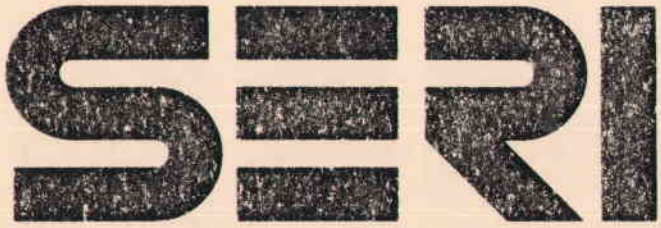
SERI/MR-251-1471 First Quarter, FY 1986

Solar Thermal Energy Program

Quarterly Progress Report

Issued January, 1986



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A Division of Midwest Research Institute

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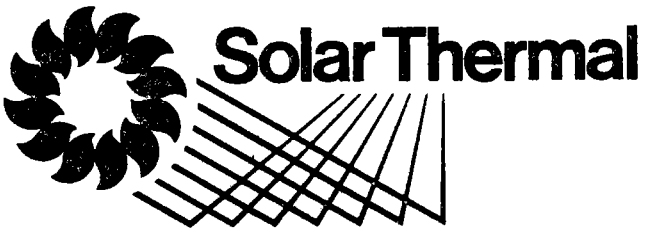

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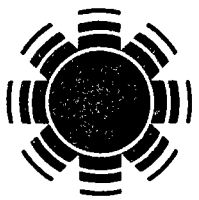

SERI

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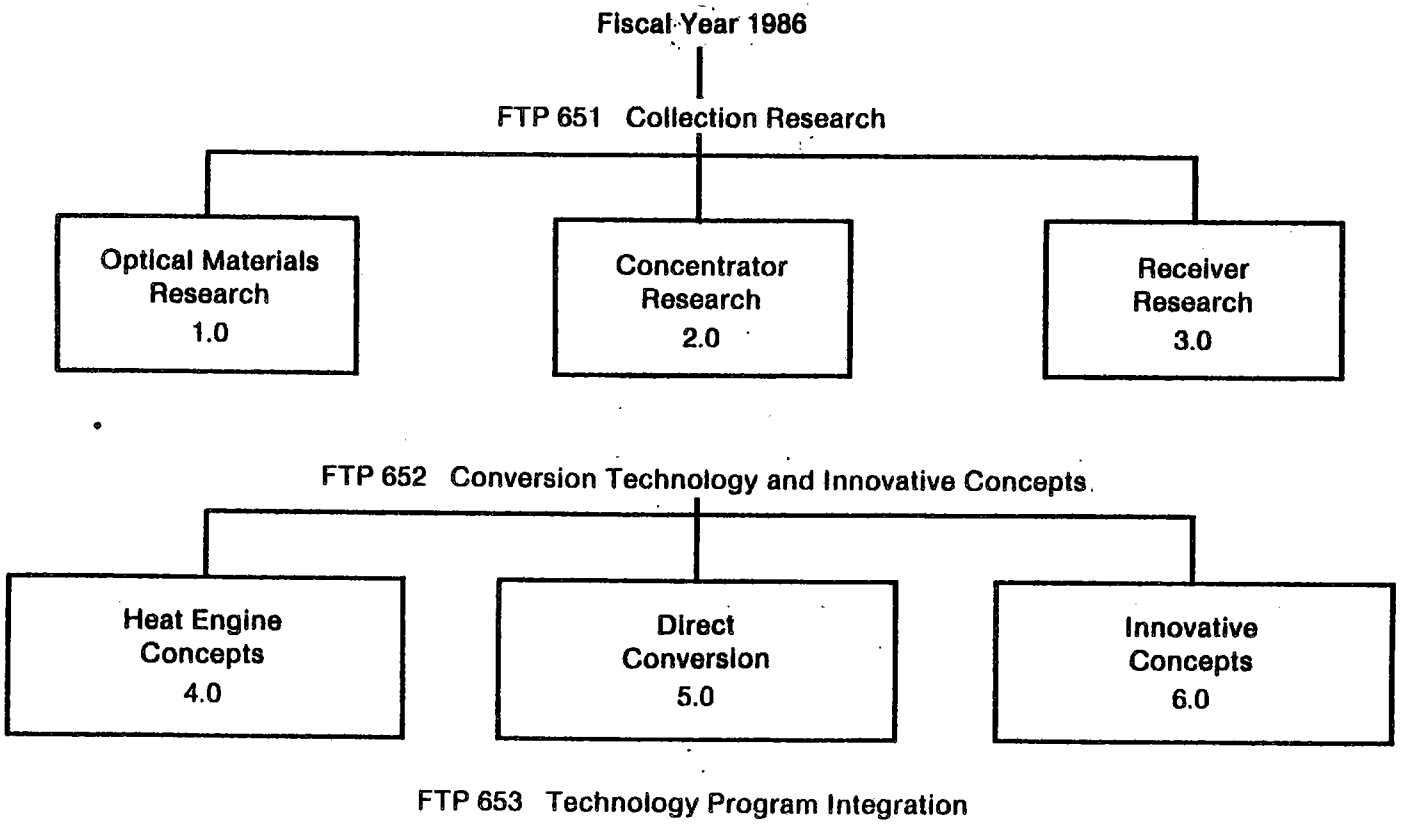

SOLAR THERMAL RESEARCH

FIRST QUARTER FY 1986 ACCOMPLISHMENTS

(DOE PROGRAM MILESTONE NUMBERS)

	Planned	Actual	Reference Page Number
Direct absorption receiver concept feasibility (12)	November 1985	November 1985	32
Issue (LOI) Request for Proposals for Enhanced University Participation in FY 1986	November 1985	November 1985	41

SOLAR THERMAL RESEARCH

FIRST QUATER FY 1986

OTHER SIGNIFICANT ACCOMPLISHMENTS (SERI AOP Milestone No. --FY 1985)

	Planned	Actual	Reference Page Number
Fresnel Lens Concept Assessment (F)	November 1985	November 1985	27
Silver/polymer film useful service life prediction (O)	December 1985	December 1985	21
New, innovative concentrator concepts assessment (R)	November 1985	November 1985	26
Recommend innovative concepts that merit continued research into Phase II (T)	October 1985	October 1985	41

SOLAR THERMAL RESEARCH

SECOND QUARTER FY 1986 PLANNED ACTIVITIES

	Planned
Stable polymer/silver film with reflectanct greater than 90% and specularity consistent with long-term goal	January 1986
Complete selection for awards of research contracts (LOI)	March 1986

TECHNICAL ACCOMPLISHMENTS—SUMMARY

TECHNICAL ACCOMPLISHMENTS

TASK 1.0 OPTICAL MATERIALS RESEARCH

Silver/Polymer Research

Alternate Reflector Concepts

Properties of Receiver Materials

Photodegradation of Materials

TASK 2.0 CONCENTRATOR RESEARCH

TASK 3.0 RECEIVER RESEARCH

Direct Absorption Receiver Research

Systems Analysis Studies

TASK 4.0 HEAT ENGINE CONCEPTS

	Reference Page
o Electrochemical tests indicate that a high degree of discharge should be feasible for the TECH converter.	35
o Thermal regenerator tests indicate complex phase behavior, but no "showstoppers" were observed.	35

TASK 5.0 DIRECT CONVERSION

University of Houston

University of Dayton

University of Hawaii

TASK 6.0 INNOVATIVE CONCEPTS AND APPLICATIONS

TECHNICAL ACCOMPLISHMENTS—DESCRIPTIVE DETAIL

FTP 651 COLLECTION RESEARCH

TASK 1.0 OPTICAL MATERIALS RESEARCH

OBJECTIVES

Research on Optical Materials involves study in the following areas: 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 high-specularity performance requirements 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 that maintains this optical performance for at least five years. The objective of research in **Alternate 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 include the UV stabilization of silver/polymer films; a weather stable, silvered stainless steel reflector with specular reflectance of over 90 percent in 4 mr half angle cone; a stable, blackened nitrate salt that can absorb some 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

- The specular reflectometer was designed and built with capability of accurate measurements below 1 mrad.

  A new specular reflectometer has been designed and built by I. Susemihl, a visiting professional from Germany. This effort was aided by consultation with Dr. R.B. Pettit of Sandia and has resulted in a versatile, precise, and accurate instrument to determine specularity and specular reflectance of silvered polymer both in a supported and in a stretched film configuration. Measurements are now made routinely below 1 mrad.

- SERI testing suggests that silvered/polymer has initial specularity of 1 to 2 mrad both as stretched film and mounted on a smooth (glass finish) substrate.

  Measurements using the new reflectometer have been completed on the 32 samples that the 3M Company has supplied. The purpose of these measurements is to define those factors that limit the initial specularity of silvered polymer mirrors.

  First, the input beam is defined. Figure 1 (page 23) shows the high quality of the beam, 0.16 mrad. The beam spread from mirrors is measured in the plane defined by the incident beam direction and the normal to the average surface of the mirror with use of a twenty-degree angle of incidence and 630 nm wavelength. Scattering of the plane of incidence can be determined by observing or photographing the two-dimensional image of the beam (or by rotating the mirror 90°). The beam spread (for example, 0.16 mrad, Figure 1) is estimated by assuming the beam has a Gaussian distribution and by determining the angles at which the beam has decreased to about 13 percent of its value at the maximum (the 95 percent point--assuming a one-dimensional Gaussian distribution). The assumption of a Gaussian distribution appears good for the input beam but is not as good for some polymer mirrors. An alternate procedure with circular rather than slit apertures is also being developed.

  Ten samples of ECP 300, Lot 7, were mounted onto glass substrates. Glass was used to define performance on an optically excellent substrate. Even the poorest sample has a spread of only 1.25 mrad. This spread is large in comparison to the input beam, but yet satisfactory for all solar thermal concentrators .

- Testing results show that the substrate smoothness and finish are now principal limitations of initial specularity.

  The same type of samples (ECP 300, Lot 7) mounted onto aluminum are quite variable and distinctly poorer than those mounted onto glass. Data taken to date where the film was mounted onto aluminum sheets 0.060" thick show the best to be 4.0 mrad and the worst to be 10.3 mrad. This points out the need for increased attention to the substrate condition, now that film itself has acheived good specular reflectance.

- Silvered polymer materials (ECL 300) altered in response to the observed blister formation of ECP 300X are not blistering.

  Mirrors with (ECP 300 Lot 7) film on glass and other substrates are being weathered in the QUV accelerated weathering chamber and outdoors. After two weeks exposure in QUV, no discernable change in specularity has yet occurred. Even this short exposure time is significant because it is this test that caused blister formation (total loss of specularity) in less than eight weeks for the ECP 300X material, the experimental material which did not have the UV protection later included by 3M Company in the ECP 300, Lot 7, material.

  Blister formation is now a secondary issue; the more important issue is a slow loss of specularity that is not detected visually but is measurable with the new reflectometer. Specifically, there is no evidence yet of blister formation in accelerated tests of ECP 300, Lot 7; ECP 300, Lot 7, has performed well for over one year outdoors in Minnesota.

