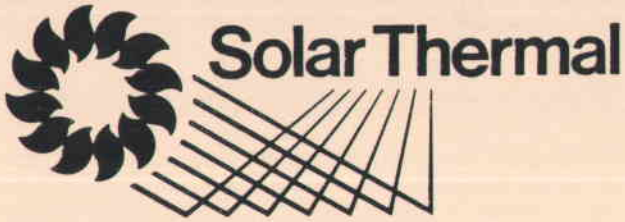
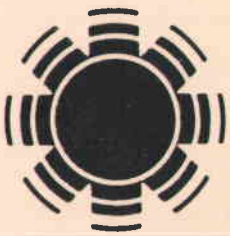
SERI/MR-251-1471 Fourth Quarter, FY 1988



Solar Thermal Energy Program

Quarterly Progress Report

Issued October 1988



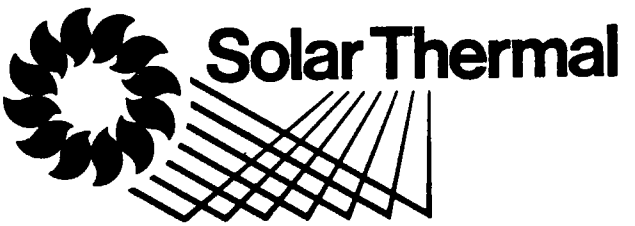
SERI

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

Operated for the
U.S. Department of Energy
Contract No. DE-AC02-83CH10093

SERI/MR-251-1471 Fourth Quarter, FY 1988



Solar Thermal Energy Program

Quarterly Progress Report

SERI

B. P. Gupta
Program Leader
Solar Thermal Energy Program

Telephone: 303/231-1760
FTS/327-1760

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

TABLE OF CONTENTS

STRUCTURE OF THE SERI SOLAR THERMAL ENERGY PROGRAM

FWP ST81-88	SOLAR THERMAL RESEARCH	
Task Number	Task Title	Task Leader/Author
1	Materials	D. M. Blake
2	Concentrators	A. Lewandowski
3	Receivers	M. Carasso
4	Heat Engines	M. Carasso
5	Direct Conversion	R. G. Nix
6	Energy Storage (No SERI Activity)	
7	Innovative Concepts	B. P. Gupta
FWP ST82-88	SOLAR THERMAL PLANNING AND ASSESSMENT	J. Thornton

SOLAR THERMAL RESEARCH

FOURTH QUARTER, FY 1988 ACCOMPLISHMENTS

(SERI MILESTONE NUMBERS FROM ANNUAL OPERATING PLAN)

	Planned	Actual	Reference Page
o Fabricate sets of candidate materials using most promising combination of coatings and substrate for site evaluation. (1.2, FY 1988 AOP)	09/88 03/89 (Reschedule)		
o Fabrication of three-meter prototype composite membrane dish (2.1, FY 1988 AOP)	07/88	07/88	22
o Complete long salt-film wave stability experiment without flux (3.2, FY 1988 AOP) (completed as rescheduled)	06/88	09/88	25
o Test solar detoxification reactor with concentrated flux (5.2, FY 1988 AOP)	08/88	08/88	31
o Verify through experiments the beneficial effects of concentrated sunlight on at least one chemical reaction that has high industrial value (5.3, FY 1988, AOP)	09/88	09/88	32
o Review progress and promise of highly concentrated solar flux (7.1, FY 1988, AOP)	09/88	09/88	39
o Draft report-symposium proceedings on storage materials (1, FY 1988, ST82A, AOP) (Request for reschedule to 01/89)	09/88 01/89 (Reschedule)		

SOLAR THERMAL RESEARCH

FIRST QUARTER, FY 1989 PLANNED ACTIVITIES
(To be incorporated into the new FY 1989 structure)

	Planned
o Complete optical assessments and reflector characterization of composite membrane dish (2.2, FY 1988, AOP)	11/88
o Test results to identify the best materials candidates for containment of RTEC working fluid in the regenerator (4.2, FY 1988, AOP)	11/88
o Draft report on recommendations and guidelines for research priorities in solar photo-decomposition of organic compounds (3, FY 1988, FWP ST82A, AOP)	10/88

TECHNICAL ACCOMPLISHMENTS — SUMMARY

TASK 1.0 MATERIALS

TASK 2.0 CONCENTRATORS

TASK 3.0 RECEIVERS

Direct-Absorption Receiver (DAR) Research

TASK 4.0 HEAT ENGINE

TASK 5.0 DIRECT CONVERSION

Solar Detoxification Research

TASK 6.0 ENERGY STORAGE

Reference Page

(No activity at SERI is being reported under this Task).

TASK 7.0 INNOVATIVE CONCEPTS

	Reference Page
o Very high concentrations and solar-pumped laser experiments continued at the University of Chicago.	39

TECHNICAL ACCOMPLISHMENTS — DESCRIPTIVE DETAIL

FWP ST81-88 SOLAR THERMAL RESEARCH

TASK 1.0 MATERIALS

OBJECTIVES

The objective of research on **Silver Ultralight Polymer Reflector** (SUPR) films is to obtain silver/polymer reflecting surfaces that meet long-term durability goals (while maintaining high-specularity performance requirements) and that operate satisfactorily in the solar environment. The objective of research on Soiling and Cleaning of Solar Reflectors is to develop effective methods for minimizing the efficiency losses of large heliostats and dishes due to soiling. This research includes identification of soil chemistry and modes of adhesion; evaluation of modified reflector surfaces for improved anti-soiling/cleaning characteristics; evaluation of cleaning solutions and methods; and development of the methods required to predict the most cost-effective cleaning strategy for any selected site.

ACCOMPLISHMENTS

Silver/Polymer Reflector Research

o Altered PMMA resin shows improved performance in several accelerated tests.

SERI and the 3M Company have conducted a large series of accelerated tests, involving a set of PMMA resins with a large set of stabilizers. The tests conducted for up to three months show that a pattern is evolving to demonstrate that Tinuvin P continues to be the best stabilizer but that new PMMA resins show improved performance over the resin currently used in ECP 300A.

o Metal interlayers continue to protect the silver interface.

Ultrathin-metallic interlayers in front of the silver or behind the silver can maintain reflectance better than samples without the metallic interlayers. After two months in the Weather-Ometer either 20 nm of chromium behind the silver or 2 nm of gold in front of the silver continues to slow loss of reflectance of silvered-polymer mirrors when compared to a witness construction with no metal interlayer.

o Adhesion measurements using a tape test and direct pull tests are being applied to thin-metal-adhesive layers.

SERI researchers are exploring two types of adhesion tests for comparing the performance of silvered polymer constructions. The tape test (ASTM D3359-78) is a qualitative test that is readily applied to metallized polymers and to structures like ECP 300 with adhesive applied. For the direct-pull test, researchers have used two instruments: the Sebastian II and an Elcometer.

One planned approach to improved adhesion is to use metal interlayers as adhesives between the silver and the PMMA. In its simplest form the metal adhesive layer would have to be optically thin, but variations could involve thicker films.

- o While the weathering of the abrasion resistance of temperature-cured hardcoats is good, the abrasion resistance of the current ultraviolet-cured hardcoats deteriorates upon weathering.

SERI scientists have studied two broad categories of abrasion-resistance coatings (ARCs): temperature-cured and ultraviolet-cured. They have demonstrated the improved abrasion resistance for both types of ARCs. Good weatherability also has resulted for temperature-cured ARCs, and some limited data suggest that temperature-cured ARCs may further slow loss of reflectance and adhesion and may improve the soiling/cleaning response. However, based upon field cleaning experience at Industrial Solar Technology, it is not demonstrated that ARCs are actually needed.

Because of concerns of potentially high costs for temperature-cured ARCs, researchers briefly explored ultraviolet-curing and successfully improved abrasion resistance. It has not been demonstrated that ultraviolet-cured ARCs slow loss of reflectance or improve the soiling/cleaning response. The 3M Company substantiated SERI's results for ultraviolet curing relative to abrasion resistance, and the Company further demonstrated that, in an accelerated test, ultraviolet curing does not provide a weatherable ARC. Thus, SERI presently does not have an ultraviolet-curable, weatherable ARC. Researchers do not plan to pursue alterations in the materials that lead to a solution unless and until outdoor use demonstrates a definite need for an ARC.

- o Preliminary tests using substrates of various painted metals are good, while bare stainless steel is poor.

Earlier tests have shown unequivocably that coil-coated aluminum weathers better than bare aluminum both in an accelerated test and outdoors in Florida and Arizona. Three substrates (aluminum, stainless steel, and glass) were coated in the laboratory with various paints (clear, white, black-acrylic-based, and white-polyester-based paints), and ECP 300A was applied. Comparison of these samples with those having the commercial, coil-coated, baked, polyester paint in an accelerated test did not show a difference. One set of bare, stainless-steel samples degraded badly even in a portion that was shielded from light.

- o Silvered polymers lose reflectance more rapidly in a pure nitrogen atmosphere than in a standard air atmosphere.

Experiments--comparing loss of mirror reflectance of a mirror housed in a nitrogen purge with a mirror in a purge using standard-grade-compressed air--confirm earlier, surprising results that degradation is more rapid in nitrogen than in air. Further measurements confirm earlier reports that the optical degradation occurs at the silver interface and not in the polymer.

Soiling and Cleaning of Solar Reflector Materials

- o Langmuir-Blodgett films on ECP 300 exhibit better soil resistance in cyclic dusting and washing tests than do a number of other materials.

Scientists tested a sample set of hardcoated and low-surface-energy-coated ECP 300 samples in the cyclic laboratory dusting and cleaning regimen. Two of the better Langmuir-Blodgett films from the Georgia Tech Research Institute (GTRI) as well as glass and uncoated ECP 300 samples were included for comparison. After ten full cycles of the soiling and cleaning procedure, most of the polymer samples performed better than glass, with some subtle differences noted among the various hardcoated and the

low-surface-energy-coated materials. Glass and one of the low-surface-energy-coated materials exhibited the poorest behavior in the soiling tests with permanent reflectance losses in the range of 20 percent to 30 percent. ECP 300 (unmodified), hardcoated ECP (number 2 and number 3 abrasion-resistance coatings), and LB-layered ECP from GTRI showed better soil-resistance with permanent reflectance losses in the range of 10 percent to 15 percent. Visually the GTRI samples were slightly better than any of the others and showed a slight edge in the measurements at smaller cone angles. Photographs have recorded the visual appearance for future comparison. These samples were removed from testing, and a set from Springborn Laboratories was entered into test.

o SERI and Sandia personnel collaborated on the design of an outdoor test stand and measurement strategy for site evaluation.

SERI and Sandia, Albuquerque, personnel met in Albuquerque to discuss the joint SERI and Sandia proposal to deploy reflector samples for site testing in the very near future. The group reached agreement on issues of sample sets, sample size, rack specifications, and measurement strategy. A decision on stow orientation for the rack has yet to be made. An engineering drawing of the test stand and the proposed sample locations has been forwarded from Sandia to SERI. SERI has circulated a letter containing the recommended set of samples for comment.

o An optical instrument for evaluating soiling rates at unattended, remote sites has been designed.

