SERI/MR-251-1471 August

Solar Thermal

Solar Thermal Research Program

Status Report

August 1983

SERI

FOREWORD

SERI submits this report to provide information on technical progress in the activities under the Solar Thermal Research Program. This report summarizes the progress within each active Work Package Agreement in the Program. Included are the following: a program summary; objectives, approach and milestone chart for Work Package Agreements; Task reports; meetings and presentations; charts on resource expenditure; and a list of publications.

This report includes main elements (Work Package Agreements) for the two fiscal years:

Fiscal Year 1983	Fiscal Year 1982
o Concentrator Advanced Development	o Applied Research
o Thermal Materials Research	o Program Planning and Coordination
o Support to Systems Test and Evaluation	o Advanced Research

All Tasks in WPA 281 for fiscal year 1982 have been completed. While the effort in Solar Pond Research is no longer a direct part of the Solar Thermal Program, progress in those Tasks is included here for information.

In addition, the Solar Energy Research Institute, consistent with the contractual requirements of the Department of Energy, prepares monthly status reports on research conducted at the Institute. The executive summary of this report is included in the Institute's report. Other status reports, which include weekly reports and quarterly reviews, are sent to D.O.E. regularly. Separate technical reports provide detailed information on progress and results on specific research activities. Coordination and editorial assistance for this report were provided by W. Traugott.

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N.B.

M

MAJOR EVENT

HIGH-TEMPERATURE MATERIALS CORROSION

Advanced Solar Thermal Systems, envisioned with operating temperatures as high as 1100°C, present challenging conditions for heat transfer fluids and for the materials that contain these fluids. Ceramics are required as containment material for most portions of these systems that operate above 800°C, since few alloys have sufficient strength or corrosion resistance to function at such elevated temperatures.

SERI's present research has been focused on the corrosion of ceramics in high temperature heat transfer fluids in an effort to identify ceramics and fluids that are compatible at 900°C. A set of twenty ceramic materials including fused-cast materials—refractory materials that are made by joining molten ceramics into a mold—high purity window grade materials, high density aluminum oxide materials, conventional refractory materials—low cost materials that are porous and are bonded by glass phase—plus high purity zirconium oxide and magnesium oxide have been evaluated for compatibility with candidate fluids.

Coupons of these materials were tested for up to 18 days. These tests were done using three high-temperature fluids, a binary eutectic carbonate of sodium and potassium (51.5 w/o, weight percent, Na_2CO_3), sodium hydroxide, and a ternary eutectic chloride salt containing 24.5 w/o sodium chloride, 55 w/o magnesium chloride with the balance potassium chloride.

The apparatus for these tests consisted of a furnace containing three 99.8% pure aluminum oxide crucibles. Each crucible contained molten salt at 900°C to a depth of about 19 cm plus thermocouples for monitoring the temperature and gas purge tubes to maintain the desired atmosphere it contacts; for instance, the partial pressure of carbon dioxide is important in the atmosphere above carbonate salts. Coupons of the ceramic were mounted on a sample holder and immersed in the salt during the test, and the weight loss and change in thickness were monitored.

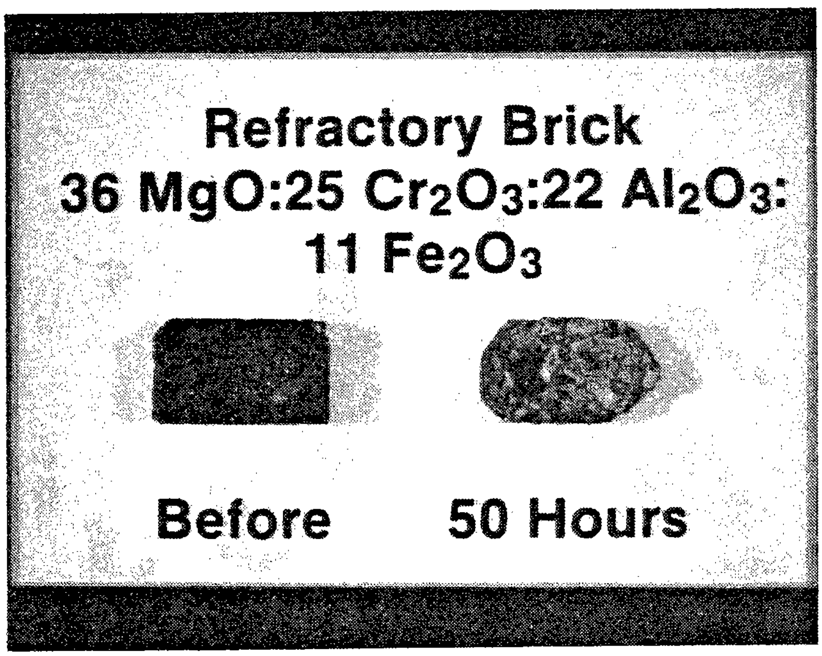
It was found that carbonate salts are the easiest to work with and that their corrosiveness to some ceramics was quite low. For instance, the corrosion rate derived from weight loss measurement of window grade sapphire and magnesium aluminate were 0.1 μ/day while some high density aluminum oxide materials actually gained weight. One zirconium oxide material corroded at the rate of 1 μ/day. These corrosion rates are encouraging for using ceramics with carbonate fluids in a receiver.

Results with chloride salts at 900°C showed very low corrosion rates for all of the ceramics that were tested; however, the chloride salts continually evolved HCl during the test which causes concern about the corrosion of alloy structural parts in the vicinity of the hot zone of the receiver if this salt were used. The results for sodium hydroxide showed it to be very corrosive to ceramics under the conditions of the test. Thus, at this point it appears that a carbonate salt is the best choice.

One promising advanced system concept using molten salts is the Direct Absorption Receiver and Thermal Storage (DARTS) concept which is a cooperative effort between the Solar Thermal Program and the Storage Program at SERI. This concept involves the use of molten salts such as carbonates, hydroxides, and chlorides as the high-temperature heat transfer fluid in a direct absorption reciever. Additionally high-temperature molten salt has shown promise in work supported by the Storage Program as a thermal storage medium using an advanced high-temperature thermocline storage tank.

The direct absorption receiver concept also has the attractive feature of requiring a minimum of strength for the receiver materials. In operation, the salt is heated directly by the concentrated insolation as it flows down a ramp inside the receiver. In this design the ramp is the part of the receiver having the highest temperature but can operate at low stress levels. This low stress gives a good change of success where alloys must be used at elevated temperatures, where they have minimal strengths, or where ceramics which are brittle and susceptible to failure at relatively low stresses must be relied upon.

Researchers are currently conducting more detailed corrosion tests in a molten carbonate salt on a 99.8% aluminum oxide material and a fused cast aluminum oxide to test the influence on corrosion of the salt chemistry (as influenced by the carbon dioxide partial pressure in the atmosphere above the salt), the salt composition (amount of lithium and other additives) and the salt temperature.



Pictured is a chrome-magnesite refractory brick coupon before and after exposure to molten eutectic $(Na,K)_2CO_3$ at 900°C for 50 hours. The material easily crumbled after exposure.

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PROGRAM SUMMARY

PART I FISCAL YEAR 1983

WPA 416A-83 CONCENTRATOR ADVANCED DEVELOPMENT

Polymers for Enclosed Concentrators

A. Polymer Mirror Research Optical characterization of the 11 samples exposed to one, two, and four weeks of testing was completed. The basic conclusions presented last month need not be altered. X-ray photoelectron spectroscopy and Ar^+ depth profiling were used to show that the 35 nm-thick Inconel backing on silvered polymers is continuous. No silver signals were evident even after removal of 10 nm to 20 nm of the Inconel.