  The visual inspection of ECP 300X during long-term outdoor tests is continuing even though optical measurements are precluded because of blistering. SERI researchers

observed that the silver remains bright and thereby proves that the polymer film can prevent corrosion of the silver for long-term (78 weeks and continuing) exposures outdoors.

o Copolymerization of stabilizers is possible, and stabilizers can be maintained in the host polymer.

SERI researchers have demonstrated that stabilizers added to the polymer are essential for protecting silver mirrors. The long-term (five-year) stability of silvered polymers may depend upon the stability of the stabilizers. One approach is to bond the stabilizers to the polymer. Two types of stabilizers (ultraviolet screens and hindered amines) are under study. The first is under study because they are shown to be very effective. The hindered amines are under study because they do not rely on absorbing ultraviolet light and, therefore, can improve mirror performance. The latter have also been shown to be effective. The chemistry of the copolymerization of each type stabilizer with methylmethacrylate has been demonstrated, and weathering and mechanistic studies are being conducted.

Alternate Reflector Concepts

o Staff completed the information search on metal substrates for front surface reflectors.

A search for information on metal stocks to use as mirror substrates was aided by a subcontract at the Colorado School of Mines. It was learned that stainless steel (400 series) can sustain an optically specular surface sufficiently perfect for use in laser mirrors. Such surface preparation is costly beyond any solar economic limit. The result proves that surface perfection is not inherently limited in such materials. Industrial sheet and strip stocks are available with finishes that produce about 85 percent specularity* (denotes surface characteristics only) in about 2 mr half angle.

o SERI scientists established practical limits of specularity for uncoated stainless steel with conventional finishes.

The practical finishing limits for commercial stainless steel strip stock are obtained in so-called "Bright Annealed" strips. This material is rolled to near-desired thickness. It is then descaled and annealed in an inert atmosphere. The final finish is provided by lightly cold-rolling the strip with diamond turned rolls. Results suggest that the turning pattern on the rolls may be a source of the observed wide-angle reflection of 15 percent.

o Staff members identified and assessed widely used industrial processes for leveling (planarizing) metal surfaces.

Industrial processes for leveling (planarizing) metal surfaces were discovered to be highly developed and widely used in the large-scale-integrated (LSI) circuit industry. The materials range from specialized polyimides to organic glass gels. Experiments in laboratories have shown that these materials do not quite achieve the surface quality needed, but they do provide the dielectric isolation needed to protect the silver from

* The reflectance of this material is much lower than that of silver so that specular reflectance is much less than 85 percent in 2 mr.

galvanic interaction with the stainless steel. Further refinements are being studied to improve the leveling qualities of the glasses and polymers.

Properties of Receiver Materials

o SERI staff summarized existing information to assess use of DAR test apparatus (Inconel 600) for molten nitrate salt tests.

Existing information on compatibility of Inconel 600® and molten sodium/potassium nitrate was used to determine that the present DAR test apparatus was suitable for use with draw salt (a sodium/potassium nitrate mixture). Little information on this matter appears in literature data bases because there is little interest in Inconel 600® for nitrate salt use - the alloy is so much more expensive that others which serve as well. Tests made at Sandia, Livermore, support the conclusion of compatibility, but those results were not widely published. Since the interest has shifted for Fiscal Year 1986 to use nitrate salt as the working fluid for initial tests, this assessment was important before the existing test loop built with Inconcel 600® for carbonate salt tests could be used, as is, for the nitrate salt tests.

o Researchers analyzed test coupons and salt samples to establish low corrosion rates and to predict adequate test life for DAR test apparatus with molten carbonates to 900°C.

Analysis of Inconel 600® coupons from the DAR carbonate tests (at Georgia Tech Research Institute) showed only limited normal corrosion. The molten carbonate leached some chromium from grain boundaries, but the life prognosis for the test apparatus was quite long (well over a year) based on these results. It should be recalled that the design was for a test duration of about three months. Spectroscopic analyses of salt samples taken from the system after several days of testing in solar flux above 700°C showed very small traces of nickel, cobalt, and iron. The low amounts of these main constituents of Inconel 600® show that very little corrosion occurred - supporting the conclusions based on the test coupons.

o SERI scientist completed phase diagrams of sodium/barium carbonate and lithium/barium carbonate.

Phase diagrams of the systems of sodium/barium carbonate and lithium/barium carbonate were produced by differential thermal analysis. This work is very important in the development of new molten salt working fluids having a low melting point and higher working temperatures. Such working fluid with wide operating range in molten condition could eliminate the need for heat tracing and could allow higher-temperature operation beyond nitrate salts. Research has shown that the physical properties of many terniary (three compounds) mixtures can be predicted from binary (two compounds) material data. The phase diagrams reported here supercede and improve on previous work in this field.* The results will be used in calculating properties of terniary carbonates and will be tested for possible use in estimating properties of quaternary carbonates. If these efforts are successful, researchers will attempt to obtain similar results for nitrates. The work would have been done on nitrates first, but the program was emphasizing carbonates at the time the work started.

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* I.N. Belyaer and I. Sholokhovich, "Reciprocal System of Sodium and Barium Chlorides and Carbonates"; Sb. Statei Obshch. Khim.; Akad. Nauk SSSR 1, p. 134 (1953).

Photodegradation of Materials

o Staff assembled Proceedings of the High Flux Workshop and distributed the materials to authors for final revisions.

During this quarter, the subtask's effort has been minimal - consisting of literature searches and analysis and of preparation of proceedings for a workshop on high-flux effects. Most of the authors of the articles in the proceedings have reviewed their articles, and staff members plan to issue the Proceedings and a report on the status of high-flux effects research during the next quarter.

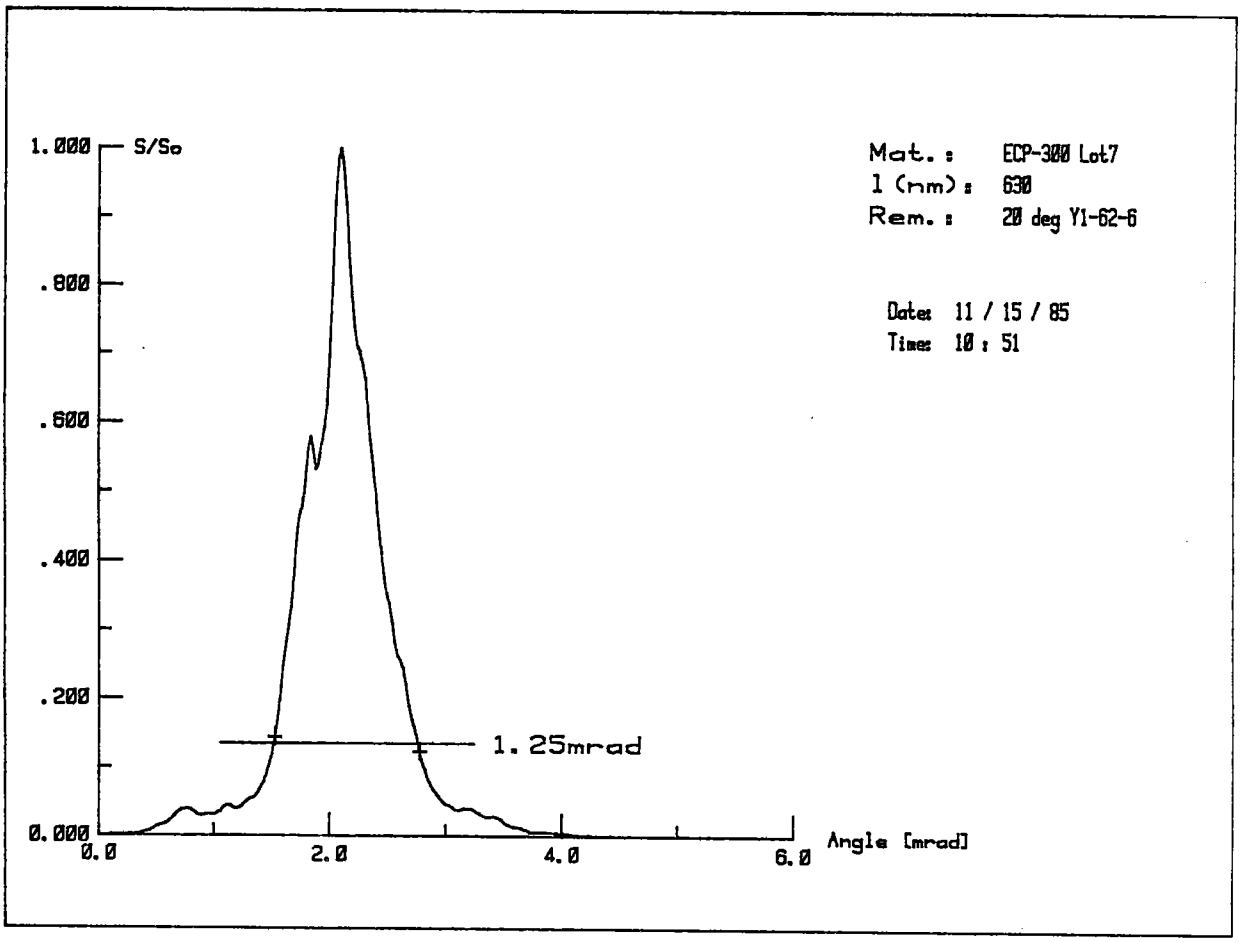


FIGURE 1

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 of 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 lowest, light-weight 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 departure from current reflector approaches and which may have the potential for 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 effectively to collect and to concentrate solar flux.

ACCOMPLISHMENTS

Membrane Concepts

o Optical and structural tests on the double-membrane, three-meter-diameter module were completed.

Staff conducted a new full complement of tests for the double-membrane, three-meter-diameter modules which include 16 loading conditions and the recording of 72 video frames of data. This retesting was required to resolve some problems associated with the earlier observed deformations in the large membrane. Data reduction was completed in December. The first draft of the letter report describing the findings has been completed, and reviewers' comments are being incorporated into the document. The letter report documents the good correlation with analysis; and, as expected, the double-membrane offers significant enhancement in stiffness to the system.

o Membrane flutter tests in the wind tunnel at Colorado State University, Ft. Collins, Colorado, have been initiated.

Colorado State University began the evaluation of the wind tunnel model for the flutter tests of the double-stretched membrane module (0.6 meters in diameter). No definitive results have been obtained to date. SERI delivered the first scale model

(0.6 meters in diameter) of a ten-meter dual membrane heliostat to researchers at Colorado State University. In preliminary tests, they found the model to be very sensitive to the supports. Because of the low membrane tension of only one pound per inch, any slight deformation of the ring caused marked non-uniformity of tension in the membranes and changed the natural frequencies and probably the modes of vibration. Higher tension and weaker (thinner or less stiff) membranes should alleviate this problem, but the resulting higher frequencies will be farther from the area of interest when the results are scaled back to the full, ten-meter size.

- o SERI staff continued to support the stretched membrane contract at Sandia National Laboratories, Livermore, California.

SERI staff supported the SAI and SKI contract reviews held by Sandia National Laboratories at Livermore, and SERI provided comments and recommendations on the design. An assessment of a potential problem in rear membrane failure was carried out. Specifically staff completed the analysis of the large membrane deformation of the rear membranes under loading from fifty-mile-per-hour winds for each commercial and prototype design. Because of the control scheme, the rear membrane may take most of the wind load, and calculations confirmed that a potential problem may exist under certain conditions. The calculations, which have been forwarded to C. Mavis at Sandia, Livermore, showed a peak amplification of the initial prestress in the membrane of more than a factor of 3.7 for the worst condition.

