems have been tested in the laboratory. Testing and operation of the system has been delayed due to approval delays for a wiring trench. The trench is needed to operate the steam cleaner remotely on an outdoor pad. The trench is expected to be dug in January, and full testing will occur after installation.

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

- Second-generation pool-boiler receiver.

Construction of the next-generation pool-boiler receiver will be completed, and on-sun testing will begin. Testing will be performed on TBC-2, which will be characterized prior to testing.

- Bare wall "advanced" pool boiler receiver.

Construction of the bare-wall pool-boiler receiver will be completed. The schedule for testing will depend upon availability of the TBC and related support equipment (used by other reflux receivers and the STM PCS)

- Durability bench-scale pool boiler test.

The first three months of the 10,000 hour (lifetime) bench-scale test are scheduled to be completed. This will consist of approximately 2000 hours of operation and 250 "diurnal" startup cycles. In addition, periodically, hot restart behavior will be evaluated and compared to the initial conditions.

- Bench-scale pool boiler documentation.

Documentation of the bench-scale pool-boiler testing will be completed.

- Thermacore 75kWt receiver testing.

Thermacore plans to deliver the completed proof-of-concept receiver early in the quarter. The receiver will be delivered fully processed and ground-tested. Testing at Sandia will begin on TBC-1 if the receiver is delivered prior to receiving the STM PCS system, also slated for testing on TBC-1.

- Sandia 75 kW Heat-Pipe Receiver testing.

Attempts will be made to re-prime the artery structure of the Sandia 75 kWt heat-pipe receiver. If these tests are successful, additional on-sun testing will be performed as TBC availability allows.

- Sandia bench-scale heat-pipe receiver testing.

The Friction Coatings Inc. wick samples will be assembled into a bench-scale test device for limit testing at Sandia. Two samples will be incorporated. One will be fitted with the current Sandia open artery structure. The second will be fitted with an advanced self-priming artery, as available. Additional studies will be performed to identify promising self-priming artery candidates for application to this and future receiver tests. The self-priming artery will improve the robustness of the liquid-metal delivery system.

- Steam cleaner testing and operation.

Operation of the second-generation steam cleaner for alkali metal cleanup will be demonstrated.

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.

Fabrication of the Detroit Diesel Corporation/Stirling Thermal Motors power conversion system progresses.

The STM4-120 engine and the induction generator have been assembled into the final package. Final assembly of the cooling system, gas transfer system, and control system into the package has also been completed. The system is undergoing system shakedown testing at the STM facility in Ann Arbor, Michigan using the STM direct flame heat input system. The unit has operated under the total control of the on-board control system up to a maximum power level of 19.5 kWe. The output power is being increased in increments while the control system stability and cooling system performance is investigated. The cooling system may require the addition of a third radiator to reduce the coolant ΔT and total heat dissipation capacity. If required, the modifications will be completed prior to delivery of the power conversion system.

Direct Insolation Receiver (DIR) fabrication delayed.

The heater head castings for the DIR were delivered to STM in October. The castings had high porosity and slumping problems in critical high stress areas of the castings. DDC and SNL have opted to delay delivery of the PCS until the castings can be reworked or replacement castings are received that allow PCS operation at the full-rated power level. This development will delay the PCS delivery until February 1993.

The tube bending tooling has been designed and fabricated. Tube fabrication has been completed for the PCS. Additional tubes will be bent to allow fabrication of spare receiver quadrants. The receiver/engine interface components have been designed and procured. Final assembly will take place after the heater head castings are received and the receiver fabrication is complete.

STM4-120 engine performance mapping.

The performance mapping of the STM4-120 engine was completed in the ETF at Sandia last quarter. This quarter the data was analyzed and a performance model

was generated from the data. The mathematical representation of the STM4-120 can be used for system performance, economic, or system optimization models. An internal Sandia report has been released detailing the testing and the test results. Formalization of the results into an archival quality document will begin in January 1993.

Planned activities for next quarter

- Complete fabrication and testing, and accept delivery of the DDC PCS at Sandia.
- Finalize the PCS test plan and safety documentation.
- Prepare the first draft of the STM4-120 performance mapping report.
- Begin physical integration of the PCS with the Sandia Test Bed Concentrator.

Hybrid receiver design reviews held.