Design work on an optical instrument capable of measuring specular transmittance of sample materials in a remote location in an unattended mode has been completed. All of the standard components that can be used in the assembly of the device have been located and priced. In related work, optical data comparing specular transmission through solid films to specular reflectance from soiled films have been plotted and illustrate a reasonably straight-forward correlation between the radiation scattered in the transmission mode and the radiation scattered in the reflected mode.

o Subcontracted work on antisoiling films has resulted in interesting observations.

Springborn Laboratories has completed work on applying soil-resistant coatings on glass and acrylic surfaces. Acrylic and glass surfaces coated with Owens Illinois Glass Coat 651 hardcoat and over-coated with Petrarch T2494 fluorosilane show improvement in soil resistance over either the untreated acrylic or the untreated glass. Five formulations have been found to be optically clear, have good adhesion, and offer better resistance to soiling than untreated glass. These are listed in order of effectiveness: Owens 651 treated with T2494; Owens 651; 3M ARC; Owens 651 treated with 3M L-1668; and acrylic/tetraethylorthosilicate IPN blended with T2494. Test coupons similar to those used by Springborn with the better treatments for soil resistance have been received for testing at SERI. Two additionally interesting observations were: (1) the soiling behavior of the experimental surfaces appeared unrelated to the measured hydrophobicity of the surface, and (2) acrylic film had to be treated first with an organosil and hardcoat before a fluorosilane surface treatment was effective at improving the soil resistance.

Georgia Tech Research Institute (GTRI) has conducted data analysis on SERI's results of accelerated soiling tests on GTRI samples. GTRI concluded: that (1) it appears that coated samples resist soiling better than uncoated controls and that three monolayers is better than one; (2) both fluorinated surfactants appear to perform equally well; and (3) the test method requires further development and replication will be required to

estimate variances. Current efforts are aimed at coating the polymerizable surfactants and at improving the reproducibility of deposition.

TASK 2.0 CONCENTRATORS

OBJECTIVES

Under **Concentrator Research** the ultimate objective of membrane dish research is to establish the technical feasibility and cost potential of the concept compared with current concepts for glass and metal dishes. The research is divided into two major categories: optical analysis and structural analysis. The objectives of Optical Analysis includes: (1) analytically to determine the optical response of various stretched membrane dish configurations; (2) experimentally to evaluate prototype dish optical performance; and (3) to provide technical support to the ongoing development of the membrane dish program. The objectives of **Structural Analysis** include: (1) analytically to determine the coupled optical/structural response of stretched membrane dish concentrators; (2) to build small prototypes to test materials and fabrication options; and (3) to provide technical support to the on-going development in the membrane dish program.

ACCOMPLISHMENTS

Membrane Dish Optical Analysis

o Alignment and calibration of the Scanning Hartmann Optical Testor (SHOT) are essentially complete.

Significant progress toward final operational status of the Scanning Hartmann Optical Tester (SHOT) has been made. Assembly and alignment of the laser-beam-scanning subsystem are now complete. The beam-scanning system was first calibrated by using a precise-checkerboard-pattern screen placed in front of the dish. The components of the beam-scanning subsystem include the laser, the laser scanner, and associated optics. the laser has been mounted on its rail along with the scanner, optics, and target. The AT computer which will control the SHOT has been remounted in an industrial chassis and has been placed into its cabinet with the scanner electronics. Software to control the scanning subsystem has been loaded in the AT and researchers are now able fully to exercise this subsystem. Components of the spot-tracking system include a scanner, a detector, and associated optics. The basic methodology is for a laser beam to be scanned toward various points on the subject dish with the position of the return beam on a target being viewed and tracked with the spot-tracking system. By directing the beam to known coordinates on a test article and detecting the deviation of the reflected beam from its expected location (based on a perfect optical surface) on the target, the surface normal errors of the dish under test can be determined. The SHOT has significant advantages over existing methods in terms of accuracy, dish size, f/D capabilities, and (eventually) portability. Work is also complete on data acquisition and reduction software.

o Preliminary testing of the three-meter composite membrane dish from the Science Applications Corporation (SAIC) has been completed.

Preliminary data have been taken on the dish mounted in the laboratory from the Science Application International Corporation (SAIC) . The beam-scanning system first was calibrated by using a precise checker-board-pattern screen placed in front of the dish. Then the screen was removed, and scans were projected across two diameters of the dish. The position of the return beam on the target was measured manually. Manual measurement was conducted because the automated spot-tracking system requires minor adjustments in sensitivity to its electronics. Reduction of the limited, preliminary data indicates that the initial shape of the dish is very close to a parabola. The data for the deformed (i.e., pressure stabilized) dish were compared to an analytical solution for an initial parabola

with no edge-pull. The comparison yields very similar root mean square slope deviations. More extensive data will be required to characterize fully the shape of the dish and to predict its optical/thermal performance.

Membrane Dish Structural Analysis

o Science Applications International Corporation (SAIC) has delivered a three-meter, prototype composite membrane to SERI.

Science Applications International Corporation (SAIC) has completed fabrication of its three-meter-diameter composite membrane dish and has shipped it to SERI. The dish includes a composite membrane 20-mil thick with ECP-300 reflective film laminated in gores, a main support ring, and a structure for the frame of the membrane. The focal length-to-diameter ratio of the membrane is approximately 0.67. The prototype consists of a front ring; the composite membrane; a back-ring and support-strut assembly; and a rigid, stainless-steel-back membrane. No external ring or other system components are included. The membrane was laid on a parabolic mold. The mold was formed by plastically deforming a thin, flat stainless steel membrane with a uniformly thick layer of molten epoxy and nonuniform hydrostatic pressure. The cured epoxy was turned upside down and smoothed to form the final three-meter-diameter mold. Researchers intend to characterize the surface shape of this dish with the Scanned Hartmann Optical Tester (SHOT). Data from the SHOT tests will be used both to assess the accuracy of SAIC's mold and fabrication process, and to validate the structural and optical analytical tools which researchers have recently developed. This completes the milestone entitled "Fabrication of three-meter prototype composite membrane dish."

o Analytical tools to predict the response of non-axisymmetric membranes dishes have been completed and developed into useful computer codes.

A visiting professional staff member with extensive experience in the structural analysis of thin shells spent the summer at SERI to continue development of analytical tools for membrane dishes. In previous work for SERI, he developed analytical solutions for both axisymmetric and non-axisymmetric response of membranes used for dish applications. During the summer, the non-axisymmetric analysis was verified against other methods. In addition, the interaction between membrane and ring-support structure was assessed. A methodology for using the analysis of membranes interactively with linear, personal-computer-based, finite-element codes was developed. An integrated computer code was developed for both non-axisymmetric membrane analysis and optical-thermal performance of the resulting shape of the membrane and was based on the work during the summer.

A presentation of recent structural and optical analytical research on membrane dishes was given at SERI on August 25. Attendees included representatives from Sandia/ Albuquerque, Science Applications International Corporation, and Solar Kinetics Incorporated. The primary focus of the current research has been on development of the non-axisymmetric structural and optical models into a form which is easy to use and provides a maximum amount of information relatively quickly. A set of computer codes has been written and utilizes the analytical model for a non-axisymmetric membrane in combination with a ray-trace optical model to show graphically the optical effects of membrane shape under a wide variety of loading conditions. An interface also has been developed between the membrane analysis code and a linear finite element structural code so that the interactions between a given overall structural system (e.g., cable-supported, central-post concept) and a membrane can be determined. This combination of codes can be used on a personal computer instead of a full, non-linear, finite-element analysis, which

requires a mainframe computer and potentially large computational costs. The purpose of the presentation was to review the background, to describe the various codes and their interfaces, to demonstrate the codes, and to provide some training. All participants were given a set of disks with the programs, example data files, plus documentation of the software.

o Structural optical analysis tools for membrane dishes are being used at Solar Kinetics, Inc., in its research on dish development.

Solar Kinetics, Inc. (SKI), has been utilizing the membrane dish structural and optical analysis tools presented at SERI on August 25, 1988. The computer models discussed and distributed at that meeting are currently being used by SKI as part of its contract with Sandia, Albuquerque, on membrane dish development. SERI researchers have been interacting with SKI engineers to adapt some parts of the code to their specific dish concept and to specific analyses that they are conducting. SERI also is advising SKI on the design and implementation of optical test equipment, which will be very similar to the SHOT. SERI will continue to work with industry to provide useful analytical tools with which to predict and to analyze membrane dish response and performance.

o Structural analysis of the central-post, cable-supported membrane dish concept has indicated potentially significant membrane-structure interactions.

The support structure which is currently under consideration for the fifteen-meter dish membrane consists of a ring suspended by spokes from an axial center post. The dish is attached to the ring, and deformations of the support ring cause dish deformations which can significantly degrade the optical performance. Dan-Ka Products has carried out a finite-element structural analysis of the ring-spoke-centerpost support structure alone and has demonstrated how this structure responds to wind loads. The ring deformations from this analysis were used as input to the code for dish-membrane analysis, in order to predict the deformation of the dish surface quite accurately. The dish-membrane analysis showed that the ring deformations, which enforced on the edge of the dish, give rise to membrane reaction forces in the dish. This result indicates that the dish and the support structure are a coupled system, and should be analyzed as such. From a structural standpoint, the membrane acts on the support ring just like the spokes, except that the membrane force is distributed around the circumference. Current estimates suggest that the stiffness of a 10 mil composite membrane is of the same order as the support-structure stiffness; a steel membrane is even stiffer. Analytical efforts are underway to determine the interaction between the membrane and the ring/support structure for a cable-supported, central-post concept.

TASK 3.0 RECEIVERS

OBJECTIVES

The goal of research on **Direct Absorption Receivers** (DAR) is to advance the state of theoretical and experimental knowledge of the phenomena involved to a point whereby the information necessary for the design of a Direct Absorption Receiver, including the specification of feasible configurations, working fluids and operating modes, is sufficient for an experienced designer to proceed to define a prototype development receiver. The objectives of the **Direct-Absorption Receiver Task** in FY 1988 is to investigate both experimentally and analytically, many of the remaining heat transfer and fluid dynamics involved in understanding the phenomena of direct absorption of concentrated solar flux in doped nitrate salt. The objective of **Materials Research** for Direct Absorption Receivers is to discover or to develop highly effective, chemically inert, nonsettling blackeners with a broad liquid-operating temperature range for high-temperature molten nitrate salt used as heat-transfer fluid and containment materials used in pipes, reservoirs, and valves.

ACCOMPLISHMENTS

Direct Absorption Receivers (DAR) Research

- SERI Researchers completed salt flow experiments on the five-meter panel, tilted at 15° from vertical.

SERI researchers completed the droplet ejection tests on the five-meter salt panel tilted 15° from vertical. After removing all possible sources of droplet ejection on the panel surface, such as weld beads and roughness, a series of measurements along the panel length was started. A tray was placed at a given distance downstream from the weir for one hour so that it caught all droplets from the salt film above that location. By weighing the tray before and after the test, the rate of droplet ejection was determined. Researchers also adjusted the salt-flow rate and temperature to determine the effect on droplet ejection of these parameters.

The test panel underwent a shakedown period during which a number of significant modifications were made. A modified heater system, in which additional heaters along the panel edges maintain a more uniform temperature across the panel and in which spring-loaded clips retain the panel against the support frame, appears to nearly eliminate thermal distortions in the panel. As a result, the salt flow down the panel is very well behaved, and researchers have begun taking data on droplet ejection and wave height. Tests were performed at 15° tilt and at a Reynolds number range of 14,000 to 33,000.