New Concepts Evaluation

- o Recommendations on future research on new concepts have been formulated and submitted to DOE.

Summary assessments on each of several research projects on concentrators have been completed. Research projects summarized include those on the spiral concentrator, the holographic concentrator, the conical concentrator, the inflatable drive system, the Fresnel concentrator, and the composite material activity. Each summary includes the major accomplishments to date, the advantages and disadvantages of each concept, the major cost and performance, the technical findings, and the recommendations for future research based on the current results. On several of the elements in concentrator research, staff completed extensive documentation of the technology evaluations and systems assessments. The summary document has been forwarded to the DOE.

- o Acurex researchers have completed the initial laboratory research and assessment of holographic concentrators.

Acurex Solar Corporation developed cost data to show that both line-focus and point-focus holographic concentrators have the potential to be cost-effective in comparison to standard trough technology. Acurex performed a cost assessment that indicated that line-focus holographic concentrators will be cost-effective when the reflection efficiency exceeds about 71 percent in comparison to a conventional collector with a reflectivity of 94 percent. Acurex also thinks that point-focus holographic concentrators will be cost-effective, in comparison to current dish technology, when the reflectance efficiency exceeds about 63 percent in comparison to a conventional collector with an efficiency of 92 percent. Earlier it had appeared that the product of efficiency and concentration ratio was a constant, and this result would make the

required point-focus application impractical because the typically required high concentration would result in an unacceptably low efficiency for the holographic stack. However, Acurex researchers have shown that the high-efficiency concentrators can be configured from holographic mosaics if each part of the mosaic is at a low-concentration ratio and high efficiency. The geometric configuration is applicable to both line-focus and point-focus collectors. Acurex researchers also are working to answer the challenge of defining how to make high-efficiency, broad-response holograms that can be stacked to obtain a high optical efficiency across the solar spectrum. Acurex researchers have achieved 43 percent with an unoptimized stack of two grams; the intermediate target will show promise of concept. They surmise that the overall goal of 85 percent is achievable in the long term for cost-effectiveness. SERI is in the process of assessing these findings.

- The assessment of linear Fresnel concentrators for thermal applications has been completed.

  As part of this effort, SERI researchers developed performance algorithms for Fresnel lens concentrators and incorporated these elements into the existing SOLIPH system performance computer model. They also defined two typical applications (100°C and 200°C) industrial process heat (IPH) for comparisons by using the SOLIPH model, and they developed detailed cost estimates for both Fresnel lens and concentrator systems. Researchers conducted comparisons of system performance for three different geographical locations with state-of-the-art PTC systems that have collectors of the Acurex design. Results in research indicate that for both applications (100°C and 200°C) the Fresnel lens concentrators have more solar energy available in the two-axis tracking than in the single-axis tracking of the PTC. For the low-temperature, hot-water application, the total amount of energy collected by the Fresnel lens and supplied to the load is also somewhat greater (about 6 percent), despite the larger system losses. For the steam application, the energy collected by the Fresnel lens concentrators is also greater than the PTC; however, higher system losses result in approximately the same energy delivery as the PTC system. This comparison assumes both continuous loads and 100 percent availability of the solar systems. Cost estimates show that a Fresnel thermal system may cost about 20 percent less than a state-of-the-art PTC system ($242 per square meter compared to $309 per square meter), and they result in as much as 26 percent decrease in the cost of delivered energy ($7.98/GJ for the Fresnel compared to $10.72/GJ for the PTC), and thus meet the MYPP cost goals for energy. These cost reductions accrue primarily from the dramatically lower estimated Fresnel collector component costs ($60 per square meter compared to $140 per square meter for PTC).

- An initial assessment of cost and performance of conical concentrators has been completed.

  SERI researchers developed and implemented a systems-level assessment to compare the cost-performance potential of conical concentrators to parabolic trough concentrators (for thermal applications) and to parabolic dish concentrators (for thermal and electric applications). In support of the system-level assessment, they developed models for thermal and optical performance applicable to a variety of designs of conical concentrator modules and configurations of receivers for the collector. Staff compared these designs to more detailed SOLIPH models and found agreement. In addition, to more fully understand the issues of fabrication and performance in the concept, they fabricated three prototypes of reflector modules (0.6 meters in diameter) with mock receivers and verified, on a small scale, that good optical performance should be attainable.

Analysis indicates that the concept potentially offers thermal performance levels that are better than those for trough systems but less than those for the best point-focused dish systems. From a practical perspective, the system is limited to an upper temperature of about 500°C. Researchers found that the costs of conical concentrators (including drive costs) are approximately half as much as advanced parabolic dish collectors per square meter ($68 to $98 per square meter compared to $212 per square meter). They also found that although the thermal performance of the conical concentrator is lower than that of a parabolic dish at 400°C, the levelized thermal energy cost of a conical collector ($5.27 to $6.46 per GJ) is comparable to that of the advanced dish ($6.64 per GJ) due to the conical concentrator's significantly lower cost. For electric generation, if a receiver-mounted ORC engine is used with the conical concentrator, staff estimated that the delivered energy costs could be in the range of $0.041 to $0.069 per kWh--depending on the assumed cost of the engine. An advanced dish/Stirling engine (based on long-term program goals) will produce electrical energy at a cost of $0.051 per kWh. The energy cost of $0.041 per kWh corresponds to an engine cost of $312 per kW, which was assumed for the advanced dish Stirling system. If, on the other hand, researchers consider a central ORC engine for both systems ($395 pr kW for the engine) and the best dish cost today (based on Lajet which has the lowest dish cost) the levelized energy cost is $0.063 to $0.068 per kWh and $0.067 per kWh for the cone and dish systems.

To further assess the value of the conical concentrator concept, SERI received three bench-scale modules of membrane conical concentrators from SERI's subcontractor, Industrial Solar Technology (IST). One ninety-degree conical concentrator module, a forty-five-degree module with a support ring, and a forty-five-degree conical module without a support ring were fabricated. Of the three models fabricated, the last module appears (based on visual observations) to have the best optical performance and is also the lightest weight of the three. This lightness can be attributed to the absence of the structural ring at the aperture which, when present, introduced surface distortions presumably caused by a noncircular shape. In addition, the weight of the ring was a substantial fraction in the overall weight of the module. A letter report summarizing the fabrication has also been received. The report includes an engineering and materials assessment for components of an inflated conical concentrator such as the reflective film, the transparent film, and adhesives for the seam between the cover and the reflector. The report concludes with recommendations for future work. Elements of this contractor report will be included in the analysis report on conical concentrator systems.

- An initial assessment of cost and performance of the air-inflated heliostat support and drive has been completed.

SERI staff formulated a systems analysis and carried out a study to compare the cost and performance of a new inflatable-drive support system as an alternative to the existing drive and various frame support elements on current heliostats. They also completed an initial cost estimate for full-scale prototypes to support the system study and performed structural analysis of the cable linkage system to estimate the accuracy in pointing and tracking that might be obtained with such a system. Analysis shows a cost for the drive support system of approximately $41 per square meter for this particular system, whereas the comparable cost for the corresponding subelements in the Arco heliostat (150 square meters) is approximately $94 per square meter (a savings of $52 per square meter). Thus, the potential for significant savings in cost appears to exist. Further, sensitivity analyses have shown that the drive and support can be less accurate than the current drive concepts and still can result in significant

cost savings. Thus, for a typical total system costing $300 per square meter, the new drive, if it had twice the tracking error of the current drive, would still result in an effective savings of $30 per square meter in system cost. Though the current analysis does not show significant degradation in performance, it is not sufficiently detailed to provide an accurate estimate of the true capability in performance of the concept. Because of the very complex non-linear load and motion response of the inflatable-bellows support sleeve, evaluation of the performance capability will require experimentation.

- o The initial phase of the analysis and testing of the wind load reduction at Colorado State University has been completed and documented in a draft report.

The focus of the research has been on identifying and characterizing approaches for potentially cost-effective wind load reduction--including those which utilize porous and solid fences and berms within the heliostat field as well as the use of spoilers mounted on the heliostats. A draft report on the findings has been completed by Colorado State University.

Study results for heliostat fields have shown that a significant potential to reduce the loading on heliostats exists, and that mean wind loads decrease with increased distance into the field, increased field density, and addition of a solid or porous fence upwind from the particular heliostat of concern. Furthermore, the mean-load reduction can be predicted from the upwind blockage per unit ground area by using a simple correlation permitting significant flexibility in optimizing the field design (a particular concern to the designer). Moreover, researchers found that peak mean wind loads on heliostats within the Barstow field are less than 30 percent of the loads on unprotected edge units. In addition, with properly designed fences or berms, the loads on the edge units can be reduced to about 30 percent of the loads on unprotected heliostats. Also, they developed a more accurate load-prediction based on the peak dynamic loads rather than on the current approach which utilizes the constant mean load multiplied by a gust factor to determine the required design load for the collectors. Furthermore, limited investigations did not establish the need for, or the potential benefits of, on-heliostat spoilers, either for the reduction of mean loads or for dynamic loads on the concentrators.

High-Flux Optics

- o An assessment of requirements for polymer mirror stacks (reflector film and substrates) has begun.

SERI researchers have initiated some sensitivity studies of the major optical performance parameters of central receiver concentrators and heliostat fields. They are looking at the various sensitivities to put the requirements on specularity for the optical materials in perspective and also to gain a better understanding of possible problems that may arise for "off-design-point" operation as well as for long-term energy delivery. A specific item in this regard is the sensitivity of system performance with respect to the sunshape dispersion assumed in the annual calculations. The sunshape can vary dramatically--depending on the time of year, the location, and the immediate local weather conditions. Design that is too small for sunshape dispersion may be one factor which will lead to significant off-design-point performance degradations. Some preliminary recommendations on specularity requirements have been generated for internal review based on these initial analyses.

PROGRESS IN OTHER AREAS

SERI received the final letter report on the fabrication of the three-meter-diameter test modules from Dan-Ka Products. This represented the Company's last deliverable under that fabricating contract. The report includes important conclusions and suggestions regarding the construction of future large, stretched-membrane modules. This information will be forwarded to Sandia, Livermore, and to Sandia's subcontractors.

Contract work statements for composite evaluations for both dish and heliostat applications have been drafted. Large deformation analysis of membrane for dish applications has begun. Staff coordinated the solicitation, evaluation, and preparation of papers for three sessions at the upcoming solar division conference of ASME in Anaheim, California.

PLANNED ACTIVITIES FOR THE NEXT REPORTING PERIOD

The assembly of the laboratory equipment for the experimental assessment of the optical quality of polymer film mirror stacks will be initiated in SERI's Field Test Laboratory Building.

The analysis of the structural and optical response of the concepts for stretched membrane dishes will be initiated. Limits on the applicability of elastic deformation design will be studied first. The contract with the University of Arizona for composite membranes of dishes and the contact with SAI for the prototype of the two-meter-diameter stretched membrane dish will be finalized and negotiated, and work will begin. The membrane flutter tests in the wind tunnel at Colorado State University will be completed, and a preliminary draft letter report of the findings will be completed.