Optical characterization of 18 sets of the polymer-sputtered, silver-backing materials has been partially completed. One of the samples which had been exposed to ultraviolet during two weeks of Weather-Ometer testing (60°C, 80 percent relative humidity) showed patches of discoloration in the film. Surface analysis of the stripped sample gave some additional information for corrosion of silver films in a humid atmosphere. Oxygen is present over the entire silver surface. From depth profiles, oxygen is limited to the surface except in the highly corroded patches where it is throughout the film. The depth profiles also suggest that the silver layer has been thinned from 100 nm to 25 nm to 50 nm in some areas. Thus a possible mechanism for both thinning the sample and also causing discoloration could be:

$$Ag + O_2 + H_2O \longrightarrow Ag_2O \xrightarrow[\text{polymer}]{\text{UV}} Ag^o \text{ (finely divided particles}$$

dissolved in the polymer) + oxidized polymer fragments.

Thus, the presence of an organic layer and ultraviolet exposure would both be necessary for the optical degradation. This agrees with the FTIR results for AgCl also. The Ag_2O formation/ decomposition may only take place as a silver-polymer interfacial reaction. The kinetics of this reaction should be limited by the porosity of the polymer layer to the reactants, O_2 and H_2O. Ultraviolet absorbers may also slow the reaction.

In support of preparing fluorination equipment for modifying polymers, surface analysis (XPS) was performed on samples of polyvinylchloride (PVC) and polypropylene that had been subjected to contact with fluorine gas. Fluorine and oxygen penetrate well into the bulk of the film. This result suggests that the polymers are permeable to the gases. In polypropylene, the carbon and fluorine XPS signals are shifted to levels suggesting that a kind of Teflon surface has been formed. The depth of the fluorinated layer depends on F_2 exposure time. A similar surface composition is formed on PVC where all surface chlorines seem to have exchanged with Fluorine and to have produced a teflon-like surface. In this sample also, the depth of fluorine penetration depends on F_2 loading. In both cases, the fluorinated layer serves as an anti-reflection coating.

Further progress was made in preparing laboratory 387 for the ultraviolet excimer/ dye laser. The laser optical bench was completed, and the excimer and dye laser units have been mounted on it. Most of the excimer gases, regulators, and safety equipment have arrived. Manufacturer's installation and alignment have been scheduled for September.

B. Polymer Synthesis and Characterization Polyacrylonitrile (PAN) film has performed well in the Weather-Ometer tests to date—better than unaltered PMMA (polymethylmethacrylate). However, in outdoor tests, PAN has delaminated and has permitted the silver to degrade while PMMA has not delaminated. Optical measurement on those portions of PAN-coated mirrors that had not delaminated when exposed outdoors showed no degradation. University of Denver researchers have observed that PAN, cast from dimethylsulfoxide onto silver, can be delaminated from silver if treated in a water-ultrasonic bath. However, if it is first exposed to a solar simulator, it cannot be delaminated ultrasonically nor can it be peeled mechanically (a patent docket has been submitted). Four SERI mirrors made by the wet chemical silver process have been coated with PAN at the University. The samples were exposed at a minimum distance to the SERI solar simulator with no filters interposed—thus maximizing overall intensity and particularly the intensity down to 245 nm, a wavelength much lower than that present in the solar spectrum. The PAN/silver mirrors showed a slight improvement visually by this three-hour exposure (less milky) but no measureable change in hemispherical reflectance. Two samples will be placed in the Weather-Ometer, and two samples will be placed outdoors to check if adhesion is improved in real exposure.

Unaltered Polymethylmethacrylate (PMMA) or PMMA with one percent additive (either National Starch or Uvinol 100 or Tinuvin P stabilizers) have been exposed in the Weather-Ometer for four weeks and outdoors for six weeks. PMMA plus Tinuvin P was essentially unaltered in each test (as was unstabilized PAN) with a hemispherical reflectance of about 88 percent. These are wet-processed silver mirrors, and tests suggest that about six percent loss is due to the metallization process. PMMA plus National Starch and PMMA plus Uvinol showed loss of reflectance in the Weather-Ometer but less or no loss outdoors. In summary, four candidates are essentially unchanged during these short-term tests: 3M-YS94; Sheldahl-Teflon; PAN; PMMA plus Tinuvin P. Specular reflectance measurements are yet to be completed; however, literature data suggest that Teflon will be relatively deficient in specularity.

The Jet Propulsion Laboratory is studying the environmental degradation of glazings—laminated for mechanical property improvement and stabilized by using bound ultraviolet absorbers. Crosslinked polymers consisting of polypropylene terephthalate crosslinked with polystyrene and incorporating one percent (by weight) of 2-(2-hydroxy 5-vinylphenyl) 2H-benzotriazole and 2-(2-hydroxy 5-propenylphenyl) 2H-benzotriazole were synthesized, and preliminary aging studies have been reported. Emission studies of these samples were carried out. Results indicated an appreciable amount of impurity was contained in polyester. A new batch of polyester was then prepared, and its emission showed within detection limits no contamination, that is, long wavelength (λ>600 nm) emission. Aging studies of this pure polyester film sample in JPL control environment chamber showed:

- Very significantly improved ultraviolet resistivity as compared to unstabilized polyester;
- Permanency of ultraviolet absorber.

Advanced Enclosed Thermal Dish Concentrators

Additional, more refined analysis confirmed the potential viability of an evacuated deep-dish receiver concept. On an annual basis the performance would be reduced by six percent compared to a cavity receiver at a process operating temperature of 538°C (1000°F). Researchers think that potential cost reductions of a deep-dish system are significantly larger than six percent.

Fabrication of the 2.44-meter-dome bases continued. Arrangements have been made to TIG-weld the 2.44-meter-dome base elements. The only metal components not in hand are the rolled rings which are due shortly. Sheldahl has begun work on fabricating the 2.44-meter-Tefzel domes. The initial step is preparation of production drawings for dome panels. The company has also prepared samples of 5 mil Tefzel seams for SERI evaluation. The Tefzel was glow-discharge-treated (an etching process) on one side of two samples and on both sides of two other samples. In all cases during tensile testing of the seams, the base material yielded before the seam failed—indicating adequate seam strength. The seam samples will be placed in the Weather-Ometer for accelerated aging at SERI. Transmittance data were also supplied by Sheldahl. The results are tabulated below. Similar transmittance tests will be performed on SERI's equipment.

TRANSMITTANCE OF TEFZEL

	Visible	UV
Untreated	91.3	82.2
One side treated	90.6	76.1
Both sides treated	90.3	73.4

Though analyses have determined the detailed load distributions within the dome membrane structure, a better definition of actual applied wind loads on spheres has been under investigation for a while. No definitive explanation for the USAF Randome Handbook discrepancy between theoretical and measured drag coefficient (C_D) has been found. It appears that the dynamic nature of windflow on the leeward side could explain the difference between the measured and calculated C_D. SERI wind turbine experts suggest this possibility also. More recent studies in the open literature have shown similar inconsistencies (but not always in the same direction) and indicate that experimental predicitions may often be unpredictable and greatly dependent on wind tunnel testing configurations.

The analytical/design solutions for the problem with membrane/ring interaction has been completed and has been validated for two simplified loading conditions by comparisons with known solutions. The NASTRAN solution validation now has begun, and the development of a membrane surface error routine was begun. This analytical/design tool will allow the rapid screening and evaluation of different ring/membrane design configurations.

