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Solar Thermal

Solar Thermal Energy Program

Quarterly Progress Report

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SERI

Solar Energy Research Institute
A Division of Midwest Research Institute

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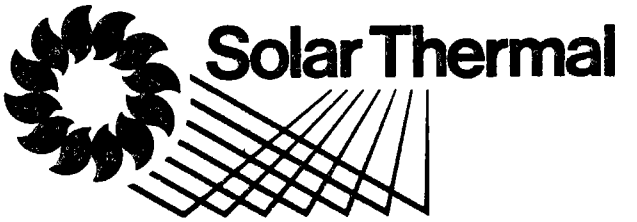

Solar Thermal Energy Program

Quarterly Progress Report

SERI

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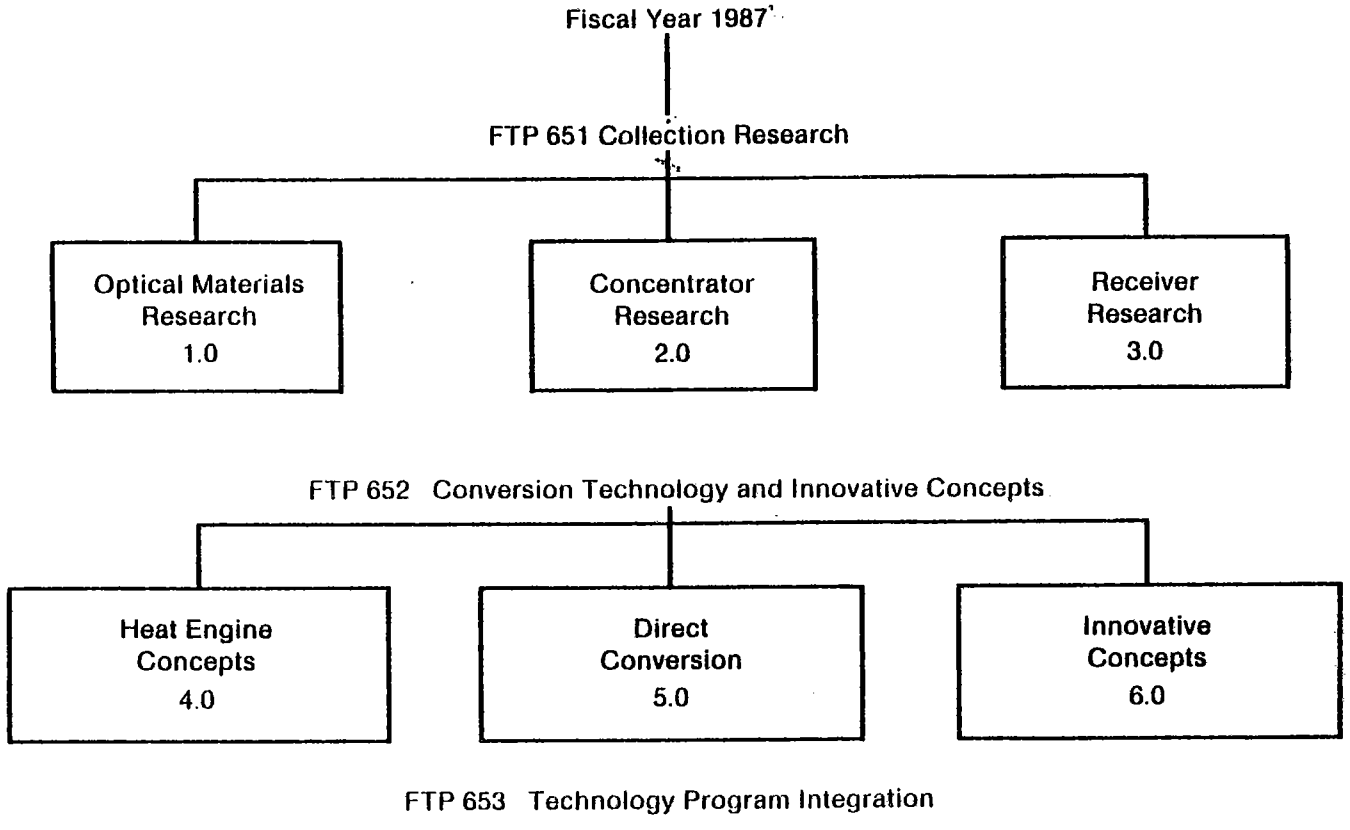
Structure for the SERI Solar Thermal Energy Program



SOLAR THERMAL RESEARCH

FIRST QUARTER FY 1987 ACCOMPLISHMENTS

(SERI MILESTONE NUMBERS FROM ANNUAL OPERATING PLAN)

	Reference Page
o Two-meter-diameter membrane mesh module ready for test (4, FY 1986)	25
o Complete two-year work plan for RTEC (9, FY 1987)	31

SOLAR THERMAL RESEARCH

FIRST QUARTER FY 1987

OTHER SIGNIFICANT ACCOMPLISHMENTS

	Reference Page
o Accelerated abrasion tests show that hard coats on polymers are very effective for improving mar resistance.	16
o An instrument (conductivity probe) for measuring wave-thicknesses in DAR salt film was developed and is ready for use with water film tests.	29
o Exploratory wind tests were completed and indicate that winds up to 45 miles per hour should not disturb salt film.	29
o Researchers at GTRI produced possibly solar-unique materials during solar furnace tests.	34

SOLAR THERMAL RESEARCH

SECOND QUARTER FY 1987 PLANNED ACTIVITIES

	Planned
o Choose primary stabilizer system for PMMA for further research and evaluation	January
o Assess salt film stability with flux in laboratory test loop.	March

TECHNICAL ACCOMPLISHMENTS—SUMMARY

TASK 1.0 OPTICAL MATERIALS RESEARCH

Silver/Polymer Research

	Reference Page
o Polymeric SERI stabilizers are more permanent than stabilizers with low-molecular weight.	15
o Deactivation of polymeric stabilizers is similar to low-molecular-weight analogues.	16
o Photodegradation of PMMA films proceeds from the film surface into the bulk and may be surface-specific.	16
o PMMA molecular-weight degradation is retarded in stabilized systems.	16
o Accelerated abrasion tests show that hard coats on polymers are very effective for improving mar resistance.	16
o Initial studies were directed toward the preparation of stabilized hard coats for PMMA surfaces.	17
o Key samples continue to show excellent performance outdoors at Golden, Colorado (SERI), but a mirror outdoors in the harsher environment at Arizona has fallen below the long-term reflectance goal (3M).	17
o Severe discolorations of mirrors (a type of ECP 300) observed at Solar One (Sandia) are not observed in Colorado, Arizona, Florida, Minnesota, or New Mexico.	18
o Under mechanical stress and in the presence of water, delamination can occur at the PMMA/silver interface in membrane-mirror applications.	18
o The University of Akron has measured the mechanical properties of biaxially stretched and annealed polyethylene teresphthalate films.	18

	Reference Page
Front Surface Reflector Concepts/Substrate Smoothness	
o Tungsten carbide rolls have been refinished and returned to Teledyne-Rodney in preparation for production of a smooth steel strip.	18
o The aluminum substrate (number 2 micro-finish) supplied by the 3M Corporation limits the optical performance of ECP-300.	19
Properties of Receiver Materials	
o Settling tests for cobalt oxide powder in molten draw salt are underway.	19
o Measurement of optical properties of draw salt and blackened salt are being performed.	20
o The chromate ion is a soluble colorant for draw salt.	20
Photodegradation of Materials	
o Two reports relating to the interaction of high solar fluxes with materials were completed during this quarter.	20
o Literature regarding surface temperature profiles was reviewed.	20
o Sample exposures have been planned at Sandia, Albuquerque.	21

TASK 2.0 CONCENTRATOR RESEARCH

	Reference Page
Membrane Concepts	
o Research activities on the new Membrane Dish Task were initiated--beginning with the implementation of the research plan.	23
o A literature search on prior activities on the membrane dish has been completed.	23
o Initial analysis of optical performance of multi-faceted designs has been completed.	24
o New analytical models for deformations of large structural membranes have identified numerous insights into membrane shapes.	24
o Through a subcontract with SAIC, a two-meter-diameter composite dish has been fabricated.	25
o SERI staff provided support to Sandia, Albuquerque, on the development of the stretched-membrane heliostat.	26
New Concepts Evaluation	
o Colorado State University and other consultants are continuing research on wind-load reduction and interpretation of data for reductions of heliostat cost.	26
o The University of Chicago has produced analytical results useful for the assessment of secondary concentrators in dish applications.	26
Holographics	
o Experimental research on holographic concentrators is complete.	27
High-Flux Optics	
o The new Large Aperture Near-Specular Imaging Reflectometer (LANSIR) is complete and is now operational.	27

TASK 3.0 RECEIVER RESEARCH

	Reference Page
Direct-Absorption Receiver Research	
o An instrument capable of measuring wave-thickness in a time series has been developed and is ready for use with water film tests.	29
o Exploratory wind tests were completed and indicate that winds up to 45 miles per hour should not disturb salt film.	29
o The problem of nitrate salt containment at the flow-channel edge has been resolved.	30
Systems Analysis Studies	
o Alternative conceptual configurations and flow patterns have been assessed for Direct Absorption Receivers, and reveal that designers will have considerable flexibility in choosing design parameters.	30

TASK 4.0 HEAT ENGINE CONCEPTS

	Reference Page
o A Request for Proposal has been issued to the Hughes Aircraft Company for the third phase of research on RTEC (Thermally Regenerative Electrochemical Converter).	31

TASK 5.0 DIRECT CONVERSION

	Reference Page
o University of Houston researchers generated data showing photoenhancement of catalytic processes.	33
o A consultant has been identified to assist with research on photoenhancement of catalytic processes.	33
o Activities are in progress to provide resources for a continuation of direct conversion research at the University of Houston.	34
o SERI reviewed research at the University of Dayton and the University of New Hampshire.	34
o Researchers at the Georgia Tech Research Institute produced possibly solar-unique materials during solar furnace tests.	34
o SERI researchers are evaluating the feasibility of a new type of quantum-thermal receiver-reactor.	35
o SERI assessment indicates possible feasibility for rapid pyrolysis of coal by using direct flux to produce hydrocarbon liquids.	35

TASK 6.0 INNOVATIVE CONCEPTS AND APPLICATIONS

	Reference Page
o SERI staff visited the University of California to discuss progress on subcontracted work.	37

TECHNICAL ACCOMPLISHMENTS — DESCRIPTIVE DETAIL

FTP 651 COLLECTION RESEARCH

TASK 1.0 OPTICAL MATERIALS RESEARCH

OBJECTIVES

Research on Optical Materials involves study in the following categories: silver/polymers; alternate-reflector concepts; properties of receiver materials; and high-flux materials effects. The objective of **Silver/Polymer Research** is to obtain silver/polymer reflecting surfaces that meet long-term durability while maintaining requirements in high-specularity performance and that operate satisfactorily in the solar environment. The long-range goals, as defined by systems analysis, are to obtain a mirror having reflectance of at least 90 percent for solar radiation (300 nm to 2600 nm) into a half-cone acceptance angle of 2 mrad to 5 mrad and to maintain this optical performance for at least five years. The objective of research in front-surface **Reflector Concepts** is to address the technical barriers which might affect the use of metal films or sheets as substrates for silvered mirrors and to establish technically attractive processes for overcoming such barriers. Direct use of metal substrates for silvering could provide an attractive alternative to glass or polymer films for concentrators. One objective of research in **Properties of Receiver Materials** is to identify promising materials for direct absorption and other innovative receiver concepts for a wide range of temperatures and applications and scientifically to characterize their optical and radiative properties in the solar thermal operating environment. The other objective is to characterize the physical and chemical properties of materials in high-temperature/high-flux solar thermal applications. The objective of work on **High-Flux Materials Effects** is to identify and to analyze the effects of concentrated solar radiation on materials in order to understand possible ways to increase the durability of materials under such conditions and possibly to utilize such high solar-flux effects for beneficial applications of the unique aspects of concentrated sunlight.

