Quarterly Progress Report:

SECOND QUARTER FISCAL 1989

# DOE SOLAR THERMAL TECHNOLOGY PROGRAM

Submitted By:

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# FOREWORD

The research and development described in this document was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. The overall goal of the Solar Thermal Technology Program is the utilization of concentrated solar energy to provide an economical, environmentally sound renewable energy supply to ensure energy security and enhance international competitiveness.

A major restructuring of the Solar Thermal Technology Program has been largely completed by the field laboratories and the DOE Solar Thermal Technology Division and a new Multi-Year Program Plan (MYPP) is in preparation. The structure, strategy, and goals of the draft new program plan are reflected in the FY89 Annual Operating Plan (AOP). This document reports progress and status relative to the AOP.

Beginning in FY89, a single Quarterly Progress Report which integrates the work of both of the major field laboratories, Sandia National Laboratories (SNL) and the Solar Energy Research Institute (SERI), is being prepared. This differs from past years in which each organization prepared their individual progress reports, and is consistent with the structure and implementation strategy of the new program plan which consists of interrelated missions and supporting core R&D requiring close coordination of the field laboratory activities.

# MANAGEMENT STATUS REPORT

## Structure of the Solar Thermal Technology Program

The Solar Thermal Technology Program is structured to focus on a number of near-term commercialization opportunities (missions) for the technology while maintaining a baseline of research and development (core) which is essential to achieving the long term technology goals. The program structure consists of three core R&D activities and three mission activities, each having several associated tasks, as shown below.

CORE RESEARCH AND DEVELOPMENT

C1. EXPLORATORY RESEARCH
1. Photon Interaction with Materials and Chemicals
2. New Optical Capability
3. Materials Processing
4. Advanced Concepts and Systems Evaluation

C2. CONCENTRATOR DEVELOPMENT
1. Heliostats
2. Parabolic Dishes
3. Optical Materials and Procedures
4. Structural Analysis

C3. SOLAR-ELECTRIC TECHNOLOGY READINESS
1. Central Receiver Technology
2. Distributed Receiver Technology
3. Conversion Devices

MISSIONS

M1. NEXT-GENERATION USER SYSTEMS
1. Project Development
2. Partner-Driven R&D
3. Design Assistance and CORECT Support

M2. PHOTOCHEMICAL SYSTEMS
1. Identification of Application Opportunities
2. Solar Processing of Dilute Aqueous Chemical Wastes
3. High-Temperature Solar Destruction of Hazardous Wastes

M3. ADVANCED ELECTRIC TECHNOLOGY
1. Technology Identification
2. Joint Venture Consortium
3. Development Requirements
4. System Experiment

## Field Management Structure and Responsibilities

Specific implementation of the Solar Thermal Technology Program is assigned to two field laboratories, the Solar Energy Research Institute in Golden, Colorado and Sandia National Laboratories in Albuquerque, New Mexico. Together, these two field laboratories are responsible for implementation of the core research and development activities and the specific missions that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts placed with private industry, other research organizations, and universities.

A field Laboratory Management Council (LMC) provides the focus for interaction with the DOE program management and for planning and coordination of the field activities. The LMC is co-chaired by a senior management representative from each laboratory and is composed of the field Activity Leaders and Activity Coordinators.

In order to provide a clear delineation of management responsibilities for each program activity, a lead responsibility and a coordination responsibility are assigned by laboratory for each of the six current program activities. In each case, the activity coordination responsibility will reside at the laboratory which does not have the activity leader responsibility. The cognizant laboratory is responsible for designating the specific individual for each function. Field activity management responsibilities for FY89 are shown below. The Activity Leaders are responsible for preparing program activity input for this Quarterly Progress Report.

### FY89 PROGRAM ACTIVITY FIELD MANAGEMENT RESPONSIBILITIES

| PROGRAM ACTIVITY | LEADER/COORDINATOR (Laboratory) | (Individual) |
|---|---|---|
| **CORE R&D:** | | |
| C1. Exploratory Research | SERI/SNL | Gupta/Klimas |
| C2. Concentrator Development | SNL/SERI | Holmes/Murphy |
| C3. Electric Technology Readiness | SNL/SERI | Klimas/Carasso |
| **MISSIONS:** | | |
| M1. Next-Generation User Systems | SNL/SERI | Otts/Gupta |
| M2. Photochemical Systems | SERI/SNL | Thornton/Holmes |
| M3. Advanced Electric Technology | SNL/SERI | Klimas/Gupta |

## Program Management Overview

- **Annual Operating Plan Development**

  The draft FY89 AOP for the Solar Thermal Technology Program was finalized and submitted to the DOE Solar Thermal Technology Division on November 30, 1988. Subsequent comments and corrections from the DOE Program Managers were incorporated in the final draft, which was approved by the Division Director on December 21, 1988. Printed copies of the AOP were distributed in early January.

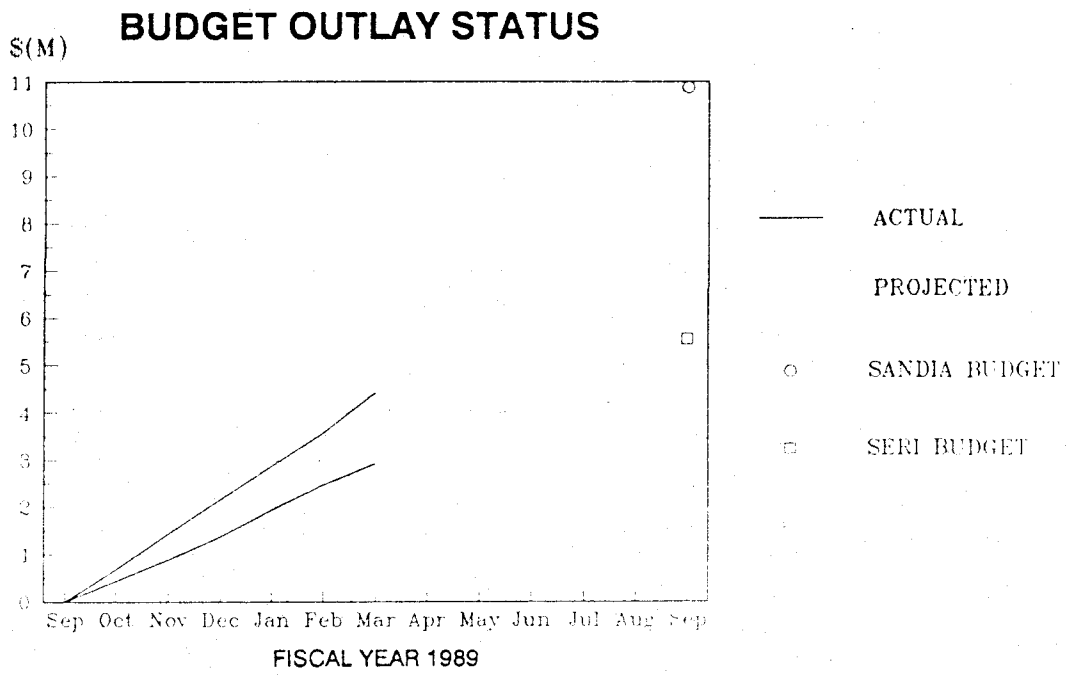
- **Multi-Year Program Plan Development**

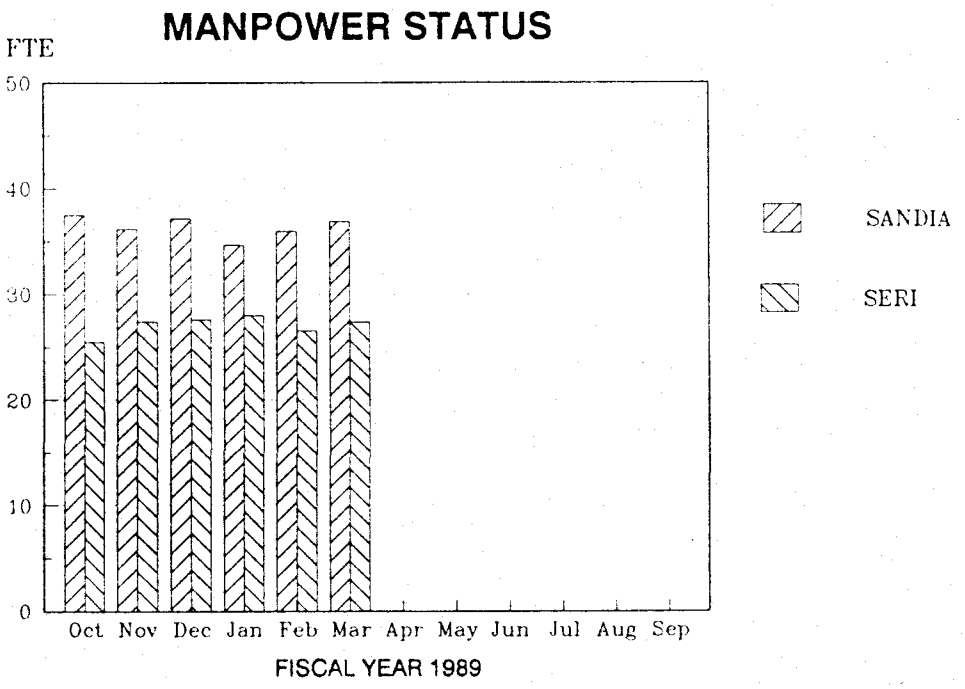
  Active work on a new MYP for the Solar Thermal Program began in the second quarter of FY89. Meetings were held within the DOE and Laboratory. Key managers are to arrive at a theme for the MYPP. Industry representatives were invited to provide input to the MYPP and help structure the document. A schedule was set up by Frank Wilkins, DOE/HQ program representative, who is leading this program. Bim Gupta at SERI and Bill Marshall at Sandia were designated as the principal field laboratory contacts. Gus Hutchison was designated the SGIA contact.

- SOLTECH89

  SOLTECH89 was held in March and included the SEIA annual meeting, the Photovoltaics Annual Systems Symposium (PASS), and the Solar Thermal Program Annual Technical Meeting. The theme for this meeting was applications in the federal, state, and local agency sectors. Special posters were created and prepared by SERI for displaying the current technology for electric applications and the emerging technologies, including detoxification of chemicals and material processing. Attendance and participation in the solar thermal technical sessions were encouraging. Sandia members of the meeting organization committee were Bill Couch and Hugh Reilly and SERI members for the solar thermal portion of the meeting were Russ Hewett and Bim Gupta. Sandia prepared the proceedings for the Annual Review.

## Resource Summary



## Procurement Summary:

| Task | Reference | Contractor | Work Title | $K Value | Technical Status | Monitor |
|---|---|---|---|---|---|---|
| C1 | SERI | National Academy | Evaluation of Solar Flux Application | 165 | Negotiation | B. Gupta |
| C1 | SERI | TBD | Chemical Test Set up | 30 | Open | D. Blake |
| C1 | SERI | TBD | RFP | 400 | Open | B. Gupta |
| C1 | SERI | TBD | Materials Test Chamber | 45 | Negotiation | R. Pitts |
| C1 | SERI | University of Houston | Chemical Research | 200 | Active | G. Nix |
| C1 | SERI | University of Chicago | Innovative Optics | 50 | Active | B. Gupta |
| C2 | SERI | Post Docs | Materials & Chemistry | 110 | Active | D. Blake |
| C2 | SNL 33-1227 | Solar Kinetics, Inc. | Membrane Heliostat | 679 | Active | D. Alpert |
| C2 | SNL 05-7867 | Science Applications | Heliostat Integration | 144 | Active | D. Alpert |
| C2 | SNL 33-1226 | Science Applications | Membrane Heliostat | 503 | Active | D. Alpert |
| C2 | SNL 90-5753 | Peerless-Winsmith | Low-Cost Drive | 487 | Active | J. Grossman |
| C2 | SNL 42-3005 | Peerless-Winsmith | Low-Cost Drive Repair | 14 | Active | J. Grossman |
| C2 | SNL40-6310 | CCP | Wind Load Analysis | 12 | Active | J. Grossman |
| C2 | SNL 55-2495 | Solar Kinetics, Inc. | Stretched-Membrane Dish Development | 900 | Active | T. Mancini |
| C2 | SNL 57-4436 | TIW FAb. & Mach. | Solar Collector Pedestal Fabrication | 57 | Active | T. Mancini |
| C2 | SERIZX-8-07233-1 | 3M Company | Industrial Support on Silver/Polymer R&D | 80 | Requested | P. Schissel |
| C2 | SERIHX-8-07247-1 | Springborn Laboratories | Protective Treatments for Membrane Mirrors | 51.5 | Requested | P. Schissel |
| C2 | SERIK-6-06034-1 | Colorado State University | Wind Load Reduction Research | 45 | Active | A.Lewandowski |
| C2 | SERI | Dan-Ka | Concentrator Structural Analysis | 25 | Active | R. Wood |
| C3 | SNL 63-6991 | B&W | DAR Panel Module Design | 60.6 | Active | J. Chavez |
| C3 | SNL 06-0312 | Foster Wheeler | DAR Design Studies | 136.9 | Active | J. Chavez |
| C3 | SNL 91-4687 | B&W | Molten Salt Subsystem/ Component Test Experiment | 7884 | Active | J. Chavez |
| C3 | SNL 55-9510 | Advanced Thermal Systems | DAR Salt Flow Loop | 49 | Active | W. Couch |
| C3 | SNL 53-8452 | Stirling Thermal | STM4-120 | 300 | Active | K. Linker |
| C3 | SNL 33-3036 | Stirling Thermal | Solar Receiver | 155 | Active | K. Linker |
| C3 | SNL 75-8851 | Stirling Thermal | 2nd STM4-120 | ???? | Nego. | K. Linker |
| C3 | NASA/LeRC | NASA LeRC | ASCS Design | 1200 | Active | K. Linker |
| C3 | SNL 55-6497 | Cal Polytechnic | IPH Report | 17 | Completed | P. Klimas |
| C3 | SNL 06-5409 | Technadyne | Technical Programmer | 81 | Completed | M. Fewell |
| C3 | SNL 01-2370 | Tech Reps | Tech Support Services | 100 | Active | R. Diver |
| C3 | SNL 01-9646 | Kirk-Mayer | Technician Support | 85 | Active | R. Diver |
| M2 | SNL 55-4032 | University of Houston | Catalyst Development and Reactor Modeling | 149 | Active | J. Fish |
| M2 | SNL 75-6779 | Delphi Research Inc. | Chemical Analyses and Analyses System Conceptual Design | 50 | Active | J. Fish |
| M2 | XX-6-06082-1 | University of Dayton | Solar Incineration of Hazardous Waste | 140 | Mod in Prog | SERI |
| M2 | | TBD | Chemical Analysis | 50 | Open | J. Thornton |

## Major Milestone Schedule

The major milestones for each program task are summarized below in chronological order and by task reference. This set of major 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 and list other significant technical accomplishments in the SIGNIFICANT ACCOMPLISHMENTS SUMMARY section.

| Date | Activity-Task Reference | Descriptive Title |
|---|---|---|
| **First Quarter, FY89** | | |
| Oct. 1988 | C3-1 | Complete DAR blackener evaluation. |
| | M2-2 | Working group meeting to define R&D issues and approaches for FY89. |
| | M2-3 | Working Group Meeting at SERI to define R&D issues and approaches for FY 1989. |
| Nov. 1988 | C2-1 | SAIC contractor report on the design and prototype fabrication for the improved stainless steel membrane heliostat. |
| | C3-2 | Complete first bench tests of a reflux pool boiler at the STTF. |
| | M1-1 | Prepare and release CBD notice, with proposals due Feb. 15, 1989. |
| Dec. 1988 | C1-1 | Initiate contract with National Academy of Sciences (NAS) to assess the role of concentrated solar flux in chemistry and materials treatment. |
| **Second Quarter, FY89** | | |
| Jan. 1989 | C1-2 | Conduct solar pumped laser experiment with very high solar concentrations. |
| | C2-2 | Contractor report on aluminum membrane dish fabrication issues. |
| | C3-3 | Initiate Preliminary Design of FPSE. |
| Feb. 1989 | C2-4 | Define wind load field test program. |
| | C3-2 | Complete first bench tests of wicked receivers. |