Acurex has submitted a proposal which is currently being evaluated for continued research on higher efficiency reflector configurations. Work on the next phase of the Acurex holographic concentrator work will be initiated, subsequent to agreement on an appropriate work statement.

The external peer review of the Fresnel study will be completed, and the internal review of the letter reports on the analysis of inflated drive and double membrane testing will be completed. The external reviewers' comments on the report on wind load reduction by Colorado State University will be incorporated into the document, and the final signatures for publication will be initiated. The internal review of the letter report on the results of testing and analysis corresponding to the three-meter-diameter double membrane will be completed, and the final version will be transmitted to Sandia, Livermore, and Sandia's contractors.

TASK 3.0 RECEIVER RESEARCH

OBJECTIVES

Research on receivers for fiscal year 1986 consists of the following Tasks: direct absorption research; receiver concepts analysis; and instrumentation and measurement. The objective of the **Direct Absorption Receiver Research** is to develop an in-depth understanding of the major technical issues associated with the direct absorption receiver concept 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 temperature use. The major objectives of **Receiver Concepts Analysis** are to study the feasibility of the direct absorption receiver (DAR) concept from a systems perspective, to determine the technical barriers, and to identify the research needed to support the eventual development and 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

o All testing in the solar flux at the ACTF was completed. The test loop has been returned to SERI where research for fiscal year 1986 will be conducted.

All tests in the solar flux were conducted using the Advanced Components Test Facility (ACTF) at the Georgia Tech Research Institute.

Test conditions are summarized as follows:

Total days of test	7 (during October 25 - November 12, 1985)
Absorber effective size	6" width × 24" length
Salt inlet temperature range	500°C - 700°C
Maximum salt outlet temperature	750°C
Average flux range	0.15 - 0.60 MW/m^2
Flow rate range	3 - 9 gpm
Maximum ΔT salt outlet to inlet	40°C (20°C per foot of length)
Absorption: % plate/% salt	approximately 80/20

In order to establish concept feasibility the existence of demonstrable means of introducing the working fluid evenly into the flow channel, containment of the working fluid in the channel, flow distribution across the entire working surface exposed to the flux under a range of flow rates of interest, and flow rate control were evaluated during the tests. By experiments with various geometries, excellent flow distribution in the entrance region was demonstrated. Similarly, containment of the working fluid in the

channel proved to be a problem which was overcome by increasing the resistance to the strong surface tension of the salt. Flow rate control was obtained by use of valves and a variable speed pump. Both means exhibited reliable operation. While excellent wetting was observed over an exceedingly wide range of flow rates during isothermal (no-flux) tests, drying of one side of the channel occurred at flow rates below 6 gpm in the solar tests at the ACTF. As of this writing, researchers do not have a satisfactory explanation of this asymmetrical phenomenon. With the assumption that this is not an artifact of this experiment (worst case assumption), a number of receiver design options are available to accommodate this, namely: blackening the salt, a geometry whereby the minimum flow rate would be higher than 12 gpm per foot of width, roughening the surface by "spoilers," and others.

While it was not a specific objective of research and tests for the feasibility of the direct absorption concept to provide engineering information on the long-term stability and compatibility of materials nor on the reliability of major test equipment, no operational difficulties of any significance were observed. The pump and valves operated as specified. Measurements were made of the corrosion of Inconel coupons which had the same history of salt exposure as the absorber plate, and these revealed minimal effects. A test of the salt composition prior to melting revealed an unexpectedly high concentration of impurities. This resulted in a spreading of the theoretical melting temperature (theoretically a melting point) over a temperature range, judged to be inconsequential to the test.

Subsequent to the completion of these tests, the test loop has been returned to SERI. It will be installed in an especially designated area in the Field Test Laboratory Building (FTLB) and subsequent to its connection to the FTLB facilities will be used for addressing the research topics planned for fiscal year 1986.

- Analysis of test results and comparison with theoretical predictions has been completed to assess the technical feasibility of the DAR concept. The concept was found feasible based on test and analytical results.

During the reporting period, testing of the DAR concept in concentrated solar flux was begun and completed; the test results were analyzed and compared with theoretical predictions of the performance of the concepts; and an assessment of the technical feasibility of the DAR was performed. The test and analytical results confirm that the concept is technically feasible and merits further research.

What distinguishes direct absorption from other receiver concepts is its potential to avoid the technical limitations associated with exposing tubes to the concentrated solar flux by absorbing and removing the energy content of that flux by a working fluid. Thus, central to the assessment of the feasibility of the concept is the heat transfer performance. SERI researchers have studied the theoretical aspects and developed mathematical models which yielded predictions of the expected performance. Experimental results were consistent with these predictions.

- Overall film efficiencies, defined as the ratio between the energy removed by the working fluid divided by the energy impinging on the absorber, in the range of 85 percent to 90 percent were observed.

- The temperature differences between the back plate and the salt at the outlet were generally consistent with theoretical predictions of the convective heat transfer rate. However, more accurate understanding will be needed for flux densities higher than these tests at the ACTF (0.60 MW/m^2 maximum).

Theoretical studies based on existing literature indicated that one could expect a stable film over the range of flow velocities of interest. This was confirmed by test observations: no problem in stability was encountered. It is worth mentioning, however, that a review of the literature has revealed that films of water, flowing over longer channels (on the order of two meters long), have exhibited an amplification in the size of lateral waves. This was not observed in the test section, perhaps due to the short length (three feet total) of the channel. This will be examined deliberately in fiscal year 1986.

- The particle receiver work conducted at Sandia, Livermore, has been transferred to SERI.

A meeting was held at Sandia, Livermore, to review and to transfer to SERI the results of particle receiver work conducted at Sandia over a number of years. All published documentation was transferred, and a briefing followed by a question and answer period. Sandia Livermore has forwarded to SERI their thoughts of what research should be conducted if this concept is considered for further investigation in the program.

Systems Analysis Studies

- Work has begun in a subcontract to SPECO; the purpose is to develop a preliminary DAR configuration and cost estimate.

A Systems Analysis study of the DAR concept continued. The effort during the reporting period consisted in scoping and initiating a subcontracted effort aimed at obtaining a preliminary configuration of a DAR receiver providing the basis for a more accurate cost estimate than that available in the past.

A subcontract was awarded to Solar Power Electric Company (SPECO) of Denver, Colorado, to develop a preliminary configuration and a cost estimate of a 320 MW_{th} nitrate salt DAR for operation at a nominally 600°C outlet temperature. The subcontract effort began in mid-November with results expected in February.

A meeting was held at Sandia, Livermore, to review DAR experiments conducted there with the use of a darkened nitrate salt. Much useful information has resulted. This information was used in planning DAR testing in fiscal year 1986.

PROGRESS IN OTHER AREAS

The solar radiation stations installed at Bluefield State College and in the Dominican Republic are both fully operational. Data processing software and procedures are being completed, and monthly summaries are to be distributed thereafter. The station for solar insolation measurement at Monte Cristi, Dominican Republic, consists of a pyrheliometer and a solar tracker for direct beam measurements, a pyronometer for global horizontal measurements and a data acquisition system for recording five-minute and hourly averages and daily totals. Two engineers from the Dominican Electric Corporation, trained to operate the equipment by SERI, are providing printed records to the Institute for processing.

PLANNED ACTIVITIES FOR THE NEXT REPORTING PERIOD

During the second quarter of fiscal year 1986, the DAR Inconel test loop will be installed for operation in the FTLB. The loop will be drained of carbonate salt and will be loaded with nitrate salt. The test configuration will be finalized. In particular, the flux source will be designated, designed and fabricated. The absorber plate test section modified based on ACTF test results will be designed, fabricated, and mounted on the test loop. Based on results of investigation of radiative transfer properties, a bypass blackener stream may be added to the test loop during the laboratory tests.

It is anticipated that much of the work under subcontract to SPECO, to develop a preliminary DAR configuration and cost estimate, will have been completed during this period.

FTP 652 CONVERSION TECHNOLOGY, AND INNOVATIVE CONCEPTS

TASK 4.0 HEAT ENGINE CONCEPTS

OBJECTIVES

Research on Heat Engine Concepts consists of a single task--Thermoelectrochemical (TECH) Conversion Research. The objective of this activity is to continue the research initiated in fiscal year 1985 to define a TECH conversion concept, to demonstrate its technical feasibility, and to assess its cost and economic potential.

ACCOMPLISHMENTS

TECH is a conversion cycle where energy-rich chemicals are changed to electricity and energy-poor chemicals in an electrochemical converter. The energy-poor chemicals are changed back to the energy-rich chemicals in a solar thermal regenerator. Research centers on the two major components, the electrochemical converter and the thermal regenerator, and their interactions.

- o Electrochemical tests indicate that a high degree of discharge should be feasible for the TECH converter.

  A series of electrochemical measurements have been made to study the effects of electrolyte composition on cell voltage. Previous electrochemical tests, using acids of various compositions, have indicated that water content may have a strong influence on cell voltage. Voltage measurements were made relative to a saturated solution of dibasic electrolyte in water into which volatile electrolyte was bubbled. Nafion® was used as the separator, and hydrogen was bubbled over platinized Pt electrodes. Total pressure was kept at 1 atm. As the temperature increases, the partial pressure of water increases and forces out volatile electrolyte from the base solution, and thus reduces the voltage contribution of volatile electrolyte. The voltage with monomeric electrolyte drops from 0.61 V at 63°C to 0.18 V at 89°C. The voltage with dimeric electrolyte, however, remains nearly constant at 0.60 V. Tests with mixture #1 (1 part dimer, 2 parts dibasic electrolyte) show a decrease with temperature but at a much higher voltage than monomeric or dimeric electrolyte. Comparisons of dimeric and monomeric electrolyte show a strong voltage contribution from the more dehydrated acid. The higher voltages measured with mixture #1 may indicate an increase in electro-osmotic coefficient, indicating a greater flux of water through the membrane. Carnot limitations indicate that regeneration will require 50 Kcal/mole at 500°C to maintain the 1.23 V at 58°C. In general, researchers think that cell performance, though complicated, is as anticipated or even better.

- o Thermal regenerator tests indicate complex phase behavior, but no "showstoppers" were observed.

  Regenerator research has focused on continued acquisition of data for the thermal regeneration of monomeric electrolyte from dibasic electrolyte mixtures. Vapor pressures and composition have been measured for various mixtures which represent the composition range of spent battery electrolyte from which reaction enthalpies were calculated. A conversion test was also conducted. Results indicate a high degree of complexity in the electrolyte system. The electrolyte phase diagram and the compositions of the mixture tested for thermal regeneration were determined. The region

below the liquidus curve represents the approximate area of adequate fluidity at 150°C. All mixtures tested were liquid at 100°C both before and after testing and showed no tendency to crystallize, consistent with an anticipated operation.