Objectives for fiscal year 1986 included the ultraviolet stabilization of silver/polymer films; a weather-stable, silvered stainless steel reflector with specular reflectance of over 90 percent in a half-angle cone of 4 mr; a stable, blackened nitrate salt that can absorb 70 percent of incident solar radiation in a 1 mm film; and identification of effects of high-solar flux on solar materials including blackened nitrate salts, pyromark paint, and oxidized Inconel 600.

ACCOMPLISHMENTS

Silver/Polymer Research

- Polymeric SERI stabilizers are more permanent than stabilizers with low molecular weight.

  The long-term durability of silvered polymer reflectors may be determined by the permanence of the ultraviolet stabilizers that researchers have proven are essential for even intermediate-term durability. Scientists have demonstrated now, in one type of accelerated extraction test, that the polymeric stabilizers developed at SERI are more permanent than low-molecular-weight stabilizers, and that they are more permanent than the stabilizers used in the 3M silvered polymers, type ECP-300 and the newer film, type ECP-300A.

o Deactivation of polymeric stabilizers is similar to low-molecular-weight analogues.

Despite the high inherent ultraviolet stability of the ultraviolet absorbers tested, researchers find that the concentrations do fall steadily during accelerated ultraviolet irradiation. The deactivation of stabilizers is generally higher during QUV exposure and lower during Weatherometer (WOM) exposure. The additives tested are deactivated during irradiation according to linear kinetics. No noticeable molecular weight change of polymer stabilizers can be observed during their irradiation. This can indicate that only cleavage and/or modifications of the pendant stabilizer groups are involved in the process. Deactivation is slow enough not to limit mirror lifetime outdoors for at least several years; however, it may become a factor after more prolonged use.

o Photodegradation of PMMA films proceeds from the film surface into the bulk and may be surface-specific.

It has been observed that the photodegradation of the tested PMMA films proceeds from the surface of the films, where protection is incomplete, into the bulk. Photodegradation may also be a function of which surface of the solution-cast films is exposed to the irradiation. For example, SERI researchers observed a reduced stabilizer consumption in a stabilized PMMA film from National Starch when the film/air surface has been exposed to the irradiation in contrast to the film/glass surface. Infrared studies on attenuated total reflection of the surfaces of such PMMA film did not reveal any significant difference in the initial concentration of stabilizer between the air and the glass sides of the cast film, at least in the first 1 μm to 2 μm from the surface. Morphology differences between both sides may be the cause for the observed phenomena.

o PMMA molecular-weight degradation is retarded in stabilized systems.

SERI scientists observed a retardation in the molecular-weight degradation of PMMA when a stabilizer is present. Molecular-weight degradation of PMMA is preceded or accompanied by an incorporation of chromophores into the polymer chain. The increase in light absorption due to these chromophores is, however, limited to wavelengths less than 400 nm, and optical performance of the stabilized films is rather uneffected by it. However, main chain scission in the PMMA-film surfaces is responsible for the formation of surface crazes that can cause considerable light scattering. Molecular-weight degradation is more severe under QUV testing conditions than under WOM test conditions.

o Accelerated abrasion tests show that hard coats on polymers are very effective for improving mar resistance.

To assess the mar resistance during cleaning for polymer mirrors, SERI researchers tested various materials on an abrasion-test facility that generally follows ASTM Standard D 1044-82 but has optical measurements modified to meet the more critical solar requirements. Initial data are very encouraging. Researchers compared the mar resistance of float glass measured on the non-tin side; Lucite SAR, which is a PMMA coated with Du Pont's Super Abrasion Resistant coating; Mar Gard, which is a polycarbonate coated with GE's mar-resistance coating; and Acrylite, which is an uncoated PMMA material from Cyro Industries. Staff used a Tabor abraser run for 100 cycles or 200 cycles with wheel (CS-10F) weights of 500 grams and 1000 grams. Before and after abrasion, they measured the transmittance in four modes. The specular transmittance is measured at acceptance angles of 4 mrad, 8 mrad, and 12 mrad. The Near

Spectral Diffuse Transmittance (NSDT) measures the radiation scattered from the incident beam into angles larger than 4 mrad and smaller than 36 mrad. By excepting the abraded Acrylite samples, the NSDT values are near noise level for these optically excellent materials. The preliminary results prove key points. While an uncoated polymer (Acrylite) is considerably more subject to abrasion than glass, the coated polymers (Lucite SAR and Mar Gard) are more nearly like glass in their mar resistance.

SERI researchers are also comparing the abrasion resistance of ECP-300, Lot 7 with hard-coat type Lot 2. Visual observation shows that the hard coat is very effective in improving abrasion resistance, and optical measurements are in progress.

- Initial studies were directed toward the preparation of stabilized hard coats for PMMA surfaces.

Initial studies were directed toward the preparation of hard coats for PMMA surfaces that have a combination of desirable properties such as abrasion resistance, decreased water diffusion, and considerable photostability. It is expected that copolymers of methacrylate and other monomers containing functional groups with silicon and fluorine atoms (hydrophobic surfaces) as well as ultraviolet stabilizers and cross-linkable groups such as epoxy moieties or pendant methacrylate groups will have such properties after curing.

Low-temperature or room-temperature curing will be favored to avoid thermal damage to the substrate film. Initial experiments will include photo-curing approaches. A literature survey of types of photoinitiators available for room-temperature photocuring revealed two main categories that can be used for the above system: (1) radical types, and (2) cationic types. There are strengths and weaknesses for each type of photo initiator.

For example, radical-type initiators can only polymerize vinyl-type monomers, and polymerizations are inhibited by the presence of atmospheric moisture. Unlike radical initiators, cationic systems can be used to cure monomers of epoxides, cyclic ethers, and lactons as well as vinyl types. Cationic photopolymerizations are also insensitive to aerobic conditions so that no inert blanketing is required. However, these salts are not commercially available and, hence, have to be prepared from available starting materials.

- Key samples continue to show excellent performance outdoors at Golden, Colorado (SERI), but mirrors outdoors in the harsher environment at Arizona have fallen below the long-term reflectance goal (3M).

Three samples mounted on glass substrates have the following-reflectances at 4 mrad after 48 weeks outdoors in Colorado: 96 percent, 96 percent, 94 percent. Thus, SERI researchers have demonstrated the maintenance of the long-range goal of reflectances greater than 90 percent at 4 mrad for almost one year. In contrast, samples in Arizona have fallen below 90 percent in 16 months, while similar samples in Florida remain above 90 percent (values obtained at 15 mrad by the 3M Company).

These samples on glass substrates recently have been augmented with a small sample set on polished aluminum and on polished stainless steel because of a potential concern that degradation at the adhesive/substrate interface may be substrate-dependent. After two months of experiments, the values at 4 mrad for mirrors mounted on stainless steel are 96.3 percent and 93.8 percent. Similar values for mirrors mounted on aluminum are 95.4 percent and 92.6 percent. Because these latter four mirrors

simulate to a higher degree anticipated applications and because they are performing in excess of the long-range goals, researchers also have initiated optical measurements before and after cleaning to obtain data on soiled samples.

- o Severe discolorations of mirrors (a type of ECP 300) observed at Solar One (Sandia) are not observed in Colorado, Arizona, Florida, or New Mexico.

  Photographs of mirror panels using ECP 300X and ECP 300 on a heliostat at Solar One show that ECP 300X is blistered and discolored and that ECP 300 is only discolored. On the basis of earlier work at SERI blistering of ECP 300X can be anticipated and avoided, and this avoidance of blistering is now further confirmed by the results at Solar One for the ECP 300 construction.

  Blistering and discoloration may be independent events. Three samples of ECP 300X in progress outdoors at Colorado at the three-year point have not yet discolored even though they had blistered months ago. In addition, none of the 30 to 40 samples (ECP 300-type) outdoors at SERI has blistered or shown discoloration. SERI researchers have also been informed that discoloration has not been observed in Florida, Arizona, Minnesota (3M Corporation), or New Mexico (Sandia). Analytical work on the discolored mirrors from Solar One is in progress at the 3M Corporation.

- o Under mechanical stress and in the presence of water, delamination can occur at the PMMA/silver interface in membrane-mirror applications.

  It has been observed and reported earlier that the adhesion between PMMA and silver is decreased in the presence of water; but when the mirror dries, higher adherence returns (3M Coporation). Experiments are in progress to improve adherence (3M Corporation). Delamination with ECP-300 type of materials is not observed in any of the accelerated or outdoor tests conducted at SERI when using small test coupons. When one sample, from an accelerated test at SERI, was intentionally delaminated, it failed at the silver/PMMA interface or elsewhere depending upon whether the interface was covered by edge tape. When covered by edge type, failure did not occur at the PMMA/silver interface. This observation may indicate the deleterious influence of ultraviolet light; however, other factors cannot yet be ruled out. Delamination was also observed at Sandia in film applied to membrane concentrator modules in cases where water was trapped on the film surface.

- o The University of Akron has measured the mechanical properties of biaxially stretched and annealed polyethylene terephthalate films.

  Work on measuring mechanical properties of some films is summarized in a sixty-page interim report submitted to SERI by the University of Akron. University researchers measured mechanical properties of biaxially stretched and annealed polyethylene terephthalate films.

Front-Surface Reflector Concepts/Substrate Smoothness

- o Tungsten carbide rolls have been refinished and returned to Teledyne-Rodney in preparation for production of a smooth steel strip.

  The forming rolls of tungsten carbide have been finished by the vendors (Van Keuren Company and VCI Laser, Inc.), and surface replicas and profilometer traces have been made. Although CVI Laser provided a smoother finish on the earlier flat pieces, the Van Keuren Company provided better finishes on the forming rolls. These results are

logical in view of the facts the CVI specializes in mirrors, and Van Keuren specializes in round-gage pins.