Thickness of salt film has been measured by integrating the output of a contact probe placed a known distance from the panel. Resulting data show that the wave heights increase essentially linearly with the Reynolds number but that at Reynolds numbers greater than about 3000, the growth rate increases. Researchers also have found an effect of temperature; at fixed Re the droplet ejection and wave height increase as temperature is decreased.

o Consistent data were obtained on salt droplet ejection.

Researchers have obtained consistent data on salt droplet ejection. Analysis is underway on the significance of this issue and on mitigating measures. The results indicate that a significant quantity of droplets were ejected from fairly high on the panel. For the test panel (0.27 meters wide), 0.1 gm per hour was measured 2 meters downstream from the weir. The quantity ejected increased exponentially to 1 gm per hour at 4 meters from the weir. Researchers expect that the rate of ejection is likely to increase faster beyond 4 meters. Near the weir, temperature and flow rate have significant effect on the droplet ejection, but these influences were less after about 3 to 4 meters from the weir. Although these data help quantify the magnitude of the ejection problem, it is now necessary to analyze the quantities ejected to determine how serious a problem droplet ejection is likely to be for the Direct Absorption Receiver (DAR).

Besides quantifying the magnitude of droplet ejection, the data help identify the mechanisms responsible for the problem. As a result, the research has pointed out some promising methods for reducing the growth of waves and droplet ejection. These include:

- Inward curvature of the absorber panel to provide additional force on the mass of liquid in the wave to retard wave growth and droplet ejection;
- Increasing the viscosity of the salt to allow operation in the laminar regime and thereby reducing some of the mechanisms for droplet ejection;
- Providing a surface roughness of approximately the substrate thickness to thicken the substrate and thereby reducing wave height;
- Providing a cocurrent air curtain which would retard wave growth via an imposed shear stress onto the salt film.

All of these ideas should be confirmed experimentally and tested to determine their impact on the overall system. SERI researchers are currently discussing these issues with Sandia personnel on how to carry on this work.

o A paper titled "Heat Transfer in Molten Salt Direct Absorption Receivers" has been accepted for publication in the Journal of the International Solar Energy Society.

Solar Energy, the journal of the International Solar Energy Society, has accepted for publication a paper entitled "Heat Transfer in Molten Salt Direct Absorption Receivers," written by SERI researchers. This paper presents results of recent experiments in which the very high convective heat transfer coefficients of an undoped salt film operating in the turbulent flow regime indicated that addition of a salt dopant may not be necessary.

o A mathematical model now predicts the effect of properties of different liquids on the film breakdown flux.

Researchers met with Prof. S. Davis of Northwestern University to discuss his progress on a SERI subcontract entitled "Instabilities in Molten-Salt Films." One result was the development of a scaling law for the breakdown process. This result allows researchers, for the first time, to predict the effect of the properties of the liquid film on the breakdown. Once validated, the model can be used simply to predict the behavior of a salt film based on water film data. Previous data taken at SERI with water and a mixture of water and glycerol have been cast in the form specified by the scaling law. The resulting plot shows that water and the water/glycerol mixture follow the same correlation line. This result is very encouraging because, for the first time, breakdown flux for liquids

with significantly different properties has been correlated. This means that a prediction of the breakdown behavior of molten salt films may be possible.

PLANNED ACTIVITIES

Experiments will continue further to define the extent of salt droplet shedding under different flow, temperature, and panel angle. Analysis of the significance of droplet shedding in typical DAR configurations and mitigation effects will continue with involvement from Sandia, Albuquerque.

TASK 4.0 HEAT ENGINES

OBJECTIVES

The objectives of the **Conversion Systems Research** are to define a Regenerative Thermoelectrochemical Conversion (RTEC) concept, to demonstrate its technical feasibility, and to assess its cost and economic potential for dishes and small central receiver systems. The primary goal of the **RTEC Regenerator Research** is to advance the state of knowledge of the thermochemical phenomena involved in the use of concentrated solar flux for the regeneration of the working fluid in the Regenerative Thermoelectrochemical Conversion cycle to a point whereby a technically feasible receiver/regenerator can be specified and its steady-state and transient performance in the solar flux can be characterized. The objective of **RTEC Materials Research** is to identify materials of construction for the regenerator in the RTEC system and to determine the relevant thermochemical properties of the working fluid used in the system. Based on this information, material of construction will be selected for the prototype receiver/regenerator and related equipment.

ACCOMPLISHMENTS

Conversion Systems Research

- o An initial set of experiments at the Hughes Corporation resulted in better-than-anticipated performance of the hydrogen-bypass membrane/electrode.

An initial set of experiments of the RTEC electrochemical cell has been sucessfully completed at the Hughes Corporation, and with excellent performance. The experiments were with an electrode-membrane assembly provided by the Dow Chemical Company. A number of factors contributed to good membrane performance. Low membrane resistance was obtained once the membrane was fully hydrated. A second factor favoring good performance was a large ratio of hydrogen to ammonia in the base vapor. Researchers are continuing experiments to understand and to optimize this electrode system, as well as other electrode systems.

- o The tests on the fabrication of bipolar-cell-support structures and on condensers have been completed.

A cell support structure, amenable to bipolar cell experiments and developed by Hughes for other company-sponsored RTEC experiments, will be available for SERI's RTEC bipolar experiments. This cell-support structure was developed with resources not from this subcontract and constitutes a savings to the Solar Thermal Program. Kinetic condenser tests at Hughes have been completed and have resulted in the measurement of recombination rates that are fast enough so that no particular process accommodation must be designed for a closed-loop operation.

RTEC Regenerator Research

- o Redesign of the adiabatic-expansion-regeneration experimental apparatus involving graphite coated with silicone carbide is complete, and fabrication is nearing completion.

Redesign of the high-temperature portion of the apparatus for conducting the adiabatic expansion regeneration experiment has been completed, and the drawings specifying the design have been sent to potential manufacturers. Corrosion of the inside of a

molybdenum tube prevented the flow of working fluid in the previous version of the apparatus. The current design consists of a heater tube section 40 inches long, made of amorphous graphite (1 inch, outside diameter), having an inside diameter of .250 inches. The tube will be coated with one coat of silicon carbide on the inside and the outside. The existing Hastelloy expansion chamber will be retained. A Variable Orifice Expansion Device (VOREX), consisting of a micrometer actuated mandrel penetrating into a conical section at the end of the heater tube section inside the expansion chamber, is a part of the redesign.

- o Experiments on thermochemical equilibrium regeneration--yielding consistent data of high- ammonia yield and low pressure--are nearing completion.

Researchers at SERI are nearing the completion of experiments on thermochemical equilibrium regeneration. This set of experiments, conducted entirely with graphite containment, resulted in the highest concentration of ammonia and the lowest total pressure for any given equilibrium temperature thus far obtained. Documentation of this set of experiments has begun in the form of a peer-reviewed paper to be published in the *Journal of Chemical and Engineering Data.*

Materials Research

- o Graphite coated with silicon carbide performs well in corrosion tests at 600°C in the working media.

Long-term tests with various silicon carbide products have been started, and the products show great promise in withstanding the corrosive mixture. Two samples of silicon carbide coated graphite were supplied by Midland Materials. They were tested for 184 hours at 600°C and gave a pressure of 340 psi. One of the samples had a 1.5-mil layer of silicon carbide and the other had a 3.0-mil-thick layer covering all surfaces. Both samples had some flaking of the silicon carbide after the run and also showed a small weight gain. A call to Midland Materials brought out the fact that the silicon carbide had been put down in two separate deposits at different times. The final coat was flaking off while the first coat remained adherent. A scratch test indicated a very hard coat remaining over the complete surface of both samples, except for an edge of one sample. A permanent weight gain of 4 percent to 5 percent of both samples is probably due to the phosphate seeping between the two layers of silicon carbide coating. Midland Materials has sent new samples of single coated silicon carbide coated graphite to test, and these are currently being evaluated.

Planned Activities

Research at the Hughes Corporation will continue on both electrodes for the purpose of improving the performance of this critical component in overall cell performance. Experiments with the regeneration apparatus will begin.

TASK 5.0 DIRECT CONVERSION

OBJECTIVES

The objective of research on **Solar Detoxification** is to define and to validate the feasibility of using direct concentrated sunlight (500+ suns) efficiently to convert hazardous wastes such as chlorinated hydrocarbons to environmentally acceptable materials. Specific objectives for FY 1988 include (1) understanding how the concentrated sunlight beneficially changes the chemistry (laboratory experiments) and (2) validating the concept through a solar test. The objective for **Photoenhanced Chemical Reaction Research** is to define and to validate the feasibility of using high flux solar radiation (500+ suns) to initiate and to sustain endothermic chemical reactions, with emphasis on reactions to produce transportable fuels and industrially important chemicals. Specific objectives are to understand the nature and breadth of solar photoenhancements, to identify specific chemical systems, to provide the basis for an assessment of potential for the concept, and to provide the basis for a solar test. The objective of research on **Solar-Induced Surface Transformations of Materials (SISTM)** is to identify, to analyze, and to understand beneficial transformations on material surfaces induced by highly concentrated solar radiation. The objective of **System Evaluation and Analysis** is to assess the potential for direct conversion of solar thermal energy by evaluating the performance and economics of two or more promising direct-conversion reactions in a solar environment.

ACCOMPLISHMENTS

Solar Detoxification Research

o Solar tests resulted in 99.9998 Percent destruction of a dioxin.

SERI and University of Dayton researchers performed solar tests of the detoxification of a dioxin by using the White Sands Solar Furnace (WSSF). Previous testing, plagued by unfavorable weather and reactor difficulties, resulted in 99.999 percent destruction, compared to a goal of 99.9999 percent. The reactor was redesigned to eliminate residence time distribution effects and to ensure a hot wall. The feed introduction technique was changed to minimize large surges in the dioxin feed rate. The goals of this test were to attain the 99.9999 percent destruction with a cleaner chemistry, and to show definitely the difference between the thermal and the photo/thermal performance.

The reactor redesign included addition of an Inconel canister surrounding the fused quartz reactor. The canister serves as a radiation shield or cavity to ensure uniform and controllable temperatures of the quartz reactor wall. This feature resulted in excellent temperature control during the actual solar tests, with effluent gas temperatures as high as 935°C and Inconel canister temperatures as high as 975°C.

Different reactor configurations were built--including a four-pass quartz reactor. The original single pass reactor was subjected to a smoke test prior to the WSSF test. This smoke test showed no secondary flows and a uniform flow which suggests minimal short circuiting of reactants. The original reactor design was used in the WSSF tests.

Reactor performance was excellent during the tests. There were some weather-related time losses, which precluded operation with the four-pass reactor and operation with the catalytic reactor. However, a significant number of runs was performed with the single-pass reactor at temperatures ranging from 700°C to 935°C and in both a concentrated

sunlight beam and a concentrated sunlight beam filtered to remove the radiation less than about 400 nm.