NREL and Sandia researchers attended a preliminary design review of the Cummins Power Generation, Inc. (CPG) Hybrid Receiver project. The meeting was held at Thermacore headquarters in Lancaster, Pennsylvania and was also attended by personnel from Cornell University. CPG has made significant progress on this project, but several important design issues are yet to be decided upon. To date, CPG has determined the receiver specifications, generated several alternative receiver concepts, selected the best concept, and has performed preliminary sizing and system calculations. The receiver will be based on their existing design and will be designed for continuous operation at 35 kW and will utilize natural gas at 80% efficiency at full load. The controls will be set up such that it can operate continuously at the full power rating by adjusting the gas fire rate depending on the availability of solar insolation. The receiver concept involves firing the natural gas along a cylindrical extension of the receiver housing behind the absorber dome. This arrangement allows efficient coupling of the combustion heat into the sodium vapor and also allows for fairly simple implementation of a combustion air preheater that is required to achieve the high thermal efficiencies they desire. Exhaust-gas recirculation will be used to control NOx and to also increase thermal efficiency. CPG has also assembled, and is preparing to test, 1/6 scale models of the receiver. These models will allow them to test burner concepts, to determine the performance of heat transfer augmentation concepts needed for the primary heat transfer surface as well as that for the combustion air preheater. Cornell researchers have completed a computational fluid dynamics model of the flow in the combustion chamber. This model is being used to determine the local heat flux to insure that the heat pipe will not dry out in regions of high heat flux and as input to stress models. In the future after this model is validated, Cornell can use

the model to help CPG optimize hybrid receivers. A final design review will be held in early January with on-sun testing planned for October 1993, either at NREL or at one of the CPG solar-test facilities.

Stirling Technology Company (STC) hosted a review of their Phase I effort on the Hybrid Receiver subcontract. NREL and Sandia researchers and Ed Becker of Southern California Gas attended the review meeting which was held at STC headquarters in Richland, Washington. STC has been working under subcontract to NREL for about six months on the design of a 10kW, solar/natural gas-hybrid, pool boiler receiver for use in dish/Stirling systems. Southern California Gas has cost-shared the project with NREL and Mr. Becker is the project manager. Three major areas of discussion included the boiler design, the receiver mechanical design, and the burner design. Some of the boiler design issues are probably the highest risk elements of the project because they have the least experience and theoretical basis for understanding. For example, the minimum heat flux required to maintain stable nucleate boiling is not well understood. This parameter affects the receiver turndown when operating on natural gas. STC has built small "test capsules" that will allow them to explore this variable so that they can better predict the range of operability of the receiver. Another related issue is the effect of one boiling surface on another since the receiver will be operating with solar input simultaneously with burner input at least some of the time. The concern is how boiling on the burner surface will affect the ability to start boiling on the solar surface when sun becomes available in the morning or after an extended cloud passage. With respect to the burner design, STC presented experimental data that confirmed their hypothesis that their 8radiant burner concept would lead to very low NO_x and CO production. They also reported reliable operation of the burner at anticipated operating conditions. STC is currently reassessing their Phase II plans. On-sun testing is expected before the end of the fiscal year.

III REIMBURSABLES

NATIONAL SOLAR THERMAL TEST FACILITY/NSTTF

Accomplishments

There were no significant accomplishements this quarter.

Planned activities for next quarter

- **Hot boresight error measurement facility.**

  The Applied Physics Laboratory (APL) of Johns Hopkins University is upgrading the Hot Boresight Error Measurement Facility at the NSTTF. The system will be refurbished, brought into compliance with current safety requirements, and upgraded to accommodate radars with different wavelengths. Work has started to remove the existing equipment from the Solar Tower for shipment back to APL.

  At the present time, there are not any reimbursable tests planned at the NSTTF. The following organizations are expressing interest in conducting future tests at the NSTTF:

  Atlantis Energy Ltd. - Large-scale test of Volumetric Air Receiver.

  Applied Physics laboratory - Radome test (Test to be sponsored by U.S. Air Force.)

  Northrop Corp. - Material test on aircraft transparencies (Test to be sponsored by U.S. Air Force.)

Publications in FY93:

None.

Publications in Progress:

Alpert, D., Houser, R. M., Strachan, J. W., SAND92-1381, "Testing and Evaluation of the Large Area Heliostats for Solar Thermal Applications."

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

Cameron, C. P., SAND92-1348, " A Summary of Recent Activities at the National Solar Thermal Test Facility."

Cameron, C. P., SAND93-0229, " High Heat Flux Engineering in Solar Energy Applications."

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

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

Jorgensen, G., Wendelin, T., SERI/TP-257-4628, "Uniform Flux Dish Concentrators for Photovoltaic Application." Golden, Colorado, National Renewable Energy Laboratory.

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

Peterka, J. and Derickson, R. G., "Wind Load Design Methods for Ground Based Heliostats and Parabolic Dish Collectors."

Moreno, J. B. and Moss, T. A., SAND92-2253, "Bench-Scale Screening Tests for a Boiling-Sodium-Potassium-Alloy Solar Receiver."

Ralph, M. E., SAND92-2167, "Thermal Effects Testing at the National Solar Thermal Test Facility."

Strachan, J., SAND 92-2789, "Revisiting the BCS: A Measurement System for Evaluating the Optics of Solar Collectors."

Scientific Meetings and Presentations:

None

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