The two rolls used had a peak-to-peak roughness of 660 Angstroms (averaged over eight places on each roll). The CVI finish reduced the roughness to 168 Angstroms (p-p), and the Van Keuren finish reduced it to 83 Angstroms (p-p). The Van Keuren finish is less pitted as shown by microscopic examination, and the surface shows less variation from point to point.

The specularity of the surface of rolled sheet appears to be related to the smoothness of the forming rolls so that the best rolled finish by Teledyne-Rodney has a specularity of 74 percent in 12 mr. This finish is produced by a roll with about 485 Angstrom (p-p) roughness. Scientists estimate, based on the roughness-to-specularity relation, that steel rolled with the CVI and Van Keuren finished rolls will have specularity of 90 percent and 95 percent at 12 mr.

Teledyne Rodney Corporation, the firm that will roll the sample stock, reported that the superfinished rolls were so much smoother than the Company had ever worked with that the Coporation could not measure the roughness. The production run at the mill has been scheduled for late February.

- o The aluminum substrate (number 2 micro-finish) supplied by the 3M Corporation limits the performance of ECP 300.

It has been established that the substrate finish, if poor enough, degrades the performance of ECP 300 but that the ECP 300 limits the performance when substrates of near optical perfection are used. Researchers can determine, therefore, an optimum substrate smoothness which will give maximum optical quality without wasted finishing costs.

The study of aluminum and stainless steel as substrate materials for ECP 300 reflectors is continuing with optical tests of ECP 300 on the two metals. The optical properties of polished stainless steel and aluminum blocks before and after being covered with ECP 300A have been measured. The specularity of the polished stainless steel (laser) mirrors decreases when they are covered with the silvered polymer. The reverse is true for the polished aluminum substrates. Clearly, the number 2 micro-finish on the aluminum as supplied by the 3M Company is still limiting the performance of the silvered polymer.

Properties of Receiver Materials

- o Settling tests for cobalt oxide powder in molten draw salt are underway.

Settling tests of cobalt oxide blackener in draw salt at 500°C have been performed. The 500°C temperature was chosen to permit use of a Pyrex cell, but the settling rates at 600°C would only be about 30 percent greater and could be calculated from the 500°C data.

The results of the settling tests showed that, with cobalt nitrate as the starting material, most of the material had fallen past the field of view in about 30 seconds. The distance fallen was about 3 cm, which implies a fall velocity of about 0.1 cm per second. The theoretical fall velocity under the conditions tested is 0.33 cm per second for 44 micrometer (325 mesh) particles of Co_3O_4. It is apparent that the particles in this test have a maximum effective diameter of about 24 μm.

Settling tests made with 325 mesh (44 μm) Co_3O_4 showed a wide range of particle sizes with extensive clustering of the finer particles. Computer models of the settling of blackeners having distributions of various sizes are being studied in an effort to estimate the flow velocities required to keep the cobalt oxide dispersed. Preliminary estimates based on these models suggest that over 85 percent of 325 mesh Co_3O_4 will be suspended by turbulence velocities of 0.3 cm per second, which is a very modest velocity. Further results will be available in the next two months.

o Measurement of optical properties of draw salt and blackened salt are being performed.

The high temperature integrating sphere reflectometer required re-alignment, and the control program required revision to permit larger apertures for better signal/noise ratios. Those corrections have been made, and all measurements (hemispherical reflectance, diffuse reflectance, hemispherical transmission, and diffuse transmission) can be made within a few-percent error on solar-weighted averages. Individual measurements of hemispherical transmittance and reflectance can be made to less than one percent in comparison with NBS standards.

o The chromate ion is a soluble colorant for draw salt.

Alternate colorants for draw salt are being sought in an attempt to avoid the settling problem encountered with cobalt oxide. The present approach is to seek oxyanions such as chromate, molyblate, etc., that can produce color but will be immune to oxidation by the nitrates. One such ion, $CrO_4^{=}$, has been added as K_2CrO_4 to 5 wt%. This additive produced a deep red color and appeared stable in short term (a few hours) observation.

Photodegradation of Materials

o Two reports relating to the interaction of high solar fluxes with materials were completed during this quarter.

The first is a document assessing the potential for beneficial effects of high solar flux on materials processing and for the production of chemicals. This report was integrated with one prepared by G. Nix. The second document is a review of the literature of high solar flux interactions with materials. This report is published as SERI/SP-25533046 by Prof. H. Harris, University of Missouri at St. Louis.

o Literature regarding surface temperature profiles was reviewed.

In order to address the question of thermal gradients in the impingement region of high solar fluxes, researchers reviewed some of the current literature addressing similar problems pursued by people interested in modifying the surface properties of materials with photon or electron beams. All of the current interest is with semiconductor materials, but it is possible that the methods can be adapted to solar applications. Most of the literature deals with methods of calculating temperature profiles. However, a few references were uncovered and deal with making direct-surface-temperature measurements. This is a difficult field that will require a greater fraction of task effort, if it is decided actually to make such measurements.

o Sample exposures have been planned at Sandia, Albuquerque.

Preliminary arrangements have been made to expose samples to high solar flux conditions in air at the solar furnace at Sandia, Albuquerque. A sample jig that is compatible with the target frame has been designed. Uses of the high flux environment to modify surfaces of metals by processes such as alloying have been identified as fruitful areas of investigation. Some preliminary experiments may be incorporated into the planned sample exposures.

PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

During the next quarter, work will begin on exposing high-temperature alloys and coatings to high solar fluxes in air. In addition, a shift in emphasis to exploring the possibility of using high solar fluxes for surface metallurgical applications is expected.

TASK 2.0 CONCENTRATOR RESEARCH

OBJECTIVES

Research on concentrators is structured into the following tasks: membrane concepts with nonmetallic materials; wind impact studies; new concepts evaluation including the holographic concentrator concept. One objective of research on **Membrane Concepts** with **Nonmetallic Materials** is to estimate the technical benefits and potential performance using composite materials in fabricating stretched-membrane dish, trough and heliostat concentrators. Another objective is to find efficient ways of utilizing such low-cost, high-strength composites in effective ways for crucial concentrator subelements. The ultimate objective of **Wind Impact Studies** is to develop sufficient understanding of the wind-loading environment on concentrators such that it can be controlled to allow low-cost, lightweight concentrators to evolve. One objective of the research is to demonstrate the technical feasibility of promising concepts in concentrator wind-load reduction identified in Fiscal Year 1985 and to estimate benefits of their performance in a field of heliostats or other appropriate solar concentrators. Another objective is to define the requirements of wind-load design for fields of collectors. The major objective of work on **New Optical Concentration Concepts** is to identify and to provide a preliminary evaluation of new concentrator concepts and concentrator subelements which incorporate optical concentration approaches that represent a dramatic improvement in performance relative to current concentrator technology. The thrust of this effort is exploratory in nature. A secondary objective is to evaluate the potential performance of emerging innovative component and subelement adaptations to existing collector concepts as the need arises. Included herein are the Fresnel and holographic concepts and the assessment of their potential to effectively collect and concentrate solar flux.

ACCOMPLISHMENTS

Membrane Concepts

- Research activities on the new Membrane Dish Task were initiated--beginning with the implementation of the research plan.

  The research plan for membrane dishes has been finalized. A structural consultant met with members of the Membrane Dish Task to discuss the plan and to determine priorities. Discussion centered on the important issue of membrane/frame interaction. It was decided that for single-faceted designs, the issues of structural response differ considerably from those of stretched-membrane heliostats due to lower tensions, greater out-of-plane stiffness, and shorter focal length (which requires that the ring be close to a perfect circle). It was decided that during preliminary analyses of structural response, multi-faceted designs will be kept as an option. Work already has begun on comparing the optical performance of multi-faceted designs by using the CIRCE code (a dish optics code developed by Sandia, Albuquerque).

- A literature search on prior activities on the membrane dish has been completed.

  An eight-page memorandum describing the results of the literature search on related prior stretched-membrane-dish research has been completed. Over 90 papers and reports have been cited as being applicable to the membrane dish research. The information contained in these reports was divided into eight subjects. These areas are early DOE efforts, aerospace applications, Russian work, patents, deformation of flat membranes, SERI heliostat research, current designs (e.g., German and LaJet dishes), and miscellaneous.

The greatest amount of useful information came from the aerospace category. SERI researchers found details of membrane and adhesive material selection and techniques in gore cutting and seam fabrication. Examination of the early DOE efforts such as the Transolar, Summit, and Boeing dishes has identified problems with membrane shapes that need to be avoided. Analytical and experimental work on the behavior of stretched membranes dating back to 1915 was uncovered. The literature search on membrane mirrors also identified many ongoing research efforts, such as the Air Force program, the European space program, and work on lightweight telescope mirrors.

o Initial analysis of optical performance multi-faceted designs has been completed.

Initial analysis of the optimum number of facets for a stretched membrane dish has been conducted. This analysis has focused on the geometry of multi-faceted concentrators having 3, 7, and 18 facets. The location and orientation of the individual facets have been analyzed for a given stacking pattern and focal-length-to-diameter ratio (f/D) of a single-faceted case. Two cases were constructed for comparison with a single-faceted concentrator, one with equivalent areas and the other with equivalent overall f/D. In the second case, a single facet is circumscribed about the multi-faceted membranes. These data are being used as the basis for data on facets in the CIRCE computer code for calculating flux profiles and optical performance of the concentrators.

Based on the developed geometries, a number of baseline CIRCE runs for the single-faceted case have been completed. These include a comparison of ideal parabolas with realistic parabolic and spherical single-faceted dishes. Several three-faceted dish cases have been run also. No conclusions can be drawn until a sufficient number of cases have been run.

o New analytical models for deformations of large structural membranes have identified numerous insights into membrane shapes.

SERI researchers have been investigating the distortions of pressure-loaded membranes which in their initial unloaded and unstressed states are quite close to parabolic. Under realistic loading conditions, the membranes remain quite close to their initial shape; however, the incremental distortions are quite nonparabolic for f/D values of about 0.6. In fact, researchers have found that the distortions are most strikingly non-parabolic near the attachments; that fact is of significance, since reflector area is greatest near the edges. Further, researchers found that linear classical solutions developed for inflated building technology are not very good models for situations in which high surface accuracy is required.

Staff continued to develop simple analytical models for determining the stresses and displacements in a membrane deformed by wind loads. These results are being compared with ANSYS results generated by the subcontractor. These analyses will help to determine required membrane modulus, thickness, and strength, as well as will allow staff to determine ultimately optical degradation as a function of wind and weight loads.

Dr. C. Tuan of the University of Nebraska resolved problems in computer hardware and supplied SERI with ANSYS displacement results for a preshaped twenty-mil polymer membrane stabilized at a differential pressure of 2000 Pa and subjected to an incremental wind pressure of 65 Pa. The results indicate that a non-reinforced polyester membrane formed in a parabolic shape will deviate significantly from that shape when subjected to the 2000 Pa stabilization pressure. Thus, either it must be preformed in a

shape which will stretch to the required paraboloid when pressurized, or it must incorporate a reinforcing material such as glass fiber.

o Through a subcontract with SAIC, a two-meter-diameter composite dish has been fabricated.