Researchers at the University of Dayton are completing the chemical analyses of dioxin samples from the solar-detoxification test at White Sands. The samples of residual dioxin are dissolved in toluene and are analyzed by using a gas chromatograph with a mass spectrograph detector. If the "as-received" samples do not give a detectable signal when dissolved in 90 ml of toluene, the level of destruction is greater than 99.9 percent. Then, the 90 ml of toluene is gently boiled down to 2 ml, and the sample is reanalyzed. No detectable signal means the level of destruction exceeds 99.999 percent. Additional manipulations are required then to analyze a sample with higher levels of destruction.

Early analyses indicate that one sample exceeded 99.9998 percent destruction, with most samples showing some contamination of dioxin. Analysis is continuing with efforts on defining what feed and sampling techniques are necessary to eliminate the contamination.

The Dayton researchers are ready to complete the laboratory experiments to measure the destruction profiles to 99.9999 percent in a very controlled fashion under both oxidative and pyrolytic conditions. The laboratory runs, coupled with the White Sands field tests, will provide a good basis for understanding the chemistry at high-destruction levels. Final development of the analytical techniques for measuring residual dioxin concentrations is also essential to successful completion of the laboratory experiments to 99.9999 percent.

o SERI expanded its capability to model solar reactors.

SERI research staff reviewed work by Dr. S. Kumar of the University of California on modeling the radiative transfer in a detoxification reactor. The results reviewed were from the Differential-Discrete-Ordinate-Method (DDOM), developed jointly by Dr. Kumar and Professor C. L. Tien, and a ray-tracing method to the particular configuration of the detoxification receiver/reactor tested by SERI at the White Sands Solar Furnace. This work was part of a subcontract whose purpose is to begin to develop within SERI the capability to model the radiative transfer, gas dynamics, and reaction kinetics of a variety of detoxification receiver/reactors. His purpose was accomplished, in part, by having on SERI computing machines mathematical models of both the DDOM and the ray-tracing method for application to different configurations of detoxification reactors as well as other solar receivers where small particles or molecules are the absorbers. The general methodology is designed to enable the incorporation of a variety of gas dynamics patterns and chemical reaction equations. Due to the complexity of the mechanisms involved, their mathematical representations, and the approximations necessary for the solution of these representations, experimental validation of the models remains an item of high priority.

Photoenhanced Chemical Reaction Research

o University of Houston researchers investigated solar-enhanced photochemical reactions.

Researchers at the University of Houston continue to investigate the use of direct-concentrated radiation to enhance catalytic chemical reactions. Researchers have established that a significant solar photoenhancement exists for the decomposition of 2-Propanol over a titanium dioxide catalyst on a silica support. Earlier experiments had shown the same for a vanadium pentoxide catalyst on a silica support. The major

difference between the two catalysts is that the apparent threshold wavelength for the titanium dioxide is about 390 nm to 400 nm compared to 340 nm for the vanadium pentoxide. The photoenhancement is manifest in the yield of propene product as a function of time. The situation is complicated because the product distribution also appears to be dependent upon the catalyst loading. This reaction is an interesting case for laboratory investigation, but is of little commercial value. The researchers are performing additional experiments to provide the data necessary to understand the mechanism of the photoenhancement and to provide the basis to assess the potential for practical application.

Reactions of potential commercial value are the reforming of straight chain paraffin compounds such as normal hexane to aromatics such as benzene, or cracking to olefins such as ethylene. Both the aromatics and the olefins are of commercial importance, and both appear to represent upgrading in value. Researchers have found that the reaction path is very dependent upon the presence of specific alkali promoters in the catalyst. In one thermal case, with no light, the yield to ethylene is significantly greater than that achievable with current commercial practice. A patent application is being prepared for this catalyst. In other cases with light, high benzene yields are achieved. An assessment is underway to define the significance of these observations to practical application of concentrated sunlight for chemical reactions.

Researchers at the University of Houston have submitted a paper to *Solar Energy*; the paper documents the effects of the wavelengths of available light on catalytic chemical reactions. The research has shown solar-specific effects of two varieties on solar enhanced catalytic reactions. The most dramatic effect is a complete change in the products from a reaction, and shows that the light is making available reaction paths which are not used by thermal reactions. The second type is a change in the rate and the selectivity of the reaction when light is used and is compared to a normal thermal reaction. The researchers are examining various reactions to provide a basis for evaluating the concept. They have filed a patent application for a thermal catalyst that they discovered, and are considering filing for a photocatalyst.

Solar-Induced Surface Transformation of Materials (SISTM)

- Testing of cladding materials bound to tool steel and additional experiments in phase transformation hardening have produced interesting results.

Microhardness testing was performed on two additional samples of a Ni-CR hardfacing alloy that had been melted and bound onto an A2 steel substrate in the solar furnace at Sandia, Albuquerque. The results on cross-sections of the samples yielded some interesting results. The A2 substrate had been substantially hardened by the thermal treatment during exposure. The interfacial zone was somewhat softer than either the hardened substrate or the hardfacing overlayer. Then the hardness increased again across the hardfacing layer to a value somewhat less than the hardened A2 value. This may be taken as evidence that the interfacial zone has been formed by a reaction of the substrate material and the overlayer material. Additional data on the second sample indicate that the underlying steel was substantially involved in the overlayer material on the first sample. This process is not yet optimized, but the results are encouraging, since two beneficial transformations occurred during the solar exposure: transformation hardening of the substrate material and metallurgical bonding of the coating.

Experiments in phase-transformation hardening were carried out at the solar furnace at Sandia also. These experiments included exposure of half-inch-thick steel plates which

were translated under the beam at various speeds under various conditions of flux. Some of the targets have been sectioned, polished, and analyzed under the optical microscope. Regions exposed to the highest flux (200 W/cm^2) at the slowest scan speeds (1.25 mm/s) were hardened. The transition zone between the hardened steel and the material that was not heat affected was 3 to 5 mm in depth. These preliminary results point out the need for higher fluxes of this application.

o Preparations for a new set of experiments at the solar furnace at Sandia, Albuquerque, have been completed.

All pieces of the new (vaccum) sample vessel have been fabricated, assembled, and leak-tested. Process gases and target substrates have been received. The next planned experimental work includes: phase-transformation hardening (pulsed heating); carburizing and bonding of steels; cladding of steels (stellite 6, NiAl).

o Progress in research on carbon fiber and strategic materials was reported by Georgia Tech Research Institute (GTRI).

In Carbon Fiber Research, purchase orders were placed for a pneumatic-hydraulic press (internal GTRI funds). Carbon fiber samples and resin systems (epoxies and polyimides) were ordered. SERI staff designed apparatus and procedure for sample preparation and began methods development for measurement of ILSS using a microdebonding method and single-fiber pullout. They completed a study on moderate temperature isothermal TGA oxidation rate on AS4, IM6, and HMS fibers for over 100 hours and paralleled earlier accelerated-temperature results and the superior oxidation resistance of solar-treated fibers. Fiber surface morphology studies were completed and demonstrated greater surface roughness of solar-exposed fibers using SEM. Staff continued to attempt solution to difficulties of microtoming the transverse cross-section of solar-exposed fibers.

System Evaluation and Analysis

o An assessment is underway to identify the best market for high-temperature, high-flux solar detoxification.

Analyses of potential markets for the solar destruction of toxic wastes have concentrated recently on organic sludges and solid wastes and the use of rotary kilns for their destruction. In the primary chamber of a rotary kiln, the toxic substances are heated to volatilization and then are decomposed at higher temperatures in the secondary chamber. The most effective use of solar would probably be in the secondary combustion chamber where the photons could assist in the decomposition. The use of solar in the primary chamber would be only as a source of thermal energy and, therefore, would probably not be competitive in the near-term with conventional fossil fuels. Researchers are continuing to investigate the role of solar in both chambers, the energy requirements and temperatures of each in conventional rotary kilns, and any design limitations that might restrict the optimum use of solar. Several potential consultants have been identified to assist SERI in this research.

o SERI researchers are reviewing potential uses of solar processing of materials.

SERI staff visited three firms involved with laser materials surface processing: Westinghouse; Quantum Laser; and Viner Enterprises. The purpose of these visits was to learn about their processing requirements and techniques as well as to receive information on the potential of solar-surface processing. In summary, because surface processing of materials with a laser is in its infancy, most current applications are niche markets for

which the laser possesses some inherent advantage. Typically, the applications take advantage of the high-flux density (equivalent to more than 100,000 suns) of the laser over a very small surface area (e.g., strips 0.1 inches wide) to ensure that high temperatures are reached only at the material surface and that distortion of the treated piece does not occur. In applications where distortion or difficulty of access are not issues, other less-expensive methods such as induction or flame heating are preferred.

The consensus from all the contacted firms engaged in laser surface processing is that solar also will have to identify specific niche markets for surface processing in order to take advantage of the differences between solar and other methods. The most obvious differences are the ability of solar to deliver very large power levels over a range of wavelengths and over a large area (i.e., lower flux densities than lasers). None of the contacts to-date has been able to identify a specific application tailored to these solar-processing capabilities. Researchers are investigating the capabilities of induction heating to refine further the characteristics of the niche markets most suitable for solar processing.

TASK 6.0 ENERGY STORAGE

OBJECTIVES

(There is no activity in this task at SERI.)

TASK 7.0 INNOVATIVE CONCEPTS

OBJECTIVES

The objective of work under **New Concepts Research** is to generate significant new ideas relating to the solar thermal technologies and to do sufficient research to define generally the potential for the concept to contribute significantly to solar thermal technology development. The objective of **International Energy Agency (IEA) Project Participation** is to interact with research organizations internationally and keep abreast of the research being conducted by other countries and to exchange information on research projects that are of mutual interest.

ACCOMPLISHMENTS

o Very high concentrations and solar-pumped laser experiments continued at University of Chicago.

The University of Chicago's work on achieving laser pumping with solar concentration continued. The contract for the third-year effort was renewed with the objective of achieving higher concentrations with improved optical elements and to demonstrate solar-pumped lasing capability. Progress so far has been very good. The appropriate laser crystals have been procured, and reflector coating on the crystal and the other optical elements have been procured. Lasing was achieved by using Argon laser input, and alignment techniques were developed with information from researchers who have prior experience in this area at Weizman Institute in Israel. Parts for the solar experiment are being assembled for the solar-pumped laser experiment in the next quarter. Techniques for using non-linear optical elements in the laser cavity were being evaluated from available literature to see how frequency doubling may be achieved. Such frequency tailoring could result in a unique source of coherent, monochromatic radiation peaked at wavelengths of interest in photochemical decomposition and synthesis.

FWP ST82-88 SOLAR THERMAL PLANNING AND ASSESSMENT

TECHNICAL PROGRAM INTEGRATION

OBJECTIVE

The function of the Technical Program Integrator (TPI) is to provide support to the DOE Solar Thermal Technology Program Manager with the goal of formulating and managing a focused and well-balanced program. Analysis, evaluation, and planning are used to define key research that will respond to Congressional budget guidance and will provide a potentially high return for each research dollar invested. Additionally, these activities must serve to communicate the impact of the work, to enhance the image of the program, and to broaden the constituency to ensure the continuance of a user community capable and willing to utilize options for solar thermal technology.

ACCOMPLISHMENTS

The major emphasis of the last quarter was directed toward the implementation of a new FY 1989 Annual Operating Plan (AOP) that reflects the changing thrust of the program and integrates the effects of both SERI and Sandia, Albuquerque. Consisting of three missions and three core research tasks, the program directs a significant portion of its resources toward some near-term applications, both electric and non-electric.