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|---|---|---|
| | C3-3 | Kickoff meetings held for Advanced Stirling Conversion System. |
| | M2-1 | Preliminary cost comparison of solar photocatalytic water detoxification with conventional technologies. Analysis has been completed and has been reviewed with SNLA. Final documentation is in preparation. |
| Mar. 1989 | C1-3 | Determine if the solar treating of metals and/or ceramics can result in desired properties (e.g., hardness) with reduced reliance on strategic materials. |
| | C2-1 | SKI contractor report on the design and prototype fabrication for the improved aluminum membrane heliostat. |
| | C3-1 | Initiate pump & valve scale test performance evaluation. |
| | C3-3 | Demonstration of Stirling Thermal Motors' KSE at ETF. |
| | M1-3 | Participate in the SOLTECH 89 joint meeting. |
| | M2-1 | Analysis of opportunities for field experiments. Analysis was completed in March and is now in review at SERI and SNLA. Final documentation is expected to be released in April. |

Third Quarter, FY89

| | | |
|---|---|---|
| Apr. 1989 | C2-2 | Report on evaluation of LaJet innovative dish performance. |
| | C2-2 | Decision Point - Start second dish design, prototype fabrication, and test program based on SANDIA/SERI tradeoff studies and DOE budget constraints. |
| | C2-3 | Interim report on polymer film-to-silver adhesion. |
| | C3-1 | Initiate 6m DAR salt flow testing. |
| | C3-2 | Complete fabrication and checkout and initiate on-sun testing of the first reflux heat-pipe solar receiver at the STTF. |
| | C3-3 | Negotiate contract for second Stirling Thermal Motors' KSE. |
| | M1-1 | Select joint-venture partner for fielding improvements to a commercial solar thermal electric system. |
| | M2-2 | Review by external advisory group of analyses and experiments characterizing the effect of solar concentration and other process variables on the mineralization of chemical contaminants. Revision of R&D priorities as necessary. |

| | | |
|---|---|---|
| | M2-3 | Complete experiments demonstrating "six nines" destruction of dioxin and decomposition of concentrated solvents to EPA standards. |
| | M2-3 | Advisory Group meeting to review results of SERI and Sandia tests and advise regarding future directions for R&D. |
| May 1989 | C1-1 | Obtain results from laboratory experiments to explain the role of UV radiation (wavelength) in decomposition of toxic chemicals. |
| | C1-2 | Assess merit of scaling up laser experiments and optical concepts for achieving a source of lower wavelength laser beam. |
| | C1-3 | Convene an advisory group to evaluate progress and promise of carbon fiber treatment with concentrated solar flux, based on work at GTRI. |
| Jun. 1989 | C2-1 | SAIC contractor report on the design of a commercial, integrated stainless steel membrane heliostat based on test results for the improved 50 $m^2$ mirror module. |
| | C2-4 | Topical report on structural/optical analysis of membrane dish prototype. |
| | C3-3 | 25 kWe bench testing Stirling Thermal Motors' KSE at ETF. |
| | M1-1 | Complete contract negotiations and award contract. |
| | M2-3 | Complete CAESAR experiment. |

Fourth Quarter, FY89

| | | |
|---|---|---|
| Jul. 1989 | C1-4 | Establish economic potential of materials treatment with solar compared to other technologies. |
| | C1-4 | Initiate laboratory tests on closed loop 10W RTEC system. |
| | C2-3 | Define protective overcoat for silvered metal reflectors. |
| | M1-2 | Complete an R&D plan and initiate R&D activities. |
| | M3-2 | Begin preparation of RFP for system experiment. |

| | | |
|---|---|---|
| Aug. 1989 | C2-1 | Initiate contract to build prototype stainless steel integrated heliostat. |
| | C2-2 | Deliver 7m diameter aluminum membrane dish optical element, for testing at the STTF. |
| | C2-3 | Document cost potential of silvered metal structural mirrors. |
| | C3-3 | Initiate STM4-120 tests on-sun. |
| Sept. 1989 | C1-1 | Results of a working microscopic model to explain and predict the performance of $TiO_2$ catalyst in an aqueous contaminated solution. |
| | C2-1 | SKI contractor report on the design of a commercial, integrated aluminum membrane heliostat based on test results for the improved 50 $m^2$ mirror module. |
| | C2-1 | Topical report on SANDIA's optical and environmental evaluation of SAIC and SKI improved 50 $m^2$ membrane mirror modules. |
| | C2-2 | Decision Point - Begin commercial scale design or refine 7m optical element design to improve performance. |
| | C2-3 | Interim report on corrosion inhibition using altered polymers and metal interlayers. |
| | C2-4 | Topical report on innovative heliostat drive system performance. |
| | C3-2 | Decision on heat pipe vs. pool boiler receivers for further development. |
| | M2-1 | Preliminary cost comparison of high-temperature solar detoxification with conventional technologies. |
| | M2-2 | Completion of the preliminary testing of the pilot-scale experiment. Brief advisory group on the results and implement recommendations towards further experimentation or modification of activity priorities. |
| | M3-1 | Several attractive market/technology combinations will be characterized. |
| | M3-3 | Initial identification of development requirements for advanced electric technology. |

# SIGNIFICANT ACCOMPLISHMENTS SUMMARY

| MAJOR MILESTONE | PLANNED | ACTUAL |
|---|---|---|

Core 1. Exploratory Research

- **INITIATE CONTRACT WITH NATIONAL ACADEMY** — **DEC 88** — **FEB 89**

  A contract with the National Academy of Sciences (NAS) to assess the role of concentrated solar flux in chemistry and materials treatment is being negotiated. Complexities in the negotiation process have delayed placement of the contract to February.

Core 2. Concentrator Development

- **SOLAR KINETICS, INC. COMPLETED NEW 50-SQUARE-METER STRETCHED-MEMBRANE MIRROR MODULE** — **FEB 89** — **FEB 89**

  The new 50-square-meter prototype stretched-membrane completed by Solar Kinetics, Inc. was installed at the Solar Thermal Test Facility on February 7.

Core 3. Solar-Electric Technology Readiness

- **INSTALLATION OF THE PANEL RESEARCH EXPERIMENT SALT PIPING BEGINS** — **FEB 89** — **MAR 89**

  Installation of the salt piping for the Direct Absorption Receiver Panel Research Experiment has begun. The contractor expects installation of the piping to take 6-8 weeks due to the difficulty of welding the stainless steel pipe.

- **COMPLETED THE INITIAL DESIGN OF THE 6-M PANEL/FRAME DESIGN FOR THE PANEL RESEARCH EXPERIMENT** — **FEB 89** — **MAR 89**

  We have completed the initial design of the 6-m long panel/frame for the 3 MWt panel research experiment. A design review meeting was held on March 29, 1989, to evaluate the panel/frame design prior to it being sent out for fabrication bids.

- **COMPLETED THE WATER FLOW TESTING, FILM THICKNESS MEASUREMENTS ON THE 8-M PANEL** — **MAR 89**

  The film thickness measurements, using water on the 8-m long panel, tilted at 15° has been completed. The data is currently being analyzed. These data will be used for characterizing the falling film and validating the SERI salt film thickness results.

| MAJOR MILESTONE | PLANNED | ACTUAL |
|---|---|---|

- **COMPLETED A CONTROL ALGORITHM FOR THE PANEL RESEARCH EXPERIMENT** — **FEB 89**

  A control algorithm for the Panel Research Experiment was developed during the past quarter. Besides aiding in the development of control, the simulation model will help characterize the performance of the receiver during the experiment.

- **COMPLETED THE DESIGN MODIFICATIONS TO A SALT LOOP WHICH WILL BE USED FOR MAKING THERMOCAPILLARY BREAKDOWN MEASUREMENTS** — **FEB 89**

  To accomplish the measurement of thermocapillary breakdown in the most efficient manner, the existing Direct Contact Heat Exchange test loop will be modified. Designs for these modifications have been completed and the necessary parts are ordered.

- **COMPLETED OVER 1000 HOURS OF OPERATION ON THE PUMP AND VALVE HOT LOOP** — **MAR 89**

  The molten salt pump and valve hot loop has operated for over 1000 hours. Although there have been valve packing failures, the hot loop has been operating in automatic mode since January 1989.

- **BEGIN INSTALLATION OF THE SANDIA VOLUMETRIC RECEIVER ABSORBER AT THE PLATAFORMA SOLAR DE ALMERIA** — **OCT 88** **MAR 89**

  Installation of the Sandia volumetric receiver absorber was begun this past quarter. The Sandia porous ceramic absorber is to be tested on the volumetric receiver at the Plataforma Solar de Almeria during the next quarter.

- **DELIVERY OF STIRLING THERMAL MOTORS' RECEIVER DELAYED** — **FEB 89** **TBD**

  Delivery of Stirling Thermal Motors' heat-pipe solar receiver has been delayed because flow losses in the wick structure were higher than expected. Flow tests performed by Sandia on a section of STM's wick showed that the wick's permeability was a factor of 200 lower than the value STM had calculated. The lower permeability, which is a result of the hydroforming process used in forming the dome, renders the wick unsuitable for STM's proposed receiver. Efforts are now under way to identify an alternate approach for forming the wick structure.

- **BENCH TEST OF HEAT PIPE DELAYED** — **FEB 89** **MAY 89**

  Testing a tubular heat pipe on Sandia's radiant bench test system was a planned activity for the second quarter of FY89. The test has been delayed because a faulty welder damaged the heat pipe's wick structure. The damaged parts are being replaced, and the tests have been rescheduled for May 89.

| MAJOR MILESTONE | PLANNED | ACTUAL |
|---|---|---|

- **DEMONSTRATED THE STIRLING THERMAL MOTORS KINEMATIC STIRLING ENGINE AT THE ETF** — PLANNED: FEB 89, ACTUAL: MAR 89

  The Stirling Thermal Motors' kinematic Stirling engine was demonstrated for the first time at Sandia's Engine Test Facility (ETF) on March 20. During lower power testing the engine produced 2-3 kW of shaft power.

- **CONDUCTED KICKOFF MEETINGS FOR THE ASCS PHASE II DEVELOPMENT** — PLANNED: JAN 89, ACTUAL: FEB 89

  Kickoff meetings for the preliminary design of the Advanced Stirling Conversion System (ASCS) were held at Stirling Technology Company (STC) and Cummins Engine Company.

Mission 1. Next-Generation User Systems

- **SOLTECH89 SUPPORTED** — MAR 89

  Sandia and SERI technical and management staff presented 16 talks covering all program core and mission activities.

- **PREPARE AND RELEASE A CBD NOTICE** — NOV 88 DEC 88

  A Commerce Business Daily (CBD) notice requesting expression of interest in participating in Mission 1 was prepared and published. Replies were received from 13 different companies.

Mission 2. Photochemical Systems

- **SERI EXPERIMENTS CONFIRMED DIOXIN DESTRUCTION TO GREATER THAN "SIX-NINES"** — JAN 89

  SERI researchers have shown that concentrated sunlight can reproducible destroy a dioxin to greater than 99.9999 percent (six-nines) destruction. They have shown existence of solar photo effect and are beginning to develop a good laboratory-field correspondence.

- **SNL COMPLETES INITIAL ENGINEERING-SCALE WATER DETOXIFICATION EXPERIMENTS** — FEB 89

  Initial experiments have been completed demonstrating the effectiveness of the SDW process in destroying organic contaminants in water. Using both engineering-scale heliostat and trough systems, we have successfully destroyed low concentrations of a model organic compound salicylic acid at rates a hundred to a thousand times those achievable to simple "one-sun" systems. Reaction rates appear to be linear in absorbed UV power over a broad range of solar concentration ratios. Processing times, as short as a few seconds, are commercially attractive.

| MAJOR MILESTONE | PLANNED | ACTUAL |
|---|---|---|

- **SERI RESEARCHERS COMPLETE CHARACTERIZATION OF RED TEXTILE DYES** — **MAR 89** **MAR 89**

  Characterization of red textile dyes has been completed in the SERI solar simulator for flux concentrations and reacting rates. A simple trough unit was placed in service to confirm the laboratory results with the outdoor solar experiments.

- **PRELIMINARY COST COMPARISON OF SOLAR PHOTOCATALYTIC WATER DETOXIFICATION WITH CONVENTIONAL TECHNOLOGIES.** — **FEB 89** **APR 89**

  Analysis has been completed and has been reviewed with SNLA. Final documentation is in preparation.

- ANALYSIS OF OPPORTUNITIES FOR FIELD EXPERIMENTS — MAR 89 APR 89

  Analysis was completed in March and is now in review at SERI and SNLA. Final documentation is expected to be released in April.

Mission 3. Advanced Electric Technology

- **REQUEST FOR INFORMATION APPROVED** — **MAY 89**

  A public request for information regarding potential program definition has been approved and will be released in May 1989.

# TECHNICAL STATUS REPORT

Core 1. Exploratory Research

Objectives: To establish the scientific base and to understand the phenomena involved in effective use of the unique attributes of concentrated solar energy, to develop and demonstrate, in cooperation with industry, a capability for the industrial application of materials processing using concentrated solar radiation.

Accomplishments

## TASK 1. PHOTON INTERACTION WITH MATERIALS AND CHEMICALS

- **An annotated bibliography of the literature on the high temperature destruction of hazardous wastes has been partially completed.**

  References obtained in a literature search begun last quarter have been surveyed, and the first two sections of a bibliography have been compiled. These cover the nonphoton processes relating to catalytic destruction and pyrolytic destruction. The section on the photochemistry of relevant classes of compounds is near completion as is that on combustion processes.

- **Trial runs of the photo/thermal and thermal/catalytic reactors are underway.**

  The quartz reactors for photo and catalytic experiments have been received. The furnaces required for the preheating stages have not been received. However, testing of the reactors and gas delivery systems is being done with borrowed equipment. The pyrolysis of chlorinated methanes, CClxH4-x (where x=1 to 4), and chloronaphthalene has been run to provide baseline data on the destruction chemistry of compounds in dark, noncatalytic conditions. These experiments demonstrated the great utility of the molecular beam mass spectrometer (MBMS) system for detecting products of destruction reactions. Products such as HCl, $Cl_2$, chlorinated ethylenes, and high molecular weight aromatic compounds could easily be detected and identified as products in these reactions. The major product, as expected, was carbon in the form of soot.

  The excimer laser to be used as the source of 308 nm light was serviced but still can be used only at about 95% power. This should not impact the experiments, but the problem with the system may adversely affect the lifetime of components in the laser. Documentation covering the design of the photoreactor system, and the optics for the measurement of the absorption spectrum of the hazardous compounds at reaction conditions, is progressing.

- **University of Houston research continued to show the technical feasibility of producing high-value chemicals photocatalytically.**

  University of Houston researchers performed thermodynamic calculations to guide experimental research on the photoenhancements of reactions of n-paraffins and methanol; aromatics and methanol; normal paraffins and acetone; and aromatics and acetone to produce high-value alkylated and oxygenated products. Calculations on the normal paraffin-methanol reactions show essentially complete conversion of starting reactants with up to 65 wt% selective yield to xylenol, about 2% production of olefins, plus some other fragments (by-products). For the aromatic-methanol reactions, complete conversion of reactants was predicted with about 75 wt% xylenol and the balance as by-products. For paraffin-acetone reactions essentially complete reaction was predicted with primary products (68 wt%) as benzyl cyclopropanone and 4-methylbenzylcyclopropanone and the balance as by-products. For the aromatic-acetone reaction, a wider distribution of products was predicted.