Under the contract to SERI in fiscal year 1986 (through the University of Arizona), Science Application International Corporation (SAIC) has fabricated a two-meter-diameter dish membrane made from a combination of two layers of fiberglass cloth and a polystyrene resin. First, a silica-loaded (quartz) gelcoat was applied on a mold to form a smooth surface on top of an inflated polyethylene mold. Subsequently, a polystyrene-impregnated layer of fiberglass was molded to the gelcoat. A completed dish including frame, attachments, and vacuum pump is to be ready in January. In the first attempts, the gelcoat layer used to prevent print-through of the fabric reacted with the inflated polyethylene mold. This problem was solved by a spray application of polyvinyl alcohol. The first dish shows good surface smoothness with only minor print-through in areas where the gelcoat evidently did not cure completely. A second dish is now being fabricated, and greater time will be allotted for gelcoat curing.

SAIC also sent blueprints and results of structural analysis for the membrane-dish frame to SERI. The frame consists of a mild steel channel ring with curved steel tube supports in a shape like an umbrella. Stress analysis indicates that deflections are minor and buckling will not be a problem even under high wind conditions. Current plans for the back membrane are to use a rejected front membrane and to attach it with fiberglass to the inside of the tubes. Since the spokes are attached to the bottom of the ring and the front reflective membrane is attached to the top, there will be no interference or contact between the two membranes.

SERI staff met at the University of Arizona with K. Ramohalli (University of Arizona), B. Butler (SAIC), and K. Beninga to discuss the fabrication of membrane-dish scale modules. Ramohalli displayed several composite membrane-dish modules as well as the plaster of Paris mold on which they were fabricated. Murphy also met with Ramohalli and S. Joshi in a separate meeting to discuss composite materials issues, such as anisotropic behavior. To allow SERI to model the structural response of the dish membrane fabricated by SAIC, Ramohalli agreed to provide data on the material property of the glass/polystyrene composite. This will include density, modulus of elasticity, Poisson ratio, and ultimate strength. In addition, he plans to make several NASTRAN runs to predict stresses and displacements and will also test the thermal-cycling characteristics of the membrane and reflector combination. The analyses of SERI and the University of Arizona will be compared. Finally, to provide a better perspective on the various options for fabricating dishes, B. Butler and K. Ramohalli will write a comparison of three concepts: the lay-up design described earlier, the use of a reinforced thermoplastic that is formed thermally to the proper shape, and a floating reflector having a separate "fishnet" membrane for structural support.

A drafted Statement of Work has been prepared and covers the work for fiscal year 1987 to be performed by the University of Arizona and SAIC. At this time, the following Tasks have been proposed.

1. Further refinements will be made to the two-meter-diameter fiberglass/ polystyrene dish fabricated in December, 1986. Emphasis will be on improving membrane shape and eliminating print-through.

2. Several new polymer membrane concepts will be evaluated analytically and experimentally. These may include an open-weave structural mesh with rigid tiles, a dish made from flat reinforced thermoplastic sections thermally formed to the proper shape, and an open-weave structural membrane with a foam buffer to prevent print-through. The concept considered to be the best by mid-year will be recommended for prototype fabrication in Task 3 (below).

3. The best concept from Task 2 will be fabricated into a three-meter prototype membrane dish which will be supplied to SERI for testing.

o SERI staff provided support to Sandia, Albuquerque, on the development of the stretched-membrane heliostat.

SERI visited Sandia, Albuquerque, to investigate possible solutions for the wrinkling problems experienced with the stretched-membrane heliostat module from SAI. Several recommendations have been communicated to Sandia and SAI, and the implications of these and other solutions proposed by Sandia were assessed.

New Concepts Evaluation

o Colorado State University and other consultants are continuing research on wind-load reduction and interpretation of data for reductions of heliostat cost.

A consulting agreement with the University of Colorado to study the potential costs for strategies in wind-load reduction in central receiver heliostat fields is nearing completion. Work will include identifying various techniques in wind blockage and estimating the cost of constructing them at the Solar One site in Daggett, California.

A consulting agreement with a principal scientists at Advanced Thermal Systems—to conduct an assessment of the impacts on heliostat design of reduced wind loads—is also nearing completion. This work will focus on identifying the current state-of-the-art in heliostat design as well as current component costs. A draft of the final report has been delivered to SERI for review. The basic conclusions from this work are that with the ability to reduce static wind loads on the heliostat up to 50 percent, a cost savings of almost 22 percent may be realized. This is for the case in which the array size is increased so that the total original design load is attained, even though the load per unit area is reduced by 50 percent. For the case in which the reduced load is used and the component requirements are reduced, the cost savings do not appear as great. A thorough review of these results will take place over the next reporting period.

The data from these two consultants will form the basis on which to assess the impacts of reduced wind loads on various components within a heliostat and ultimately to assess the potential for cost savings.

o The University of Chicago has produced analytical results useful for the assessment of secondary concentrators in dish applications.

The University of Chicago has completed a simple ray-tracing computer code suitable for use on a personal computer. This code is now being used to assess some of the optical system tradeoffs associated with using a secondary concentrator in dish systems. One initial study looked at the effect on overall system efficiency as a function of various assumptions concerning the shape-of-error distributions. Results indicate that little error ensues if a Gaussian distribution is assumed rather than a pillbox distribution. In reality, it appears that resultant error distributions are somewhere

between the pillbox and Gaussian. The greatest error seems to occur in systems with very large surface errors. Differences of 1 percent to 2 percent exist in systems within the expected range of surface errors for state-of-the-art dishes.

A new method for estimating the throughput (or efficiency) of a trumpet secondary concentrator was incorporated into the analysis codes for secondaries in point-focus collector performance. This method accounts for the variation of throughput as a function of intercept factory and concentration ratio. The amount of flux that passes untouched through secondary exit aperture is calculated with the amount of flux that is intercepted by the secondary surface. For trumpet secondaries in the focal-length range of general interest (0.5 to 1.0), there is, on the average, only a single reflection from the secondary surface. A more accurate throughput is calculated from flux and effective reflectivity information. The calculated values are very close to those measured for trumpets in tests conducted on existing dishes. The use of this methodology will result in more accurate estimates of the performance of dishes with secondaries.

Holographics

o Experimental research on holographic concentrators is complete.

The Broadbent Development Laboratory moved from Mountain View to San Diego, California, at the end of October. The experimental work has been completed and will not be resumed in San Diego. The holographic equipment has been placed in Government storage. The emphasis of the program was shifted to Task 10, Technical Analysis, and to analysis and reporting on holographic data. The technical analysis and the holographic data analysis will be completed and will be incorporated into the final report, which will be issued in January. This will complete the contractual requirements of this research. A review of all work is planned at Acurex in early January with the help of a consultant from the University of Chicago.

High-Flux Optics

o The new Large Aperture Near-Specular Imaging Reflectometer (LANSIR) is complete and is now operational.

The new Large Aperture Near-Specular Imaging Reflectometer (LANSIR) is now complete and operational. The LANSIR is being used to assess polymer mirror materials, structural substrates, laminated mirror stacks, and, indirectly, lamination and fabrication techniques. A sixteen-inch Newtonian telescope will be used to study scatter from large surface scattering features, which may result from basic material limitations or fabrication methods. Researchers completed a modification to the remote, manual-gain control feature (added to the video camera). Since it was not possible to modify the electronics in either the remote control or the camera, a neutral density filter was added to the optical system just in front of the camera. This filter reduces the amount of light entering the camera so that images using the full aperture size are no longer saturated. A detailed test plan was completed; it describes the full characterization of mirror samples to be tested. The plan includes background for the tests, description of the optical system, characterization of the optical system, and tests to be conducted on the various samples on hand.

A system for measuring tension system was devised and installed to support the LANSIR tests. During a test the membrane is held taut over the end of a machined circular anvil (a section of sixteen-inch steel pipe). The plenum behind the membrane is sealed, and a slight vacuum causes a small amount of deflection in the membrane.

By measuring the amount of vacuum and the resulting deflection, the average tension in the membrane can be calculated. The deflection is measured optically by observing the angular spread of small diameter spots created by placing a mask in the optical train. This results in a precise and highly sensitive measure of the membrane tension with only the slightest vacuum and, therefore, with minimal deformation imposed on the membrane.

Testing has been completed on a sample of three-mil, stainless-steel-backed membrane material (ECP-300) from the SAIC stretched membrane heliostat. By using a sample size of 36 cm, the scatter of light from the membrane is being measured as a function of membrane tension and instrument-aperture size. At the largest instrument aperture, 36 cm, data at various tension levels up to 140 N/m (80 lb/in) have been taken. Additionally, at a relatively low tension level, data at various instrument aperture sizes and mirror sample locations have been taken. Five aperture sizes (2.5 cm, 5 cm, 10 cm, 25 cm, and 36 cm) were utilized. At all but the largest aperture size, data were taken at a number of different mirror locations.

Preliminary analysis of the data on the SAIC sample indicates, as expected, a decrease in the scatter as tension is increased. Additionally, there is some anisotropic behavior in this sample, which appears to be relatively consistent in direction. A more thorough analysis of the data is currently underway to quantify the results in detail.

The SKI sample (ECP-300 from 3M, laminated to 10-mil aluminum) is now under evaluation. It will be followed by testing on a film sample of ECP-300 from the 3M Company; then samples from LaJet and possibly from Acurex will follow.

A video tape is being prepared; it shows the operation of the LANSIR and some qualitative results from the SAIC tests. This video will be edited into a brief presentation package to be used to introduce the instrument, its capabilities, and some initial results to interested technical personnel.

PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

During the next reporting period, emphasis in the **Membrane Dish Task** will be placed on continued analysis of structural and optical performance of various dish design options. In **New Concepts,** final reports from consultants on wind-load reduction will be completed and an evaluation of the impacts of the costs of reducing wind loads and the cost benefits on heliostats will be completed. Reports and an evaluation of secondary concentrators will be completed and subcontract extensions for any further research will be initiated. In the **High-Flux Task,** tests on all remaining reflective film samples will be completed on the LANSIR and the impacts of the test results will be evaluated.