Vapor pressure curves show similar overall characteristics for each curve, but significant variation with respect to vapor composition, and enthalpy. A pressure limitation of 175 psi prevented temperatures greater than 550°C from being investigated. Enthalpies per mole of gas ranged from 3.9 to 23.2 Kcal/mole and tended to increase with temperature and dimeric electrolyte content. Enthalpies per mole of volatile electrolyte had a larger variation, due to the wide range of volatile content in the vapor phase. Enthalpies from specific mixtures are compatible with the results of the higher voltage electrochemical tests performed earlier. These tests indicate that although the system is complicated, performance should be similar to expectations.

PROGRESS IN OTHER AREAS

Discussions are on-going between DOE-SAN and Hughes in an attempt to settle the question of ownership of intellectual property. This must be settled prior to continued funding. The current DOE/SERI contract with Hughes is nearing expiration.

PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

The intent in the next quarter is to complete the thermal regenerator for experiments, to draft and review the final report, and to cease all work until the intellectual property ownership question is settled or until a reasonable alternative course of action is determined by DOE and SERI.

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 photo-enhanced 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°-$500^{\circ}C$). 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

UNIVERSITY OF HOUSTON

o Solar beneficial enhancement of chemical reactions was observed in research on photo-assisted bond breaking.

W. Wentworth has constructed and operated a fluidized bed reactor to collect experimental data on solar-unique or beneficial effects for bond-breaking reactions. Systems investigated include decomposition of methanol and ethanol; dehydration of methanol, ethanol, 1-propanol, 2-propanol and isopropanol; and decomposition of acetone. Various catalysts and supports have been used and investigated in the small fluidized bed reactor illuminated with a xenon arc lamp. Results indicate a significant (10-100X) enhancement in rate for the methanol decomposition, with effects for other alcohols. This is thought to be a consequence of the rapid rate of heating, a solar-unique effect. It appears to be independent of wavelength; so it is not a quantum effect. Preliminary experiments with ethanol decomposition with chromium oxide catalyst on alumina indicates possible existence of a quantum effect. The experimental system is being refined to allow collection of more definitive data.

o Researchers made significant progress in fabricating an experimental reactor for photo-enhanced catalysis.

A proof-of-concept experiment with the methanation of synthesis gas (hydrogen and carbon monoxide) has shown a yield improvement of about two orders of magnitude over a corresponding thermal reaction. The catalyst was a cooled block of polycrystalline nickel. An experimental apparatus suitable for detailed data collection has been designed and is being fabricated. It is expected to be operational in March, with capability for in-situ surface analysis, control of catalyst characteristics, and mass spectrographic analysis. Simultaneously, an effort is underway to identify and to set priorities on reactions suitable for investigation. The results of this literature assessment should be available by March. This research is being coordinated with W. Wentworth at the University of Houston and A. Hunt at LBL.

o In chemical storage of energy, a classical thermodynamic model was developed to predict fusion temperature of complex salt mixtures.

Researchers at the University of Houston are investigating the Ammonium Hydrogen Sulfate (AHS) system for thermochemical energy storage. Researchers had earlier defined a system configuration which superimposes the AHS decomposition in a stream of circulating compatible molten salt (CMS) to give the combined system the best features of both sensible energy and thermochemical energy systems. Sulfur trioxide and ammonia-water streams are separated and stored for later reaction to release stored energy as heat and to reproduce the AHS. The key to making the concept work is the identification of a compatible molten salt. This research is nearing a critical point. The Principal Investigator, H.W. Prengle, has completed the development of a classical thermodynamic model to permit interpretation of laboratory data and projection of the minimum fusion temperature for salt mixtures of up to seven or more components. Laboratory experiments are underway to confirm the predicted performance. Sufficient data should be available in about one month to allow a technical assessment of the probability of making such a complicated system work in a cost-effective manner.

UNIVERSITY OF DAYTON

o Experiments have demonstrated that direct concentrated sunlight enhances destruction of toxic wastes.

Research on the solar detoxification of hazardous wastes has resulted in experiments which have shown a beneficial enhancement for every compound investigated. The implication is that this is a general effect and not a compound specific effect. Further, the applicability of the effect has been shown to increase with increasing temperature, since absorption of solar energy shifts toward the red. The data have validated a general photothermochemical model which predicts an exponential improvement with radiant intensity. This effect has been shown true up to 60 suns, the limit of the existing experimental equipment. It was hoped that the effect would be manifest as a lowering of the reaction temperature with no change in performance. The observed effect was smaller than hoped (up to 100°C decrease observed), but the significance is a substantial improvement in performance. At constant temperature, a waste which is destroyed to 99.99 percent destruction could be destroyed to 99.99999999 percent at about 1000 suns. The University of Dayton researchers are considering a pyrolytic process, starved for air, with direct flux. This would result in a substantially reduced investment in the plant, reduced operating costs, and enhanced performance.

UNIVERSITY OF HAWAII

o High flux solids decomposition experiments are underway to define beneficial effect on $ZnSO_4$ of high heating rates.

Hawaii researchers believe they are beginning to understand the mechanism of zinc sulfate decomposition. Slow heating results in formation of an oxysulfate intermediate followed by decomposition of the oxysulfate to sulfur trioxide and zinc oxide. The first reaction appears complicated with multiple pathways and intermediate products. The decomposition to final products appears relatively simple and straight forward. Researchers have confirmed previous observations by University of Houston researchers that there exist many unsuspected variables or effects, such as presence of

catalysts. If platinum is present, the sulfur trioxide tends readily to dissociate to sulfer dioxide and oxygen, with the effect of driving the decomposition reactions more rapidly to equilibrium. It appears that such effects are at least as important as the rate of heating.

Hawaii researchers are currently performing analyses to determine intermediate compounds and compositions. That data will be used to validate models for comparison of high-heating-rate data and low-heating-rate data. Experiments are being planned and performed to provide definitive high-heating-rate data. In addition, researchers are working to assess how these possible solar-specific effects can be used for solar beneficial conversions.

o New experiments were defined to show effects of trigger reactions.

Hawaii researchers continue to probe the use of trigger reactions to accomplish solar beneficial conversions. The concept is to use a small portion of the solar spectrum to improve beneficially the conversion of the balance of the solar spectrum. In preliminary experiments, at relatively low concentrators, Hawaii and SERI researchers showed the potential of increasing the length of a hydrocarbon chain while preserving a double bond. Houston researchers independently showed the same effect. Researchers at both institutions are collecting data to understand the chemical mechanisms and to provide the basis of an assessment of whether this phenomenon provides the basis for practical conversion processes.

PROGRESS IN OTHER AREAS

UNIVERSITY OF NEW HAMPSHIRE

Researchers at the University of New Hampshire have made progress in experimental research to understand photochemical production of an intermediate chemical in caprolactam production. Behavior has been shown to be as described in the literature, with observed yields higher than anticipated. This reaction is thought to be typical of a large class of reactions available to production via solar thermal driver conversion. Researchers are performing a literature survey to identify other chemicals suitable for this type of process. Earlier assessment had indicated the potential for cost effectiveness.

LBL RESEARCH

Researchers at LBL have submitted a report on their general assessment of high-flux-solid reactions. They break reactions into classes including solids decompositions, gas-solid reactions, and catalytic reactions. They think that catalytic reactions represent one of the better opportunities. Their reports are in review, and the information is being shared with other researchers with similar interests, such as the University of Houston and the University of Hawaii.

TASK 6.0 INNOVATIVE CONCEPTS AND APPLICATIONS

OBJECTIVES

The objectives of this Task are to encourage and harvest new 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 include: (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 assessed promise of ongoing research projects on innovative concepts.

Four projects were under way and reached the stage where their merit for further research could be evaluated. One at Southern Research Institute aimed at developing Front Surface Mirror Protection. Using the Langmuir-Blodjett film showed sufficient promise to consider continued support. The films showed that silver stayed protected for one month even under exposure to a harsh moist sulphur environment which without the coating affects silver catastrophically. A second project at the University of Chicago to evaluate materials and to design a concept of Compound Secondary Concentrators useful for dish technology was successfully completed. Tests conducted at the ACTF showed that expected optical efficiencies of 95 percent were obtained. Also the actively cooled secondary concentrators could be maintained within 5 percent of ambient temperature while passively cooled designs ran as high as 130°C above ambient at the exit aperture. These temperatures are considered within acceptable limits for reflective surface life. These encouraging results merit continued research in this area. The third project at the University of Arizona to investigate Spectrally Selective Beam Splitters developed conceptual designs of liquid filters and stacked interference filters. The analysis and experimental results indicate that both methods to achieve selective spectral splitting are practical although the liquid approach is more cost effective. Data on a limited number of liquids were obtained to show feasibility. Further work is merited to evaluate other liquids which maintain the desired properties under higher concentration and at elevated temperature so that the heat collected performs the dual function of filtering and as a heat source. The fourth project at Hughes Aircraft investigating the spectral shifting using Welsbach effect evaluated the physical properties of materials and characterized their performance. Based on data to date, this approach appears to be more suitable and useful for PV cells; hence, further research will be discontinued within the Solar Thermal Program.

o SERI issued a Letter of Interest (LOI) solicitation for increased university participation.

In order to increase the university participation in the program, a solicitation in the form of a Letter of Interest (LOI) was issued. This approach allows for a short description of the proposed idea and research plan. Upon evaluation and if it merits further consideration, a more detailed research plan will be solicited from only a few respondents. Initial selection is expected to be completed by the end of March.

ACTIVITIES FOR NEXT REPORT PERIOD

Staff will issue contract modifications for work in progress that merit continued research, and they plan to receive proposal responses and to complete initial selection.

FTP 653 TECHNICAL PROGRAM INTEGRATION

OBJECTIVE

This FTP covers planning and evaluation activities for the DOE Solar Thermal Technology Program in fiscal year 1986. The objective is to develop short-term and long-term strategic plans for the Solar Thermal Technology Program to achieve cost competitiveness of solar thermal systems. Specifically for fiscal year 1986, the objective is to conduct special studies and analysis to obtain the data necessary to form the basis for a sound long-term research and development program plan.

The highest priority for this activity is to achieve a long-term program plan so that strategic decisions can be made by DOE and other research and development centers for future activities. Planning will consider input from the research and development center, industrial views, need for exploring new and innovative concepts and applications, and budgetary constraints. Particular emphasis will be placed on analyzing the available data and information from tests conducted in the laboratory, on prototype components, and through system experiments. Such analysis will establish the potential of different approaches in order to develop a sound basis for the program analysis and evaluation of ideas which have not reached the same state of maturity as others, and to understand the reasons for discrepancies between the predicted performance of current systems and their actual performance. Analysis will include evaluation of new nonelectric applications and economic advantages of small electric and hybrid systems.

The Technical Program Integrator (TPI) will participate in programmatic and technical topical reviews, conferences, and workshops in order to: (1) coordinate research and technology development, (2) provide opportunities for industry and end-users to make contributions to the program, (3) determine critical research needs, and (4) establish priorities.

The TPI will also participate in other technology-transfer-related activities to ensure the prompt, accurate and continuous flow of information on significant research and technology development to industry and energy users.

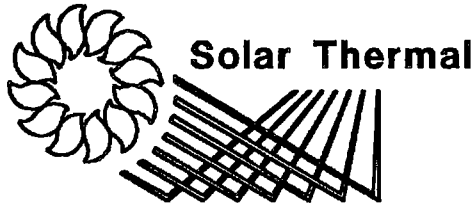
ACCOMPLISHMENTS

During the first quarter of fiscal year 1986, a new Technical Program Integrator (John Thornton) was selected to manage the program planning and evaluation functions. Effective December 1, 1985, the TPI began the detailed planning of fiscal year 1986 tasks and the development of an operating structure that would meet the needs of both DOE and the laboratories (SERI and SNLA).