Further experiments and literature search have indicated the wide applicability of photon-enhanced decomposition of toxic organic compounds in water. SERI researchers successfully have degraded trichlorelhylene and two textile dyes well below EPA standards. Experiments were performed under both ultraviolet light and natural sunlight. The results will be used to develop a framework of knowledge and to guide efforts in Research and Development under the new AOP.

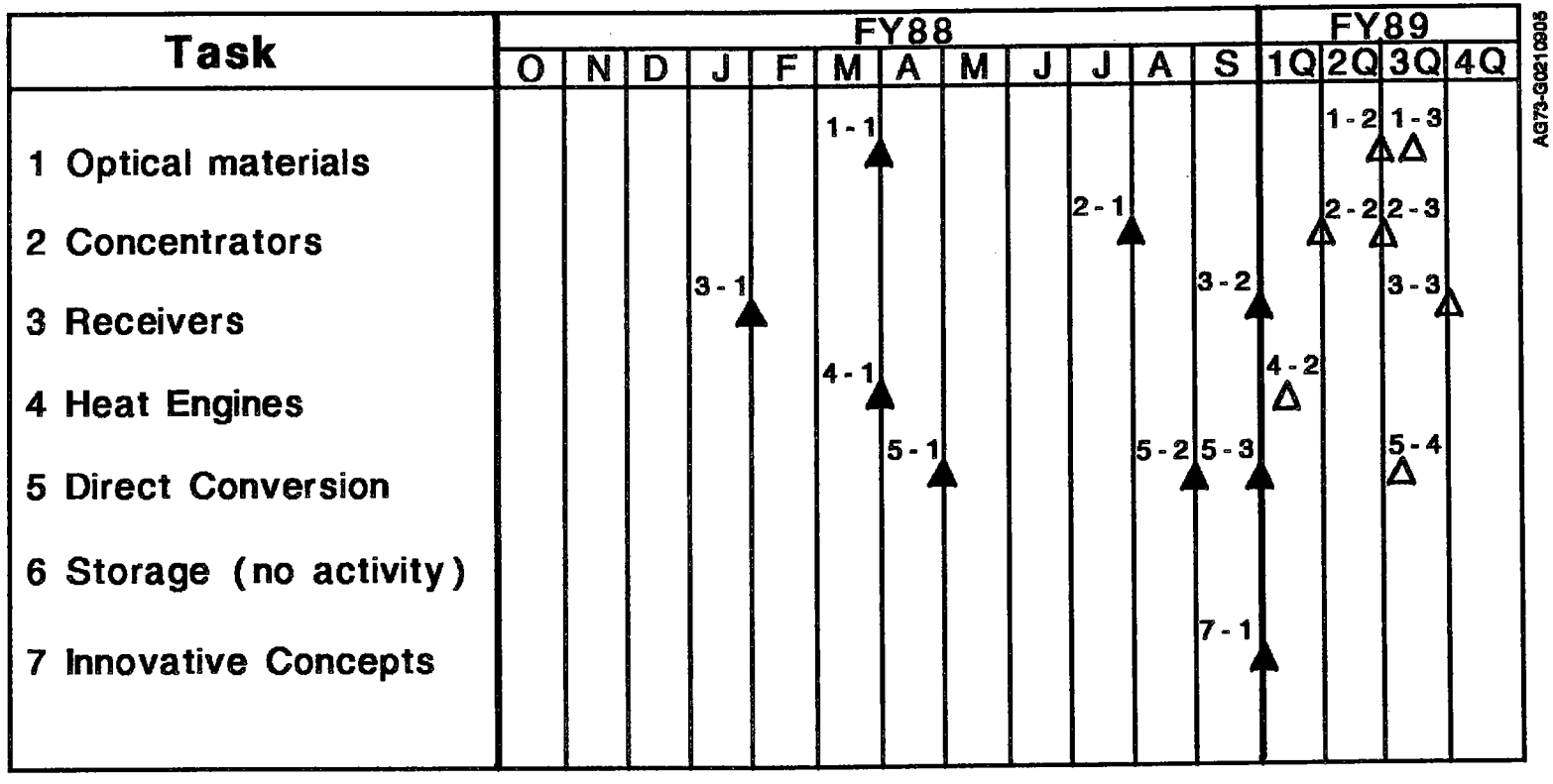
APPENDIX A

MILESTONE SCHEDULE AND STATUS

Solar Thermal

Solar Thermal Research

Milestone Schedule for FY 1988/1989



MILESTONES FOR FY 1988 THERMAL RESEARCH

1-1 Experimental verification of absorption as a function of dopant concentration in salt
1-2 Fabricate sets of candidate materials using most promising combination of coatings and substrate for site evaluation
2-1 Fabrication of three-meter prototype composite membrane dish
2-2 Complete optical assessments and reflector characterization of a composite membrane dish
3-1 Complete doped-salt, high flux panel test
3-2 Complete long salt-film wave stability experiment without flux
4-1 Complete experimental characterization of equilibrium regeneration of RTEC working fluid in the regenerator
4-2 Test results to identify the best materials candidates for containment of RTEC working fluid in the regenerator
5-1 Analyze coatings exposed to solar flux and pick the most promising materials treatment applications
5-2 Test solar detoxification reactor with concentrated flux
5-3 Verify through experiments the beneficial effect of concentrated sunlight on at least one chemical reaction which has high industrial value
7-1 Review progress and promise of highly concentrating solar flux

FY 1989 PRELIMINARY MILESTONES (FOR INFORMATION)

1-3 Abrasion and soil resistant polymer reflector films available for tests
2-3 Completion of wind load reduction research for dish systems
3-3 Study the effects of panel surface roughness on DAR performance
4-3 Complete adiabatic regeneration experiments on RTEC working fluid
5-4 Quantify parametrically the performance improvements in carbon fibers under various concentrated flux and operating conditions

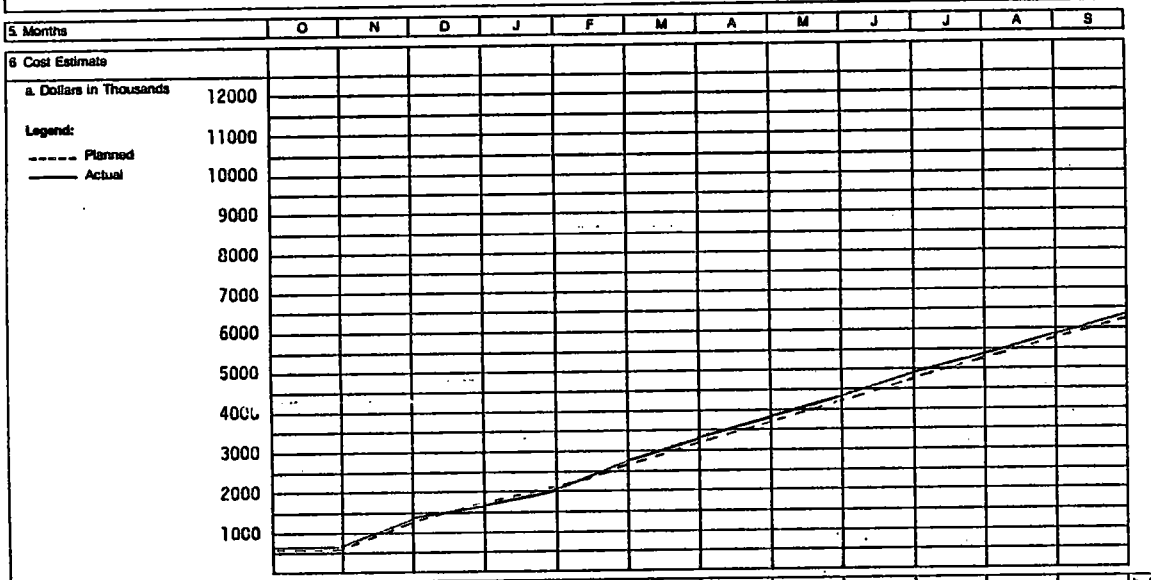
APPENDIX B

RESOURCE EXPENDITURES

RESOURCE EXPENDITURE

Budget Status

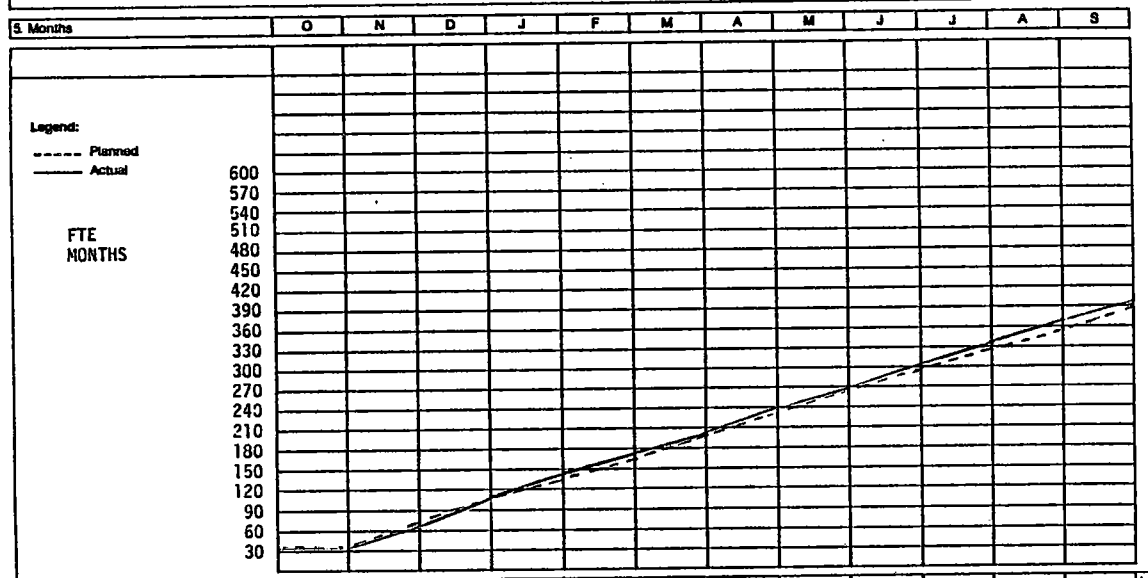
1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401
2. Reporting Period	From: 10/1/87 To: 9/30/88
3. Program Identification	FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM
4. WPA/Task	COST SUMMARY: OVERALL PROGRAM TOTALS



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	538	1132	1692	2212	2674	3181	3654	4192	4733	5270	5751	6227	b. Planned
	c. Actual	560	1137	1668	2199	2712	3295	3754	4277	4877	5393	5873	6302	c. Actual
	d. Variance	(22)	(5)	24	13	(38)	(114)	(100)	(85)	(144)	(123)	(122)	(75)	d. Variance

Manpower Status

1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401
2. Reporting Period	From: 10/1/87 To: 9/30/88
3. Program Identification	FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM
4. WPA/Task	FTE SUMMARY: OVERALL PROGRAM TOTALS



Accrued		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	35	68	100	134	167	205	236	267	296	327	357	386	b. Planned
	c. Actual	35	67	101	136	172	207	240	271	304	339	369	395	c. Actual
	d. Variance	0	1	(1)	(2)	(5)	(2)	(4)	(4)	(8)	(12)	(12)	(9)	d. Variance