WPA 417A-83 THERMAL MATERIALS RESEARCH

Receiver and Materials Research

A. Ceramic Materials Research A compliance calibration was done on 2 three-point loading samples of different cross sections—one with a width to height ratio of 1.25 and the other 1.50. The results were fitted to a standard curve of the form $C = a + b + Ce^{d\alpha}$ where C is the compliance, α is the dimensionless crack length, e is the Napierian base for natural logarithms, and the small letters are constants. These results will be compared with the results of compliance calibration by other workers. By using the compliance calibration, the fracture toughness of Coors AD 90 alumina was determined to the 3.384 $MPam^{1/2}$ compared to a published value of 3.49—very good agreement.

Literature on sample preparation equipment was collected, and a number of suppliers gave recommendations on equipment to allow easier and more accurate preparation of fracture samples.

At TerraTec Engineering, the pressureless sintering of SiC-Al_2O_3 composites in closed crucibles was studied. There is no significant densification at temperatures to 1900°C, whereas TiC-Al_2O_3 sinters readily at 1700°C. The densification of SiC and Sic-Al_2O_3 will be performed by hot-pressing. Further efforts to densify Sic and Sic-Al_2O_3 without pressure will be studied.

B. High-Temperature Materials and Fluids Corrosion studies on platinum in molten eutectic $(Na,K)_2$ CO_3 showed corrosion rates of about 1.6 μm/day and retention of a highly specular surface which could allow Pt to be used in reflecting light back through molten salts to measure optical absorption.

Single crystal sapphire (Al_2O_3) and high purity polycrystalline $MgAl_2O_4$ spinel showed the least reactivity of the ceramic materials studied in molten eutectic Na_2CO_3/K_2CO_3 at 900°C for 18 days—an atmosphere of 3000 ppm CO_2 was used in the cover gas above the molten salt. The corrosion rate was 0.1 μm/day.

The result reported above for sapphire contrasts with a slight weight gain for Coors 99.5 percent Al_2O_3, a 1.4 μm/day loss rate for Frenchtown 99 percent Al_2O_3 and a 5 μm/day loss rate for Coors 90 percent Al_2O_3 in the same tests. The glassy phase in the lower purity materials is thought to result in the increased interaction with the salt compared to the high purity materials. A fusion cast $MgAl_2O_3$ material was found to have a corrosion rate of 5 μm/day; again the higher rate is probably due to a more glassy phase in this material than in the high purity $MgAl_2O_4$.

An MgO stabilized ZrO_2 material was found to have a low corrosion rate of 1 μm/day in these eighteen-day carbonate tests while a porous MgO material showed a significant weight gain and no sign of degradation. One candidate refractory material, a magnesia chrome material, showed 5 μm/day, an encouragingly low rate for a commercial material.

Assembly of a quadropole mass spectrometer system for temporary use was completed; it will be used to monitor the chemistry of carbonate salts by detecting the CO_2 partial pressure.

New sample holders have been prepared as well as coupons for a series of corrosion tests in ternary eutectic (Li, Na, K)$_2$ CO_3 which has a melting point of 397°C. Two of the more promising ceramic materials, Coors 99.8 percent Al_2O_3 and Monofrax M fusion cast Al_2O_3 will be studied for corrosion rate and corrosion mechanisms in this salt.

C. Receiver/Heat Transfer Analyses were performed on a direct absorption receiver. A two-dimensional model is now operating, and data are being generated for both laminar and turbulent flow correlations. With proper design of the receiver, excessive temperature differences can be avoided (that is, a high efficiency receiver is possible). Several approximations are still in the model, and future work is needed both in model development and validation.

The analyses have shown that a minimum scale for the direct absorption receiver is one meter. To perform a model validation experiment, only ACTF (Georgia Tech) or CRTF (Albuquerque) is large enough. Plans are being drawn to conduct an experiment in fiscal year 1984.

A falling film of molten salt is expected to have a variable thickness due to varying flow rates and viscosity. The film in some conditions is laminar and is turbulent in other conditions and will also be affected by surface roughness. A device to measure film thickness is now operational—employing water as the medium. Under some conditions, dry spots are observed—implying a burn-out condition. Data are being collected so that dry spots can be avoided in real receivers.

WPA 440-83 SUPPORT TO SYSTEMS TEST AND EVALUATION

Trough/IPH Evaluations Validation efforts for SOLIPH continued in detail for USS Chemicals and were begun for Home Laundry. At USS Chemicals, errors in reported data through April were identified by the contractor and make comparison impossible. Performance data have shown unreasonably high collector performance (~60 percent). The optical efficiency of the SKI T-700 is 65 percent. With a dirty reflector estimated to have an optical efficiency of 59 percent and a 10 percent heat loss, then the collectors cannot possibly achieve 60 percent efficiency. It is thought that errors exist in calculation of incident energy in the plane of the collector—causing low radiation values and correspondingly higher efficiencies. This issue is under investigation with USS Chemicals. At Home Laundry, an apparent error of the same type was identified and caused high reported efficiencies. This result is also under investigation with Home Laundry.

An abstract entitled, "Modeling of the DOE Sponsored IPH Field Test Experiments" was submitted to ASME for the Solar Energy Division Sixth Annual Technical Conference to be held in Las Vegas, Nevada, on April 8 to 12, 1984. Coauthors of the abstract are A. Lewandowski, R. Gee, and K. May.

FY83 SERI SOLAR THERMAL RESEARCH PROGRAM

MILESTONE SCHEDULE

1. Concentrator Advanced Development

   a. Complete installation of the two-meter-diameter stretched membrane reflector SRE at SERI

   b. Complete detailed design of dome enclosure

   c. Release RFP for advanced enclosed dish design

   d. Install two-meter dome at CRTF

2. Polymers for Enclosed Concentrators

   a. Identify ultraviolet screens and absorbers as additives

   b. Complete identification of degradation factors in polymers

   c. Modify optical characterization capabilities for metallized polymers

3. Thermal Materials Research

   a. Complete definition of requirements and recommendations for high-temperature test facility

   b. Develop requirements for high-temperature containment

   c. Complete preliminary design for high-temperature facility

   d. Complete preliminary ceramic materials testing

Solar Thermal

SERI Solar Thermal Research Program
FY 83 Milestone Schedule

Program/Task	Fiscal Year 1983											
	O	N	D	J	F	M	A	M	J	J	A	S
(1) Concentrator Research		a ▼					b ▼			c ▽		d ▽
(2) Polymers for Enclosed Concentrators						a ▼				b ▼		c ▽
(3) Thermal Materials Research						a ▼		b ▼			c ▽	d ▽

PART I FISCAL YEAR 1983

SECTION 1

WPA 416A

CONCENTRATOR ADVANCED DEVELOPMENT

OBJECTIVE

The purpose of this research is: (a) to establish technological readiness of low-cost mirror modules and enclosures through research on polymers and other low-cost or high-performance materials and through evaluation of innovative concentrator concepts; and (b) to perform research and systems analysis and to assess the engineering and systems potential of enclosed collector concepts.

PROGRAM PROGRESS

Reports on the Tasks within this Work Package Agreement are given on the following pages.

TASK 1.1 Polymers for Enclosed Concentrators

Tasks under this activity include polymer research and polymer mirror and enclosure research for concentrators.

For work on polymers, the early years in the research will include materials testing, characterization, and evaluation. This research will be followed by: defining degradation mechanisms, interface reactions, and other phenomena; modifying existing polymers to incorporate the required characteristics; field-testing (hopefully at existing sites like CRTF and Barstow); and finally testing materials feasibility of low-cost, relatively high-performance, transmitting and reflecting polymers. Involvement of Industrial participants during all aspects in the strategy will ensure successful achievement of objectives.