These plans will be presented to the DOE in January, 1986. It is expected that staffing will be complete and activities will be well underway by then.

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 Δ			2 Δ									14 Δ
Concentrators												3 Δ	4 Δ	15 Δ		
Receivers							5 Δ	6 Δ				7 Δ	8 Δ			
Heat Engines															16 Δ	
Direct Conversion											9 Δ				17 Δ	
Innovative Concepts		10 Δ				11 Δ								18 Δ	19 Δ	

MILESTONE DETAIL

FY 1986 (INCLUDING FIRST QUARTER FY 1987) FUNDED BY FY 1986 FTP'S

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. Three-meter-diameter membrane mesh module ready for test.
5. Complete systems study for intermediate temperature DAR.
6. Evaluate stability of large, thin flowing films for the direct absorption concept.
7. Fabrication and preliminary testing of second generation, four-color pyrometer.
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 1987 PRELIMINARY (NEW FY 1987 FUNDING REQUIRED)

14. Stability of silver/polymer reflector with outdoor exposure tests.
15. Membrane dish laboratory test module.
16. Transfer TECH concept to engineering development program - initiate transfer.
17. System evaluation of the potential of promising direct conversion concepts and applications.
18. Mid-term evaluation of the University Research Projects.
19. Continuation (second-phase awards) of promising concepts at the Universities.

APPENDIX B

RESOURCE EXPENDITURES

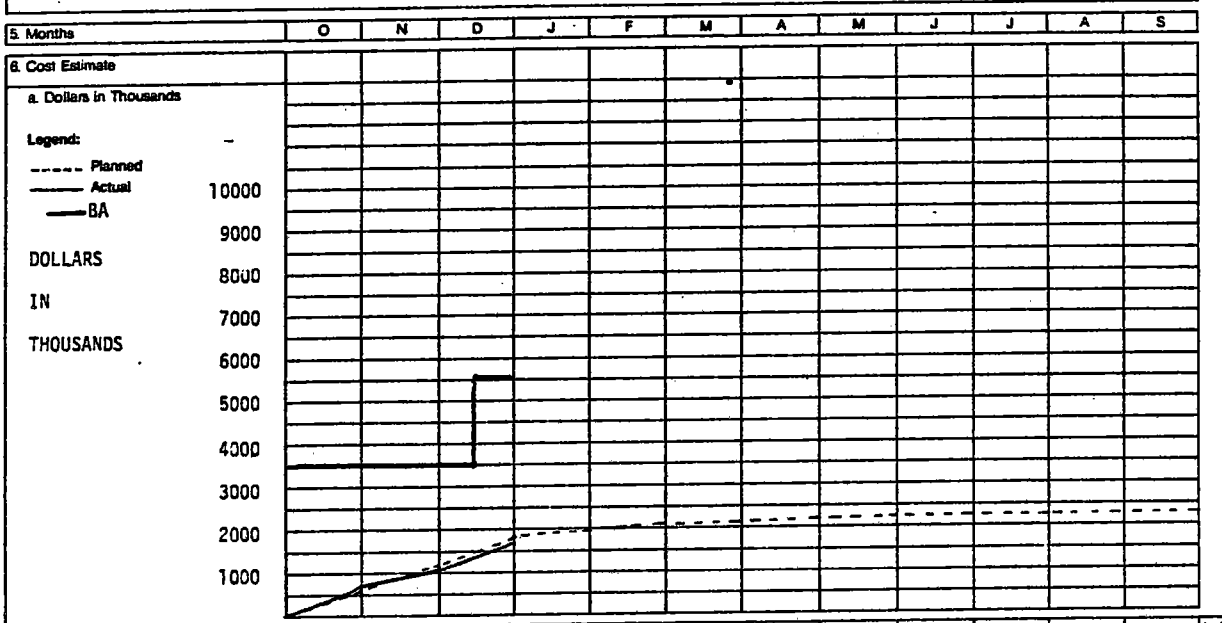
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/85 To: 9/30/86

3. Program Identification: FISCAL YEAR 1986 SOLAR THERMAL RESEARCH PROGRAM

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



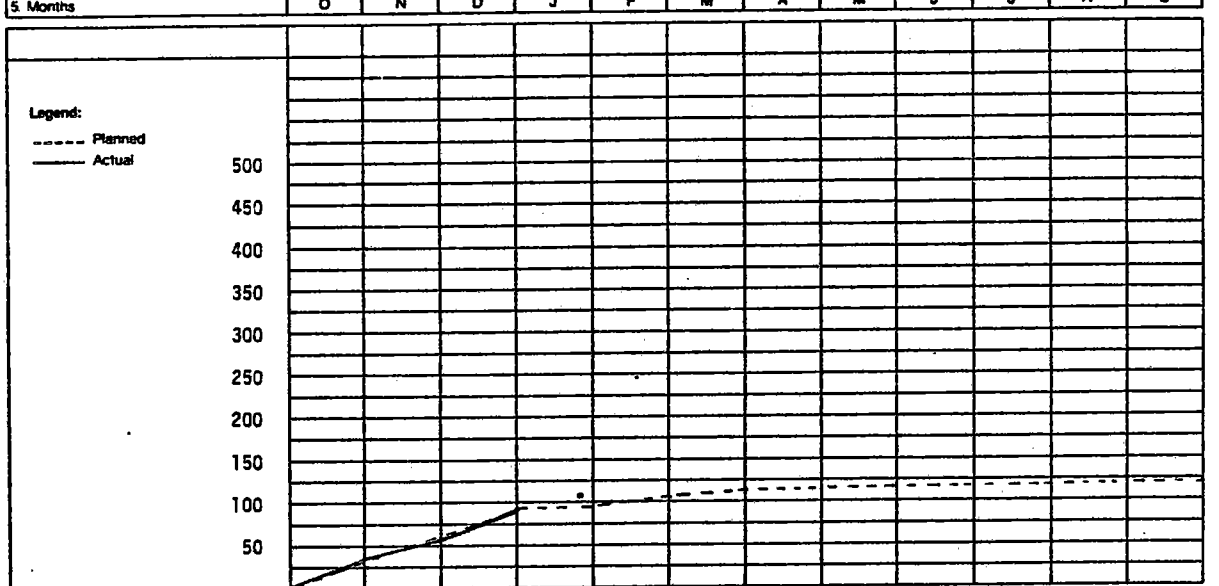
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	569	1145	1796	1979	2114	2221	2273	2305	2323	2340	2344	2348	b. Planned
	c. Actual	598	1104	1742										c. Actual
	d. Variance	(29)	41	54										d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/85 To: 9/30/86

3. Program Identification: FISCAL YEAR 1986 SOLAR THERMAL RESEARCH PROGRAM

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



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	31.0	60.7	90.0	98.0	105.0	112.0	114.0	116.0	118.0	120.0	121.0	122.0	b. Planned
	c. Actual	31.3	59.2	90.3										c. Actual
	d. Variance	(.3)	1.5	(.3)										d. Variance

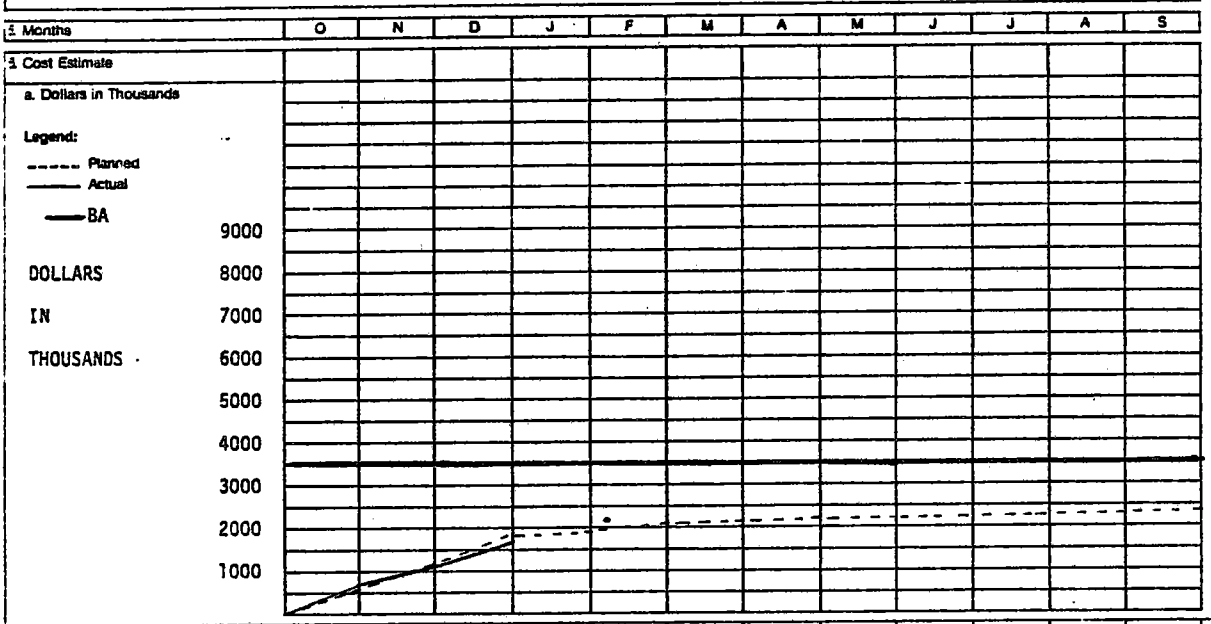
RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/85 To: 9/30/86

3. Program Identification: FISCAL YEAR 1986 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: COST SUMMARY: FISCAL YEAR 1984--FTP 463, FISCAL YEAR 1985--FTP 510, FTP 511