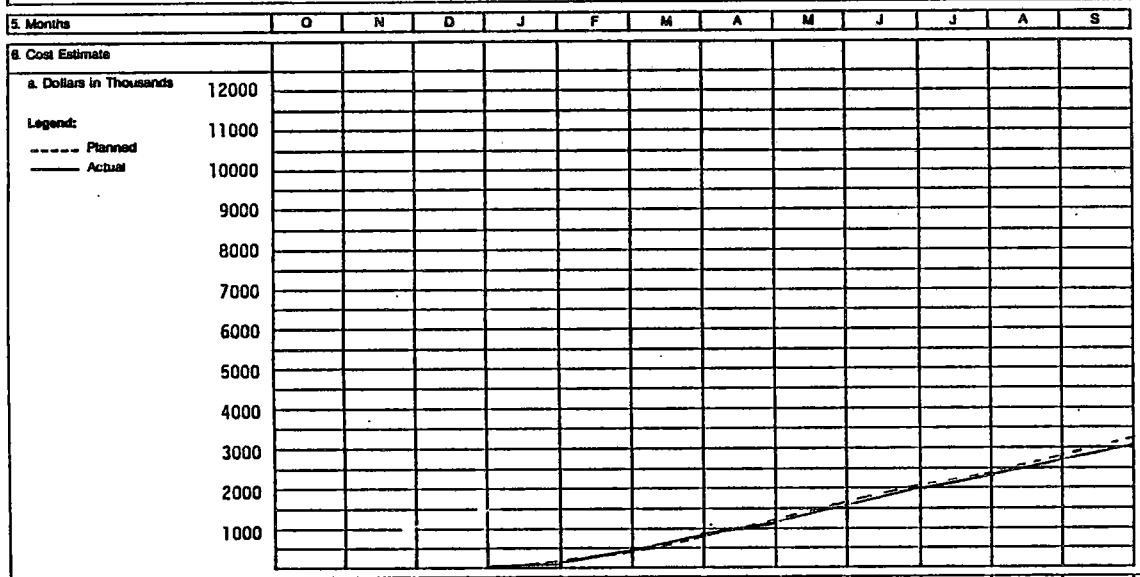
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/87 To: 9/30/88

3. Program Identification: FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: COST SUMMARY: ST81-88, ST92-88



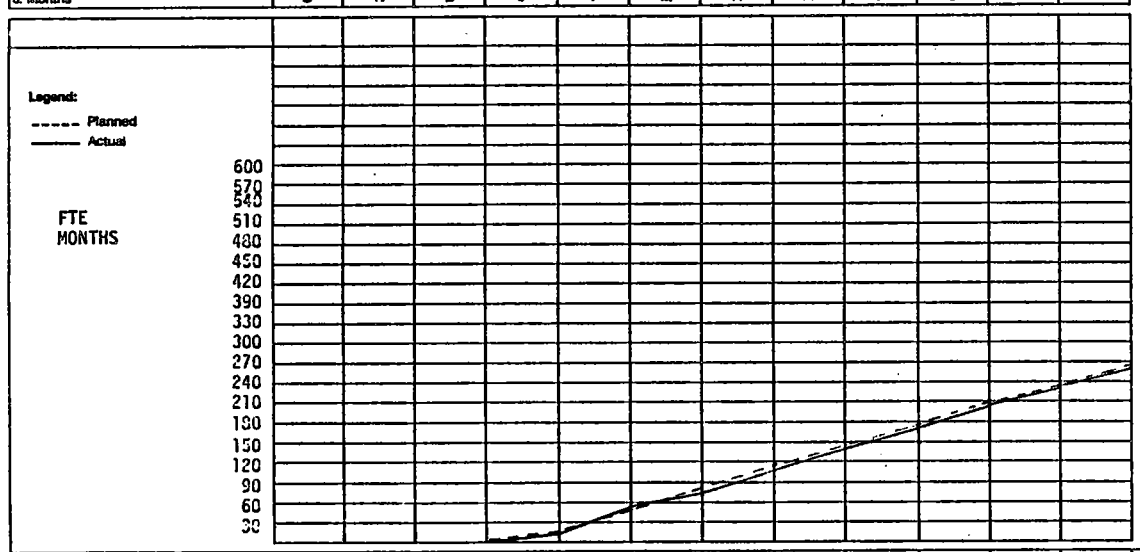
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	-	-	-	150	453	832	1193	1533	2029	2452	2852	3259	b. Planned
	c. Actual	-	-	-	149	462	858	1191	1559	2015	2410	2779	3128	c. Actual
	d. Variance	-	-	-	1	(9)	(26)	2	24	14	42	73	131	d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/87 To: 9/30/88

3. Program Identification: FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: FTE SUMMARY: ST81-88, ST82-88



Accrued		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	-	-	-	17	49	87	119	149	179	210	240	269	b. Planned
	c. Actual	-	-	-	17	50	83	113	143	173	207	236	262	c. Actual
	d. Variance	-	-	-	0	(1)	4	6	6	6	3	4	7	d. Variance

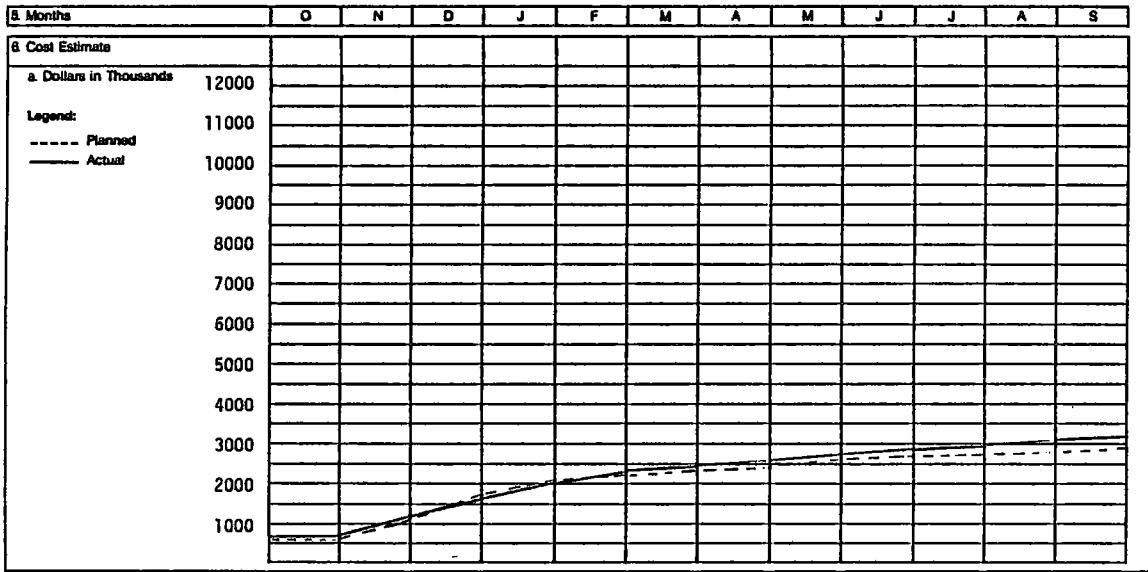
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/87 To: 9/30/88

3. Program Identification: FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: COST SUMMARY: ST61B-86, ST62A-86, ST71A-87, ST72B-87



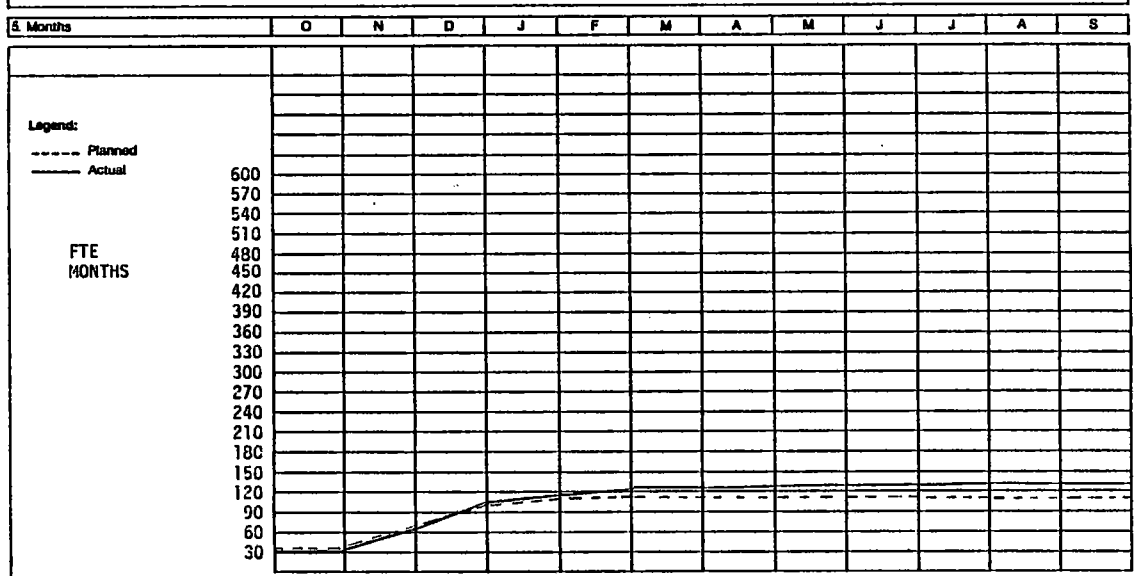
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	538	1132	1692	2062	2221	2349	2461	2509	2704	2818	2899	2968	b. Planned
	c. Actual	560	1137	1668	2050	2250	2437	2563	2718	2862	2983	3094	3174	c. Actual
	d. Variance	(22)	(5)	24	12	(29)	(88)	(102)	(109)	(158)	(165)	(195)	(206)	d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/87 To: 9/30/88

3. Program Identification: FISCAL YEAR 1988 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: FTE SUMMARY: ST61B-86, ST62A-86, ST71A-87, ST72B-87



Accrued		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	35	68	100	116	119	118	117	118	117	117	117	117	b. Planned
	c. Actual	35	67	101	118	122	124	127	128	131	132	133	133	c. Actual
	d. Variance	0	1	(1)	(2)	(4)	(6)	(10)	(10)	(14)	(15)	(16)	(16)	d. Variance

APPENDIX C

PROCUREMENT SUMMARY

FY 1986 SERI SOLAR THERMAL ENERGY PROGRAM SUBCONTRACTS (Exceeding $20K)

Task No.	Subcontractor	Subcontract Title/Activity	Value (000$)	End Dates	Type Business	Status	Technical Monitor
1.	U. of Akron	Polymer research	61	2/89	Univ.	Awarded	P. Schissel
	3M Company	Materials	40+	10/88	Industry	Awarded	P. Schissel
4.	Hughes	TECH conversion	325	12/89	Industry	Awarded	M. Carasso
7.	U. of CA, Berkeley	Composite membranes	293.6	8/89	University	Awarded	B. Gupta
	U. of Chicago	High flux concentration	150	8/88	University	Completed	B. Gupta

*S.B. - Small Business

+ - Cost shared contract

FY 1987 SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS (Exceeding $25K)