The researchers are attempting to answer two important questions. One is which starting material, paraffins or aromatics, is preferred? The calculations indicate $C_6$-$C_7$ aromatics are preferable to $C_6$-$C_7$ paraffins because fewer by-products are produced. The second is should methanol or acetone be used as the oxygen donor? It appears that methanol will yield cresols and xylenols while acetone will yield cyclic ketones. The choice will depend on the products desired, based on their value.

These results will be used to guide the experimental efforts. Experiments are expected to show enhancements in rate and product selectivity due to solar photons. Activities are underway to modify the research subcontract with the University of Houston to provide funds for continuing research.

## TASK 2. NEW OPTICAL CAPABILITY

- **SERI made significant progress in optical analysis and design of the outdoor high flux optical system.**

Both analytical and design-related work on the SERI outdoor high flux optical system proceeded on schedule. The site development work includes design and engineering for the site by a local A/E firm. Most of the optical hardware for the high flux experiment is either being fabricated or design work is underway. The initial dish mirror facets should be delivered to SERI early in April. The support structure for the dish facets is being fabricated at a local shop. Modifications to the heliostat support structure are currently being analyzed and a final design will be selected in early April. A control system subcontract for the heliostat is currently being negotiated and will be issued in April.

A local A/E firm, under subcontract, has completed the design work. They have completed engineering specifications for the grading, foundations, buildings and utilities required for the site. The drawings and specifications were delivered by the contractor.

Responses from an RFP for fabricating an individual heliostat control system for the facility have been evaluated. The contract with the selected bidder is in negotiation and work should begin in early April.

Fabrication of the dish mirror facets for the facility is proceeding on schedule. Eight of the 25 facets have been ground and polished and are at the coater where the enhanced aluminum reflective surface will be applied. SERI researchers expect shipment of the coated facets to Glass Mountain Optics for inspection at the beginning of April. Once inspected, measured against specifications, and tagged, they will be shipped.

The support structure design for the dish mirror facets has been completed by Dan-Ka Products, under subcontract. The support structure includes the mounting and alignment fixtures for the facets as well as the beams to which these fixtures are attached. Dan-Ka Products is now fabricating the structure. The structure will be assembled at the FTLB and available mirror facets will be attached so that trial methods of facet alignment can be tested.

Dan-Ka Products has also begun analysis of various modifications to the Martin Marietta heliostat structure required to support the new, flat mirror facets. The mirror facets will be front-surface, enhanced aluminum on float glass. A supplier of these glass mirrors has been identified and discussions regarding glass selection options (e.g., size, thickness, flatness, etc.) have been initiated.

## TASK 3. MATERIALS PROCESSING

- **The transitioning from SERI to Sandia/Albuquerque of the R&D on using concentrated solar flux to strengthen carbon fibers was initiated.**

  Procurement of a new subcontract with Georgia Tech Research Institute (GTRI) was initiated by Sandia during the quarter. (This subcontract had been administered by SERI during previous years.) During the present quarter, Sandia visited GTRI to review previous work and to write a statement of work. Based on an in-depth technical review, Sandia believes the work at GTRI shows promise and is worth funding for at least one additional year. The objective of the work is to use concentrated solar energy to develop unique grades of carbon fibers with improved oxidation resistance. Improvement of this property is especially important for applications where the fiber will be exposed to elevated temperatures (i.e., greater than 400°C). These situations typically occur in space vehicles and turbine applications that employ carbon-fiber composites. During the proposed subcontract period, GTRI will complete its research on oxidative resistance and compare the results with other nonsolar research conducted in this area by several U.S. and foreign organizations. If the solar processing proves to be favorable relative to other nonsolar techniques, a U.S. industrial partner will be sought to bring the new product to the marketplace. In addition, this subcontract calls for limited maintenance of the U.S. DOE Advanced Components Test Facility (ACTF) located at GTRI. This maintenance is required to keep the ACTF in mothball status, pending a decision by DOE regarding its future.

  A study was initiated at Sandia that compares the economics of solar and nonsolar material-processing technologies. In this study, the cost/performance of treating materials with a solar furnace is being compared to similar treatment with high intensity electric-arc lamps.

## TASK 4. ADVANCED CONCEPTS AND SYSTEMS EVALUATION

- **Shakedown testing of the regenerator for the 10 Watt electric (We) integrated regenerative thermoelectrochemical converter (RTEC) system experiment was completed, and design and fabrication changes were completed.**

  SERI researchers concentrated their efforts on shakedown runs on the RTEC regenerator. SERI researchers have successfully completed two pressurized, adiabatic expansion, regeneration shakedown experiments. Operating conditions for the second experiment included a flowrate of 2 ml/sec of typical RTEC fluid, a pressure in the range of 140-300 psi, and a temperature of the dissociated products of 300-430°C. (It should be noted that the temperature is estimated to drop approximately 100°C during the dissociation process, giving an upstream temperature of approximately 400-530°C.) No leaks or other anomalies were detected during or after the shakedown experiments. The ammonia yield was .012 gm per gm of working fluid, and the water to ammonia ratio was 4.5:1. These data should be considered as indicators that the regeneration process has been demonstrated, but not as measurements of performance. A number of modifications and refinements are planned for the following troubleshooting experiments, including increasing the regenerator heater section pressure, measuring the temperature prior to the adiabatic dissociation, and observing the rate of the dissociation reaction.

  Prior to beginning the sequence of shakedown tests with a pressurized heater section, a set of runs was made allowing the dissociation to occur along the entire length of the heater. For these runs, outlet temperatures ranged from 513°C to 580°C. A maximum of 0.042 gm of ammonia per gm of circulating RTEC fluid was obtained. Also, a maximum of 29.6 wt% of ammonia and 70.4 wt% of water were obtained.

These runs were made using the RTEC regenerator configuration that will be sent by SERI to Hughes for inclusion in their closed-loop experiment. Design and fabrication changes were also made during the reporting period to accommodate the existence of hydrogen in solution in the working fluid throughout the closed-loop cycle. These included the fabrication of all metal components from Carpenter 20 where they come in contact with the working fluid. Also, the stripper was redesigned and fabricated exclusively from graphite.

- **SERI and Sandia/Albuquerque staff completed the planning of the analysis subtask and identified the major thrusts.**

  A subtask planning meeting was held with SNLA personnel, with definition of a task structure and composition of a draft task plan. There are three major thrusts within the analysis subtask: (1) Reactor Receiver Modeling, (2) Materials Processing Assessment, and (3) New Concepts Generation and Evaluation.

- **A review of literature on radiative transport modeling was initiated.**

  Researchers began reviewing literature on radiative transport modeling techniques in order that the most appropriate techniques can be applied to high flux solar receiver/reactors currently under consideration for various applications. A popular subject of many papers is to compare results from several modeling techniques for a given problem with a range of problem parameters (optical density, scattering albedo, etc.). Quite often, the discreet ordinate method is taken as the reference method by which all others are compared. One paper compared the discreet ordinate method (20 ordinates) with a six flux, two flux, and one flux (Beer's law) methods for a one-dimensional water layer with scattering particles. Their final conclusion was that the six flux method was to be recommended because it gave results very close to the discreet ordinate method and was straightforward to implement. To test the latter conclusion, SERI researchers assembled a full three-dimensional, six-flux model of a simple geometry and have begun exercising it. Initial observations were that the six-flux method is appealing because its implementation is quite straightforward, it is easily applied to two or three dimensional problems (unlike the discreet ordinate method), gives a very good physical feel to the problem, and should couple very well with finite difference formulations for the mass, momentum, and species conservation equations. An obvious difficulty, as in all finite difference formulations, will be applying the method to complicated geometries.

- **SERI completed an assessment of the feasibility of using neutron transport codes to model radiative transport in receiver reactors.**

  The feasibility of using neutron transport codes for modeling radiative transport in receiver/reactors was discussed with Professor C. L. Tien, a leading expert on radiative transport. Professor Tien indicated that there are no fundamental reasons why these codes could not be used to model radiative transport since the equations are the same. He expressed concern about being able to correctly model realistic radiative boundary conditions (e.g., reflective) with these codes and being able to model more than one wavelength band. However, most such codes now allow flexible boundary conditions including reflective boundaries and allow several dozen energy groups (equivalent of wavelength for the radiative transport problem) to be tracked. Professor Tien also addressed the problem of radiative properties needed for carrying out these calculations. For dispersed spherical particles in a gas or liquid, Mie theory or simplifications can be used to calculate the radiative cross sections and phase function. Some current receiver/reactors under consideration use or propose to use a monolithic absorber such as a porous alumina sponge, however. In this case, because the absorbing/scattering particles are not independent, Mie theory may not be applicable and experimental measurements of the radiative properties may be needed. Professor Tien has worked in this area and noted that, under certain conditions, Mie theory can be used to calculate properties

to reasonable accuracy thus saving a considerable experimental effort. Researchers are currently reviewing publications in this area to assess further the need for experimental determination of radiative properties of potential receiver/reactor absorbers.

Researchers received documentation on a one-dimensional neutron transport code (ANISN) from ORNL. The SERI Computing Services Branch has evaluated the possibility of running the code on the Sun minicomputer at SERI and found that this is possible. ORNL also sent documentation on a two-dimensional code (DORT) which is likely to meet all our needs for receiver reactor modeling. The Computing Services Branch evaluated this code and found that it would run best on the SERI IBM mainframe although SERI will be on the SuperNet in April and this would open the possibility of running DORT on a supercomputer, a better long-term solution.

Another field in which the radiative transport equations are solved is in atmospheric research where the transport of light through particle laden gases is of interest. With this in mind researchers have contacted NCAR and NOAA to determine whether they actively use any codes for such calculations and whether such codes could be made available for analysis of radiative transport in receiver/reactors.

This search led us to Dr. Warren Wiscombe at Goddard Space Flight Center who sent the source code, documentation, and test programs for the DISORT code. This is a one-dimensional discrete ordinate code used primarily for calculating scattering and absorbing in the atmosphere. Although it is limited to one-dimensional calculations in planar geometries, it is very well suited for receiver/reactors which fit these limitations, e.g., the aqueous detox/falling film receiver/reactor and the silicon carbide felt receiver cases. This is because the code is written as a FORTRAN subroutine and can be easily incorporated into larger codes. To use the code for receiver/ reactor modeling, one would write a program which calculates chemical reactions and fluid flow and which could then call the DISORT subroutine as needed to calculate the radiative transport part of the problem. Researchers have loaded the subroutine on the SERI Sun minicomputer, have run the test programs and are now evaluating the results. In addition, the code is being used to evaluate the optical depth of water/titanium dioxide suspensions of various particle sizes and particle concentrations in support of the Solar Detoxification of Water task.

Next Quarter Planned Activities:

- For the photon/materials interaction research, a SERI technician will go to Sandia/Albuquerque to learn the techniques for depositing the rhodium catalyst on the alumina supports for use in experiments on the steam reforming of methylene chloride. Photothermal experiments on destruction of xanthone and tetrachlorodioxin will be initiated. The initial survey of the literature on destruction of hazardous compounds will be completed.

- Researchers at the University of Houston will complete an assessment of a chemical reaction system to define the potential for solar enhancement of chemical reactions. They will also perform experiments to define the extent of solar enhancement for specific systems.

- Construction will begin on the SERI high flux optical system.

- Solar pumped laser experiments will be conducted at the University of Chicago with improved optical components.

- For materials processing (Task 3), the subcontract between Sandia/Albuquerque and GTRI will be established.

- For the RTEC research, a set of experimental data runs will be made using the existing regenerator at SERI. After these runs are made, the regenerator assembly will be sent to Hughes Aircraft for inclusion in the closed-loop, 10 We system experiment. A senior SERI technician will install the regenerator at Hughes and instruct staff there on operating procedures and safety. In parallel, experiments using a duplicate regenerator will continue to refine measurement techniques and obtain performance data.

## Core 2. Concentrator Development

Objectives: To develop cost effective concentrators in support of the National Solar Thermal Program. The major goal of the Concentrator Development Activity is to establish the commercial readiness of the heliostats and parabolic dishes by FY93 and FY95, respectively.

Accomplishments

# TASK 1. HELIOSTATS

- **New 50-square-meter stretched-membrane mirror module completed by Solar Kinetics, Inc.**

  Solar Kinetics, Inc., completed the fabrication of a new 50-square-meter prototype stretched-membrane mirror module. The mirror module was installed at the Solar Thermal Test Facility for testing and evaluation on February 7. SKI's design incorporates a number of improvements over its 1986 design including a focusing system that should perform better in windy conditions, a passive defocusing system for use in the event of loss of power, a simplified method for tensioning the membranes, and a lower cost mirror support ring and back structure.

  A preliminary analysis of the quality of the reflected beam was completed. A single beam profile was recorded with our beam characterization system, and the measured beam profile is shown in Figure 1. The recorded beam data have been compared with data predicted by the HELIOS computer code to estimate both the fraction of module area that is reflecting sunlight onto the target and the dispersion error of the reflective surface. Allowing for the area at the center of the mirror where the focusing fan is mounted, our preliminary results indicate that nearly 96% of the mirror's surface area reflects sunlight onto the target; most of the lost area corresponds to the bare metal along the welded seams in the aluminum membrane. A HELIOS-generated flux profile, assuming a circular normal error distribution with a sigma 1.4 ± 0.2 mr (2.8 mr beam dispersion), provides a good match to the measured flux profile. A 2.8 mr slope error is the same as that measured for SAIC's second and SKI's first mirror modules. The performance of the mirror's focus control system on windy days, its defocusing speed, and its use of parasitic power will be measured next quarter.

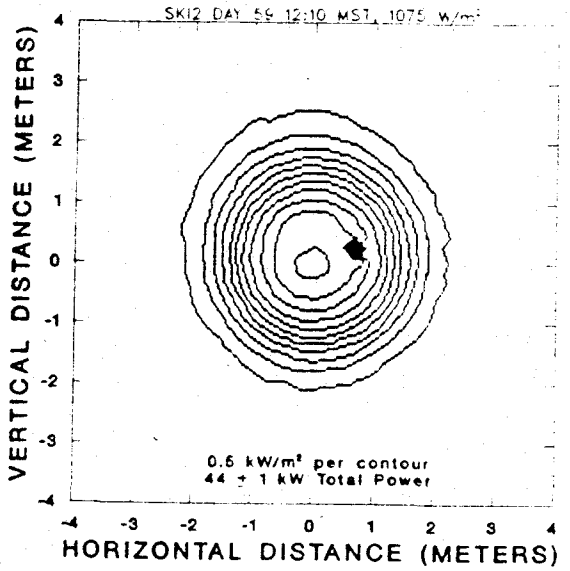


Figure 1 - Measured flux contours of the beam spot from SKI's 50-square-meter prototype stretched-membrane mirror module. The image was recorded at 12:20 MST on Feb. 28, 1989. Insolation was 1075 W/square meter. The dark area is the hole in our BCS target.

- **Specularity of Solar Kinetics, Inc.'s reflector measured.**

  A sample of ECP-300A film laminated to 0.010 inch-thick aluminum from SKI's second stretched-membrane mirror module was evaluated with SERI's Large Aperture, Near Specular, Imaging Reflectometer (LANSIR). At a membrane tension of 35 lbs/in, the measured beam dispersion was less than 1 mr, slightly better than the previous samples analyzed.