TASK 3.0 RECEIVER RESEARCH

OBJECTIVES

Research on receivers for fiscal year 1986 consisted of the following Tasks: direct absorption research; receiver concepts analysis; and instrumentation and measurement. The objective of the **Direct Absorption Receiver (DAR) Research** is to develop an in-depth understanding of the major technical issues associated with the direct absorption receiver concept by using a liquid working fluid. This includes theoretical and experimental assessments to provide the technology base necessary for development of a high-flux DAR for early use in 600°C to 700°C (medium) temperature while providing the basis for further improvements in receiver performance and possible higher temperatures. The major objectives of **Receiver Concepts Analysis** are to study the feasibility of the Direct Absorption Receiver from a systems perspective, to determine the technical barriers, and to identify the research needed to support the eventual development and the implementation of this concept. Another objective is to develop a more detailed and accurate understanding of the receiver/optical interface for both central receiver and dish applications which can lead to more effective receiver/field combinations. The objective of research on **Instrumentation and Measurement** is to continue the research initiated previously to identify and to meet those programmatic instrumentation and measurement needs that cannot be met by commercial state-of-the-art. As the program develops new concepts and technologies, there exists the need to measure how well they perform. The ability to conduct such measurements at times exceeds the current commercially available instruments.

ACCOMPLISHMENTS

Direct Absorption Receiver Concept Research

- An instrument capable of measuring wave-thickness in a time series has been developed and is ready for use with water-film tests.

  A new instrument based on the measurement of conductivity in the water film—a conductivity probe—has been fabricated by Industrial Welding and Supply and delivered to SERI. This probe will enable the acquisition of time-series data of the film thickness to provide accurate continuous definition of the wavy pattern in the film. A second channel of the electronic circuit for film thickness has been completed and checked out. Final assembly of the circuit in a panel is also complete. A procedure for probe calibration was developed, and a cell for the probe calibration was fabricated.

  Data obtained from these tests will be used to validate the mathematical model of the film now on SERI's computers. The validated model will then be used to predict the salt film behaviour to be observed when laboratory modifications are completed for long, salt-film tests in fiscal year 1987.

- Exploratory wind tests were completed and indicate that winds up to 45 miles per hour should not disturb salt film.

  SERI researchers have completed a preliminary, exploratory experiment to assess whether the salt film is susceptible to wind. Air flow from a one-inch pipe at about 30 to 45 miles per hour was directed at the salt film at various angles. At some angles researchers observed small ripples in the film, but only when the jet was directed straight into the film was it possible to cause salt droplets to be thrown off the film. This is because a one-inch jet impinging normally on the plate can produce a local

stagnation in the film which leads to the film being ejected from the absorber plate. Most likely, a wind of 30 to 45 miles per hour over the entire surface would not disturb the film significantly. However, the absorber plate seems to be too short to exhibit fully developed waves which may be more susceptible to the wind effect. It seems that this issue will have to await its conclusive resolution until larger scale experiments are conducted in fiscal years 1987 and 1988.

- o The problem of nitrate salt containment at the flow-channel edge has been resolved.

  SERI researchers have succeeded in containing molten nitrate salt at the edges of open channels in a no-flux environment. This problem was identified during testing at the Advanced Components Test Facility in 1985 with carbonate salts. Containment of the nitrate salt is significantly more difficult than that of carbonate salts primarily due to the lower viscosity of the nitrate salt.

  A number of different configurations were tested. A special C-shaped edge configuration succeeded in containing the salt. Tests showed that the molten salt was totally contained on the inconel DAR test panel (15 cm wide by 60 cm long) at flows up to 10 gpm (the maximum for the DAR flow loop). This edge containment configuration shows promise to succeed in flux conditions. Tests to verify this design will be performed in the near future.

  Although a commercial Direct Absorption Receiver will operate most likely at higher specific salt flow rates (gpm per foot), it appears that this method of salt containment will work well beyond 20 gpm per foot and that, if necessary, further refinements would allow the method to work at any flow rate.

System Analysis Studies

- o Alternative conceptual configurations and flow patterns have been assessed for Direct Absorption Receivers, and reveal designers will have considerable flexibility in choosing design parameters.

  Included in this study are discussions on flux gradients expected from cloud passages and sunrise/sunset conditions, methods for flow control to accommodate these gradients, film stability considerations, and effect of absorber flow dividers on absorber temperature and heat-transfer augmentation. Results of the study indicate that the flux gradients will require that the absorber panel flow be controlled in several flow zones to control outlet temperature. Several flow-control strategies were identified; a tradeoff between flow schematic simplicity and the number of control zones will be needed. Physically dividing the film flow is not desirable because fluid near the divider will overheat and will force one to more narrow control zones. Without the dividers, natural mixing occurs, and this tends to smooth the fluid temperature gradients at the zone boundaries. The report recommends performing experiments on zone mixing. These experiments have been planned for fiscal year 1987.

TASK 4.0 HEAT ENGINE CONCEPTS

OBJECTIVES

This activity involves research on Heat Engine Concepts of a single task--Regenerative Thermoelectrochemical Conversion Research (RTEC). The objective is to continue the research initiated in Fiscal Year 1985 to define a RTEC conversion concept, to demonstrate its technical feasibility, and to assess its cost and economic potential.

ACCOMPLISHMENTS

- o A Request for Proposal has been issued to the Hughes Aircraft Company for the third phase of research on RTEC (Thermally Regenerative Electrochemical Converter).

  SERI researchers met with Hughes Aircraft researchers to plan further the RTEC research project for the Thermally Regenerative Electrochemical converter (RTEC). RTEC is a thermally regenerative electrochemical converter of solar thermal energy to electricity and has the promise of thermal efficiency approaching 40 percent, with a low maintenance life of 40,000 to 100,000 hours, and a low potential capital cost of $200 to $500 per kilowatt. RTEC has the potential to serve equally well as an engine for dishes and as a larger engine for a central receiver system.

  RTEC research is planned as a combination of in-house SERI research and subcontracted research at the Hughes Aircraft Company. Hughes research will emphasize the electrochemical converter, while the SERI research will emphasize the solar thermal regenerator and the integrated systems and will guide the electrochemical converter research. Planning activities center on the stripper and the condenser for regenerating the working fluids, and on materials questions throughout the system. The contract Statement of Work for a two-year research project is complete, and contracting activities have been initiated with the goal of having the Hughes contract in place in March, 1987. A request for proposal has been issued to Hughes, with a response expected in mid-February. Final contract placement is contingent upon complete resolution of intellectual property ownership, proprietary data rights, and cost-sharing questions between DOE and Hughes. DOE/SAN is handling these under guidance from DOE/Headquarters. The research project is planned to validate the concept through an integrated system operation at the ten-watt level in the laboratory, with an intermediate goal of achieving 30 percent efficiency. This research project is expected to make a significant contribution to the increased efficiency of solar thermal systems, particularly dish modules. This conversion concept could have a significant potential for application to other energy areas—such as automotive application, since General Motors (parent company of Hughes) has expressed continuing interest by cost-sharing this phase of research with DOE.

PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

SERI researchers will receive and review the Hughes proposal in the next reporting period. Contract placement will continue. SERI also will work with DOE and Hughes to help achieve final resolution of questions of ownership of intellectual property, proprietary data rights, and cost-sharing.

TASK 5.0 DIRECT CONVERSION

OBJECTIVES

Research on direct conversion is structured into the following tasks: solar unique or beneficial phenomena and innovative absorption concepts. Research on **Solar Unique or Beneficial Phenomena** is aimed at understanding excited state phenomena and how they can be used in the direct conversion of solar energy. Also photoenhanced catalytic process research is to study possible enhancement of heterogeneous catalytic reactions under high-flux solar irradiation (1-3 MW/m^2) and at elevated temperatures (100°C to 500°C). The objective of research on **Innovative Absorption Concepts** is to characterize promising absorption concepts and to stimulate their introduction into new energy conversion concepts.

ACCOMPLISHMENTS

o University of Houston researchers generated data showing photoenhancement of catalytic processes.

The University of Houston researchers are generating interesting data on the photoenhancement of catalytic processes. The researchers had observed earlier that samples of nickel subjected to high direct flux tend to form oxide layers faster than samples heated to the same temperature in a dark oven. This effect was attributed to an interaction of photons with the internal bonds of the oxygen leading to rupture of the oxygen-oxygen bond and more rapid rates because the atomic oxygen is more reactive than is molecular oxygen. The researchers hypothesized that this effect could be used beneficially to enhance the rate of catalytic processes where the rate-limiting step is the breakage of an internal bond. The potential practical application is to enhance significantly the rate of many industrially important catalytic reactions by the use of direct solar flux.

The University's experiments with the reaction of carbon dioxide and hydrogen on a polycrystalline catalytic foil show enhancements of a factor of 10 in the rate of formation of methane. Experimental measurement of the activation energy with irradiation gives a value about half the value for the thermal reaction in the dark implying that the reaction occurs by different mechanisms in the light and the dark. Additional data are being collected by using an eximer laser, rather than the Xe arc image furnace to define further the effect. Corresponding experiments with the ammonia synthesis reaction have failed thus far to show a corresponding enhancement, which is very puzzling to the researchers. The researchers have developed and used a low-energy, electron-diffraction technique to measure accurately and to correlate the actual surface temperature with the measured bulk temperature. The difference between the hotter surface and the bulk of the catalyst is sufficient to explain the observed enhancement in the ammonia synthesis in terms of known kinetics. Researchers are continuing to examine other reactions in hope of discovering a phenomenon which will serve as the basis for a practical process for direct conversion of solar flux.

o A consultant has been identified to assist with research on photoenhancement of catalytic processes.

A potential consultant in catalytic chemical reactions has been identified, and action has been initiated to establish a consulting agreement. Professor J. L. Falconer of the University of Colorado is a nationally recognized expert, particularly in the catalysis

of methanation reactions, carbon gasification reactions, and organosilicon reactions. His research approach is experimental and tends to be fundamental in understanding the relevant surface processes. Prof. Falconer will assist SERI in the review and evaluation of the University of Houston research on direct conversion, especially on photoenhanced catalysis research and solar-assisted chemical reaction research. Prof. Falconer will also assist SERI researchers in generating new ideas and concepts for direct conversion of concentrated solar thermal energy. It is anticipated that Prof. Falconer's activities will be beneficial to the University of Houston researchers by providing them with an expert consultant and advisor. A visit to the University of Houston is planned in mid-January to review progress.

- Activities are in progress to provide resources for a continuation of direct conversion research at the University of Houston.

  Under research on solar-unique and beneficial phenomena, efforts are underway to extend the research contract with the University of Houston through calendar year 1987. The statement of work emphasizes research on direct flux, with specific tasks in photoenhanced catalysis, solar-assisted bond breaking, and photodegradation of materials. In addition, researchers are interpreting the data from the solar-unique tasks and are defining significant applications. This research is expected to contribute significantly to bringing the solar-unique and beneficial research to a point where sufficient data are available to allow a decision to be made on continuing research in some areas.

- SERI reviewed research at the University of Dayton and the University of New Hampshire.

  SERI staff members visited the University of Dayton (Ohio) for a technical and progress review of its research for fiscal years 1986 and 1987 on assessing the feasibility of using solar thermal energy (at fluxes up to 500 suns) to detoxify hazardous wastes. The work is progressing on schedule. While at the University, SERI staff members saw the experimental apparatus (which uses simulated solar energy) and observed preliminary experiments aimed at calibrating the instrumentation for measurements. If this work is successful, it may be possible to detoxify specific organic wastes to standards mandated by the Environmental Protection Agency at lower temperatures than in conventional incineration systems.