For concentrator and enclosure research, the strategy is indicated in three stages. Briefly, the first stage will include systems analysis and engineering assessment to establish targets for costs on materials and components and requirements and applied research on bench-scale modules. The second and third stages will go beyond SERI's activities, will involve other laboratories, and will establish the core of a polymeric concentrator industry. This industrial base will be analogous to that already established for the steel/glass heliostat. These latter two stages will be focused on dome-enclosed concentrators.

TASK 1.1.1 Polymer Mirror Research—A. W. Czanderna

OBJECTIVE

The objectives of this Task are: (1) to identify promising silver/polymeric materials combinations for reflector applications; (2) to perform accelerated and real-time testing of the effect of environmental conditions on the stability of the polymeric mirrors; (3) to deduce the principal mechanisms of degradation of the mirrors; and (4) to develop analytical procedures for determining a relationship for predicting real-time durability from accelerated and/or abbreviated testing.

PROGRESS

Accelerated Testing of Silvered Polymers Optical characterization of the 11 samples exposed to one, two, and four weeks of testing was completed. The basic conclusions presented last month need not be altered. Analysis of the data and collection into a usable form are planned for completion by early September.

X-ray photoelectron spectroscopy and Ar^+ depth-profiling were used to show that the 35 nm-thick Inconel backing on silvered polymers is continuous. No silver signals were evident even after removal of 10 nm to 20 nm of the Inconel.

Optical characterization of 18 sets of the polymer-sputtered, silver-backing material has been partially completed. Weather-Ometer testing will be resumed as soon as the optical measurements are completed.

One of the samples which had been exposed to ultraviolet during two weeks of Weather-Ometer testing (60°C, 80 percent relative humidity) showed patches of discoloration of the film. Surface analysis of the stripped sample gave some additional information for corrosion of silver films in humid air. First, oxygen is present over the entire silver surface. From depth profiles, oxygen is limited to the surface except in the highly corroded patches where the oxygen is throughout the film. The depth profiles also suggest that the silver layer has been thinned from 100 nm to 25 nm to 50 nm in some areas. Thus a possible mechanism for both thinning the sample and also causing discoloration could be:

$$Ag + O_2 + H_2O \longrightarrow Ag_2O \xrightarrow[\text{polymer}]{\text{UV}} Ag^o \text{ (finely divided}$$

particles dissolved in the polymer) + oxidized polymer fragments.

The presence of an organic layer and ultraviolet exposure would both be necessary for the optical degradation. This agrees with the FTIR results for AgCl also. The Ag_2O formation/decomposition may only take place as a silver-polymer interfacial reaction. The kinetics of this reaction should be limited by the porosity of the polymer layer to the reactants, O_2 and H_2O. Ultraviolet absorbers may also slow the reaction.

Optical Characterization Facility An outline has been prepared for the report on modifying the equipment for optical characterization of polymer mirrors. Completion of the report is planned for September.

Fluorinating Polymers In support of preparing fluorination equipment for modifying polymers, surface analysis (XPS) was performed on samples of polyvinylchloride (PVC) and polypropylene that had been subjected to contact with fluorine gas. Fluorine and oxygen penetrate well into the bulk of the film. This result suggests that the polymers are permeable to the gases. In polypropylene, the carbon and fluorine XPS signals are shifted to levels suggesting a Teflon- like surface has been formed. The depth of the fluorinated layer depends upon F_2 exposure time.

A similar surface composition is formed on PVC where all of the surface chlorines seem to have exchanged with fluorine—producing a Teflon-like surface. In this sample also, the depth of fluorine penetration depends upon F_2 loading. In both cases, the fluorinated layer serves as an anti-reflection coating.

Ultraviolet Laser Further progress was made in preparing a laboratory for the ultraviolet excimer/dye laser. The laser optical bench was completed, and the excimer and dye laser units have been mounted on it. Most of the excimer gases, regulators, and safety equipment have arrived. Manufacturer's installation and alignment have been scheduled for September.

Polymer Degradation Researchers have prepared another series of PAN-coated mirrors by using the DMSO process for SERI testing. A glass saw has been fitted with a special device, designed and built to prepare glass flats of any size for the vacuum, sputtering or chemical deposition of silver. This facility solves a major problem which researchers have encountered in preparing mirrors of various sizes as required for the several test devices. A preamplifier has been built in hopes of improving the sensitivity of the MCT detector for the IR-RA studies of polymer films. It will be tested during the next project period when irradiation studies will be resumed.

TASK 1.1.2 Polymer Synthesis and Characterization—P. Schissel

OBJECTIVE

The objective of this Task is to establish an effort on polymer synthesis, modification and characterization and to initiate polymer modification to improve durability (performance over time).

PROGRESS

Silver Mirrors with Cast Polymer Films Polyacrylonitrile (PAN) film has performed well in the Weather-Ometer tests to date—better than unaltered PMMA (polymethylmethacrylate). However, in outdoor tests, PAN has delaminated-permitting the silver to degrade while PMMA has not delaminated. Optical measurement on those portions of PAN-coated mirrors that had not delaminated when exposed outdoors showed no degradation.

Workers at the University of Denver (DU) have observed that PAN, cast from dimethylsulfoxide onto silver, can be delaminated from silver if treated in a water-ultrasonic bath. However, if it is first exposed to a solar simulator, it cannot be delaminated ultrasonically nor can it be peeled mechanically. (A patent docket has been submitted.) Four SERI mirrors made by the wet chemical silver process have been coated with PAN at DU. The samples were exposed at a minimum distance to the SERI solar simulator with no filters interposed-thus maximizing overall intensity and particuarly the intensity down to 245 nm, a wavelength much lower than that present in the solar spectrum. The PAN/silver mirrors showed a slight improvement visually by this three-hour exposure (less milky) but not measurable change in hemispherical reflectance. Two samples will be placed in the Weather-Ometer and two outdoors to see if adhesion is improved in real exposure.

Unaltered Polymethylmethacrylate (PMMA) or PMMA with 1 percent additive (either National Starch or Uvinol 100 or Tinuvin P stabilizers) have been exposed in the Weather-Ometer (four weeks) or outdoors (six weeks). PMMA plus Tinuvin P was essentially unaltered in each test (as was unstabilized PAN) with a hemispherical reflectance of about 88 percent. These are wet-processed silver mirrors, and tests suggest that about 6 percent loss is due to the metallization process. PMMA plus National Starch and PMMA plus Uvinol showed loss of reflectance in the Weather-Ometer but less loss or no loss outdoors.

In summary, four candidates are essentially unchanged during these short-term tests: 3M-YS94; Sheldahl-Teflon; PAN; PMMA plus Tinuvin P. Specular reflectance measurements are yet to be completed; however, literature data suggest that Teflon will be relatively deficient in specularity.

Glazings The Jet Propulsion Laboratory (JPL) is studying the environmental degradation of glazings—laminated for mechanical property improvement and stabilized by using bound ultraviolet absorbers.

The direct fluorination process has been designed, built, assembled, and tested. The first use of the equipment has demonstrated that fluorination of polypropylene film increases its transmittance by effectively forming an antireflective coating.

Studies on Polyesters Containing Bound Ultra-violet Asborbers

Crosslinked polymers consisting of polypropylene terephthalate crosslinked with polystyrene and incorporating 1 percent (by weight) of 2-(2-hydroxy 5-vinylphenyl) 2H-benzotriazole and 2-(2-hydroxy 5-propenylphenyl) 2H-benzotriazole were synthesized and preliminary aging studies have been reported. Emission studies of these samples were carried out. Results indicated an appreciable amount of impurity was contained in polyester (1). A new batch of polyester (1) was then prepared, and its emission showed within detection limit, no contamination, that is, long wavelength (λ>600 nm) emission.