- **Mid-Term review meeting held with Science Applications International Corp.**

  Science Applications International Corp. presented its ideas for optimizing the design of a commercial stretched-membrane heliostat at a February 7 meeting at which the status of its contract with Sandia was reviewed. SAIC evaluated more than a dozen different conceptual designs for supporting and driving a membrane heliostat before selecting two that were thought to be less costly than the existing design, which uses a single pedestal for support. One of the selected designs uses two mirror modules mounted to a single torque tube; SAIC considers the second to be proprietary. Both designs allow the mirror module to be stowed face down, an advantage for extending the life of the reflector and for lowering the rate of soiling. SAIC will complete a comparison of the cost, performance and fabricability of the the two designs before a decision is made next quarter on the course of future activities.

- **Repairs completed on the drive for Solar Power Engineering Co.'s 200-square-meter heliostat.**

  Hub City completed the repairs on the elevation drive for SPECO's 200 square-meter heliostat, and it was returned to Sandia. The drive was X-rayed by Sandia to determine if there were voids or other flaws in the new worm gear. The X-rays showed only a small number of small voids that were believed to be insignificant.

- **Solar Power Engineering Co's heliostat drive fails static load test.**

  The repaired drive used on SPECO's 200 square meter heliostat was statically tested to ensure it meets its design specification. The test results were satisfactory at the first five locations tested on the worm gear; however, the drive failed at the sixth. The failure occurred at about 85% of the design load. At the end of the quarter, the drive was being inspected to determine the cause of the failure. A decision on the repair of the drive will be made next quarter.

- **Low-cost drive fails due to water accumulation.**

  During sub-freezing weather, the azimuth housing of the low-cost drive failed. The drive failed during operational testing with ATS's 150-square-meter heliostat. Inspection of the drive by Sandia and Peerless Winsmith determined that a large amount of water (at least 4 liters) had accumulated inside the cast-iron housing and had frozen. The pressure created by the ice caused the housing to break into 15 pieces. There was also minor damage to the heliostat. The water apparently entered the housing through bolt holes in the top of the drive; the bolts had vibrated loose during normal operation. Peerless-Winsmith will make minor design changes to better seal the housing and to prevent the bolts from loosening.

- **Cracks repaired in two stretched-membrane mirror modules.**

  A number of small cracks were found in welds on both Solar Kinetics, Inc's, first and in Science Applications International Corp.'s second prototype stretched-membrane mirror module. The cracks were in the welds that attach the mirrors' support ring to the support trusses; the cracks were only in the welds. SKI's mirror module was installed in June 1986 and SAIC's in July 1988. Cracks were found in three out of SKI's six supports and in all five of SAIC's supports. Our examination indicated that the welds were not of high quality. On SAIC's unit the welds were too thin and undercut and on SKI's they were too thin and the weld-termination craters had not been properly filled. We have rewelded all the ring-to-truss attachment points. The two contractors were advised of the situation and are considering possible design modifications. In addition, both will reassess their quality assurance procedures.

Next Quarter Planned Activities:

- A final review meeting will be held with Solar Kinetics, Inc., on its improved stretched-membrane heliostat design, and a final report will be completed. Completion of the report, scheduled for this quarter, was delayed due to manpower conflicts at SKI.

- Dan Sallis, a consultant for SERI, will review the structural analyses performed by SKI for its second membrane mirror module. Sallis's review will help clarify the reasons SKI encountered difficulties in tensioning membranes and attaching them to the mirror module.

- Inspection of the damaged drive from SPECO's 200-square-meter heliostat will be completed. A decision on the repair of the drive will be made.

- Science Applications International Corp.'s final report on its improved design for a stretched-membrane heliostat will be published.

- Peerless-Winsmith will modify all three prototypes of the low-cost drive to prevent water from leaking into the drive's housing. A new housing to replace the one damaged by ice will be fabricated. In addition, new drive shafts will be installed on all three drives; an improperly hardened shaft was the cause of earlier failures on two of the drives. Peerless-Winsmith's final report on the design of a low-cost drive will be published.

## TASK 2. PARABOLIC DISHES

- **Decision made to test the LaJet Innovative Concentrator.**

  Evaluation of the LaJet Innovative Concentrator showed that the collector has been substantially stiffened by the addition of braces and the changes made to the structure. As the collector tracks the sun, the relative motion of the concentrator gores has been halved. The facets are currently being focussed and aligned. We will begin testing the collector during the next reporting period using flux mapping and calorimetric techniques.

- **Stretched-Membrane Dish Development Project - Task 1 Design Review conducted.**

  On March 3, 1989, a Task 1 Design Review for the Solar Kinetics, Inc. Stretched-Membrane Dish Development Project was held in Dallas, Texas. Representatives from Sandia, SERI, and consultant Vern Goldberg were in attendance as the Technical Review Committee. Task 1 of the project addressed optical element fabrication issues related to creep and fatigue in the polymer films, the effects of metal and polymer seams on the optical performance of the concentrator, and the repeatability of the selected membrane fabrication process.

  Solar Kinetics made a very detailed and thorough presentation of their results. They have selected stainless steel over aluminum as the metal membrane material because of the margin between the yield and ultimate stress for steel. To establish the repeatability of the forming process, SKI made 3 membranes, 3.7-m dia. with $f/d = 0.6$, using identical materials and procedures. Measurement of the formed membranes showed them to have 2.6, 2.9, and 2.8 milliradian slope errors including the optical effects of both the metal and polymer seams. These slope errors are very low and could result in a collector performance that exceeds the project goals. In summary, there are no known obstacles to keep us from proceeding with the next task of the project, the design and fabrication of a 7-meter diameter, stretched-membrane, optical element.

  Solar Kinetics has developed the schedule and costs for design and fabrication of the 7-meter diameter optical element. The Task 1 Topical Report (AOP MM C2-2 scheduled for January 1989) will not be completed until May. The 7-m optical element installation at the Sandia Test Facility is also delayed from August to the first quarter of FY90.

- **Dish concentrator meeting held.**

  A dish concentrator program meeting was held at Sandia on February 14, 1989. The purpose of the meeting was to determine whether or not a second dish development effort (in addition to the Stretched-Membrane Dish Project) should be considered. The meeting was attended by representatives of SERI, Sandia, and DOE Headquarters. The results of the meeting are: agreement that a near-term alternative to the stretched-membrane dish should be considered, the establishment of five criteria for the relative evaluation of alternatives, and discussion of two specific options. The two concentrator options discussed at the meeting, a stretched-membrane, faceted dish and a sheet-metal concentrator, are being evaluated in more detail. A meeting of SERI, Sandia, and DOE personnel will be held in April to establish a near-term, commercial development plan.

**Next Quarter Planned Activities:**

- A meeting of SERI, Sandia, and DOE personnel will be held in April to establish a near-term, commercial dish development plan.
- On-sun testing of the LaJet Innovative Concentrator will begin during the next reporting period. The first test will be calorimetric measurement of the power delivered to the receiver aperture. The second test will be video flux mapping of the power-density distribution in the receiver aperture plane.
- The Solar Kinetics' Topical Report for the Stretched-Membrane Dish Development Project (AOP MM C2-2 scheduled for January 1989) on membrane fabrication issues will be delivered in May 1989.
- Preliminary review of the Solar Kinetics' 7-m diameter, stretched-membrane optical element design will be held in June.

# TASK 3. OPTICAL MATERIALS AND PROCESSES

- **A test matrix used to compare degradation of different polymers and stabilizers helps define improved silvered polymer for mass production.**

  A large test matrix that enables a comparison of three types of PMMA each with five stabilizer types, on aluminum or coil-coated aluminum, used for weathering samples in the QUV and Weather-Ometer test chambers, continues to yield significant data after months of testing. These results, in conjunction with similar data generated at 3M, have defined the best PMMA and the type and concentration of (UV) screen that is to be used in the next production runs of silvered polymer. 3M is currently projecting production of this new combination to begin July 1, 1989.

- **Evidence accumulates that a purer PMMA and more UV screen retard degradation.**

  A solar simulator test facility provides a very accelerated test that has demonstrated the following results: (1) Mirrors degrade more rapidly in pure nitrogen than in dry air. A possible explanation is that oxygen with its triplet ground state quenches a reactive excited triplet species which is then prevented from reacting with silver. (2) Perhaps more significantly, mirrors made with the current production PMMA degrade rapidly in moist air, compared to dry air, while mirrors made with purer PMMA and/or higher levels of UV screen do not. Apparently, sensitivity to moisture can be greatly decreased by either providing a moisture barrier or by using purer polymer and/or more UV screen. The latter two alternatives are easier to accomplish and are to be used in the future production.

- **Inconel back layers retard corrosion.**

  Results with a special sample set tested for six months in the Weather-Ometer suggests that a thin Inconel layer behind the silver can be used in place of coil-coated aluminum to slow silver corrosion. Comparing the production polymer that contains very low stabilizer levels (like ECP 300X) with either 50 or 150 nm of Inconel behind the silver, on either aluminum or coil-coated aluminum, and silvering by either sputtered or evaporated silver, shows that they all degrade at the same very slow rate. This striking result (the independence of corrosion from the kind of substrate used) does not occur for samples without Inconel.

- **Silver/Hostaphan polyester adhesion is excellent.**

  A series of adhesion measurements on a variety of sample configurations show that thick (100 nm) layers of silver have excellent adhesion to Hostaphan polyester that has a special surface treated. By comparison, the adhesion of silver or aluminum to PMMA (acrylic) is poor. The relationship of adhesion to delamination as it occurs in the field is uncertain but 2' x 2' samples in the Weather-Ometer are simulating delamination to some extent. Samples 4' x 8' in high humidity rooms have been used by 3M in the past with some success in providing an accelerated delamination environment.

- **Long-term weathering in Florida.**

  3M reports that samples of ECP 300A, Lot 10, mounted on coil-coated aluminum, continue to perform well after 21 months of exposure in Florida (92.8% reflectance, in a 15 mrad full core acceptance angle measured using the Devices and Services reflectometer). 3M has also compared unbacked samples with samples backed with plywood and find no significant difference in performance.

- **Overcoats on front-surface, silvered metal mirrors evaluated.**

  Samples of overcoats on sol-gel planarized metal substrate mirrors were received from Midwest Thin Films and GM Vacuum. Midwest Thin Films had problems applying silver to the sol-gel layer and the optical quality of the $SiO_X$ and $Al_2O_3$ protected mirrors was poor. GM Vacuum has a proprietary process for applying silver to glass that resulted in $Al_2O_3$ protected samples having total hemispherical reflectance values of about 95% and 15mr specular values of 92%.

Next Quarter Planned Activities:

- Further experiments are planned to improve PMMA/silver adhesion including thin layers of inorganic coupling agents at the interface. Coupling agents of tin, nickel, or copper (or their oxides) may be tried, and electrochemical considerations suggest these results may also passivate corrosion. Studies will continue on corrosion mechanisms and long-term degradation.

- A study to establish the relative costs of producing ECP silvered polymer films and front-surface, sol-gel mirrors will be initiated.

- Baseline samples of the GM Vacuum overcoated, silvered metal mirrors will be sent to SERI for evaluation in the Weather-O-Meter. We will continue to evaluate sources of overcoats for silvered, sol-gel planerized mirrors.

## TASK 4. STRUCTURAL ANALYSIS

- **The capability of OPTDSH, the computer code for analyzing the optical performance of dish concentrators, has been expanded to accommodate data from a wider variety of sources.**

  SERI researchers have added the capability to the dish optical analysis code OPTDSH to analyze discrete data obtained from finite element structural analysis in the form of randomly spaced deformed surface coordinates. This option, which utilizes a non-linear interpolation method, was tested by generating finite element-like data using the DISH structural analysis program. This data was then used as input to OPTDSH and analyzed using the finite element option. These OPTDSH results were then compared with those of the DISH/OPTDSH analytical interface. The two methods agreed very well for both axisymmetric and non-axisymmetric edge distortions.

  SERI researchers have also added the capability to the same code to analyze data from both the SERI Scanning Hartmann Optical Test (SHOT) and SKI's Hartmann test. With this option, random rays can be traced using the same non-linear interpolation method as the finite element interface or they can be generated at the Hartmann test points. This enables users of the program, including SKI, to analyze the performance of their dish, based on their own measurements.

  As a result of discussions with Solar Kinetics, further additions and enhancements have been planned for OPTDSH and are currently underway. The more important ones include the ability to mask the dish edge, the reporting of the number of rays falling within a specified radius on the target plane, the ability to interactively move the target plane location, and the addition of an optical efficiency plot.

SERI researchers traveled to Dallas on March 12 to present the enhanced versions of the DISH and OPTDSH codes to Solar Kinetics Inc. and to work with them on refinements to their Hartmann test device and method. The DISH and OPTDSH codes are tools that will be used extensively by SKI in the design and subsequent analysis of the 7-meter membrane dish they will be building for SNLA. A tutorial was given on the use of the analytical DISH structural code and on OPTDSH, the new non-axisymmetric optical ray-trace code.

- **SERI support of SKI DISH Program**

  The on-line measurement of the surface shape of the SKI 7- meter membrane dish during fabrication presents a number of non-trivial problems, mostly related to size. Adaptations and extensions of the current Hartmann method were explored which might help to improve the quality of their data while accommodating the many physical constraints imposed by their process and facilities. Other measurement issues and schemes are being investigated also.

- **Verification of the DISH structural analysis model by comparison with the more general ANSYS model indicated excellent correspondence, increasing confidence in the capability of DISH.**

  SERI researchers continued with the verification of the DISH structural analysis code. Earlier comparisons with ANSYS used a model with approximately 480 nodes (20 radial and 24 circumferential). Comparison of the displacements calculated with the two codes revealed reasonable agreement, but it was thought that the finite element mesh might be too coarse and that the addition of more elements might improve the results. A new ANSYS model was then generated with approximately 1920 nodes (40 radial and 48 circumferential). Using this ANSYS model, the displacements were in better agreement with those of the DISH analytical program than the earlier ANSYS model. This indicates that the agreement between DISH and ANSYS is even better than previously thought. The OPTDSH finite element capability was then used to compare the optical and thermal performance using the DISH code with the ANSYS finite element data. Agreement was achieved with rms target radii differing by less thant 5% and optimum thermal efficiencies differing by less that 1%.

  A second ANSYS membrane model was generated using a slightly different set of boundary conditions than the first model. The first model did not allow circumferential motion at the dish edge. Such motion would be a more realistic representation of the edge response to a non-axisymmetric deformation, thus this constraint was removed in the second ANSYS membrane model. With the appropriate set of boundary conditions, the DISH code was then used to model a stainless steel membrane dish subject to 2 mm radial edge-displacements spaced 180 degrees apart (n=2). A comparison of the circumferential displacements calculated by both codes along a radial line 45 degrees from the n=2 line-of-action again revealed excellent agreement.

- **To enhance the quality of the programmatic decision regarding a choice of a dish concept to be selected for future development, SERI researchers are analyzing the performance of off-axis, elastically formed membrane facets.**

  SERI researchers are currently investigating the off-axis optical performance of elastically formed membrane facets shapes and comparing these to the results obtained using a spherical shape approximation. An extensive amount of work has already been done looking at multi-facet dishes assuming spherical facets. This work predicts acceptable performance. Production facets, elastically

formed, depart somewhat from spherical. How this affects the optical and thermal performance of a 12-19 facet membrane dish concentrator is important to know if the multi-facet concept is to be considered for further research. Equations describing the elastic deformation of tensioned membranes formed by pressure pressure loading have been developed previously by SERI researchers. These are being used to describe the shapes of off-axis facets to be analyzed using CIRCE. The optical/thermal performance will be used to evaluate the technical risk involved in choosing a dish program based on the performance of these facets. The results will then be compared with the performance assuming off-axis spherical facets to determine whether the differences are significant.