  Staff members also visited the University of New Hampshire (Durham, New Hampshire) for a technical and progress review of its two SERI-funded research projects. The two projects are assessing the feasibility of using solar thermal technology to produce high-value chemicals and assessing the feasibility of using solar thermal energy to remove organic sulfur from coal. These projects are being performed in parallel and are on schedule; however, SERI authorized the University to emphasize the research to remove organic sulfur from coal. If the sulfur removal research is successful, it can be the basis for developing a novel approach to desulfurize coal that is potentially less expensive than approaches with chemical treatment, and a method for using solar energy to photo-oxidize other hazardous or polluting sulfur-bearing organic compounds.

- Researchers at the Georgia Tech Research Institute produced possible solar-unique materials during solar furnace tests.

  Researchers at the Georgia Institute of Technology have made significant progress in showing that the application of high direct solar flux can result in solar-unique effects

in the processing of materials. Researchers have prepared successfully ceramic whiskers with chemical vapor deposition by using the Georgia Tech Solar Furnace (GTSF). Several whisker types were grown, with preliminary analyses indicating that hafnium oxide, carbon, and hafnium carbide whiskers were formed in the experiment. Whiskers are single crystal fibers which have exceptional strength and hardness properties, and which are difficult to prepare by using conventional techniques. They may have the potential for use in high-value composite materials of strategic importance to both the space efforts and the Department of Defense.

The experimental technique consisted of providing appropriate feed gases, such as hafnium chloride and methane, to a fused silica reactor at the focal point of the GTSF, where the reaction occurred to form the whiskers by chemical vapor deposition. Whisker growth was catalyzed by using nickel powder and nickel wires on the graphite substrate to act as sites for whisker growth. A quirk of the experiment apparatus appears responsible for the three different kinds of whiskers. The hafnium chloride sublimator was difficult to control--resulting in hafnium-chloride-rich flow in the early part of the experiment and methane-rich flow in the latter part of the experiment. This is thought to have resulted in hafnium oxide whiskers in the early part, in hafnium carbide whiskers in the middle of the experiment when the flows were balanced, and in carbon whiskers during the methane-rich flows. Researchers are now performing the appropriate physical and chemical analyses to confirm the results and to understand better how to control the process of deposition of solar-chemical vapors to maximize the solar-unique effects on the process and the resulting material properties.

The GTRI contract is being modified for continuing research in FY87 to emphasize high value materials with unique properties. Potential products include carbon fibers, very hard carbon materials for composites, unique ceramics, and transparent coating to mitigate the soiling of reflector surfaces. The research will use the Georgia Tech Solar Furnace rather than the ACTF. GTRI is marketing aggressively ACTF testing capabilities to other potential clients such as NASA.

o SERI researchers are evaluating the feasibility of a new type of quantum-thermal receiver-reactor.

The work to evaluate the feasibility of a new design for a quantum-thermal receiver-reactor is underway. Researchers performed preliminary calculations based on energy balance and found that with 100 suns radiative flux, a ten-ton-per-day production of caprolactam will require a reactor surface of about 90 square meters for photochemical reaction, and a receiver area of 3 square meters for infrared heating. This shows that the concept to separate solar band from infrared spectra without using beam-split mirrors is promising. Researchers used the process of caprolactam production to illustrate the concept. After carefully reviewing the model, researchers concluded that they have to improve the model to include a more accurate estimate of reflective losses from all glass surfaces containing photosensitive species where reactions occur. They also must estimate the flow rate of the photosensitive mixture, the general configuration of the receiver and reactor, and the effect of temperature rise in the receiver on the photochemical process efficiency.

o SERI assessment indicates possible feasibility for rapid pyrolysis of coal by using direct flux to produce hydrocarbon liquids.

An evaluation of a promising application for using concentrated solar flux directly, such as producing liquid fuels and chemicals from coal by means of a solar-driven pyrolysis process, revealed a possible solar application. Previous coal-pyrolysis

research, sponsored by the DOE Coal Liquefaction Program, has shown that the conversion rate and the liquids yield are strong functions of the coal heating rate—an area that is one of the strengths of concentrated solar flux. A concept for a 100 MW_t solar thermal coal-hydropyrolysis plant was developed, its cost was estimated, and a very preliminary estimate of its technical and economic performance was made. The system is estimated to operate about 7 hours per day (annualized basis, 350 days per year), to process 120 metric tons of coal per hour, and to produce about 3250 barrels of liquid per day (assuming a 60 percent carbon-to-liquid conversion rate). If the Solar Thermal Program cost and performance goals are met, the estimated capital cost of the plant is about $86 million, with the potential to produce liquids from coal at a levelized cost of $22 to $25 per barrel, compared to the DOE Coal Liquefaction Program goal of $30 per barrel. The sensitivity analysis showed that if the costs for capital, operations and maintenance remain the same, the solar coal-pyrolysis plant can meet or exceed the $30 per barrel goal as long as at least 42 percent of the carbon is converted to liquids.

PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

The research at the University of Houston on photoenhancement of catalytic processes and solar-assisted chemical reactions will be reviewed by SERI, DOE, and a consultant. The direct-conversion effort will be thoroughly reviewed at the SERI Solar Thermal Annual Research Symposium on February 18 to 20 in Golden, Colorado. Papers will be presented to describe all major projects, and an overview will be presented to describe the strategy, the program directions, and the significance of research. Professor V. K. Mathur of the University of New Hampshire is beginning to understand the possibility of using direct solar energy to photodesulfurize coal. It is expected that his data will be sufficient to provide a clear definition of technical feasibility. The SERI assessments on photo-oxidation of dilute organic pollutants in water and on the rapid direct-flux pyrolysis of coal will be reviewed, will be strengthened as necessary, and will be used as appropriate to plan future research. Additional data on carbon fiber processing and on chemical vapor deposition of ceramics should allow GTRI researchers to assess better the potential of direct-flux materials processing.

TASK 6.0 INNOVATIVE CONCEPTS AND APPLICATIONS

OBJECTIVES

The objectives of this Task are to encourage and to harvest ideas and innovative concepts from a vast pool of information and ability in industry, universities, and innovators at large. The new ideas will assist the solar thermal technology to make progress toward achieving the long-term cost and performance targets. During fiscal year 1986, the objectives included: (a) evaluation of projects currently in progress and assessment of their potential contribution to solar thermal technology; (b) issuing solicitation and award contracts for a research effort to increase participation from university researchers.

PROGRESS

o SERI staff visited the University of California to discuss progress on subcontracted work.

SERI staff visited the University of California in Berkeley to review subcontracted work with the University. The subcontract was one of the two awarded in FY 1986, and involves use of composite materials for stretched membrane heliostats. Work began in October, 1987, and progress so far has been mainly in the a nalysis area. Software developed at SERI has been transferred to U.C., Berkeley, and evaluation of the cost-effectiveness of using composite materials for heliostats has begun. Tour of the laboratories revealed that the capability of preparing composite materials also exists there, and this capability combined with the analytical capability may allow some experimental work to begin this year. This three-year research program includes both analysis and experimental work to achieve scale model units for evaluation. Research plan for each year with priorities of work has also been developed.

FTP 653 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

Bowl Evaluation

Completion of the solar bowl evaluation remained the major objective of the first quarter. Four full simulations were completed, each of which represented a specific design for a solar bowl. Two simulations represented the base 60° bowl concept with steam and molten salt receivers. The other two simulations represented more advanced concepts with a thirty-degree bowl design.

Sensitivity analyses were used to test the effect of uncertainties in the cost and performance data upon the results. Potential improvements that might result from several new and, as yet, poorly-defined innovations in components or subsystems were also checked with sensitivity analyses.

Final briefings were held with Texas Tech University and DOE Headquarters on December 4 and 11, 1986. Texas Tech is requesting a further meeting with DOE Headquarters in January, 1987. TPI staff shifted emphasis toward documenting the results of the bowl evaluation. A preliminary draft is expected to be delivered to DOE Headquarters in 1987.

Other Studies

Work continued on the documentation of major analytical studies that have affected program direction. Former staff of the TPI office at Sandia, Livermore, were interviewed to ensure completeness of the list of significant studies. The results of some of these studies have never been published.

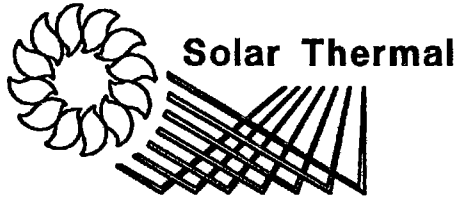
Development of future program strategies also continued. Investigation of some of the many program issues resulted in two issue papers being produced. The first, "A Brief Investigation of the Value of Generation Plant Modularity to Electric Utilities," (SERI/MR-250-3076, November, 1986), examined the lower limit of the range of capacities that utilities are willing to consider in a modern power plant. Although smaller plants cost more per unit of capacity, they actually may have increased value to a utility because of the shorter construction time and smaller amount of required capital. Consequently, utilities are considering seriously modular sizes of 100 MWe to 200 MWe. Both modern coal burning plants and combustion turbines in their capacity range are under development.

A second issue paper, "Some Perspectives on the Potential for Solar Detoxification of Hazardous Wastes" (TPI-87-3), was forwarded to DOE Headquarters for comment. The

detoxification of hazardous wastes is becoming a major national issue and may represent a significant application with which constituents of the Solar Thermal Program may become involved in the near future. TPI staff members are continuing their studies to assess the magnitude of the problem of hazardous waste and the various ways that solar thermal technologies might aid in its solution.

APPENDIX A

MILESTONE SCHEDULE AND STATUS



Major Milestone Schedule

Task	FY86												FY87			
	O	N	D	J	F	M	A	M	J	J	A	S	1Q	2Q	3Q	4Q
Optical Materials				1 ▲			2 ▲									12 △
Concentrators												3 ▲	4 ▲	13 △		
Receivers							5 ▲	6 ▲				7 ▲		8 △		
Heat Engines																
Direct Conversion											9 ▲					
Innovative Concepts		10 ▲				11 ▲								14 △	15 △	
Program Planning										A ▲			B ▲			

MILESTONE DETAIL

FY 1986 (INCLUDING FIRST QUARTER FY 1987) FUNDED BY FY 1986 FTPS

1. Stable polymer/silver film with reflectance greater than 90% and specularity consistent with long-term goal
2. Evaluate progress in front surface reflector options and select most promising approaches
3. Achieve definitive efficiency data and projections, including tracking requirements, for holographic concentrator
4. Two-meter-diameter membrane mesh module ready for test
5. Complete systems study for intermediate temperature DAR
6. Evaluate stability of turbulent flowing films for the direct absorption concept
7. Assess potential of concentrated sunlight for beneficial material effects
8. Upper bounds of solar flux absorption in DAR
9. Assessment of ways to maximize photolytic enhancement in chemical dissociation
10. Issue LOI (request for proposals for innovative research)
11. Complete selection for awards of research contracts

FY 1986 PROGRAM PLANNING AND EVALUATION (FTP 653)

A. Draft multi-year program plan, 1987-1991.

B. Presentation of results on bowl evaluation.

FY 1987 PRELIMINARY (NEW FY 1987 FUNDING REQUIRED)

12. Stability of silver/polymer reflector with outdoor exposure tests
13. Membrane dish laboratory test module
14. System evaluation of the potential of promising direct conversion concepts and applications
15. Mid-term evaluation of the University Research Projects

Heat Engine task milestones will be determined after agreement is reached between DOE and Hughes.