Aging studies of this pure polyester (1) film sample, in the JPL control environment chamber showed:

> Very significantly improved ultraviolet resistivity as compared to unstabilized polyester. Researchers have illustrated the absorption spectra of polyester (1) and unstabilized polyester, respectively, as a function of aging. With up to 28 days of aging, very little change can be detected in

UV-VIS absorption spectrum of the polyester (1), whereas, the unstabilized polyester showed a large increase in long wavelength absorption (yellowing) in less than 100 hours of aging.

Permanency of ultraviolet absorber. Since the extinction coefficient of the ultraviolet absorber is 20,000 lt mole ^{1} cm ^{1} in the 300 nm to 400 nm wavelengths, any loss of the ultraviolet absorber will result in an appreciable decrease in absorbance in this wavelength region. The invariance of absorbance of Polyester (1) between 380 nm to 400 nm after 28 days of aging leads to the conclusion that physical loss of the ultraviolet absorber does not appear to be a problem.

Validation of the Long-Range Excited State Quenching

Characterization of four polystyrene (PS) film samples have been initiated. They are: (1) pure PS; (2) PS with 1 percent 2-Hydroxyphenyl benzotriazole (T) physically incorporated; (3) PS with 5 percent T, physically incorporated and; (4) Copolymers of styrene and 4 percent 2(2-Hydroxy 5-vinylphenyl) 2H-benzotriazole (CoPS).

TASK 1.2 Advanced Enclosed Thermal Dish Concentrators

This activity is investigating the feasibility of enclosures and enclosed dish concentrators for thermal and other applications. Tasks include analysis of enclosure and dish systems and an RFP to industry for design and development. It is anticipated that the innovative low-cost concentrators and enclosures will establish through industry the feasibility of meeting cost and performance targets for solar thermal energy systems. Technical issues include unidentified failure modes, cost effectiveness, beam walk-off, long-term durability, and the presence of a mid-to-high temperature heat source within the enclosure.

TASK 1.2.1 Enclosure and Dish Concept Study and Development—R. Gee/L. Murphy

OBJECTIVE

This Task performs research and systems analysis on the engineering and systems potential of polymer-based enclosures and enclosed thermal dishes, builds and tests scale-model enclosures, and extends the investigation of other innovative concentrators concepts such as the stretched membrane.

Also with this Task, research on polymer enclosure fabrication and assembly technology will be conducted, and materials performance and testing requirements, as well as research needs for polymer enclosures and materials, will be established. Specific issues to be investigated include plastic dome fabrication techniques, attachment design, seam design, engineering advantages of laminates, and increasing the tear strength of thin polymer sheets. Results of this Task will be used in the Industrial Designs Development Task to support design recommendations. Findings will be disseminated to industrial developers and other laboratories working on domed concentrators.

Through systems analysis, the dish optical thermal performances and economic potential of the concept are to be assessed (while realizing that other current research is addressing additional crucial issues in systems such as high piping and transport costs). Close coordination with the Materials Branch and the work on applicable materials will be maintained to arrive at recommendations on materials requirements and research. Coordination with related work at the Jet Propulsion Laboratory will be maintained.

A full-scale or two-meter scale dome SRE is to be configured and is to be built to test domes of various approaches to materials attachment and seaming. The SRE is to be flexible to allow relevant testing for either enclosed thermal dishes or heliostats. Research and systems analysis on innovative concentrators will continue to offer additional collector options to meet the D.O.E. value-based goals of $\$50/m^2$ and \$5/GJ delivered energy.

PROGRESS

Analysis confirmed the potential viability of an evacuated deep-dish receiver concept. On an annual basis the performance would be reduced about 6 percent compared to a cavity receiver at a process operating temperature of 538°C (1000°F). Researchers estimate that potential cost reductions of a deep-dish system are significantly larger than 6 percent.

Fabrication of the 2.44-meter dome bases continued. Arrangements have been made to TIG-weld the 2.44-meter dome base.

Sheldahl has begun work on fabrication of the 2.44-meter Tefzel domes. The initial step is preparation of production drawings for the dome panels. Samples of 5 mil Tefzel seams have been prepared for SERI's evaluation. The Tefzel was glow-discharge-treated (an etching process) on one side of two samples and on both sides of two other samples. In all cases during tensile testing of the seams, the base material yielded before the seam failed and thus indicated adequate seam strength. The seam samples will be placed in the Weather-Ometer for accelerated aging at SERI. Transmittance data were also supplied by Sheldahl. The results are tabulated below. Similar transmittance tests will be performed on SERI's equipment.

TRANSMITTANCE OF TEFZEL

	Visible	UV
Untreated	91.3	82.2
One side treated	90.6	76.1
Both sides treated	90.3	73.4

Though analyses have determined the detailed load distributions within the structure of the dome membrane, a better definition of actual applied wind loads on spheres has been under investigation. No definitive explanation for the USAF Randome Handbook discrepancy between theoretical and measured drag coefficient (C_D) has been found. It appears that the dynamic nature of wind flow on the leeward side could explain the difference between the measured and calculated C_D. SERI wind turbine experts suggest this possibility also. More recent studies in the open literature have shown similar inconsistencies (but not always in the same directions) and indicate that experimental predictions may often be unpreditable and greatly dependent on testing configurations in the wind tunnel.

The analytical and design solution for the problem of the membrane and ring interaction has been completed and has been validated for two simplified loading conditions by comparisons with known solutions. The NASTRAN solution validation has now begun, and the development of a membrane-surface-error routine was begun. This analytical and design tool will allow the rapid screening and evaluation of different ring and membrane design configurations.

TASK 1.2.2 Industrial Design Development

OBJECTIVE

The objective of this Task is to develop and to release an RFP for conceptual design of enclosed thermal dishes. The resulting contracts will be managed by SERI.

Thermal dishes have been identified as having the technical potential of providing solar thermal process heat in the range of 600°F to 1000°F. This activity can be done most effectively where relatively small fields are required (assuming that the high cost of transport and piping can be resolved). Further, by enclosing the thermal dishes, significant cost reductions may be possible if the associated engineering difficulties can be overcome. The proposed RFP and resulting subcontracts are to provide the first concepts which may exploit the cost-reduction potentials and may resolve the engineering difficulties with this concept.

PROGRESS

This Task has not been initiated pending results from Task 1.2.1.

SECTION 2

WPA 417A

THERMAL MATERIALS RESEARCH

OBJECTIVE

The objective of this activity is: (a) to perform research on thermal materials and thermal fundamentals including ceramics, high-temperature receivers, storage concepts transport of heat, and heat transfer research; and (b) to develop innovative concepts for conversion of thermal energy to fuels and chemicals.

PROGRAM PROGRESS

The progress on individual Tasks is outlined on the following pages.

TASK 2.1 Receiver and Materials Research

This activity encompasses Tasks in high-temperature receiver research, high-temperature heat transfer research, ceramic materials research, facility design, and materials and fluids research.

Information from universities, from the Fuels and Chemical Subprogram, and from current large-scale experiments at CRTF, PDTS and other places is to provide response to resolve technical issues and to set initial requirements. It is anticipated that, once materials and concepts have been proven technically feasible at SERI, large-scale experiments at CRTF, GIT, and at a high-temperature dish facility will be required on some concepts to verify technical readiness. Industry will be involved in the resolution of some issues and even more heavily in the design, fabrication, and testing. Again, help of advisory panels will be sought to critique research and to recommend future directions in research.

TASK 2.1.1 Ceramic Materials Research—T. Coyle

OBJECTIVE

Receivers for solar thermal applications greater than 870°C require ceramic materials to function as absorbers, heat exchangers, and windows transparent to solar radiation. The objective of this Task is to identify suitable ceramics for these applications by characterizing the mechanical, optical, and thermal properties of candidate materials. Candidate materials initially are commercially available materials with the probable requirement that, after the first year, materials more closely tailored to suit the requirements of these applications will have' to be fabricated by using laboratory or small-scale procedures in development.