- **SHOT instrument enhancements.**

  The SERI Scanning Hartmann Optical Test (SHOT) allows measurement of the precise optical shape of relatively deep, large solar dishes in the laboratory and in the field. Light from a laser scanner is projected from a point near the average center of curvature of the dish onto various points on the subject mirror. The reflected light returns to strike a small calibrated screen, also near that "center." The position of the spot on the screen, which indicates the mirror slope, is automatically recorded.

  Enhancements to the SHOT are nearing completion. These have already greatly improved the data collection rate to over one point per second. High speed is desirable not only to increase productivity, but to enable outdoor data collection where changes in ambient conditions could invalidate data sets taken over long periods. Some software procedural changes have also been implemented in order to make the system and data forms more compatible with the SKI Hartmann hardware and methods.

- **Wind load field-test program initiated.**

  A computer control and data acquisition system has been assembled and is in check out. Cermak Peterka Petersen, Inc. (CPP) wind engineering consultants, have been retained to assist in instrumentation, data analysis, and site selection. A meeting was held at Sandia with CPP and SERI to review the program plans. A draft of the field test program plan document has been issued. Equipment procurement is continuing. The heliostat pedestal, now being used for the 50 sq m SAIC mirror module, has been modeled to determine strain ranges for choosing strain gauges.

Next Quarter Planned Activities:

- **OPTDSH development and use will continue.**

  SERI researchers will continue to enhance and add features to the optical analysis code OPTDSH, and begin a set of parametric runs testing the overall performance sensitivity to different design options. Planned additions include the capability to mask the dish edge, a reporting of optical efficiency as a function of target radius, and the generation of a flux map in the target plane. This work will be done in order to further increase the code's capabilities for in-house research as well as provide continued support to users such as Solar Kinetics, Inc.

SERI researchers will continue with the analysis of off-axis elastically formed facets in a multi-facet dish configuration in order to compare the performance with that using off-axis spherical facets. This will aid in the determination of whether the concept warrants future consideration.

- **Wind load field-test program will be finalized.**

  The field test program plan will be finalized. Checkout of the data system will continue as will procurement of equipment. Model of the pedestal will be used to aid in the placement of strain gauges and the resolution of loads.

## Core 3. Solar-Electric Technology Readiness

Objectives: Continue the thrust of the Solar Thermal Program to develop the components and systems needed to establish technical readiness of electric power production applications for solar thermal central receiver and distributed receiver systems. Technical readiness is defined as the development of near-optimal performance in components and systems that also feature designs that are amenable to low-cost production at medium to high volume. The goal of the development activities in this mission is to achieve technical readiness and be economically cost competitive in major domestic markets by the late 1990s.

Accomplishments:

# TASK 1. CENTRAL RECEIVER TECHNOLOGY

- **Installation of the Panel Research Experiment salt piping begins.**

  Installation of the salt piping for the Direct Absorption Receiver (DAR) Panel Research Experiment has begun. In a DAR, the heat absorbing fluid (a blackened molten nitrate salt) flows in a thin film down a flat, vertical panel (rather than through tubes) and absorbs the concentrated solar flux directly. To allow flow testing with molten nitrate salt and to provide a test bed for DAR testing with actual solar heating, we are designing and building a 3 $MW_t$ solar Panel Research Experiment (PRE).

  The basic structure for the PRE was completed last year. The installation of the salt piping was delayed because the PRE panel design was changed from 10-m to 6-m in length which affected the piping layout. The stainless steel piping that is used for the salt piping is very difficult to weld. Consequently, the contractor expects the installation of the piping to take from 6-8 weeks.

- **Completed the initial design of the 6-m panel/frame design for the Panel Research Experiment.**

  We have completed the initial design of the panel/frame for the 3 MWt panel research experiment (PRE). During the last quarter we made the decision to make the PRE panel 1-m wide by 6-m long for both the flow and solar tests. Previously, the panel was to have been 0.5-m x 10-m for the flow testing and 1-m by 4-m for the solar testing. However, because of the decision to use Intermediate Manifolds (IM's) to solve the fluid loss problems the 1 x 6-m panel will be sufficient to address all the planned testing and allow us to proceed with solar testing much more quickly.

  A panel/frame design review meeting was held on March 29, 1989. The 6-m panel design is similar to the preliminary design of the 0.5-m x 10-m long panel (based on the commercial DAR design of Foster Wheeler) that was completed by Babcock & Wilcox (B&W) last quarter. The design uses a thin (3 mm) stainless steel panel, tensioned both vertically and horizontally to closely simulate the commercial design. The tensioned panel is supported in a structural steel frame which mounts to the front of the PRE flow loop structure.

  The panel/frame design is being completed and then it will be sent out for bids and construction. We expect to have the panel installed by October 1989. All components of the PRE have been through the final design, except for the IM's and the water cooled shielding for the solar test. Both the IM's and the shielding will not be needed until after the initial salt flow testing has been completed on the PRE.

- **Completed the water flow testing, film thickness measurements on the 8-m panel.**

  The film thickness measurements, using water on the 8-m long panel, tilted at 15° has been completed. The data is currently being analyzed. These data will be used for characterizing the falling film and validating the SERI salt film thickness results. A report on the water flow testing conducted at Sandia has been drafted. Some initial intermediate manifold design has been completed, and the 8-m water flow panel will be used for conducting intermediate manifold testing.

- **Completed a control algorithm for the Panel Research Experiment.**

  A control algorithm for the PRE was developed during the past quarter. The control algorithm was developed with the aid of a newly created computer model that simulates the dynamics of the entire flow loop. Three separate feedback loops were defined which control the following system parameters: 1) temperature of the salt at the outlet of the solar receiver, 2) surge tank pressure, and 3) temperature of the salt at the outlet of the heat-dump heat exchanger. Optimal controller gains were also determined with the simulation model. The simulation indicates that the flow loop should be relatively easy to control during steady-state and transient operation. These control loops and gain settings will be programmed into the Bailey Net-90 control system during startup of the PRE.

  Besides aiding in the development of control, the simulation model will help characterize the performance of the PRE during the experiment. A user-friendly graphics interface was also created to facilitate understanding of the process dynamics by project personnel and various visitors from government and industry.

- **Completed the design modifications to a salt loop which will be used for making thermocapillary breakdown measurements.**

  To accomplish the measurement of thermocapillary breakdown in the most efficient manner, the existing Direct Contact Heat Exchange test loop will be modified. The modification involves installation of a heater rod (a vertical 2.54 cm o.d. by 2.5 m long pipe with internal heater). A molten salt film will be distributed on the outside surface of the heater rod and sufficient power will be applied to cause the film to break down. Designs for these modifications have been completed and the necessary parts are ordered. Some of the hardware modifications and the data acquisition software development have been completed.

- **Completed over 1000 hours of operation on the Pump and Valve hot loop.**

  The molten salt pump and valve hot loop has operated for over 1000 hours. The pump and valve testing consists of two pumped loops, one to simulate the hot side of the receiver (565°C) and one for the cold side (285°C). Each loop contains a pump and six representative valves scaled for a 60-$MW_e$ commercial solar power plant. The molten salt pump and valve loop is intended to demonstrate the effectiveness of full-scale hot and cold salt pumps.

  The hot loop has been operating in automatic mode since January. During one period in February and March the hot loop operated continuously for 240 hours. The loop has been shut down a number of times because of catastrophic failures of the valve packing materials. We are currently evaluating new packing material to replace the existing carbon fiber packing material. The test schedule calls for the loop to be operated for 5700 hours. The cold loop is currently shut down and we are waiting for the cold pump and motor. The pump has been repaired and is to be shipped from the manufacturer (Byron-Jackson) in late March. The motor bearing castings are being replaced and they will be shipped to Sandia in May. Work has started on the cold loop system to checkout and operate all components prior to the return of the cold loop pump and motor.

- **Begin installation of the Sandia volumetric receiver absorber at the Plataforma Solar de Almeria.**

  Installation of the Sandia volumetric receiver absorber was begun this past quarter. The Sandia porous ceramic absorber is to be tested on the volumetric receiver at the Plataforma Solar de Almeria. Installation and testing of the Sandia absorber was delayed because of other high priority programs at the Plataforma and because there were problems with the absorber fitting on the volumetric receiver. A Sandia staff member visited the Plataforma in January to evaluate the absorber fit problems with the Plataforma personnel.

  While at the Plataforma the Sandia absorber and test bed were inspected to determine the extent of the problems. The problems were a result of distortions in the pressure plate of the volumetric receiver test bed. The Plataforma staff agreed to make minor modifications to the absorber and the method of affixing it. The installation of the absorber began in late March 1989.

- **Participation in European solar work.**

  A Sandia staff member participated in an experts' meeting on volumetric receivers held in Cologne, West Germany. The meeting was held at the request of the International Energy Agency/Small Solar Power Systems (IEA/SSPS) Executive Committee as part of the Task 3 work on solar receivers. The purpose of the meeting was to evaluate the potential of volumetric receivers and to make recommendations for future testing. The conclusions and recommendations of the experts were that volumetric receivers have a high potential for applications in central receiver power plants; the volumetric receiver test bed (200 $KW_t$) at the Plataforma in Almeria, Spain, should be upgraded for testing various absorbers; and that a 3-$MW_t$ volumetric receiver test bed (with a wire pack absorber) should be built and tested at the Plataforma.

  A Sandia staff member met with representatives from the solar energy department of CIEMAT to exchange information on the status of our respective falling-salt-film receiver development and test programs. The meeting was beneficial in that additions or modifications to the two test programs were discussed, the DAR (U.S.) and the IFR (Spain), that would allow the programs to complement each other. Also, a meeting is tentatively planned for this Fall, to coincide with the beginning of the DAR panel research experiment at the Central Receiver Test Facility.

  The Europeans appear to have a strong commitment to solar energy applications; in particular, the Swiss and Germans are strongly promoting the volumetric air receiver. Much of the European excitement about solar central receivers has to do with the PHOEBUS consortium, which plans to build a 30-MWe solar power plant within the next 5 years.

**Next Quarter Planned Activities:**

- The Byron-Jackson pump and motor should be reinstalled in the cold loop in late May or early June. Checkout and operation of the valves and salt cooler in the cold loop system will continue so that the cold loop should be ready to begin operation in late June 1989. The hot loop will continue to be operated in automatic mode, 7 days a week, 24 hours a day.

- All the necessary equipment to modify the DCHX for making thermocapillary breakdown measurements will be received next quarter. Initial shakedown tests of the new test apparatus should begin next quarter.

- The design of the panel/frame for the Panel Research Experiment (PRE) will be finalized and then sent out for bid. It is expected that the bidding process will take six weeks and construction of frame/panel will take 8-12 weeks. The installation of the salt piping will continue. Once the piping installation is far enough along the heat trace and insulation will begin.

- Testing and development of intermediate manifolds will continue with designs to be tested on the water flow panel.

- Meetings will be held on April 6 and 7 to evaluate the Direct Absorption Receiver development program. On April 6 a group of experts in falling-film-flow phenomenon will discuss the droplet ejection that has been observed in the water flow tests of the DAR. The purpose of the meeting is to determine if there are any simple solutions to the problem. Then, on April 7 another group will review SERIs research program on the DAR.

- The Sandia volumetric receiver absorber that is being installed at the Plataforma de Almeria will be tested next quarter. We will begin with low power tests to evaluate the capabilities of the ceramic foam material. The test schedule calls for gradual increases in power and temperature up to a maximum of 1000°C. After steady-state testing is completed, transient testing will be conducted. In addition to the test at the Plataforma, a volumetric receiver-absorber material test apparatus will be built to test absorber material at the CRTF solar furnace.

## TASK 2. DISTRIBUTED RECEIVER TECHNOLOGY

- **Preparations for on-sun tests of Reflux Heat-Pipe Receivers continue**

  Fabrication of support hardware for on-sun testing of prototype pool boiler and heat pipe solar receivers proceeded throughout the quarter. This equipment consists of: (1) hardware for mechanically supporting receivers on the Test Bed Concentrators, (2) insulation housings; (3) data acquisition and control hardware; and (4) special assembly equipment. Two sets of hardware are being fabricated, which will be capable of supporting a wide range of receiver configurations. All equipment has been either designed or ordered, and much of it has been assembled into sub-assemblies. During the next quarter the pool boiler receiver will be assembled, mounted on a Test Bed Concentrator, and tested.

- **Sandia develops capability to measure flow properties on formed wick samples.**

  Sandia has developed the capability to measure flow properties on formed wick samples. The property measurement system allows proposed wick structures to be qualified before they are subjected to expensive on-sun testing. A schematic of Sandia's property measurement system is shown in Figure 2. In the system, a vacuum is used to draw fluid through the screens and into the collection flask. Fluid is held in the wick by surface tension in the meniscus that forms along the wick's top surface. Based on measured pressure drops and collection rates, the permeability of the wick structure can be determined. This system was used to detect fabrication problems in the wick structure proposed for STM's heat-pipe solar receiver.

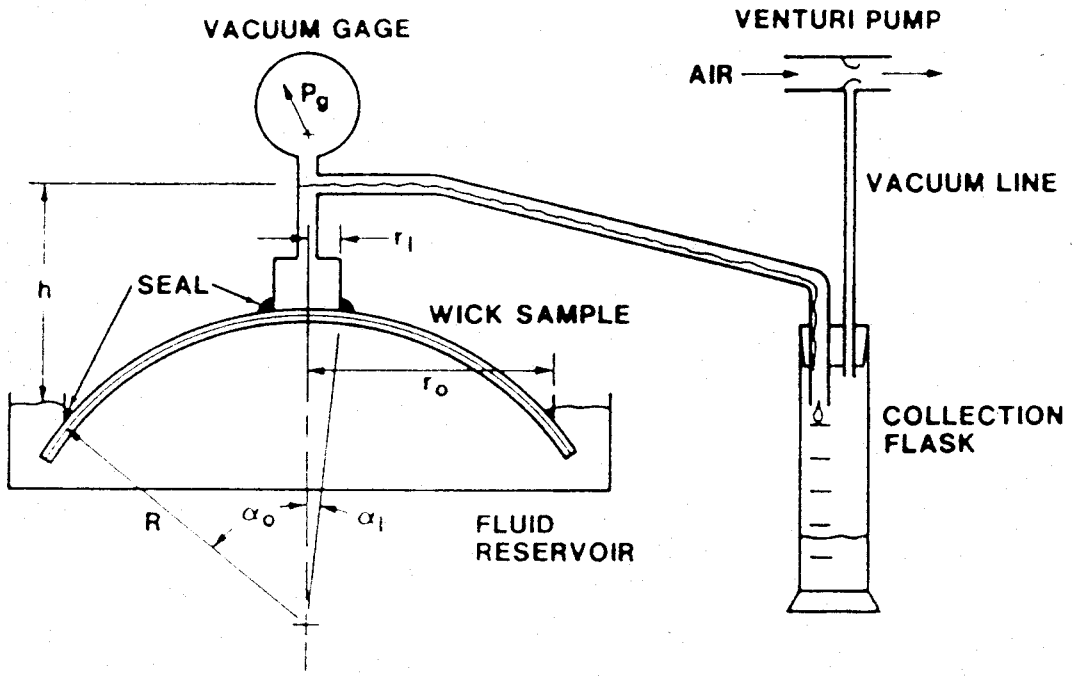


Figure 2. Rig for Measuring the Permability of Fabricated Wick

- **Wicks analyzed for Cummins Heat Pipe solar receiver.**

  Cummins Engine Co., Inc., is privately funding a venture to develop a 7-1/2 kWe dish electric system using a free piston Stirling engine and a heat-pipe solar receiver. Thermacore, a subcontractor in the development effort, established a base-line design for the wick used in the heat pipe receiver. Sandia reviewed the wick design and provided a more rigorous analysis of the flow in the wick using a model that had been developed earlier. The analysis showed that the wick design was probably well suited for the proposed application. At the request of Thermacore, Sandia provided additional model computations with minor variations in the wick properties.