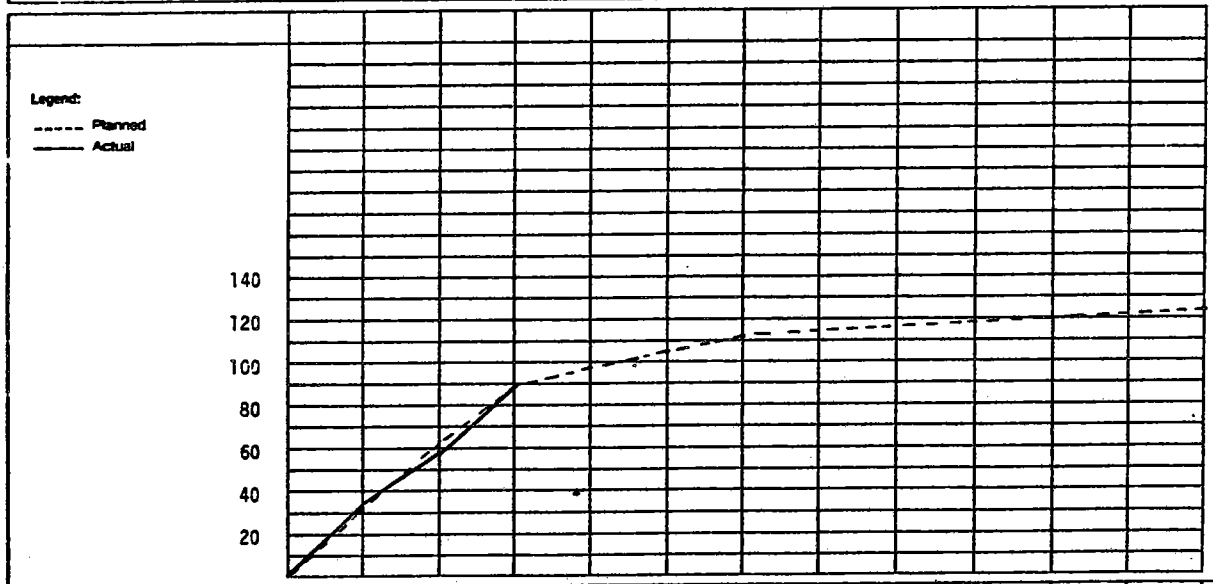
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	569	1145	1796	1979	2114	2221	2273	2305	2323	2340	2344	2348	b. Planned
	c. Actual	598	1104	1742										c. Actual
	d. Variance	(29)	41	54										d. Variance

Manpower Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/85 To: 9/30/86

3. Program Identification: FISCAL YEAR 1986 SOLAR THERMAL RESEARCH PROGRAM

4. WPA/Task: FTE SUMMARY: FISCAL YEAR 1984--FTP 463, FISCAL YEAR 1985--FTP 510, FTP 511



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	31.0	60.7	90.0	98.0	105.0	112.0	114.0	116.0	118.0	120.0	121.0	122.0	b. Planned
	c. Actual	31.3	59.2	90.3										c. Actual
	d. Variance	(.3)	1.5	(.3)										d. Variance

APPENDIX C

PROCUREMENT SUMMARY

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

Subcontractor	Subcontract Title/Activity	Value ($000)	Type Business	Status	Technical Monitor
The 3M Company	Silver/polymer research	50.0	Industry	Awarded	P. Schissel
Jet Propulsion Lab.	Polymer stabilization	50.0	Fed. Lab.	Awarded	P. Schissel
University of Denver	PAN polymer research	40.0	University	Awarded	P. Schissel
Acurex Solar Corp.	Front surface reflectors	35.0	Industry	Awarded	P. Schissel
Southern Res. Inst.	Reflector protective coatings	68.3	Non-profit Corp.	Awarded	Nix/Gross
To Be Determined	Optically uniform surfaces	TBD	TBD	Planned	G. Gross
To Be Determined	Polymer films research	TBD	TBD	Planned	P. Schissel
Acurex Solar Corp.	Holographic solar concentrators	230.7	Industry	Awarded	Nix/Murphy
University of Nebr.	Membrane dynamic analysis	31.2	University	Awarded	M. Murphy
Colorado State Univ.	Wind impact studies	50.0	University	Awarded	M. Murphy
University of Ariz.	Composite membrane materials	78.8	University	Awarded	M. Murphy
ENTECH, Inc.	Refractive concentrator eval.	45.0	Industry (S.B.*)	Awarded	M. Murphy
SPECO	Receiver concept analysis	28.5	Industry (S.B.*)	Planned	M. Murphy
GIT	ACTF experimental research	895.0	University	Awarded	G. Nix
Ind. Welding Supply	Salt test loop fabrication	226.0	Industry (S.B.*)	Completed	M. Carasso
U. of Houston	University research	350.0	University	Awarded	G. Nix
Hughes Aircraft	TECH research	221.7	Industry	Awarded	G. Nix
U. of New Hampshire	Solar photochemical research	56.0	University	Awarded	G. Nix
Lawrence Berk. Lab.	Direct flux research	32.6	Fed. Lab.	Awarded	G. Nix
U. of Hawaii	Direct flux research	74.7	University	Awarded	G. Nix
U. of Arizona	Spectral splitters	69.5	University	Awarded	G. Nix
Hughes Aircraft	Spectral shift (Welsbach Effect)	58.9	Industry	Awarded	G. Nix
U. of Chicago	Terminal concentrator research	77.1	University	Awarded	G. Nix

*S.B.-Small Business

FY 1986 SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS AWARDED TO DATE

Subcontractor	Subcontract Title/Activity	Value ($000)	Type Business	Status	Technical Monitor
GIT	Experimental Research	741.5	University	Awarded	G. Nix

APPENDIX D

PUBLICATIONS

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COMPLETED IN FISCAL YEAR 1985

Atkinson, J.F., *Entrainment and Thermohaline Double-Diffusive Systems: Application to Salt Gradient Solar Ponds.* Ph.D. Dissertation, MIT Technical Report No. 300, September 1984. SERI/STR-252-2733. Golden, Colorado: Solar Energy Research Institute.

Atkinson, J.F., Adams, E.E., Salhotra, A., and Harleman, D.R.F., *User's Manual for MIT Solar Pond Program (MITSOL).* Ralph M. Parson Laboratory Report, October 1984. SERI/STR-252-2679. Golden, Colorado: Solar Energy Research Institute.

Bergman, T.L., Incropera, F.P., and Viskanta, R., "Correlations of the Mixed Layer Growth in a Double Diffusive Stratified System Heated from Below." Submitted to the *Journal of Heat Transfer.*

Bhaduri, S. and Murphy, L.M., *Wind Loading on Solar Collectors.* SERI/TR-253-2169. Golden, Colorado: Solar Energy Research Institute, June 1985.

Boehm, R.F., *Laboratory Measurements of a Direct Contact Heat Exchanger.* SERI/STR-252-2678. Golden, Colorado: Solar Energy Research Institute.

Coyle, R.T., Thomas, T.M., and Schissel, P., *Specularity and Stability of Silvered Polymers.* SPIE Conference. SERI/TP-255-2743. San Diego, California, August 1985.

Gupta, B.P., Carasso, M., and Nix, R.G., *The Solar Thermal Research Program.* SERI/TP-251-2671. Golden, Colorado: Solar Energy Research Institute, March 1985.

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Jorgensen, G., et al., *Optical Properties of High-Temperature Materials for Direct Absorption Receivers.* SERI/TP-255-2791. SPIE Conference. San Diego, California, August 1985.

Jorgensen, G., et al., *An Integrating Sphere Spectrometer for High-Temperature Materials Characterization.* SERI/TP-255-2771. SPIE Conference. San Diego, California, August 1985.

Kirkpatrick, A.T., Gordon, R.F., and Johnson D.H., *Experimental Observations of Double Diffusive Natural Convection in Solar Ponds with Nonlinear Salinity Profiles.* ASME 84-WA/Sol-20. SERI/TP-252-2677. Golden, Colorado: Solar Energy Research Institute.

Meyer, R.T. and Hersch, P., editors, *Silver/Glass Mirrors for Solar Thermal Systems.* SERI/SP-281-2293. Golden, Colorado: Solar Energy Research Institute.

Neidlinger, H.H. and Schissel, P., et al., *Solar Thermal Technology Program: Polymer Synthesis and Modification Subtask Annual Progress Report.* SERI/TR-255-2590. Golden, Colorado: Solar Energy Research Institute.

Schissel, P., et al., *Solar Thermal Technology Program: Identification of Chemical and Physical Phenomena Causing the Degradation of Silvered PMMA.* SERI/PR-255-2493. Golden, Colorado: Solar Energy Research Institute.

Schissel, P. and Czanderna, A.W., *Specularity and Stability of Silvered Polymers.* SERI/TP-255-2743. SPIE Conference. San Diego, California, August 1985.

Schissel, P., *Photodegradation Inhibitors for Polycrylonitril/Ag (PAN/Ag) Films: Annual Report.* SERI/STR-255-2723. Golden, Colorado: Solar Energy Research Institute.

Schissel, P., Neidlinger, H.H., and Czanderna, A.W., *Silvered Polymer Reflectors.* SERI/TP-255-2670. Golden, Colorado: Solar Energy Research Institute.

Smith, D.M., Chughtai, A.R., Sergides, C.A., and Schissel, P., *Photodegradation Studies of Silver-Backed Polycrylonitrile (PAN) Films.* SERI/TP-255-2751. SPIE Conference, San Diego, California, August 1985.

Solar Thermal Research Program Annual Conference Proceedings. Held on February 20-22, 1985. SERI/CP-251-2680. Golden, Colorado: Solar Energy Research Institute, April 1985.

Solar Thermal Advanced Research and Development Bibliography. SERI/SP-271-2644. Golden, Colorado: Solar Energy Research Institute, May 1985.

Solar Thermal Research: An Industry/University Perspective and Research Recommendation. SERI/MR-252-2790. Golden, Colorado: Solar Energy Research Institute, July 1985.

Wang, K.Y. and Kreith, F., *Heat Transfer Research for High Temperature Solar Thermal Energy Systems.* SERI/TP-252-2790. Golden, Colorado: Solar Energy Research Institute.

Wang, K.Y., Newell, T.A., and Copeland, R.J., *Film Stability for Direct Receivers.* (Prepared for ISES/SESCI Intersol '85, Montreal, Canada) SERI/TP-252-2739. Golden, Colorado: Solar Energy Research Institute.

Wood, R., *The Optics of Flat Mirror Vee-Troughs.* SERI/TP-253-2447. Golden, Colorado: Solar Energy Research Institute.

Zangrando, F. and Johnson, D.H., *Review of SERI Solar Pond Work.* SERI/TP-252-2322. Golden, Colorado: Solar Energy Research Institute.

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Anderson, J.V., Murphy, L.M., Short, W.D., and Wendelin, T. (December 1985), *System Performance Analysis of Stretched Membrane Heliostats.* SERI/TP-253-2819. 6 pp. Prepared for the ASME Division Annual Conference, Anaheim, California, 14-17 April 1986. Available NTIS: order no. DE85016885.

Bohn, M.S., Fisher, E.M., and Anderson, R. (December 1985), *Development of an Interferometer for Natural Convection Enhancement Research,* 1 January 1984 - 31 December 1984. SERI/PR-252-2598. 44 pp. Available NTIS: order no. DE85016895.

Chaturvedi, S.K. and Murphy, L.M. (November 1985), "Energy Conservation Potential of Large Capacity Solar-Assisted Heat Pumps for Low Temperature IPH Applications." *Journal of Solar Energy Engineering* (107:4). pp. 286-292. Work performed by Old Dominion University, Norfolk, Virginia, and the Solar Energy Research Institute, Golden, Colorado.

Ives, J., Newcomb, J.C., and Pard, A.G. (October 1985), *High Temperature Molten Salt Storage Concept: Final Subcontract Report.* SERI/STR-231-2836. 96 pp. Work performed by Rockwell International, Canoga Park, California. Available NTIS: order no. DE85016874.

Jorgensen, G.J. and Schissel, P.O. (December 1985), "Effective Antireflection Coatings of Transparent Polymeric Materials by Gas-Phase Surface Fluorination." *Solar Energy Materials* (12:6), pp. 491-500.

Masterson, K., Jorgensen, G., Burrows, R., and Schissel, P., *An Integrating Sphere Spectrometer for Optical Characterization of High Temperature Materials.* SERI/TP-255-2771. Golden, Colorado: Solar Energy Research Institute.