Task No.	Subcontractor	Subcontract Title/Activity	Value (000$)	End Dates	Type Business	Status	Technical Monitor
1.	Multiple	Research Post Docs	100	9/88	Univ.	Awarded	P. Schissel
	Multiple	Dish Composite Materials	53	9/88	Univ./S.B.	Awarded	P. Schissel
	Springborn	Mirror Protective Treatment	25	4/88	Small Business	Completed	P. Schissel
2.	University of Arizona	Dish Membrane Research	50	8/88	Univ.	Completed	M. Murphy
	Science Applications	Dish Membrane Research	100	8/88	Ind.	Completed	M. Murphy
	Colorado State Univ.	Wind Effects Research	60	5/88	Univ.	Completed	A. Lewandowski
	University of Chicago	Secondary Concentrator Research	50	12/87	Univ.	Completed	A. Lewandowski
	Dan-Ka, and others	Dish Structural Analysis	45	9/88	Ind.(Multiple)	Awarded	M. Murphy
3.	Multiple	DAR Research	155	6/88	Multiple	Awarded	M. Carasso
	University of Nevada	Materials for Blackeners	30	9/88	Univ.	Completed	D. Blake
4.	TBD	Receiver/Regenerator Research	50	TBD	TBD	Planned	M. Carasso
	Hughes	RTEC Research	148+	12/89	Ind.	Awarded	G. Nix
	TBD	RTEC Materials and Consultants	55	TBD	Multiple	Planned	G. Nix
5.	GTRI	GTRI Research	511	3/88	Univ.	Completed	D. Blake
	Univ. of Houston	UH Research	95	3/88	Univ.	Completed	G. Nix
	TBD	Consultants	58	TBD	Multiple	Planned	G. Nix
	Univ. of Houston	UH Research	150	1/88	Univ.	Completed	G. Nix
6.	TBD	RTEC Chemical Storage	50	TBD	Univ.	Planned	M. Carasso
	Univ. of Houston	UH Research	100	1/88	Univ.	Completed	G. Nix

[+]Part of Hughes cost shared effort.

FY 1988 SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS (Exceeding $25K)

Task No.	Subcontractor	Subcontract Title/Activity	Value (000$)	End Dates	Type Business	Status	Technical Monitor
FWP ST81-88							
1.	TBD	Silver Polymer Research	50	TBD	TBD	Planned	TBD
	GTRI	Advanced Optical Materials Research	90	3/89	Univ.	Awarded	P. Schissel
		Soiling and Cleaning	25	TBD	TBD	Planned	TBD
2.	TBD	Membrane Optical Performance	100	TBD	TBD	Planned	TBD
	CSU	Membrane Structural Analysis	50	6/89	Univ.	Awarded	A. Lewandowski
3.	Multiple	DAR Experimental Hardware	50	12/88	Multiple	Awarded	M. Bohn
	Multiple	DAR Materials Research	25	12/88	Multiple	Awarded	M. Bohn
4.	TBD	RTEC Experimental Hardware	75	TBD	TBD	Planned	TBD
5.	U. of Dayton	Solar Detoxification	100	6/89	Univ.	Awarded	G. Nix
	U. of Houston	Photoenhanced Chemical Research	250	3/89	Univ.	Awarded	G. Nix
	GTRI	High Solar Flux Effects on Materials	250	3/89	Univ.	Awarded	D. Blake
FWP ST82-88							
		Evaluation of Thermal Storage Options for Solar Electric Power Plants	28	TBD	TBD	Planned	TBD

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

COMPLETED IN FISCAL YEAR 1988

Anderson, J. V.; Weaver, N. *High-Temperature Solar Central Receivers for Electricity Production.* June 1988; SERI/TR-253-3196; 82 pp. Available NTIS: Order NO. DE88001171.

Anderson, J. V.; Short, W. D.; Wendelin, T. J.; Weaver, N. L. (August 1987). *Direct Absorption Receiver (DAR) Systems Assessment.* SERI/TR-253-3162. 50 pp. Available NTIS: Order No. DE87012277.

Bohn, M. S.; Wang, K. Y. (February 1988). "Experiments and Analysis on the Molten Salt Direct Absorption Receiver Concept." *Journal of Solar Energy Engineering* (110), pp. 45-51.

Book of Abstracts, Fourth International Symposium on Research, Development and Applications of Solar Thermal Technology. June 1988; SERI/CP-250-3340; 200 pp. Available NTIS: Order No. DE88001157.

Gomez, P. M.; Neidlinger, H. H. (1987). *Incorporation of Ultraviolet Stabilizers into Acrylics Prepared by Group Transfer Polymerization (Abstract).* Abstracts of Papers; 193rd ACS National Meeting: American Chemical Society; Denver, Colorado; April 5-10, 1987. Washington, DC: American Chemical Society: POLY 128.

Lewandowski, A. A.; O'Gallagher, J. J. (April 1988). *Performance Sensitivities for Point-Focus Dish Systems with Secondary Concentrators.* SERI/TP-253-3324. 6 pp. Prepared for the Annual Meeting of ASES, 20-24 June 1988, Cambridge, Massachusetts. Available NTIS: Order No. DE88001152.

Maxwell, E. L.; Rymes, M. D. (November 1987). *Initial Development of a Methodology for Siting Solar Power Plants.* SERI/TR-215-3117. 44 pp. Available NTIS: Order No. DE88001126.

Murphy, L. M.; Mancini, T. R., Eds. (1988). Solar Engineering-1988: Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, Colorado, April 10-14, 1988. New York: The American Society of Mechanical Engineers; 553 pp.

Murphy, L. M.; Guven, H. M.; Lowrey, P., eds. (1987). Solar Energy Technology SED-Vol. 4. New York: The American Society of Mechanical Engineers; 171 pp. Presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, Boston, Massachusetts, December 13-18, 1987. Work performed by Solar Energy Research Institute, Golden, Colorado and San Diego State University, San Diego, California.

Neidlinger, H.; Czanderna, A. "Polymers in Solar Technologies." Published in *Adhesives, Sealants, and Coatings for Space and Harsh Environments.* New York: Plenum Press.

O'Gallagher, J. J.; Winston, R. September, 1987. *Performance and Cost Benefits Associated with Non-Imaging Secondary Concentrators Used in Point-Focus Solar Thermal Applications.* SERI/STR-253-3113. Golden, Colorado: Solar Energy Research Institute.

Peterka, J.; Tan, Z.; Bienkiewicz, B.; Cermak, J. *Mean and Peak Wind Load Reduction on Heliostats.* SERI/TR-253-3212. Golden, Colorado: Solar Energy Research Institute.

Schissel, P. O., Neidlinger, H. H. (September,1987). *Polymer Reflectors Research During FY 1986.* SERI/PR-255-3057. 133 pp. Available NTIS: Order NO. DE88001101.

Tracy, C. E.; Gross, G. E. (April 1988). *Specular Steel Surfaces for Solar Mirror Substrates.* SERI/TR-255-3242. 44 pp. Available NTIS: Order No. DE88001153.

Wendelin, T. J.; Lewandowski, A. (1988). "A Performance Comparison of Multi-Facet and Single-Facet Dishes." Solar Engineering-1988: Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, Colorado, April 10-14, 1988, Murphy, L. M.; Mancini, T. R., eds. New York: The American Society of Mechanical Engineers; pp. 271-279.

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

IN PROGRESS

Anderson, J. V. (In Progress) *Internal Film Receiver Systems Assessment Study.* SERI/SP-253-3312. ACCNR: 10160. Golden, CO: Solar Energy Research Institute.

Anderson, J. V.; Weaver, N. L. (In Progress) *High Temperature Solar Central Receivers for Electricity Production.* ACCNR: 10196. Golden, Colorado: Solar Energy Research Institute.

Anderson J. V.; Weaver, N. L. (In Progress) *Comparison of Three High-Temperature Solar Central Receivers.* Golden, Colorado: Solar Energy Research Institute.

Beninga, K.; Kutscher, C. (In Progress) *Composite Membrane Parabolic Dish Research.* To be presented at the 1988 ASME Solar Energy Division Conference. Golden, Colorado: Solar Energy Research Institute.

Bohn, M. S., Green, H. J. (In Progress) *Heat Transfer in Molten Salt Direct Absorption Receivers.* SERI/J-253-0343. Golden, Colorado: Solar Energy Research Institute.

Burch, J. D.; (In Progress) *Comments on the Proposed Energy 1 Project.* SERI/TP-254-3346. ACCNR; 10324. Golden, Colorado: Solar Energy Research Institute.

Carasso, M.; (In Progress) *Cobalt Oxide as a Dopant in Nitrate Salts for DAR Applications.* SERI/SP-253-3277. ACCNR: 9890. Golden, Colorado: Solar Energy Research Institute.

Chuah, Y. K.; Anderson, J. V.; Wendelin, T. J. (In Progress) *Terminal Concentrators for Central Solar Receiver Applications.* SERI/TR-253-3007. Golden, Colorado: Solar Energy Research Institute.

Copeland, R. J. (In Progress) *Comparative Evaluation of Solar Bowls with Other Solar Thermal Technology Options.* SERI/TP-252-3155. Golden, Colorado: Solar Energy Research Institute.

Czanderna, A. W. (In Progress) *Photodegradation of Polymer Films on Reflecting Substrates.* Golden, Colorado: Solar Energy Research Institute.

Green, M. J.; Bohn, M. S.; Carasso, M. (In Progress) *Hydrodynamic, Thermal, and Radiative Transfer Behavior of Molten Salt Films as Applied to the Direct Absorption Receiver Concept.* Golden, Colorado: Solar Energy Research Institute.

Hewett, R. (In Progress) *Compendium of Major Analytical Studies Performed in the Solar Thermal Technology Program During the Period FY 1983-FY 1986.* SERI/MR-250-3043. Golden, Colorado: Solar Energy Research Institute.

Hewett, R. (In Progress) *Dish Solar System State of the Art: The Concentrator Subsystem.* SERI/SP-253-3093. Golden, Colorado: Solar Energy Research Institute.

Hewett, R.; Short, W. D. (In Progress) *Review of the OTA Report. New Electric Power Technologies: Problems and Prospects for the 1990's.* SERI/MR-250-3041. Golden, Colorado: Solar Energy Research Institute.

Hull, J. L. (In Progress) *Holographic Solar Concentrator Development - Phase II and III.* SERI/STR-253-3326. ACCNR: 10238. Golden, CO: Solar Energy Research Institute.

Jorgensen, G. J.; Schissel, P. O. (In Progress) *Optical Performance and Durability of Silvered Polymer Mirrors.* Golden, Colorado: Solar Energy Research Institute.

Kidney, K.; Pitts, J. R. (In Progress) *Solar Reflector Soiling Pattern Distributions and Reflectance Measurement Requirements.* Golden, Colorado: Solar Energy Research Institute.

Kowalski, G. J. (In Progress) *Transient Response of an Optically Thick Medium Exposed to Short Pulses of Laser Radiation.* Golden, Colorado: Solar Energy Research Institute.

Kutscher, C. F.; Short, W. D.; Lewandowski, A. A. (In Progress) *Systems Analysis/ Innovative Concepts Midyear Progress Report.* Golden, Colorado: Solar Energy Research Institute.

Lewandowski, A. A. (In Progress) *Report on the Feasibility Study for a High-Flux Solar Furnace.* SERI/SP-253-3101. Golden, Colorado: Solar Energy Research Institute.