- **Completed supplemental pool-boiling bench tests.**

  Supplemental sodium boiling tests were completed this quarter. The objectives of these tests were to characterize sodium boiling at off-design operating conditions, including reduced power, reduced temperature, combinations thereof, and hot re-starts. Stable boiling was observed under the reduced power and temperature conditions. The hot re-starts were used to simulate cloud transients. In some cases, the incipient boiling superheat upon re-starting was sufficiently high to trigger an emergency shutdown. These particular situations may be geometry/flux-distribution dependent, or may be addressed as a controls issue.

- **Completed post-text analysis of bench test boiler.**

  The bench test pool boiler has been drained of sodium and cut open for visual and metallographic analysis. The objectives were to determine: (1) the dimensions of the artificial cavities, (2) the extent of cracks and pits in the heated surface and how they compare with those in the material as delivered, (3) microstructural changes in the heated surface, and (4) if possible, why the vacuum, sodium fill and thermocouple feedthrough tubes and their weldments can now be easily fractured.

No significant cracks or pits were found on the surface, and no microstructural change was detected. The cause of the embrittlement of the small-diameter tubes has been determined to be intermetallic precipitation at grain boundaries. These results mandate weldment reinforcement where possible and limiting test time at temperature to 100 hours. The dimensions of the deepest of the artificial cavities were not determined before the part was lost or destroyed. Visual analysis suggested a cavity 0.01-inches in diameter and 0.01-inches deep.

- **Completed artificial cavities in receiver absorber.**

Electric-discharge machining to install artificial cavities in the receiver absorber surface has been completed. The dome now has 35 cylindrical blind holes spaced approximately equidistant over the wetted surface. A 30% sample run by inspection shows depths from 0.0181 to 0.0219 inches and diameters from 0.005 to 0.0095 inches. Figure 3 shows a cross section of several sample cavities.

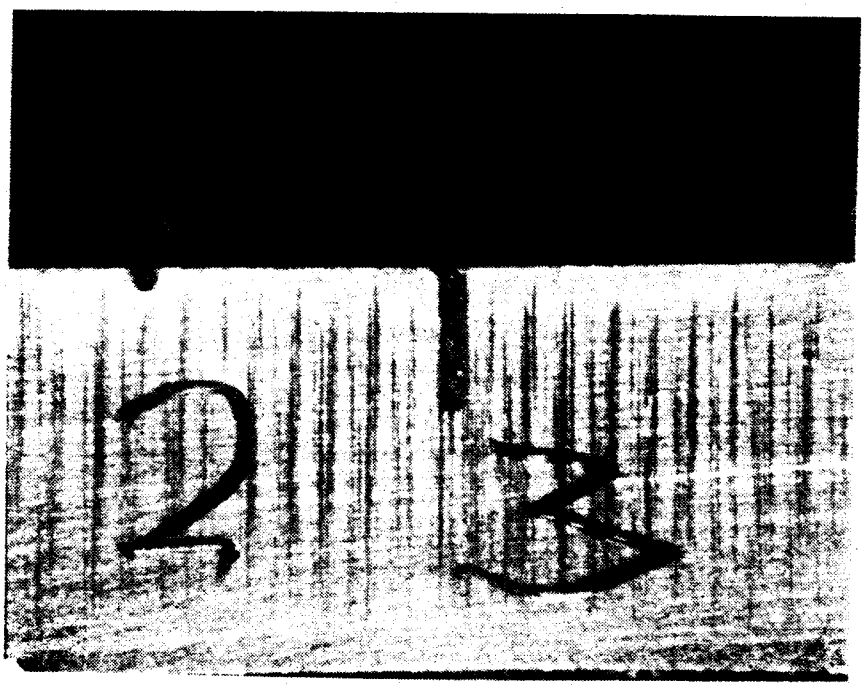

Figure 3. Cross section (35X) of electric-discharge machined artificial cavities. Number three is typical of those machined in pool-boiler absorber. Diameters of cavities cannot be accurately determined from cross sections because cut is not necessarily centered on cavity.

- **Hardware assembly for reflux heat-pipe solar receiver on-sun tests tests begun.**

A sample set of domes has been welded together along with a section of condenser pipe to verify manufacturing processes (Figure 4). The rear dome for the on-sun test has been welded to the first segment of condenser pipe, and the dome has been cut away within the boundary of the pipe. Thermocouples have been brazed to the inside of the absorber dome. Most of the small parts have been machined and await assembly.

Figure 4.
First pair of domes and section of
condenser welded together to verify manufacturing
processes for pool-boiler receiver.

Next Quarter Planned Activities:

- **Complete fabrication of pool-boiling reflux receiver.**

  The receiver shell domes with artificial cavities will be assembled into a complete receiver and filled with sodium. Fabrication of the calorimeter and the receiver support structure will be completed. The control system used in the bench tests will be replicated and modified as necessary for the on-sun tests.

- **Begin on-sun operation of pool-boiling reflux receiver.**

  The pool boiler receiver will be mounted on a TBC. The on-sun tests will begin with low-power system checkout tests. The receiver and support systems will be prepared for one month of daily on-sun testing.

## TASK 3. CONVERSION DEVICES

- **Demonstrated the Stirling Thermal Motors' Kinematic Stirling Engine at Sandia's Engine Test Facility.**

  The Solar Thermal Electric Technology Division and Solar Thermal Test Facility Division achieved a major milestone in the Solar Thermal Program, on March 20, with the initial operation of the Stirling Thermal Motors, STM4-120 kinematic Stirling engine. The STM4-120 is being bench tested using propane combustion to provide heat to the engine. With STM personnel assisting, the STM4-120 delivered 2.1 kW of shaft power for one hour at Sandia's Engine Test Facility. This power level was accomplished while operating at a mean cycle pressure of 30 bar (440 psig) and a heater head temperature of 780°C. A second operation test was conducted with a heater head temperature of 790°C. During this run the engine produced 2.7 kW of shaft power. The initial operation at the lower power levels is intended to prove that the engine will run in the Sandia test cell and shake down the engine controls, emergency controls, and data acquisition system constructed by Sandia. The operation of this engine was the first time a Stirling engine has been operated at Sandia and also the first time a STM4-120 has operated outside the STM test facilities. In the coming month the STM4-120 will be retro-fitted with new heater heads which will allow the engine to operate at the full mean cycle pressure of 120 bar (1760 psig) at 800°C. Under these conditions the engine should deliver 25 kW of shaft power with a conversion efficiency of 40-45%.

- **Conducted preliminary design kickoff meetings for the Phase II Development of the Advanced Stirling Conversion System (ASCS)**

  Stirling Technology Company (STC) and Cummins Engine Company (CEC) held their kickoff meeting for the preliminary design of the Advanced Stirling Conversion System (ASCS) on February 23 and March 2, respectively. NASA Lewis Research Center (NASA/LeRC), through an Interagency Agreement with DOE, is providing technical management for the development of an Advanced Stirling Conversion System (ASCS) for Sandia. STC and CEC were chosen as two contractors to complete a preliminary design and eventual fabrication of an ASCS for on-sun test at Sandia. Attendees of the meeting included NASA/LeRC, Sandia, and various subcontractors to STC. STC has proposed a free-piston Stirling engine which pumps hydraulic fluid through a rotary generator. In addition, STC will be conducting the preliminary design of a reflux boiler solar receiver to integrate with their engine. CEC has proposed a free-piston Stirling engine which utilizes a linear alternator.

CEC is also proposing a reflux heat pipe receiver. STC and CEC are scheduled to complete the preliminary design of their ASCSs in six months. During this period monthly progress meetings will be held at alternate locations including NASA/LeRC, STC, and Sandia with a final preliminary design review in six months at NASA/LeRC. The STC and CEC contract includes four tasks which are:

Task I - services to complete preliminary design of an ASCS

Task II - services to complete the final design, fabrication, build and delivery of a system to Sandia for test

Task III - services to provide field support at Sandia for testing

Tasks II, III, and IV will be options in the contracts which can be exercised depending on funding levels. The next scheduled meeting is the first of April when STC will present an update of their conceptual design.

Next Quarter Planned Activities:

- **Begin 25 kW testing of Stirling Thermal Motors' kinematic Stirling engine at Sandia.**

  During the next quarter, the Stirling Thermal Motors' STM4-120 kinematic Stirling engine will be retro-fitted with new heater heads. These heads will allow the STM4-120 to achieve the 25 kW of shaft power it has been designed to deliver. Prior to operating the new heater heads the engine will be operated at low power to accumulate experience with the engine.

- **Negotiate contract for delivery of second Stirling Thermal Motors Kinematic Stirling Engine to Sandia.**

  Sandia will be negotiating a contract for the delivery of a second Stirling Thermal Motors STM4-120 kinematic Stirling engine. This engine will incorporate several minor design changes to improve reliability and efficiency. This particular engine will be integrated with a reflux receiver and tested on a Sandia Test Bed concentrator.

**Mission 1. Next-Generation User Systems**

Objectives: Achieve a significant reduction in the cost of electricity produced by currently available commercial solar thermal electric systems. The goal will be to enhance the marketplace competitiveness of these systems by the mid 1990's through collaborative, cost-shared, near state-of-art R&D with an industrial partner. Key milestones are verification of approaches through pilot field tests by FY90 and commercial implementation of verified approaches by FY92.

Accomplishments:

## TASK 1. PROJECT DEVELOPMENT

- **RFQ prepared for issue to qualified bidders.**

  A Request for Quotation (RFQ) was prepared and furnished to Sandia's Purchasing Organization on March 5, 1989. The RFQ will soon be issued to 16 companies that indicated interest in the program in response to a Commerce Business Daily (CBD) notice published on December 9, 1989. Prior plans for a bidder's pre-RFQ conference with the qualified respondents were postponed in favor of a briefing after the RFQ is issued.

Next Quarter Planned Activities:

- Future activities include issuance of the RFQ to qualified suppliers by April 15, 1989, and holding a bidder's conference one week later to answer questions. Responses to the RFQ are currently scheduled for return by May 19. The proposals will be evaluated and winners selected by June 9, 1989, so that contracts may be issued by June 30, 1989, and awards finalized by July 31, 1989.

## TASK 3. DESIGN ASSISTANCE AND CORECT SUPPORT

Objectives: The objectives of this task are to accelerate the use of solar thermal systems through cooperative efforts with private industry, to assist and educate the potential users, and to support the industry and users in the selection, design, characterization, and demonstration of promising solar thermal systems.

Accomplishments:

- A major milestone for this task was to participate in the SOLTECH 89 meeting held in Washington, DC on March 6 through 9. Sandia and SERI technical and management staff presented 16 talks covering all of the Core and Mission activities. In addition, the Solar Thermal Design Assistance Center (STDAC) presented a large display and some handout materials that described the Government's current research and development efforts in Solar Thermal technologies.

**Other design assistance activities included the following:**

- Sandia staff members met with Camp Pendleton (Marine base) and Roan Corp. officials to discuss the planned renovation of SOLAR PLANT ONE. The Camp Pendleton commander has approved an agreement to purchase the plant's solar electric power. The U.S. Navy officials who are tasked to finalize a contract have asked for Sandia's technical guidance about the project. Other meetings will be scheduled as needed.

- Sandia staff are continuing to work with Cummins in their effort to demonstrate an advanced generation dish Stirling system by late FY89. The project is progressing normally with an emphasis on improving system reliability and performance. Sandia has assisted in the project by performing structural and thermal stress analysis on the receiver and receiver/engine interface.

- An insolation and weather monitoring station was installed at the LUZ plant at Kramer Junction, CA. The installation of this station was in response to a request by LUZ for assistance in monitoring weather and solar radiation at the SEGS plants. More weather stations are planned for the other SEGS sites.

- At SAIC's request, Sandia and SAIC staff representatives met with officials of the U.S. Army to discuss the potential of using solar thermal electricity to augment utility supplied power at Army forts and bases. The Army's main objective is to improve energy security for critical military facilities. Several viable options were discussed.

- The United Nations has asked Sandia to provide information about the application of STM's Stirling engines for application in third world countries. Sandia staff is currently providing input to the UN on the matter.

- **SOLERGY modified to support Bechtel.**

  Bechtel is involved with an European/American consortium (PHOEBUS) building a central receiver power plant. One key issue confronting PHOEBUS is the choice of receiver design; currently under consideration are designs using molten salt, water/steam, and air. The Sandia-developed computer code "SOLERGY" is being used to compare the three alternative technologies. We are working with personnel from Bechtel and Interatom to adapt SOLERGY for the necessary calculation. In addition, SOLERGY has been modified to allow hybrid operation using a fossil-fuel-fired boiler.

Next Quarter Planned Activities:

- The STDAC is planning to write a descriptive document that outlines the objectives and capabilities of the STDAC. The document will focus on the current and planned solar thermal research and development activities at Sandia and SERI, and will be written for technical managers in both the public and private sector. Its main purpose is to engender interest and enthusiasm for the potential benefits of applying solar thermal technologies. The document is tentatively scheduled to be completed by the end of calender year 1989.

**Mission 2. Photochemical Systems**

Objectives: Develop the technology required to field a project demonstrating solar-driven chemical processes with an emphasis on the destruction of hazardous chemicals. At least one pilot-scale experiment representing a commercially replicable solar hazardous chemical destruction process will be testing in the field by 1994.

Accomplishments

## TASK 1. IDENTIFICATION OF APPLICATION OPPORTUNITIES

- **Preliminary analysis of aqueous organic chemical treatment completed.**

An initial survey of waste sites indicated that trichloroethylene (TCE) would be a good demonstration candidate for the solar process due to its presence in the ground water of the Southwest, and its published vulnerability to destruction under UV light exposure. The work then shifted to examining the existing methods of destruction, their performance, their costs and the projected performance and cost of a solar process to destroy this waste.

Researchers have completed a comparative analysis of the potential cost effectiveness of concentrating solar systems for water detoxification relative to the cost of conventional processes. The analysis considers the removal of trichloroethylene (TEC) at 200 part per billion (the level of TCE contamination at the Tucson airport National Priority List site) from contaminated ground water. Although there are very few ground water streams contaminated only with TCE, it is the most prevalent contaminant in the Southwest and has been shown to be highly susceptible to photocatalytic decomposition.

The principal driver and the largest uncertainty in our analysis is the rate of reaction. Initial analysis is based on reaction kinetics results published by Dave Ollis of North Carolina State University. At the low TCE concentrations we are considering, Ollis' reaction kinetics are relatively slow. They indicate that a trough system costing $\$200/m^2$ could process the contaminated ground water at a cost of approximately $4 per 1000 gallons, which is several times more expensive than carbon adsorption and air stripping processes for the same TCE contamination level. Although SERI's initial photocatalytic experiments with TCE appear to substantiate Ollis' findings, they also indicate that there are a number of variables that can be optimized to improve the rate of reaction, possibly by more than one or two orders of magnitude. These include the oxygen content, pH, catalyst size and loading, etc. Such an improvement will produce a processing cost substantially below that of current conventional processes.

Investigations into conventional and emerging technologies for treating contaminated water have gathered performance and cost information on air stripping, air stripping with off-gas control, granular activated carbon (GAC), ozonation, ultrafiltration, and reverse osmosis. These appear to constitute the main technologies for treating TCE in groundwater. The last three are emerging technologies. In addition, there are a few variations on ozone treatment (using hydrogen proxide and/or UV), as well as variations on the method used for off-gas control of air stripping plants. Sources of information have included manufacturers, users, and regulators. Because of the diverse nature of the waste streams and the technologies, this data must be normalized before it can be used to provide a good comparison to the proposed solar systems. One interesting note is that while air

stripping is common and very inexpensive, the practice is not accepted in certain areas of the country now and may not be permitted nationally in the future. Southern California and several other states in the Midwest require off gas control to obtain a permit. This trend in community rejection of the air stripping treatment method is the primary reason for the interest in these emerging technologies. (Another reason is that air-stripping may not be effective at some highly contaminated sites in reducing the TCE level to the mandated 5 ppb). It is anticipated that the market for technologies costing more than air stripping will grow as communities reject the concept of emissions from a waste processing plant.