APPENDIX B

RESOURCE EXPENDITURES

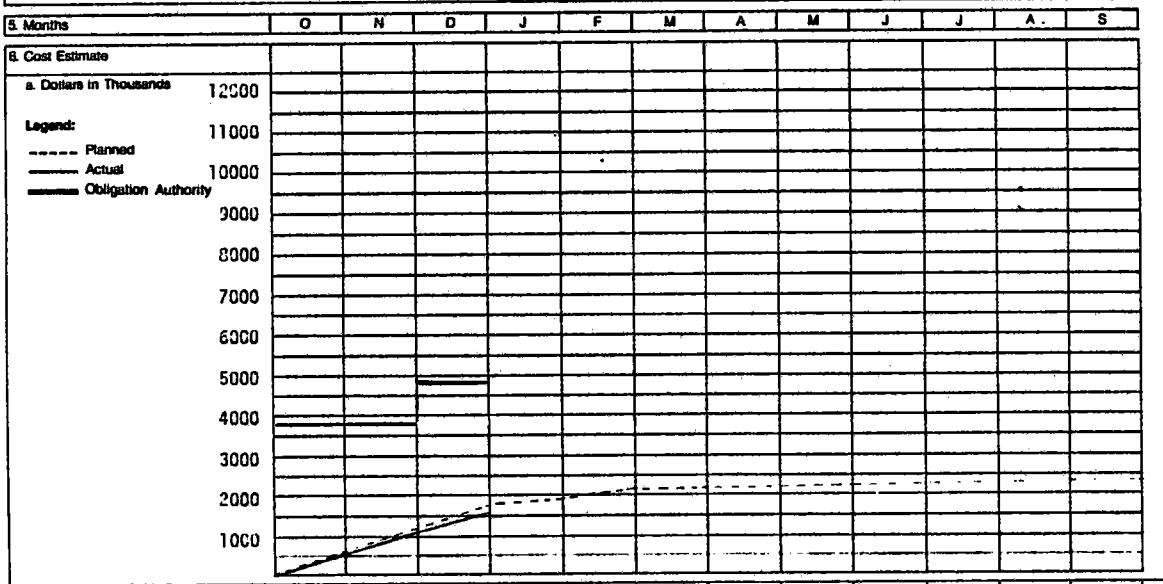
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/86 To: 9/30/87

3. Program Identification: FISCAL YEAR 1987 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: COST SUMMARY: OVERALL PROGRAM TOTALS



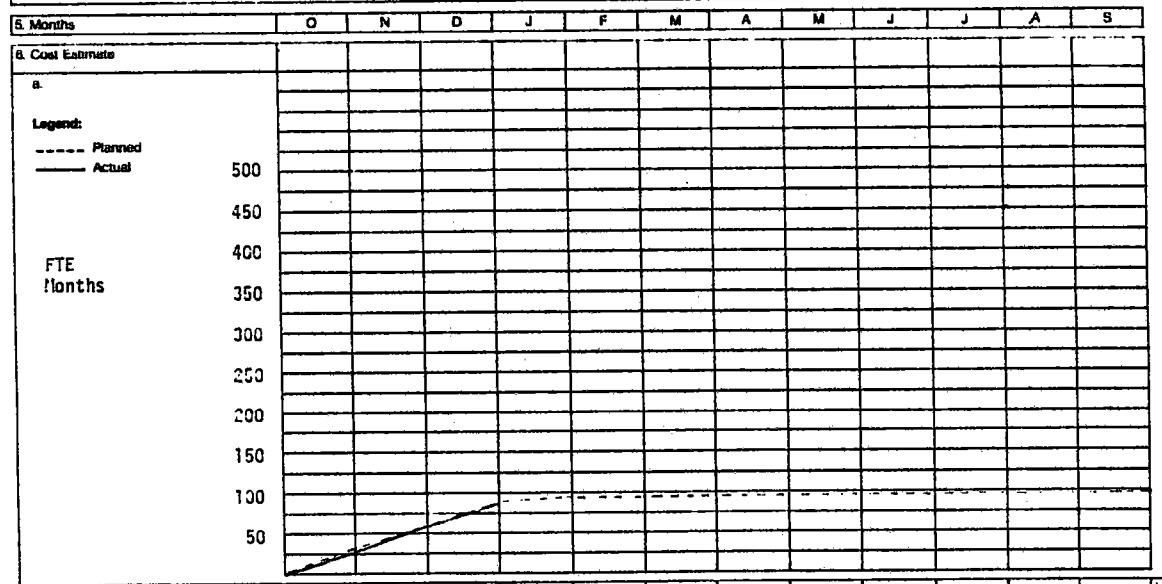
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	599	1205	1806	1996	2127	2182	2221	2250	2272	2294	2316	2323	b. Planned
	c. Actual	574	1137	1687										c. Actual
	d. Variance	25	68	119										d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/86 To: 9/30/87

3. Program Identification: FISCAL YEAR 1987 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	30	61	93	96	98	99	99	99	99	99	99	99	b. Planned
	c. Actual	29	61	93										c. Actual
	d. Variance	1	0	0										d. Variance

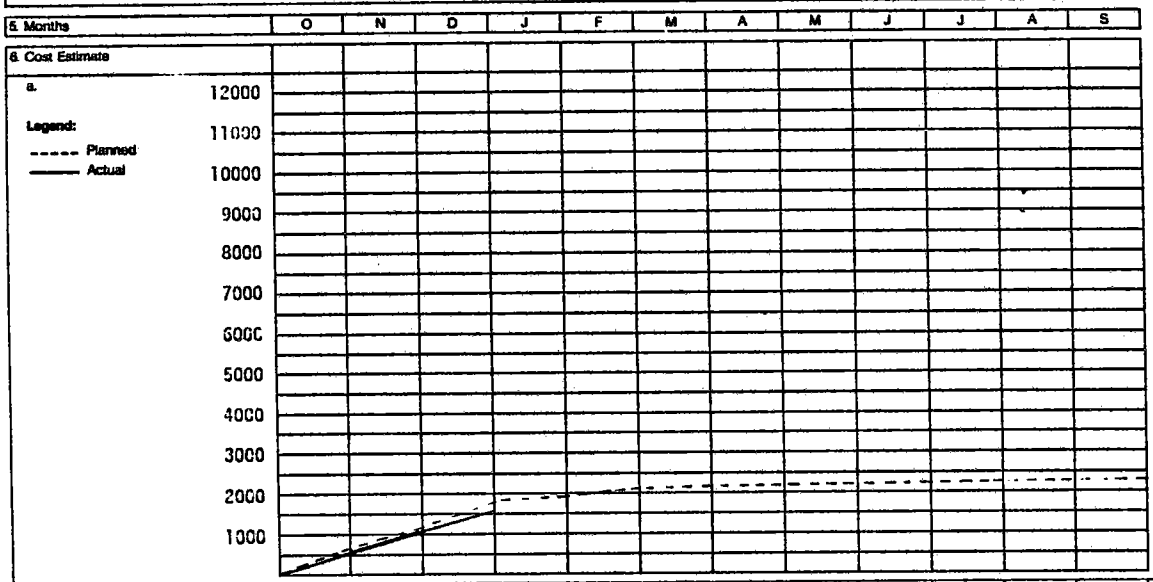
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/86 To: 9/30/87

3. Program Identification: FISCAL YEAR 1987 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: COST SUMMARY: FTP 651, FTP 652, FTP 653



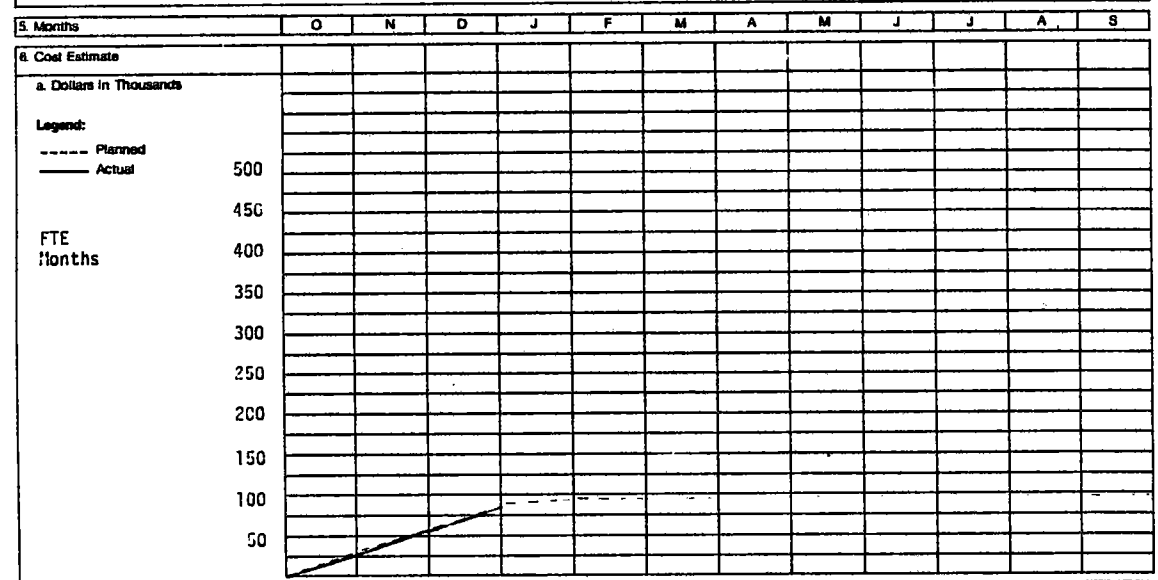
Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	
b. Planned	599	1205	1806	1996	2127	2182	2221	2250	2272	2294	2316	2323	b. Planned
c. Actual	574	1137	1687										c. Actual
d. Variance	25	68	119										d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/86 To: 9/30/87

3. Program Identification: FISCAL YEAR 1987 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: FTE SUMMARY: FTP 651, FTP 652, FTP 653



Accrued	O	N	D	J	F	M	A	M	J	J	A	S	
b. Planned	30	61	93	98	98	99	99	99	99	99	99	99	b. Planned
c. Actual	29	61	93										c. Actual
d. Variance	1	0	0										d. Variance