PROGRESS

A compliance calibration was done on 2 three-point loading samples of different cross sections—one with a ratio in width to height of 1.25 and the other with a ratio of 1.50. The results were fitted to a standard curve of the form $C = a + b + Ce^{d\alpha}$ where C is the compliance, α is the dimensionless crack length, e is the Napierian base for natural logarithms, and the small letters are constants. These results will be compared with the results of compliance calibration by other workers.

By using the compliance calibration, the fracture toughness of Coors AD 90 alumina was determined to be 3.384 $MPam^{1/2}$ compared to a published value of 3.49-very good agreement.

Literature on sample preparation equipment was collected, and a number of suppliers gave recommendations on equipment to allow easier and more accurate preparation of fracture samples.

A Nicolet oscilloscope interfaced with a computer (Hewlett-Packard 85) was employed, with the help of Computer Services, to measure the compliance of fracture samples.

Corrosion studies on platinum in molten eutectic $(Na, K)_2 CO_3$ showed corrosion rates of about 1.6 μm/day and retention of a highly specular surface which could allow Pt to be used in reflecting light back through molten salts to measure optical absorption.

At TerraTec Engineering, the pressureless sintering of $SiC-Al_2O_3$ composites in closed crucibles was studied. There is no significant densification at temperatures to 1900°C, whereas $TiC-Al_2O_3$ sinters readily at 1700°C. The densification of $SiC-Al_2O_3$ will be performed by hot-pressing. Further efforts to densify SiC and $SiC-Al_2O_3$ without pressure will be studied.

TASK 2.1.2 High-Temperature Facility Design and Specification—L. Murphy

OBJECTIVE

This Task is to determine the high-temperature facility requirements needed to support solar thermal and materials research at SERI. A recommended plan for the fabrication, installation, and funding levels for the test facility will be developed.

PROGRESS

The revised report entitled "Solar Thermal Research Test Facility Requirements" was approved by SERI's management and was transmitted to the D.O.E.

TASK 2.1.3 High-Temperature Material/Fluids Research—T. Coyle

OBJECTIVE

The overall objective is to select and to qualify high-temperature structural materials and heat transfer fluids for use in solar thermal systems. One long-range objective is to qualify refractory materials for containment of working fluids at temperatures up to 1370°C by 1987. The objective is to identify containment material/heat transfer fluid pairs which are compatible at temperatures up to 1370°C and to develop some understanding of how interactions affect the mechancial properties of these containment materials.

PROGRESS

Single-crystal sapphire (Al_2O_3) and high-purity polycrystalline $MgAl_2O_4$ spinel showed the least reactivity of the ceramic materials studied in molten eutectic Na_2CO_3/K_2CO_3 at 900°C for 18 days—an atmosphere of 3000 ppm CO_2 was used in the cover gas above the molten salt. The corrosion rate was 0.1 μm per day.

The result reported aobve for sapphire contrasts with a slight weight gain for Coors 99.5 percent Al_2O_3; a 1.4 m per day loss rate for Frenchtown 99 percent Al_2O_3; and a 5 μum per day loss rate for Coors 90 percent Al_2O_3 in the same tests. The glassy phase in the lower purity materials is thought to result in the increased interaction with the salt compared to the high purity materials. A fusion cast $MgAl_2O_3$ material was found to have a corrosion rate of 5 μum per day; again, the higher rate is probably due to a more glassy phase in this material than in the high purity $MgAl_2O_4$.

An MgO stabilized ZrO_2 material was found to have a low corrosion rate of 1 μum per day in these eighteen-day carbonate tests, while a porous MgO material showed a significant weight gain and no sign of degradation. One candidate refractory material, a magnesia chrome material, showed 5 μum per day, an encouragingly low rate for a commercial material.

Assembly of a quadrapole-mass-spectrometer system for temporary use was completed; it will be used to monitor the chemistry of carbonate salts by detecting the CO_2 partial pressure. New sample holders have been prepared as well as coupons for a series of corrosion tests in ternary eutectic $(Li, Na, K)_2\ CO_3$ which has a melting point of 397°C. Two of the more promising ceramic materials, Coors 99.8 percent Al_2O_3 and Monofrax M fusion cast Al_2O_3 which were initially tested under the storage program, will be studied for corrosion rate and corrosion mechanisms in this salt.

TASK 2.1.4 Receiver/Heat Transfer Research—R. Copeland

OBJECTIVE

The objective of this Task is to determine the technical feasibility of a promising concept for solar central receivers to supply high-temperature (800°C) heat for electric power production, industrial process heat, and production of fuels and chemicals. The SERI concept makes use of a molten salt which can withstand high temperatures as the working fluid in the receiver. The molten salt is directly exposed to concentrated solar radiation as a film flowing down the inner walls of a cavity receiver at atmospheric pressure. The molten salt has much better heat transfer characteristics than air. The flowing film eliminates the problem of joining tubes at high temperature. Since the receiver operates at atmospheric pressure, it may be possible to eliminate window materials.

PROGRESS

Analyses were performed on a Direct absorption Receiver. A two-dimensional model is now operating, and data are being generated for both laminar and turbulent flow correlations. With proper design of the receiver, excessive temperature differences can be avoided, (that is, a high efficiency receiver is possible). Several approximations are still in the model, and future work is needed both in development and validation of the model.

The analyses have shown that a minimum scale for the direct absorption receiver is one meter. To perform a model validation experiment only ACTF (Georgia Tech) or CRTF (Albuquerque) are large enough. Plans are being drawn to conduct an experiment in fiscal year 1984. Researchers have tentatively selected ACTF with detail design and fabrication of the experiment to be performed by a subcontractor. Initial discussion with Georgia Tech is planned for September.

A falling film of molten salt is expected to have a variable thickness due to varying flow rates and viscosity. The film in some conditions is laminar, is turbulent in other conditions and will be affected by surface roughness. A device to measure film thickness is now operational-employing water as the medium. Under some conditions, dry spots are observed—implying a burn-out condition. Data are being collected so that dry spots can be avoided in the actual receiver.

Viscosity data for the molten carbonate have been reviewed. The data are conflicting with an indicated order of magnitude variation in reported viscosity for the same salt at the salt temperature.

TASK 2.2 Advanced Research Program Management Support to DOE/SAN—B. Gupta/ F. Krawiec

OBJECTIVE

The objective of this Task is to provide technical support to the DOE/SAN office for the Solar Thermal Advanced Research Program (STARP)—providing technical data, specific areas of future research, and the priorities in those areas of research. Specific functions include:

- o Technical support in preparation of solicitation, as required, and in evaluation of the proposals expected;
- o Review of technical results in relation to solar thermal cost and performance goals;
- o Recommendations for research to be included in subsequent solicitations and for more detailed investigation.

PROGRESS

Status on this Task is being reported under WPA 401-82, Advanced Research, until the depletion of funds for fiscal year 1982.

TASK 2.3 Silver-Glass Mirror Research—A. W. Czanderna

OBJECTIVE

The objectives of this research include: (1) assessing the current problems and opportunities of commercially available mirrors; (2) deducing the principal mechanisms of degradation of mirrors of the type currently deployed in central receiver systems.

PROGRESS

Redirected funding for this Task reduced the objectives to those already accomplished and reported.

2.4 Program Management—B. Gupta

OBJECTIVE

The objective of the Program Management Task is to plan, to coordinate, to evaluate, and to report on the activities of the Solar Thermal Program assigned to SERI. This activity includes the in-house SERI solar thermal effort, selected Tasks at other national laboratories, and subcontracts to industry and universities.