Murphy, L.M. (October 1985), *Variational Approach for Predicting the Load Deformation Response of a Double Stretched Membrane Reflector Module.* SERI/TR-253-2626. 60 pp. Available NTIS: order no. DE85016873.

Murphy, L.M., Anderson, J.V., Short, W., and Wendelin, T. (December 1985), *System Performance and Cost Sensitivity Comparison of Stretched Membrane Heliostat Reflectors with Current Generation Glass/Metal Concepts.* SERI/TR-253-2694. 96 pp. Available NTIS: order no. DE85016892.

Murphy, L.M., "Stretched-Membrane Heliostat Technology." Revised and accepted for publication in the *JSEE.* December 1985.

Murphy, L.M., "Moderate to Large Axisymmetric Deformations of Optical Membrane Surfaces." Submitted for publication to the *JSEE.* December 1985.

Parsons, B.K., Bharathan, D., and Althof, J.A. (September 1985), *Thermodynamic Systems Analysis of Open-Cycle Ocean Thermal Energy Conversion (OTEC).* SERI/TR-252-2234. 184 pp. Available NTIS: order no. DE85016867.

Penny, T.R. (November 1985), *Composite Turbine Blade Design Options for Claude (Open) Cycle OTEC Power Systems.* SERI/TP-252-2792. 6 pp. Prepared for the 5th International Symposium and Exhibit on OMAE, Tokyo, Japan, 13-22 April 1986. Available NTIS: order no. DE85016876.

Samra, S.S. and Dhir, V.K. (November 1985), "Study of Thermal Oscillations at the Dryout Front in Half Heated Tubes." *Journal of Solar Energy Engineering* (107:4), pp. 343-351. Washington. Work performed by School of Engineering and Applied Science, University of California, Los Angeles, California.

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IN PROGRESS

Clausing, A. (in progress), *Effect of Variable Fluid Properties on Convective Losses from Solar Receivers.* Golden, Colorado: Solar Energy Research Institute.

Copeland, R.J., Newell, T.A. and Wang, K.Y. (in progress), *A Report on Direct Absorption Receiver Falling Film Flow Characteristics.* SERI/TR-252-2641. Golden, Colorado: Solar Energy Research Institute.

Direct Absorption Receiver System Steady-Phase II (in progress). SERI/SP-253-2592. Golden, Colorado: Solar Energy Research Institute.

Lazaridis, A., Copeland, R., and Althof, J.

Lazaridis, A., Copeland, R., and Althof, J. (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.

Lewandowski, A., et al. (in progress), *Direct Absorption Receiver Study - Phase I.* SERI/SP-253-2438. Golden, Colorado: Solar Energy Research Institute.

Maxwell, E. (in progress), *An Assessment of Instrumentation and Measurement Needs of the Solar Thermal Technology Program.* SERI/TR-215-2611. Golden, Colorado: Solar Energy Research Institute.

Maxwell, E. (in progress), *Spectral Measurements at the Solar One Power Plant.* SERI/TR-215-2612. Golden, Colorado: Solar Energy Research Institute.

Murphy, L.M., Sallis, D.V., and Simms, D. (in progress), *Structural Design Considerations for Stretched Membrane Heliostat Reflector Modules with Stability and Initial Imperfection Considerations.* SERI/TR-253-2338. Golden, Colorado: Solar Energy Research Institute.

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Peterka, J.A., et al., *(in progress) Wind Load Reduction for Heliostats,* Contractor Report, Colorado State University, Fort Collins, Colorado, September 1985.

Schell, D., Karpuk, M., and West, R. (in progress), *Engineering Systems Analysis of a Hybrid Quantum/Thermal Process for Fuels and Chemicals Production.* Golden, Colorado: Solar Energy Research Institute.

Short, W.D. and Wendelin, T., (in progress) *Briefing Package on the Cost/Performance of Conical Concentrators for Thermal and Electric Applications.* Golden, Colorado: Solar Energy Research Institute, November 1985.

Short, W.D., (in progress) *Cost/Performance Analysis of an Inflated Conical Concentrator.* SERI/TR-253-2872. Golden, Colorado: Solar Energy Research Institute, November 1985.

Simms, D. and Lewandowski, A., (in progress) *System Performance and Cost Studies of Linear Concentrating Fresnel Lens Solar Thermal Collectors.* SERI/TR-253-2870. Golden, Colorado: Solar Energy Research Institute, November 1985.

Wendelin, T., (in progress) Internal letter report on the cost performance potential of an innovative inflatable heliostat drive/support subsystem. Golden, Colorado: Solar Energy Research Institute, November 1985.

Wood, R. (in progress), *Single, Stretched Membrane Structural Module Experiments.* SERI/TR-253-2736. Golden, Colorado: Solar Energy Research Institute.

Zangrando, F. (in progress), *Survey of Density Measurement Techniques for Application in Stratified Fluids.* SERI/TR-252-2221. Golden, Colorado: Solar Energy Research Institute.

APPENDIX E

SCIENTIFIC MEETINGS AND PRESENTATIONS

SCIENTIFIC MEETINGS AND PRESENTATIONS

J. Webb attended the NATO Advanced Study Institute on Photophysical and Photochemical Tools in Polymer Science in San Mineato, Italy, on October 13 to 14 and gave a poster presentation entitled "End-Group Effects on the Wavelength Dependence of Laser-Induced Photodegradation in Bisphenol-A Polycarbonate."

G. Gross held discussions with researchers at Georgia Tech Research Institute and the University of Houston on high-flux effects to bring about greater coordination and unity of direction to the solar thermal materials research. Research papers were presented at the Semiannual Research Review meeting at Williamsburg, Virginia.

K. Wang presented the paper entitled "Heat Transfer Research for High-Temperature Solar Thermal Energy Systems," coauthored with F. Kreith, at the 1985 U.S.-Japan Heat Transfer Joint Seminar in San Diego, California, on September 17 to 20. The proceedings will be published by the Hemisphere Publishing Corporation in 1986.

The abstract of the paper entitled "Rapid Heating of Gas/Small Particle Mixture," written by K. Wang and W. Yuen (University of California, Santa Barbara), has been accepted for presentation at the AIAA/ASME Heat Transfer and Thermophysical Conference.

M. Carasso participated in a research coordination meeting at the invitation of P. DeLaquil, who heads the study effort funded by Bechtel Corporation. The meeting was hosted by G. Braun at Pacific Gas and Electric (PG&E). Participants in the meeting, apart from the above, included A. Hunt, J. Ianucci, and J. Loring. The meeting resulted in an understanding of the need for a strong analysis of the absorber thermal behavior. G. Braun expressed interest in a more extensive study of high-temperature concepts in the Solar Thermal Program.

G. Nix presented the University of Chicago terminal concentrator research and the Hughes thermoelectrochemical convector research at the Solar Thermal Semiannual Review at Williamsburg, Virginia. In addition, B. Gupta presented the overview of the Research program, G. Gross presented the program in high flux effects on materials, and M. Bohn presented data on DAR concept research.

H. Neidlinger presented a paper entitled "Polymers in Solar Energy Applications" at the Energy for the Americas Conference in San Juan, Puerto Rico, and attended the First Pan American Chemical Congress from October 13 to 18.

H. Neidlinger attended the International Conference on Ultrastructure in Polymers in Amherst, Massachusetts, from October 20 to 24.

H. Neidlinger visited the Center for Polymeric Engineering at the University of Akron, the Department of Plastics Engineering at the University of Lowell, and the Department of Polymer Science and Engineering at the University of Massachusetts to discuss the type of polymer engineering research required for optically uniform polymer films in solar thermal systems.

As an American Chemical Society (ACS) tour speaker, A. Czanderna presented the talk "Solar Energy—The Quest and the Questions" at Bakersfield, California, on October 29, and at Las Vegas, Nevada, on October 30. The talk "Overview of Ion Spectroscopies for

Surface Analysis and Applications to Solar Energy Materials: was presented at Phoenix, Arizona, on October 31, and at Tucson, Arizona, on November 1.

SERI staff members working on Reflector Materials have established close contacts with Owens Illinois Technical Products, Allied Corporation's Electronic Chemicals Division, and Innotech Glass Products. These contacts have already yielded much guidance and several samples of promising materials.

The American Society of Mechanical Engineers (ASME) conference paper on "Systems Analysis of Stretched-Membrane Heliostats" has been accepted for presentation at the ASME Solar Division Conference in April 1986, and has been approved by SERI management.

K. Wang completed a paper entitled "Rapid Heating of Gas/Small Particle Mixture," co-written by W. Yuen at the University of California, Santa Barbara. The paper has been sent to the 1986 AIAA/ASME Heat Transfer and Thermophysics Conference for review.

K. Wang visited N. Brown of Lawrence Berkeley Laboratories and R. Sawyer of the University of California, Berkeley, in November. The progress that the researchers have made on nonequilibrium chemical reactions was presented to the professors, and they agreed that SERI's methodology is basically correct. They also offered some suggestions, such as including more recent test results and references.

Y. Hayashi (Kanazawa University, Kanazawa, Japan) and K. Aoki (Technological University of Nagaoka, Japan) visited SERI. Y. Hayashi also gave a seminar entitled "Heat Transfer Enhancement with Mist Flow."

K. Wang attended the 1986 ASME Winter Annual Meeting at Maimi Beach, Florida, from November 18 to 22. He has joined the K-6 Committee (Energy Systems) of the Heat Transfer Division and the Fundamentals Committee of the Solar Energy Division.

In response to an invitation by the editor of *Solar Energy Materials*, the authors of "Specularity and the Stability of Silvered Polymers," (SERI/TP-255-2743, July 1985) agreed to have the document scrutinized to further peer review. They also provided original figures to the editor and advised him of the standard copyright limitations on DOE-funded work.

An abstract of the work on silver-polymer reflector research was published in the SERI *In Review* series (Vol. VII, No. 10, 11, October/November 1985).

A meeting was held between personnel of SERI and Sandia, Albuquerque, on optical reflector materials. Discussions included front surface mirrors, progress in SOLGEL approach, and other related optical materials research.

A new paper on the large axisymmetric deformations of stretched membranes has been submitted to the *Journal of Solar Energy Engineering*.

Staff solicited papers and prepared two sessions for the upcoming ASME Solar Division Annual Conference to be held in Anaheim, California, next April. These two sessions contain a total of ten papers on central receivers and distributed receiver systems.

Several meetings were held with personnel from SPECO regarding the technical issues associated with their study on Direct Absorption Receiver configuration. Contacts were also made with Sandia National Laboratories, Livermore, about details of the design studies Sandia researchers are currently conducting as part of both their Central Receiver System Improvement and Optimzied Receiver studies.

K.Y. Wang and M. Carasso attended the Solid Particle Receiver Technical Exchange Meeting held at Sandia, Livermore, on December 3, 1985. The purpose of the meeting was for SNLL to present the technical work which has been performed on the solid particle receiver during the past three years.

In collaboration with Babcock and Wilcox, equipment for a solar radiation monitoring station has been turned over to the Dominican Electric Corporation, and their engineers have been trained to operate and to maintain the station.

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