- **Analysis of high temperature photolytic applications continues.**

  Analysis in 1988 of the potential markets for high-temperature photolytic destruction of volatile organic compounds (VOC's) indicated that the detoxification of soils is one of the more promising applications for high temperature solar photolytic processes. Accordingly, SERI has begun to construct simple spreadsheet models of the performance and economics of two central receiver solar configurations and a conventional rotary kiln system (patterned after the EPA's mobile incinerator system) for the destruction of VOC's on soil. Each of the solar configurations uses the UV portion of the spectrum to decompose the VOC desorbed from the soil while the remaining energy in the spectrum is used to accomplish the thermal desorption. Preliminary spreadsheet models have been completed for the heat and mass transfer in the reactors of both the conventional rotary kiln system and the solar system and for the air pollution control subsystems associated with each concept. SERI is currently revising and expanding the level of detail of the preliminary spreadsheets as well as trying to obtain better input data.

## TASK 2. SOLAR PROCESSING OF DILUTE AQUEOUS ORGANIC CHEMICAL

- **SERI researchers complete characterization of red dye.**

  A two-level factorial experiment for assessing the effects of solar flux, $TiO_2$ particle size, $TiO_2$ loading, initial reactant concentration, temperature, and pH on the initial decomposition rate of Direct Red 79 dye via $TiO_2$ photocatalysis was conducted. Three-level experiments were done for $TiO_2$ loading, temperature, and solar flux to assess non-linearity. Solar flux showed a positive linear effect on initial degradation rate over a range spanning 12 to 85 percent of full simulator power at 330 nm (wavelength of maximum $TiO_2$ absorbance). $TiO_2$ loading had a positive non-linear effect on rate, with maximum effective loading being about 0.2 wt%. In general, the destruction rate data show a first-order kinetic dependence to a good approximation. Temperature increases show little effect on red dye destruction rate, i.e., activation energy for the process is low.

- **Analytical procedures for trichloroethylene established.**

  As a first step in implementing the test matrix for TCE, the procedure for preparing and analyzing TCE/water solutions was modified. TCE solutions having a nominal concentration of 140 ppm were prepared by stirring with mild heating for three days in a closed glass vessel with little headspace. Headspace GC analysis of these solutions gave 140 $\pm$ 10 ppm. Direct-injection GC analysis gave 140 $\pm$ 40 ppm. Polyethylene (Nalgene) containers showed attack by the TCE solutions. The preferred approach to producing and characterizing TCE/water solutions for use in these studies is, therefore, extending stirring and mild heating in a nearly filled glass container, followed by headspace GC analysis.

- **SERI outdoor test reactor completed.**

  The parabolic trough photocatalytic reactor was completed, with the exception of the catalyst filtration system. Complete assembly of the trough and fluid transport/heat exchange subsystems was followed by circulation of a solution of water containing 0.2 wt% suspended titanium dioxide ($TiO_2$) particles. Particles diameters were in the rage of 3 microns. The mass loading and particle size selected for this test represent extreme conditions which may be encountered for a particular experiment. Observations indicated no leakage throughout the system. A small amount of $TiO_2$ settling was observed. Due to the small extent and location of the settling, few problems are to be expected in operating the reactor.

- **SNL observes 10-fold increase in reaction rates in hydrogen peroxide/catalyst system.**

  In support of the engineering-scale experiments described below, a series of laboratory experiments were conducted to determine the effect of oxidizing agents on the decomposition of a model compound, salicylic acid. The results of these experiments showed that by using the combination of the catalyst (titanium dioxide) and an oxidant (hydrogen peroxide), initial reaction rates could be increased at least 10 fold over those using the catalyst alone. Heating the solution to 65°C increased the reaction rate another 30%. The results have been used to guide the engineering-scale tests described below, where the increased rates were confirmed.

- **Initial detoxification tests with engineering-scale trough system completed at SNL**

  The first drive group of the BDM trough system at SNL was fitted with glass tube reactors during the quarter and detoxification experiments were initiated. In the initial tests, about 1200 liters of a 30 ppm solution of a model contaminant (salicylic acid), 0.1 wt% $TiO_2$ catalyst, and 300 ppm hydrogen peroxide were pumped through the 3.2-cm diameter by 36-m long borosilicate glass reactor tube at flow rates of about 100 liters per minute. The data show the salicylic acid was destroyed to below measurable levels in an exposure time of less than three minutes. A thermal characterization of the system was also completed, and it was determined that boiling will not occur before the reaction is completed to tolerable levels.

- **Initial heliostat/falling-film-reactor water detoxification experiments completed at SNL.**

  Two engineering-scale experimental runs using the CRTF heliostat field and falling-film reactor were completed this quarter. In both cases, the system consisted of about 30 liters of a 300 ppm solution of salicylic acid, 0.3 wt% $TiO_2$ catalyst, and 300 ppm hydrogen peroxide. Except for solar input, both runs were identical, with about 300 liters per minute of the solution being pumped through the reactor. Destruction of the salicylic acid was observed in about 30 and 15 seconds (total exposure time) for solar concentrations of 30 and 60 suns, respectively. These two runs, coupled with the trough system data described above, show that the initial salicylic acid destruction rates vary linearly in proportion to the incident ultraviolet power input.

## TASK 3. HIGH TEMPERATURE SOLAR DESTRUCTION OF TOXIC CHEMICALS

- **SNLA completes kinetic studies of reforming on porous ceramic catalysts.**

  Measurements of the kinetics of reforming on the porous ceramic catalysts at temperatures up to 1000°C have been completed at the University of Houston. The data show a significantly higher

rate of reaction than that predicted by rate equations based on lower temperature experiments with pelleted catalysts. The measurement were carried out in a quartz reactor heated by infrared radiation and would not, therefore, include any possible photonic enhancement. Rate equations have been derived from the data and installed in the computer model to predict CAESAR results.

- **Metal DCAR reactor installed in solar furnace.**

  A metal wall DCAR reactor has been installed in the solar furnace at Sandia. It will be used to carry out various reforming experiments including carbon dioxide reforming of methane, steam reforming of methane, and reforming destruction of hazardous chemicals. The reactor consists of a 15-inch diameter aluminum shell lined with teflon which is protected in turn by internal alumina insulation. The aperture is covered with a fused silica dome 9 inches in diameter.

- **Gas handling equipment for CAESAR experiment shipped to Germany.**

  The flare, the gas supply subsystem, and the product gas analysis subsystem for the CAESAR experiment have been completed, checked out, and shipped to Germany. The first of two catalyst inserts has been loaded with 0.2 Rh.

- **Models for DCAR reactors compared.**

  Two models for DCAR reactors, one developed by Sandia and one developed by DLR (formerly DRVLR), have been compared for operating conditions anticipated during CAESAR testing. Although the models account for the effects of radiation (both solar and infrared), convection, conduction, heterogeneous reaction, and mass transport in slightly different manners, the results are in reasonable agreement.

- **Comparison of SNL and White Sands furnaces completed.**

  SERI personnel completed experiments to determine the performance of the detoxification reactor at the Sandia furnace as compared to its performance at the White Sands Solar Furnace. The test in January at Sandia showed poor reactor performance. During the week of March 20, small adjustments were made to improve the performance of the reactor. These changes included moving the focal point of the beam inside the reactor in order to produce a more uniform temperature and also matching the total power into the reactor from each furnace as opposed to matching the peak flux. These changes are expected to give better performance. Tests also included the use of high optical quality filters made by the Schott Company of West Germany. Test with these filters are intended to verify the photo effects that have been observed in previous testing using 3M filters.

- **White Sands Furnace testing continues.**

  Solar detoxification experiments were performed as planned as the White Sands Solar Furnace (WSSF) during the week of January 16. The material being destroyed is 1,2,3,4 tetrachloro-para-diobenzodioxin (1,2,34, TCDD), which is a chemically similar but relatively begin isomer of the highly carcinogenic 2,3,7,8 TCDD. The weather was quite good, with very minor cloud and wind gusting problems which did not interfere with testing. The objectives were to provide data to confirm previous destruction levels of greater than seven-nines (99.99999 percent destroyed), to confirm the existence of significant solar enhancements, to develop a laboratory-field test correspondence, and to

provide a benchmark test for comparing performance at the WSSF and the STTF furnace. Numerous experiments were performed at 950° and 750°C with and without an optical filter. A series of experiments were performed at 750°C with various residence times (2, 5, 10 seconds) to determine the effect of this variable. Wind prevented performance of planned experiments with two different types of reactors at 750°C to determine the relative importance of heterogeneous reactions in the frit and homogeneous reactions in the volume in front of the frit.

Results from the January field tests of solar destruction of a dioxin confirm results obtained in October and November. Six 9's was achieved again at the White Sands Solar Furnace (WSSF) with reproducible runs (#1,2). A large photo effect at 750° was shown by comparison runs 3,4 with runs 9,10. Photo effect at 960° is observed comparing run 11 with runs 1 and 2. Reactor performance with varying residence time gave positive results. A 10 second residence time (runs 5,6) gave slightly better performance than the 6 second residence time (runs 7,8) gave significantly poorer results as expected. The only results that differ from earlier data are runs 3,4. Previous results are 750°C with o filer gave Destruction and Removal Efficiencies (DRE's) of 0.999994. Current results are slightly better. These differences are most likely due to test condition variations that are inherent in field testing. One run was made at the SNLA furnace (1SNL). The poor performance of this run has a number of possible explanations including UV attenuation, beam geometry, and the sample loading procedure is slightly different from that at WSSF because of safe operating procedures.

| RUN | TEMP (C) | TIME (s) | FILTER | FLUX ($kW/m^2$) | SITE | DRE |
|---|---|---|---|---|---|---|
| 1 | 960 | 5 | No | 980 | WSSF | .9999990 |
| 2 | 960 | 5 | No | 980 | WSSF | >.9999995 |
| 3 | 750 | 5 | No | 560 | WSSF | >.9999995 |
| 4 | 750 | 5 | No | 560 | WSSF | .9999995 |
| 5 | 750 | 10 | No | 560 | WSSF | .9999995 |
| 6 | 750 | 10 | No | 560 | WSSF | >.9999995 |
| 7 | 750 | 2.5 | No | 560 | WSSF | .9994 |
| 8 | 750 | 2.5 | No | 560 | WSSF | .9994 |
| 9 | 750 | 5 | Yes | 630 | WSSF | .998 |
| 10 | 960 | 5 | Yes | 630 | WSSF | .995 |
| 11 | 960 | 5 | Yes | 1240 | WSSF | 99.9986 |
| 1SNL | 750 | 5 | No | 500 | SNL | .986 |

## Next Quarter Planned Activities

- SERI systems analysis will complete the preliminary assessment of the potential of high flux solar detoxification of dioxin contaminated soil. They will revise the systems assessment of solar water purification by oxidation of organics, including the substantial laboratory data which will be generated.

- Outdoor test with red textile dye planned at SERI

  Outdoor testing with small solar trough will begin at SERI. Initial checkout tests with water were completed in March. The first tests will compare the decomposition of red dye in the trough with that measured in the solar simulator.

- TCE characterization to be completed at SERI.

  The characterization of the decomposition of TCE under concentrated solar flux is expected to be completed and the results provided to SNL for comparison with data taken in their modified trough system.

- SNL trough system modifications for TCE testing to begin

  Installation of the remainder of glass hardware for an additional 5 drive groups will be completed next quarter, in addition to any modifications necessary to begin experiments with trichloroethylene. Testing with textile dyes will be initiated to verify the data available from SERI laboratory tests at the much larger scale of the trough system. Also, an initial optimization of the process for this system will be conducted by varying catalyst loading and oxidant type and concentration to assess their effects on reaction rates and system throughput.

- Gas chromatography system for TCE analyses to be purchased

  In support of the upcoming TCE testing at SNL, a GC system similar to that used at SERI will be purchased and installed.

- Development of fixed catalyst support for SDW processes to be initiated

  SNL will begin exploring possible ways to apply the titanium dioxide catalyst to a fixed support to eliminate the need for suspended catalyst. These activities involve exploring means of depositing the catalyst on the surface of a "foamed ceramic" material through which the contaminated water would flow during exposure to the sunlight. We have defined the required test matrix for catalyst application to the ceramic support and will initiate testing under contract in the upcoming quarter.

- Researchers at the University of Dayton will complete a significant group of experiments to define the beneficial reduction of products of incomplete combustion for high flux solar detoxification. Field experiments will be performed by SERI researchers to provide a basis for definition of the potential of high flux solar detoxification.

- SNL to initiate testing in metal DCAR reactor.

  Testing in the metal DCAR reactor, recently installed in the solar furnace at Sandia, will be initiated early in the third quarter. The testing will begin with thermal checkout followed in order by carbon dioxide reforming of methane, steam reforming of methane, and steam reforming of methylene chloride. If no problems are encountered, the first test with the chlorinated solvent should take place early in May.

- SNL/DLR to initiate CAESAR experiment in Germany

  The CAESAR experiment will be installed on the dish facility at DLR-Lampoldshansen and testing will be initiated. Jim Muir and Bruce Bainbridge (both Sandia) will travel to Germany to assist with the installation and to participate in the testing.

Mission 3. Advanced Electric Technology

# TASK 1. TECHNOLOGY IDENTIFICATION

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

Accomplishments:

- **Request for Information (RFI) completed and approved by DOE/HQ and Sandia.**

  A request for information (RFI) regarding potential program participants is complete and has been approved by DOE/HQ as well as Sandia management. This RFI will be published in the Commerce Business Daily in May 1989 and is intended to identify potential industrial partners in a consortium to participate in the Research and Development program aimed at fielding a next-generation solar thermal electric experiment.

Next Quarter Planned Activities:

- As part of the effort to identify and encourage private sector participation in this project, a Stirling workshop and a dish converter review meeting are being organized. Both events will be coordinated through the Solar Thermal Design Assistance Center (STDAC).

- As part of its effort to identify and encourage private sector interest in solar thermal technologies, the STDAC is planning two important events. First, a two-day Stirling Workshop is scheduled for May 1989. This workshop is being organized by EPRI, with assistance from Sandia. The purpose of the workshop is fourfold: 1) to describe the market for dish Stirling generation systems; 2) to identify milestones by which Stirling systems can be commercialized; 3) to examine risks associated with each milestone; and 4) to facilitate teaming on the part of component suppliers.

- A second effort involves a dish converter review meeting to be held during the next quarter at DOE/HQ. The objective of the meeting is to identify and discuss some of the other potential dish converter technologies that may be candidates for participation in the Mission 3 program. The discussions will cover Brayton cycle and photovoltaic converters. The meeting participants will include representatives of the industrial sector, Sandia, SERI, and DOE/HQ personnel. The discussions will center on the technical and economic feasibility of each of the technologies.

# TECHNOLOGY TRANSFER

## Publications Completed in FY89

"Optical Performance of the First Prototype Stretched-Membrane Mirror Modules," D. J. Alpert, D. K. Johnson, R. M. Houser, L. Yellowhorse, and J. VanDerGeest, SAND88-2620, October 1988.

"Analysis of Heat Pipe Receivers for Point-Focus Solar Concentrators," D. R. Adkins, SAND88-0093, October 1988.