Lewandowski, A. A. (In Progress) *System Performance and Cost Studies of Linear Concentrating Fresnel Lens Solar Thermal Collectors.* SERI/SP-253-2870. Golden, Colorado: Solar Energy Research Institute.

Lewandowski, A.; O'Gallagher, J; Jorgensen, G. (In Progress) *An Overview of Research on Secondary Concentration for Point Focus Dish System.* SERI/MR-253-3271. Golden, Colorado: Solar Energy Research Institute.

Lewandowski, A. A.; Wendelin, T. J. (In Progress) *Structural and Optical Response of Membrane Dish Concentrators.* Golden, Colorado: Solar Energy Research Institute.

Mather, V. K. (In Progress) *Solar Photochemical Production of Fuels and Chemicals.* SERI/SRR-253-2837. Golden, Colorado: Solar Energy Research Institute.

Murphy, L. M. (In Progress) *Moderate to Large Axisymmetric Deformations of Optical Membrane Surfaces.* Golden, Colorado: Solar Energy Research Institute.

Murphy, L. M. (In Progress) *Video-Solar Thermal Research.* SERI/SP-253-3280. Golden, Colorado: Solar Energy Research Institute.

Murphy, L. M.; Tuan, C. (In Progress) *Optical Membrane Concentrators Using Pressure Induced Finite Deformations.* Golden, Colorado: Solar Energy Research Institute.

Neidlinger, H. H.; Schissel, P. O. (In Progress) *Abstracts of Papers; 193rd ACS National Meeting; American Chemical Society: Denver, Colorado: April 5-10, 1987.* Golden, Colorado: Solar Energy Research Institute.

Neidlinger, H. H.; Steffeck, M. R.; Goggin, R. M. (In Progress) *Effect of Polymeric 2-Hydroxybenzophenone Stabilizers on the Weathering of PMMA Films.* Golden, Colorado: Solar Energy Research Institute.

Neidlinger, H. H.; Schissel, P. O. (In Progress) *Polymers in Solar Technologies.* SERI/TP-255-3205, Golden, Colorado: Solar Energy Research Institute.

Neidlinger, H. H.; Schissel, P. (In Progress) *Photostabilization Studies of Silver/ Polymethylmethacrylate Films.* Golden, Colorado: Solar Energy Research Institute.

Peterka, J. A.; Tan, A.; Bienkiewicz, B.; Cermak, J. E. (In Progress) *Wind Loads on Parabolic Dish Collectors.* ACCNR: 10292. Golden, CO: Solar Energy Research Institute.

Pitts, J. R.; Fields, C. (In Progress) *Assessment of Potential for Surface Modification by Highly Concentrated Solar Energy.* ACCNR: 10151. Golden, CO: Solar Energy Research Institute.

Schissel, P.; Goggin, R.; Shinton, V. (In Progress) *Durability of Silvered Polymer Mirrors.* Golden, Colorado: Solar Energy Research Institute.

Schissel, P. O.; Neidlinger, H. H. (In Progress) *Polymer Reflectors Research During Fiscal Year 1987.* SERI/PR-255-3316. ACCNR: 10161. Golden, CO: Solar Energy Research Institute.

Short, W. D. (In Progress) *Direct Absorption Receiver (DAR) Systems Assessment.* SERI/TR-253-3162. Golden, Colorado: Solar Energy Research Institute.

Short, W. D.; Wendelin, T. J. (In Progess) *Cost Performance Analysis of an Inflated Conical Concentrator.* SERI/TR-253-2872. ACCNR: 7001. Golden, CO: Solar Energy Research Institute.

Short, W. D. (In Progress) *Optical Goals for Polymeric Film Reflectors.* ACCNR: 10451. Golden, CO: Solar Energy REsearch Institute.

Sizman, R.; Nix, R. G. (In Progress) *High Temperature Solar Chemistry.* Golden, Colorado: Solar Energy Research Institute.

Thornton, J. P. (In Progress) *Perspectives on the Potential for Solar Detoxification of Hazardous Wastes.* SERI/MR-250-3122. ACCNR: 8677. Golden, CO: Solar Energy Research Institute.

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

Wang, K. Y.; Benito, R.; Carasso, M. (In Progress) *Increasing the Chemical Yield of Desirable Species Using Solar Rapid Heating.* SERI/TR-252-2953. Golden, Colorado: Solar Energy Research Institute.

Webb, J. D.; Rosenthal, R.; Hinds, P. (In Progress) *Accessory for Measuring Infrared Linear Dichroism Reflection—Absorption Spectra of Thin Films in a Controlled Environment.* Golden, Colorado: Solar Energy Research Institute.

Webb, J. D.; Czanderna, A. W. (In Progress) *End-Group Effects on the Wavelength Dependence of Laser-Induced Photodegradation in Bisphenol-A Polycarbonate (Abstract).* Golden, Colorado: Solar Energy Research Institute.

Webb, J. D.; Czanderna, A. W.; Pitts, J . R. (In Progress) *Copper Carboxylate Formation in the Thermal Oxidative Degradation of Atactic Polypropylene on Copper Oxide Films.* Golden, Colorado: Solar Energy Research Institute.

Webb, J. D.; Rosenthal, R.; Hinds, P. (In Progress) *Accessory for Measuring Infrared Linear Dichroism Reflection - Absorption Spectra of Thin Films in a Controlled Environment.* ACCNR: 10197. Golden, CO: Solar Energy Research Institute.

Welch, W. F.; Graham, S. M.; Chughtai, A. R.; Smith, D. M.; Schissel, P. O. (In Progress) *Effect of Metal Substrate (AP,* Cu, Ag, and Au) on the Photodegradation of Polymers: Polyacrylonitrile. ACCNR: 9546. Golden, Colorado: Solar Energy Research Institute.

Wendelin, T. J.; Wood, R. L. (In Progress) *LANSIR: An Instrument for Measuring the Light-Scattering Properties of Laminate Membrane Mirrors.* Golden, Colorado: Solar Energy Research Institute.

Wendelin, T. J. (In Progress) *Optical Performance Comparison of Multi-Facet Dish Concepts.* ACCNR: 8848. Golden, CO: Solar Energy Research Institute.

Wendelin, T. J.; Wood, R. L.; (In Progress) *LANSIR: An Instrument for Measuring the Light-Scattering Properties of Laminate Membrane Mirrors.* ACCNR: 10367. Golden, CO: Solar Energy Research Institute.

Wood, R. L. (In Progress) *Surface Figure Tests for Large, Point Focus Solar Concentrators Using a Scanning Hartmann Method.* Golden, Colorado: Solar Energy Research Institute.

Wood, R. L.; Wendelin, T. J. (In Progress) *Optical Materials Technology for Energy Efficiency and solar Energy Conversion VI;* 18-19 August 1987; San Diego, California.

Wood, R. L. (In Progress) *Light-Scattering Properties of Laminate Membrane Mirrors.* Golden, Colorado: Solar Energy Research Institute.

Wood, R. L.; Murphy, L. M. (In Progress) *Assessment of Tension Membrane Technology for Solar Concentrators.* SERI/SP-253-2437. Golden, Colorado: Solar Energy Research Institute.

APPENDIX E

SCIENTIFIC MEETINGS AND PRESENTATIONS

SCIENTIFIC MEETINGS AND PRESENTATIONS

A presentation of recent structural and optical analytical research on membrane dishes was given at SERI on August 25. Attendees included representatives from Sandia/Albuquerque, Science Applications International Corporation, and Solar Kinetics Incorporated. The primary focus of the current research has been on development of the non-axisymmetric structural and optical models into a form which is easy to use and provides a maximum amount of information relatively quickly. A set of computer codes has been written and utilize the analytical model for a non-axisymmetric membrane in combination with a ray-trace optical model to show graphically the optical effects of membrane shape under a wide variety of loading conditions. An interface also has been developed between the membrane analysis code and a linear finite element structural code so that the interactions between a given overall structural system (e.g., cable-supported, central-post concept) and a membrane can be determined. This combination of codes can be used on a personal computer instead of a full, non-linear, finite-element analysis, which requires a mainframe computer and potentially large computational costs. The purpose of the presentation was to review the background, to describe the various codes and their interfaces, to demonstrate the codes, and to provide some training. All participants were given a set of disks with the programs, examples of data files, plus documentation of the software.

Solar Kinetics, Inc. (SKI), has been utilizing the membrane dish structural and optical analysis tools presented at SERI on August 25, 1988. The computer models discussed and distributed at that meeting are currently being used by SKI as part of its contract with Sandia, Albuquerque, on membrane dish development. SERI researchers have been interacting with SKI engineers to adapt some parts of the code to their specific dish concept and to specific analyses that they are conducting. SERI also is advising SKI on the design and implementation of their optical test equipment, which will be very similar to the SHOT. SERI will continue to work with industry to provide useful analytical tools with which to predict and to analyze membrane dish response and performance.

Members of the University of Houston research group presented papers at the 1988 Summer National Meeting of the American Institute of Chemical Engineers. Professor A. Ignatiev and his student, A. Moshfegh, presented their work on "Photo-enhanced Catalytic Decomposition of Isopropanol." Professor W. Prengle presented his work on "The Production of Chemicals using Photo-Thermal Solar Energy." Researchers from the University of Dayton also attended the conference and presented their work on "Solar Destruction of Hazardous Organic Waste." The sessions were chaired by Professor V. K. Mahur of the University of New Hampshire and Dr. B. Volintine of the Department of Energy Solar Thermal Program.

Visits were made to the facilities of two industrial researchers using lasers for materials-surface processing. These were Dr. G. Bruck of Westinghouse Research and Development Center (Pittsburgh, Pennsylvania) and A. Blake of Quantum Laser Corporation (Edison, New Jersey). SERI staff met with these researchers and toured their facilities on August 23 and 24. Interest in SERI's experimental work was expressed, and a basis for continued interaction was established.

Contact was made with D. Stein of Man-Tech Development Institute in Ft. Worth, Texas. He is working on processes for assembling cast-to-size bronze alloy tools for the aerospace industry. It appears that it may be possible to do the joining procedure in a solar furnace, and a SERI researcher has scheduled a visit to plan some preliminary work to demonstrate feasibility.

DISTRIBUTION LIST

SOLAR THERMAL RESEARCH PROGRAM

QUARTERLY STATUS REPORT

SERI

Bath, T.
Blake, D.
Bohn, M.
Bull, S.
Carasso, M.
Czanderna, A.
Feucht, D.
Glatzmeir, G.
Gupta, B.
Hewett, R.
Hubbard, H.
Lewandowski, A.
Maxwell, E.
Murphy, L.M.
Neidlinger, H.
Nix, G.
Pitts, R.
Schissel, P.
Short, W.
Stokes, R.
Stone, J.
Thornton, J.

DOE/HQ Solar Thermal Division

Carwile, C.
Coleman, H.
Gronich, S.
O'Kelley, K.
Morse, F.
Scheve, M.
Shivers, R.
Wilkins, F.

DOE/HQ Storage

Reimers, E.
Klein, K.

DOE/SERI Site Office

Sargent, S.
Kerns, P.

DOE/SAN

Hughey, R.
Lopez, M.

DOE/ALO

Graves, D.
Weisiger, J.

SNLA

Holmes, J.
Leonard, J.
Otts, J.
Schueler, D.