APPENDIX C

PROCUREMENT SUMMARY

FY 1985 SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS (Exceeding $25K)

Task No.	Subcontractor	Subcontract Title/Activity	Value (000$)	End Dates	Type Business	Status	Technical Monitor
1.	The 3M Company	Silver/polymer research	40.0	3/87	Industry	Awarded	P. Schissel
	Jet Propulsion Lab.	Polymer stabilization	50.0	7/86	Fed. Lab.	Completed	P. Schissel
	University of Denver	PAN polymer research	40.0	11/86	University	Completed	P. Schissel
	Acurex Solar Corp.	Front surface reflectors	33.0	5/86	Industry	Completed	G. Gross
	Solar Kinetics Inc.	Front surface reflectors	25.0	9/86	Industry (S.B.*)	Completed	G. Gross
	Southern Res. Inst.	Reflector protective coatings	68.3	4/86	Non-profit Corp.	Completed	Nix/Gross
	University of Akron	Polymer films research	65.7	5/87	University	Awarded	P. Schissel
2.	Acurex Solar Corp.	Holographic solar concentrators	228.8	5/86	Industry	Completed	Nix/Murphy
	University of Nebr.	Membrane dynamic analysis	31.2	12/85	University	Completed	M. Murphy
	Colorado State Univ.	Wind impact studies	34.8	12/85	University	Completed	M. Murphy
	University of Chicago	Compound optical systems	75.0	1/87	University	Awarded	A. Lewandowski
	University of Ariz.	Composite membrane materials	78.8	5/86	University	Completed	M. Murphy
	ENTECH, Inc.	Refractive concentrator eval.	45.0	3/86	Industry (S.B.*)	Completed	M. Murphy
	Dan Ka	Stretched Membrane Analysis	25.0	9/86	Industry (S.B.*)	Completed	M. Murphy
3.	SPECO	Receiver concept analysis	28.5	4/86	Industry (S.B.*)	Completed	M. Murphy
	GIT	ACTF experimental research	895.0	12/85	University	Completed	G. Nix
	Ind. Welding Supply	Salt test loop fabrication	252.0	10/85	Industry	Completed	M. Carasso
	Univ. of Houston	University research	350.0	1/86	University	Completed	G. Nix
4.	Hughes Aircraft	TECH research	221.7	7/86	Industry	Completed	G. Nix
	Univ. of Arkansas	Specific heat of gases	50.0	4/87	University	Awarded	R. Hewett
5.	U. of New Hampshire	Solar photochemical research	56.0	3/86	University	Completed	G. Nix
	Lawrence Berk. Lab.	Direct flux research	32.6	6/86	Fed. Lab.	Completed	G. Nix
	Univ. of Hawaii	Direct flux research	74.7	6/86	University	Completed	G. Nix
7.	Univ. of Arizona	Spectral splitters	69.5	8/86	University	Completed	G. Nix
	Hughes Aircraft	Spectral shift (Welsbach Effect)	58.9	3/86	Industry	Completed	G. Nix
	Univ. of Chicago	Terminal concentrator research	77.1	2/86	University	Completed	G. Nix

*S.B. - Small business

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.	Acurex	Front surface mirror	20	5/87	Industry	Awarded	G. Gross
	I. Susemihl	Post-doc. at SERI	40	3/87	Industry	Awarded	P. Schissel
	TBD	Post-doc. at SERI	50	3/88	Industry	Planned	P. Schissel
	Dr. P. Gomez	Post-doc. at SERI	40	1/87	University	Awarded	P. Schissel
	Dr. P. Gomez	Post-doc. at SERI	40	1/88	University	Planned	P. Schissel
	TBD	Polymer research	210#	8/87	Ind./Univ.	Planned	P. Schissel
	GTRI	Receiver materials prop.	150	12/86	University	Awarded	R. Pitts
	U. of Houston	Receiver materials prop.	90	12/86	University	Awarded	R. Pitts
2.	UA/SAI	Membranes-non-metallic	150	3/87	Ind./Univ.	Awarded	M. Murphy
	CSU	Wind studies	50	12/86	University	Awarded	M. Murphy
	U. of Nebraska	Structural evaluation	20	9/87	University	Awarded	M. Murphy
	Acurex	Holographic concept	160	3/87	Industry	Awarded	R. Wood
3.	GTRI	ACTF operations	265	12/86	University	Awarded	G. Nix
	GTRI	Temp. measurements	45	12/86	University	Awarded	T. Wendelin
	JAC Construction	DAR test station setup	30	5/86	Industry	Awarded	M. Bohn
4.	Hughes	TECH conversion	350	TBD	Industry	In Negotiations	G. Nix
5.	TBD	Solar beneficial phenomena	98	TBD	Univ. (multiple)	Planned	B. Gupta
	U. of Houston	Solar beneficial research	235	1/87	Univ.	Awarded	G. Nix
	TBD	Solar beneficial research	100	TBD	Univ. (multiple)	Planned	B. Gupta
	U. of New Hampshire	Photochemical research	43	3/87	University	Awarded	R. Hewett
	U. of Dayton	Photochemical research	100	2/88	University	Awarded	G. Nix

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

Task No.	Subcontractor	Subcontract Title/Activity	Value (000$)	End Dates	Type Business	Status	Technical Monitor
7.	GTRI	Materials research	340	12/86	University	Awarded	G. Gross
	U. of Chicago	Secondary concentrator	75	3/87	University	Awarded	A. Lewandowski
	U. of CA, Berkeley	Composite membranes	293.6	8/89	University	Awarded	B. Gupta
	U. of Chicago	High flux concentration	150	8/88	University	Awarded	B. Gupta
	TBD	New Concepts Research	70		University	Planned	B. Gupta
	ENTECH	Total internal reflector	30	4/87	Industry (S.B.*)	Awarded	R. Hewett
TPI	Battelle Pacific Northwest Laboratory	TPI planning and assessment 2nd bowl systems study	300	2/87	National Lab.	Awarded	R. Hewett

*S.B. - Small Business

- 70K from FY85 funding planned for U. of Akron continuation

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

COMPLETED IN FISCAL YEAR 1986

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Gupta, B. P.; Geyer, M. (1986). "Workshop Report; Current Status and Future Needs in Solar Thermal Power Systems." Intersol 85: Proceedings of the Ninth Biennial Congress of the International Solar Energy Society; Montreal, Canada; 23-29 June 1985, Bilgen, E., Hollands, K. G. T., eds. New York: Pergamon Press, Vol. 4, pp. 2617-2619. Work performed by Solar Energy Research Institute, Golden, Colorado and DFVLR, FRG.

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Harris, H. H., *Review of Interactions of Large Solar Fluxes with Materials.* SERI/SP-255-3046. Golden, Colorado: Solar Energy Research Institute.

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Lewandowski, A. A. *Assessment of the Potential Benefits of Secondaries in Point Focus Concentrators.* Golden, Colorado: Solar Energy Research Institute.

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SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

COMPLETED IN FISCAL YEAR 1987

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SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

IN PROGRESS

Althof, J., R. Copeland, Lazaridis, A., (In Progress) *Temperature Distribution in a Solar Irradiated Liquid Layer Flowing Over a Wall of an Optical Cavity.* SERI/TR-252-2221. Golden, Colorado: Solar Energy Research Institute.

Bohn, M. S. (In Progress) *Experimental Investigation of the Direct Absorption Receiver Concept.* SERI/TP-252-2974. Golden Colorado: Solar Energy Research Institute.

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APPENDIX E

SCIENTIFIC MEETINGS AND PRESENTATIONS

SCIENTIFIC MEETINGS AND PRESENTATIONS

A representative of Luz Engineering company visited SERI's Materials Research Branch and discussed silver/polymer mirrors. J. L. Chevalier from the Centre Scientifique et Technique du Batiment visited the Materials Research Branch. Dr. D. Alpert of Sandia, Albuquerque, also visited the Materials Research Branch to discuss cleaning of silver/polymer mirrors. Dr. J. Idle from the Ashland Chemical Company visited the Materials Research Branch to discuss common research interests.

SERI's Molten Salt Laboratory was visited by Dr. Francis Yguel and Dr. Patrick LeQuere of France. Both are funded by CNRS and work on solar technologies. Dr. LeQuere worked with Professor Humphries at Berkeley on the problem of cavity convective loss. Also visiting the laboratory was Ken Friedman, Special Assistant to the Deputy Assistant Secretary for Conservation. He was primarily interested in SERI's Research capabilities in molten salt heat exchangers.

M. Carasso of SERI attended the "Tube Life Consideration Workshop" on December 4, 1986, at Sandia, Albuquerque (SNLA). The purpose of the workshop was to assure that all realize that new fatigue data obtained by SNLA will make the old procedure inappropriate, and to solicit ideas for design procedures that are consistent with the new data. In the workshop, a modified design method was proposed as a first attempt to take into account the new fatigue data. It is agreed that a new stress versus number-of-cycles curve has to be established so that designers and manufacturers can proceed with confidence.

K. Y. Wang chaired the session on "Convective Heat Transfer in Solar Energy Systems" at the ASME Winter Annual Meeting in Anaheim, California, on December 9, 1986. Three papers, two regarding energy loss from a cavity receiver and one about energy transport between rooms through door or windows, were presented.

H. Neidlinger presented ideas on materials Research for desiccants to a visiting representative of the Gas Research Institute.

H. Neidlinger presented an overview to the 3M Corporation on the Materials Research Branch's studies on photochromic and thermochromic films.

Researchers working on photodegradation of materials traveled to Wycon Chemical Company in Cheyenne, Wyoming, to observe an operating ammonia synthesis plant and to gain insight into the interrelated processes carried out during production of nitrate salts.

C. Fields and R. Pitts visited Sandia National Laboratories, Albuquerque (SNLA), on November 13 to investigate the use of the parabolic dish concentrators and the solar furnace for materials exposure.

The following individuals from West Germany visited the Materials Research Branch: J. Memming of Phillips Research Laboratories, Hamburg; M. Molitz of Flabeg, Fuerth; P. Schlotter of Fraunhofer Gessellschaft, Freiburg; M. Becker of DFVLR, Koeln; and R. Koehne and K. Erdhardt of DFVLR, Stuttgart.

Discussions were held with representatives of Coors Company (Golden, Colorado) concerning mutually interesting problems in polymer research.

Six staff members of Sandia, Albuquerque, (J. Holmes, C. Tyner, J. Chavez, B. Couch, D. Johnson, and G. Kol) toured the DAR laboratory at SERI to observe the salt film and the long-film experiments. They visited SERI to discuss mutual progress on DAR research and development.

Three DFVLR staff members (M. Becker, R. Koehne, and K. Erdhardt) visited the DAR laboratory as part of a meeting of the International Energy Agency (IEA), Task 3, at SERI. They are responsible for solid-particle DAR Research at DFVLR.

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