The Task will deliver written monthly reports of activities under its direction; quarterly review presentations; and program strategy, planning and evaluation support to D.O.E., Washington. The Task also will conduct technology-transfer activities which focus on the development, dissemination, and communication of technical information through appropriate channels to audiences involved in the Solar Thermal Program.

PROGRESS

SERI received fiscal and programmatic guidance from D.O.E., Washington, regarding the fiscal year 1984 STT Research Program—the SERI portion, the University Research Program, and the Innovative Concepts Program. D.O.E., Washington, also provided instructions on how the fiscal year 1984 Annual Operating Plan (AOP), reflecting the guidance, was to be written.

On the basis of that guidance, efforts were devoted to revising the first draft of the STT Research Program FY84 Annual Operating Plan (submitted to D.O.E., Washington, on July 1, 1983). Because the instructions for preparing the revised AOP differed significantly from those for preparing the first draft, this version required major rewriting.

Plans for next month include:

- Completion of the revised draft of the FY84 STT Research Program Annual Operating Plan and submitting it to D.O.E., Washington, and to TPI;

- Submission of the fiscal year 1984 WPP and associated FTP's for the STT Research Program to D.O.E.;
- Preparation of the hard copy materials for the fiscal year 1983 Fourth Quarter STT Program Quarterly Review;
- Participation in the fiscal year 1983 Fourth Quarter-Quarterly Review to be held at D.O.E., Washington, on September 22 to 24;
- Continuation of the writing of the report documenting STT Program research and advanced development accomplishments since fiscal year 1977;
- Preparation of the outline for the SERI portion of the Solar Thermal Technology Annual Evaluation Report and submitting it to TPI.

SECTION 3

WPA 440

SUPPORT TO SYSTEMS TEST AND EVALUATION

OBJECTIVE

This research is intended to provide technical support to solar thermal field experiments: (1) to enhance the probability of successful operation; (2) to provide a link between research and the application of solar thermal technology; and (3) to provide a return of information to ensure that research is targeted on technological barriers and issues.

PROGRAM PROGRESS

Progress on activities is reported on the following pages.

TASK 3.1 Trough/IPH Evaluations

OBJECTIVE

The purposes of this Task are to determine the extent to which the selected IPH field experiments are delivering energy, to determine the cause of any reduced performance, and to make appropriate recommendations for current system improvements and future designs. To accomplish these goals, SERI, in conjunction with and in support of the IPH project managed by Sandia, Albuquerque, will collect performance data from the field experiments and will examine on-site problems. The field experiments will be modelled on SERI's hour-by-hour solar IPH simulation program (SOLIPH) to predict how the systems should be performing. Careful study will be made to determine the nature of any discrepancies to identify measures which must be taken to correct them. SERI analysts will be particularly alert for opportunities to validate and to improve the predictive capability of SOLIPH. Additionally, SERI will review the instrumentation and data acquisition at the selected sites to determine the adequacy of contractor-reported information.

PROGRESS

Validation efforts for SOLIPH predictions continued in detail for USS Chemicals and have begun for Home Laundry. At USS Chemicals, errors in reported data through April were identified by the contractor and make comparison impossible. May performance data show unreasonably high collector performance (~60 percent). The optical efficiency of the SKI T-700 is only 65 percent. With a dirty reflector estimated to have an optical efficiency of 59 percent and a 10 percent heat loss, the collectors cannot possibly achieve 60 percent efficiency. It is thought that errors exist in calculation of incident energy in the plane of the collector-causing low radiation values and correspondingly higher efficiencies. This issue is under investigation with USS Chemicals. At Home Laundry, an apparent error of the same type was identified-causing high reported efficiencies. This result is also under investigation with Home Laundry.

Numerous other minor issues make direct comparison between SOLIPH and the reported data difficult. It is anticipated that the remaining sites will exhibit the same difficulties.

An abstract entitled "Modeling of the DOE Sponsored IPH Field Test Experiments" was submitted to ASME for the Solar Energy Division Sixth Annual Technical Conference to be held in Las Vegas, Nevada, on April 8 to 12, 1984. Coauthors are A. Lewandowski, R. Gee, and K. May.

PART II FISCAL YEAR 1982

SECTION 1

WPA 279B, WPA 803

APPLIED RESEARCH

OBJECTIVE

The objective of the SERI Applied Research Subprogram is to advance the technology base through feasibility experiments and systems analysis of advanced solar thermal systems and components.

This Work Package Agreement consists of two basic activities: (1) MISR System Evaluation, and (2) Heat and Mass Extraction for Solar Ponds.

The objectives of these activities are:

- To evaluate state-of-the-art line focus solar thermal systems fabricated by industry by conducting performance testing on a prototype MISR system at a SERI field test loop. A test loop has been designed and constructed. A MISR prototype system was installed, and testing of the system was conducted by SERI at the SERI Permanent Test Site. The test data is being provided to Sandia National Laboratories, Albuquerque.
- To design and to carry out experiments in order to determine the physical factors which limit the rate at which heat and mass may be extracted from the storage layer of a salt gradient solar pond by yet untried extraction methods, and to develop concepts for new extraction methods which are more efficient and cost-effective than existing methods.

PROGRAM PROGRESS

Progress on the Tasks is reported on the following pages.

TASK 1.1 MISR Testing—J. Thornton

OBJECTIVE

The objective of the MISR (Modular Industrial Solar Retrofit) Task is to encourage the use of line-focus based solar thermal systems within industry by conducting performance testing on a prototype MISR system at a SERI field test loop. A detailed test loop was designed and constructed. Installation of the MISR prototype system followed, and qualification testing of the system is taking place.

PROGRESS

Previous testing of equipment has been reported as completed, and no further testing has occurred.

TASK 1.2 Laboratory Experiments on Heat and Mass Extraction from Solar Ponds—D. H. Johnson

OBJECTIVE

The objectives of this Task are: (1) to design and to carry out experiments to determine the physical factors which limit the rate at which heat and mass may be extracted from the storage layer of a salt gradient solar pond by a given extraction method; (2) to develop concepts for new extraction methods which are more efficient and more cost-effective than the existing methods.

PROGRESS

Reports on subcontracted work are the following:

Colorado State University: Procedures for measuring salinity by extracting samples of brine and weighing them were developed. A preliminary experiment with a non-linear salt gradient was performed. A double diffusive instability occurred as predicted by the theory of Zangrando and Bertram.

Purdue University: A preliminary experiment on gradient layer erosion using the small test cell was completed, and data reduction is underway. Experiments on gradient layer erosion using the large test cell were initiated. These are expected to continue for two months.

University of Utah: Assembly of the experiment at the Utah Power and Light site is approximately half completed.

M.I.T.: The computer data acquisition system has been purchased and has been installed. The wind/wave flume has been prepared for experiments on wind mixing in salt gradient solar ponds.

TASK 1.3 Development of a Direct Contact Heat Exchanger for Solar Pond Power Production—D. H. Johnson

OBJECTIVE

The objectives of this Task are: (1) the analysis of a direct contact condenser for solar pond electric power production and; (2) a re-evaluation of a direct contact preheater/boiler for solar pond power production using data from experiments being conducted at the University of Utah.

TECHNICAL APPROACH

The approach to Objective 1 will be to develop an analytical model of a Direct Contact Condenser and to use it to evaluate the performance of a solar pond power production system by using it in comparison to one using a conventional shell and tube condenser. The approach to Objective 2 will be to use data supplied by the University of Utah to redo the analysis of a direct contact preheater/boiler that was done previously in using data from the literature.