"Study of the Reliability of Stirling Engines for Distributed Receiver Systems," Holtz, R. E., and K. L. Uherka, SAND88-7028, December 1988.

"Hydrodynamic, Thermal, and Radiative Transfer Behavior of Molten Salt Films as Applied to the Direct Absorption Receiver Concept," M. J. Green, M. S. Bohn, and M. Carasso, SERI/TP-253-3412, Golden, Colorado: Solar Energy Research Institute.

"A Description and Assessment of Heliostat Technology," C. L. Mavis, SAND87-8025, January, 1989.

"Dynamic Simulation of a Molten Salt Solar Receiver," G. J. Kolb, D. Neary, M. R. Ringham, T. L. Greenlee, SAND88-2895, January 1989.

"University of Houston Solar Central Receiver Code System," C. Pitman, L. Vant-Hull, SAND88-7029, January 1989.

"Reliability of the Solar One Plant During the Power Production Phase (August 1, 1984 through July 31, 1987)," (full report) G. J. Kolb, C. W. Lopez, SAND88-2664, October 1988.

"Demonstration of PC-Based Dynamic Simulation Models of Solar Thermal Systems," G. J. Kolb, D. Neary, M. R. Ringham, SAND88-1299C, November 1988.

"A Final Report on the Phase I Testing of Molten-Salt Cavity Receiver, Volume I--A Summary Report," D.C. Smith and J.M. Chavez, SAND87-2290, Sandia National Laboratories, December 1988.

"Commercial Direct Absorption Receiver Design Studies", S.F. Wu and T.V. Narayanan, Foster Wheeler Solar Development Corp., SAND88-7038, December 1988.

"Development of a Stretched-Membrane Dish Phase I," D. L. White, (Solar Kinetics, Inc., SAND88-7035, March 1989.

"Solar Thermal Technologies in Support of an Urgent, National Need Opportunities for the Photon-Enhanced Decomposition of Concentrated and Dilute Hazardous Wastes," J. P. Thornton, SERI/TR-250-3359, ACCNR: 10355, Golden, Colorado: Solar Energy Research Institute, December 1988.

"Video-Solar Thermal Research," L. M. Murphy, SERI/SP-253-3280, Golden, Colorado: Solar Energy Research Institute

**Publications in Progress**

"An Improved Design for a Stretched-Membrane Heliostat," Science Applications International Corp., SAND89-7027.

"Final Report on the Improved Design for Stretched-Membrane Heliostats," Solar Kinetics, Inc.

Final Report on the Low-Cost Heliostat Drive," Peerless-Winsmith

"NASA SCAD Concentrator Terrestrial Testing Feasibility Study", T. R. Mancini, C. P. Cameron, and V. R. Goldberg, SANDXX-XXXX

"Wind Loads on Heliostats and Parabolic Dish," Peterka, Tan, Bienkiewicz, and Cermak, SERI/STR-253-3431.

"Status of the DAR Panel Research Experiment: Salt Flow and Solar Test Requirements and Plans," Tyner, C. E., SAND88-2455.

"Water Flow Testing of the Direct Absorption Receiver Concept," Chavez, J. M., D. K. Johnson, and C. E. Tyner, W. A. Couch, SAND88-3390.

"Heat Transfer Analysis of the IEA/SSPS Volumetric Receiver," Skocypec, R. D., R. Boehm, J. M. Chavez, R. Mahoney, and W. Kim, SAND87-2969.

"DAR Final Technical Report," Bohn, M., SERI report.

"High Temperature Solar Central Receivers for Electricity Production," J. V. Anderson and N. L. Weaver, ACCNR: 10196, Golden, Colorado: Solar Energy Research Institute.

"Comparison of Three High-Temperature Solar Central Receivers," J. V. Anderson and N. L., Golden, Colorado: Solar Energy Research Institute.

"Membrane Dish Analysis: A Summary of Structural and Optical Analysis Capabilities," SERI/TR-253-3432, Balch, Steele, and Jorgensen, ACCNR: 10658, Golden, Colorado: Solar Energy Research Institute.

"Absorption Receiver: Final Technical Report," M. S. Bohn, SERI/TR-253-3438, Golden, Colorado: Solar Energy Research Institute.

"Heat Transfer in Molten Salt Direct Absorption Receivers," M. S. Bohn and H. J. Green, SERI/J-253-0318, Golden, Colorado: Solar Energy Research Institute.

"Solar Incinerability of Hazardous Waste," B. Dellinger and J. L. Graham, SERI/STR-250-3420, ACCNR: 10641, Golden, Colorado: Solar Energy Research Institute.

"Preliminary Assessment of the Feasibility of Using Solar Thermal Systems to Photodecompose Organics in Pink Water," R. Hewett, SERI/TR-250-3421, ACCNR: 10643, Golden, Colorado: Solar Energy Research Institute.

**Publications in Progress (con't)**

"Preliminary Assessment of the Feasibility of Using Solar Thermal Systems to Photodecompose Organic Chemicals in Dilute Aqueous Solution," R. Hewett, J. P. Thornton, and G. Glatzmaier, SERI/TR-250-3422, ACCNR: 10645, Golden, Colorado: Solar Energy Research Institute.

"Holographic Solar Concentrator Development - Phase II and III," J. L. Hull, SERI/STR-253-3326, ACCNR: 10238, Golden, Colorado: Solar Energy Research Institute

"Solar Reflector Soiling Pattern Distributions and Reflectance Measurement Requirement," K. Kidney and J. R. Pitts, SERI/RR-255-3369, Golden, Colorado: Solar Energy Research Institute.

"An Overview of Research on Secondary Concentration for Point Focus Dish System," A. Lewandowski, J. O'Gallagher, and J.
"Wind Loads on Parabolic Dish Collectors," J. A. Peterka, A. Tan, B. Bienkiewicz, and J. E. Cermak, ACCNR: 10292, Golden, Colorado: Solar Energy Research Institute.

"Advanced Concepts for Solar Thermal Technology," W. D. Short, ACCNR: 10569, Golden, Colorado: Solar Energy Research Institute.

"Optical Goals for Polymeric Film Reflectors," W. D. Short, ACCNR: 10451, Golden, Colorado: Solar Energy Research Institute.

"High Temperature Solar Chemistry," R. Sizman and R. G. Nix, Golden, Colorado: Solar Energy Research Institute.

"Solar Thermal Technologies in Support of an Urgent, National Need Opportunities for the Photo-Enhanced Decomposition of Concentrated and Dilute Hazardous Wastes, J. P. Thornton, SERI/TR-250-3359, ACCNR: 10255, Golden, Colorado: Solar Energy Research Institute.

"Destruction of Dioxin-Contaminated Soil in Missouri by Mobile Incineration-An Executive Summary," J. P. Thornton, Golden, Colorado: Solar Energy Research Institute.

"Times Beach, The Town that Ceased to Exist," J. Donnermeyer, Golden, Colorado: Solar Energy Research Institute.

"Carbon Monoxide Rich Methanation Kinetics on Supported Rhodium and Nickel Catalysts," D. Keehan and J. T. Richardson, SAND88-7149.

"Test Results from Bench-Scale Sodium-Pool-Boiler Solar Receiver," Moreno, J. B. and Andraka, C. E., to be published as a SAND report in April 1989.

"Assessment of Potential for Surface Modification by Highly Concentrated Solar Energy," J. R. Pitts and C. Fields, SERI/J-255-0314, submitted to MRS Bulletin.

# SCIENTIFIC MEETINGS AND PRESENTATIONS

## First Quarter FY89

"Optical Performance and Durability of Silvered Polymer Mirrors,"G. J. Jorgensen and P. O. Schissel, ACCNR: 10295, Electrochemical Society, Chicago, IL, October 1988.

"Internal Film Receiver Design Study and Systems Assessment," J. V. Anderson and T. Buha, ACCNR: 10568, ASME Winter Annual Meeting, Chicago, IL, December 1-2, 1988.

## Second Quarter FY89

"Rapid Destruction of Organic Chemicals in Water Using Sunlight," C. E. Tyner, J. E. Pacheco, C. A. Haslund, and J. T. Holmes, Proceedings of 1989 Hazardous Materials Management Conference, HAZMAT Central '89, Rosemont IL, March, 1989.

# SOLTECH89 PRESENTATIONS

The following papers were presented during the Solar Thermal Research and Development portion of SOLTECH 89, Arlington, VA, March 8-9, 1989:

Moreno, J. B., and C. E. Andraka, "Pool Boiler Solar Receivers for Stirling Engines."

Diver, R. B., "The Reflux Heat-Pipe Solar Receiver Development Program."

Adkins, D. R., "Heat Pipe Solar Receivers for Stirling Engines."

Linker, K. L., and K. S. Rawlinson, "Kinematic Stirling Engine Status for Solar Thermal Electric Systems."

Chavez, J. M., W. A. Couch, and K. A. Boldt, "The Status of Direct Absorption Receiver Testing."

Bohn, M., "Fluid and Thermal Behavior of the Direct Absorption Receiver."

Rush, E. E., and C. Matthews, "Testing of Large-Scale Molten Salt Pumps and Valves."

Chavez, J. M., "Design, Analysis, and Testing of a Volumetric Receiver."

Menicucci, D. F., J. M. Diggs, and W. Short, "The Advanced Electric Technology Cooperative Program."

Fish, J. D., "High-Temperature Solar Destruction of Hazardous Wastes."

Thornton, J. P., "Opportunities for the Solar Processing of Toxic Waste."

Nix, G. and Glatzmaier, G., "Solar Field Testing for Photothermal Destruction of Hazardous Wastes."

Webb, J. D. and Magrini, K. A., "Photocatalytic Destruction of Organics in Dilute Aqueous Solutions."

Dellinger, B., Graham, J. L., and Bauchert, K. A., "Solar Thermal/Photolytic Destruction of PCB's."

Tyner, C. E., Pacheco, J. E., Rush, E. E., and Yellowhorse, L., "Engineering Studies of the Photocatalytic Destruction of Organics in Water."

Klimas, P. C., "Advanced Electric Generation Technology."

Chavez, J. M., "An Overview of Advanced Central Receiver Concepts."

## Third Quarter FY89

"The Economic Potential of a Photovoltaic Central Receiver Power Plant," D. F. Menicucci, G. J. Kolb, SAND88-2407C, April 1989, presented at the 1989 ASME International Solar Energy Conference, April 1989, San Diego, CA.

"Improved Operational Performance of the Shenandoah Solar Total Energy Project," R. F. Nelson and A. A. Heckes, SAND88-1693C, Proceedings of the 1989 ASME International Solar Energy Conference, April 2-4, 1989.

"A Performance Comparison of Multifacet and Single Facet Dishes," T. J. Wendelin and A. A. Lewandowski, SERI/TP-253-3208, ACCNR: 9482, ASMR Solar Energy Conference, Golden, Colorado, April 11-14, 1988.

"An Assessment of the Optical Performance of Stretched-Membrane Mirror Modules," D. J. Alpert and R. M. Houser, SAND88-1651C, Proceedings of the 1989 ASME International Solar Energy Conference, April 2-4, 1989.

"Reliability of the Solar One Plant During the Power Production Phase" (conference paper) G. J. Kolb, C. W. Lopez, SAND88-2748C, May 1989.

"Heat Transfer and Pressure Drop Measurements in an Air/Molten Direct Contact Exchanger," M. S. Bohn, SERI/TP-253-3426, ACCNR: 10649, ASME Solar Energy Division Conference; San Diego, CA, April 1989.

"Drop Ejection in Molten Salt Direct Absorption Central Receivers," M. S. Bohn and C. H. Stern, ACCNR: 10584, ASME SED Conference; San Diego, CA, April 1989.

"Reactor Design for Solar Chemistry," G. C. Glatzmaier, M. S. Mehos, and G. Nix, Conference paper for ASES Annual Conference, June 19-23, 1989.

"A Preliminary Assessment of the Effect of Sunshape on the Performance of Central Receiver Power Plants," D. Menicucci, SNLA, to be presented at the American Solar Energy Society SOLAR 89 Conference, June 1989, Denver, CO.

"Structural and Optical Response of Membrane Dish Concentrators," A. A. Lewandowski and T. J. Wendelin, ACCNR: 10368, ASME Solar Energy Division Conference; April 2-5, 1989; San Diego, CA.

"LANSIR: An Instrument for Measuring the Light-Scattering Properties of Laminate Membrane Mirrors," T. J. Wendelin, SERI/C-253-0376, ASME International Solar Conference, San Diego, CA, April 2-4, 1989.

"Surface Figure Tests for Large, Point Focus Solar Concentrators Using a Scanning Hartmann Method," R. L. Wood, ACCNR: 10366, ASME Solar Energy Division Conference; April 2-5, 1989; San Diego, CA.

"The Economic Potential of a Photovoltaic Central Receiver Power Plant," D. F. Menicucci and G. Kolb, SNLA, presented at the 1989 International Solar Energy Conference, April 1989, San Diego, CA.

## Fourth Quarter FY89

"Pool Boiler Solar Receivers for Stirling Engines," C. E. Andraka and J. B. Moreno, to be presented during the Intersociety Energy Conversion Engineering Conference, Washington, DC, August 7-11, 1989.

SERI researchers are organizing and will chair a session on "Heat Transfer in Solar Energy Applications," to be held at the 1989 National Heat Transfer Conference (August 6-9, 1989) in Philadelphia, PA. The session is sponsored by the Solar Energy Committee of the Heat Transfer and Energy Conversion Division of the American Institute of Chemical Engineers. This Committee, composed of individuals from SERI, DOE and other DOE laboratories, has organized and chaired technical sessions at each of the last 5 National Heat Transfer Conferences, as well as at other National AIChE meetings. These sessions have provided a forum for the discussion of the unique heat transfer problems which arise in the various solar technology areas. Since this Division of AIChE has recently reorganized, the charter of the Solar Energy Committee has been expanded to include the various energy conversion areas, in addition to heat transfer. The Committee is expanding to meet the challenges of increasing the scope, quantity and quality of the technical sessions. These activities are an opportunity to tell other professional engineers of the potential of solar energy to solve important national problems.

"Stretched-Membrane Heliostats for Solar Central Receiver Power Plants," D. J. Alpert and R. M. Houser, SAND89-0893A, Optical Materials Technology for Energy Efficiency and Solar Energy Conversion VIII, part of SPIE's 33rd Annual International Technical Symposium on Optical & Optoelectronic Applied Science and Engineering, August 6-11, 1989.

"Development of Concentrating Collectors for Solar Thermal Systems," J. T. Holmes, D. J. Alpert, T. R. Mancinni, L. M. Murphy, and P. O. Schissel, Proceedings of 24th 1989 ISCEC International Forum on Energy Engineering, Washington DC, August 6-11, 1989.

"Testing of the STM4-120 Kinematic Stirling Engine for Solar Thermal Electric Systems", Linker, K. L., D. R. Adkins, and K. S. Rawlinson, SAND88-3286C, 1989 Intersociety Energy Conversion Engineering Conference, Washington D.C., August 1989.

"Recommendations for Improvements in the Design and Operation of Future Solar Central Receiver Power Plants Based on Experience Gained from the Solar One Power Plant," G. J. Kolb, to be presented at the IECEC-89 Conference, Washington,DC, August 1989

"Development and Testing of Advanced Solar Central Receivers," J. M. Chavez, to be presented at the IECEC-89 Conference, Washington, DC, August 1989

"Kinematic Stirling Engine Statis for Solar Thermal Electric Systems," K. L. Linker, Solar Thermal Technology Program Annual R&D Review, 1989, Washington, DC.

"Improved Operational Performance of the Shenandoah Solar Total Energy Project," R. F. Nelson and A. A. Heckes, SAND88-1693C, Proceedings of the 1989 ASME International Solar Energy Conference, April 2-4, 1989.

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