PROGRESS

Methods of removing non-condensibles dissolved in brine from the evaporation pond were analyzed. A flash deaerator will control concentration of non-condensibles to acceptable levels.

Three candidate direct contact condensers were analyzed. Spray and packed column condensers have problems (in separating working fluid from brine) which are avoided in a bubble-type condenser.

TASK 1.4 Solar Pond Surface Mixed Layer Studies—D. Johnson

OBJECTIVE

The ultimate objective of this work is to develop an inexpensive, but effective method of limiting the depth of the surface mixed layer which develops in a solar pond.

PROGRESS

The computer data acquisition system has been purchased and has been installed. The wind/wave flume has been prepared for experiments on wind mixing in salt gradient solar ponds.

SERI

SECTION 2

WPA 280

PROGRAM PLANNING AND COORDINATION

OBJECTIVE

The mission of the SERI Solar Thermal Program Planning and Coordination Subprogram is to identify long-term, high-payoff R.&D. options for the Solar Thermal Program, to recommend goals and objectives, and to assess potential benefits of long-term R.&D. options.

This Work Package Agreement has included the following: (1) R.&D. Assessment; (2) Systems Analysis; and (3) R.&D. Benefits. The objectives of R.&D. Assessment are: to determine energy and systems-level performance and cost goals for solar thermal technology, to identify options and to recommend priorities for long-term R.&D., and to develop a multiyear plan for solar thermal research. The objectives of Systems Analysis are: to identify and to analyze crucial performance and cost allocation targets for materials and components, and to evaluate innovative concentrator concepts using systems sensitivity analysis. The objective of R.&D. Benefits is to assess the relative benefits of various advanced R.&D. options for solar thermal systems in industrial applications.

PROGRAM PROGRESS

The Program report on each Task now in progress within this Work Package Agreement is given on the following pages.

TASK 2.1 Research and Development Assessment

OBJECTIVE

The objectives of this Task are to determine and to recommend targets for energy and systems-level cost and performance for solar thermal technology based on market value; to identify options and to recommend priorities for the Solar Thermal Advanced R.&D. Program; to develop an advanced R.&D. MYPP; and to support D.O.E. Solar Thermal Technology Program in the MYPP and other planning and assessment activities.

PROGRESS

The revised draft of the SERI report, Solar Thermal Cost Goals Committee: Activities and Recommendations, was completed and was submitted to the D.O.E., Washington, and to TPI for review.

Plans for next month include sending the revised draft to as many members as possible from the Solar Thermal Costs Goals Committee (STCGC) for review. After the reviews from D.O.E. (Washington), TPI, and the Committee, SERI will prepare a final version of the report.

TASK 2.2 Research and Development Benefits—L. Flowers

OBJECTIVE

The intent of this Task is to assess benefits of Advanced R.&D. for the industrial sector in support of the Multiyear Program Plan, Cost Goals Committee, and Sunset Review Documentation.

PROGRESS

The report describing the IPH Potentials (IPHPOT) computer model and the results obtained in using the model to generate estimates of solar IPH market potential in 1990 and 2000 has been completed except for several figures.

SERI has encountered numerous difficulties in publishing and disseminating the report for review because of limited staff and the assignment of priorities. As staff becomes available, plans for next month include completion of the figures, publication of the report, and submitting it to D.O.E., Washington, and to TPI for review.

SERI

SECTION 3

WPA 401

ADVANCED RESEARCH

OBJECTIVE

The Work Package Agreement has the following as its objectives:

1. To provide technical support to the DOE/SAN office for the Solar Thermal Advanced Research Program (STARP), providing technical data, specific areas of future research and the priorities in those areas of research. Specific functions include:

   - Technical support in preparation of solicitation, as required, and in evaluation of the proposals expected;
   - Review of technical results in relation to solar thermal cost and performance goals;
   - Recommendations for research areas to be included in subsequent solicitations and for more detailed investigation during Phase II of the first solicitation.

2. To conduct an effort to identify the most promising solar fuels and chemicals production based on photochemical (i.e., quantum) and thermal principles when used in a hybrid manner to enhance the overall solar conversion efficiency. Technical and economic potential and risks will be assessed.

PROGRAM PROGRESS

The Program report on each Task is given on the following pages.

TASK 3.1 Advanced Research Program Management Support to DOE/SAN—B. Gupta/ F. Krawiec

OBJECTIVE

The objective of this Task is to assist DOE/SAN in coordinating the effort at the two universities—the University of Houston and Georgia Institute of Technology—and to assist in the development and initiation of an advanced research program.

PROGRESS

Plans were discussed with DOE/SAN for fiscal year 1984 effort at the universities and were included in the SERI Annual Operating Plan. Discussions were also held on the members of the advisory group, and all advisors were appointed to each of the twelve contracts.

TASK 3.2 Photo-Chemical Research—F. Kreith/D. Johnson

OBJECTIVE

The objective of this Task is to explore the potential of photon-enhanced processes and their applicability to solar thermal technologies. Based on the evaluation, a future effort in this long-term research will be recommended.

PROGRESS

Researchers continue monitoring work on the publication activities of the workshop proceedings—processing through the Editing Department and related matters.

SERI

MEETINGS AND PRESENTATIONS

On July 27 presentation on "Solar Materials Research" was made by A. W. Czanderna for the SOLERAS Workshop held at SERI from July 24 to 28.

On August 16 "Effects of Chloride Contamination in Accelerating Photodegradation of PMMA Films on Silver Surfaces" by J. D. Webb was presented at the Rocky Mountain Conference of SAS in Denver, Colorado.

On August 25 an invited presentation on "Polymer Degradation on Reflecting Metal Films: FT-IR RA Studies" was delivered by J. D. Webb at the 26th International Technical Symposium, SPIE in San Diego, California.

J. D. Webb and T. M. Thomas attended several sessions of the Rocky Mountain Conference of SAS in Denver, on August 15 to 17.

J. D. Webb and E. Tracy attended the 27th International Technical Sumposium, SPIE (International Society for Optical Engineering), at San Diego, California, from August 22 to 25.

A. W. Czanderna and P. Schissel met with D. Duffy and H. L. Morse of Acurex on July 27 to discuss prior silver/glass mirror work and current polymer mirror research at SERI.

H. H. Neidlinger presented a review of the polymer activities at D.O.E., Washington.

Technical discussions by SERI staff were held with representatives from Acurex, the Arizona Solar Energy organization, Ramada Energy Systems, and Power Kinetics.

Staff presented the SERI Concentrator Development Effort to D.O.E./Washington Solar Thermal Program Managers and Branch Chiefs in Washington, D.C., on August 9.

R. Mikesell, a visiting summer professor from South Dakota State University in Brookings, gave a seminar entitled "Compliance Calibration of Chevron Notched Three Point Loading Specimens" at SERI on August 12.

A paper entitled "A Computer Assisted Technique for Measuring the K_I-V Relationship" was accepted for publication in an ASTM STP on "Chevron Notched Specimens."

T. Coyle met with J. Woodard and D. Dawson from Sandia-Livermore's Solar Programs Division to discuss SERI activities and how to coordinate efforts between the SERI and Sandia programs. A tour of Materials Laboratories was also conducted.

B. Gupta attended the design review at GA Technologies for the pressurized reactor tests planned during fiscal year 1984.

SERI
SOLAR THERMAL ENERGY PROGRAM
SUBCONTRACT LIST

Research Area	Subject	Subcontractor	FY82 ($K)	Award Date
A Solar Pond/ORC DCHX	Laboratory Tests of a	University of Utah Brine/Pentane DCHX	100	1/83
Solar Pond Heat and Mass Exchange Research	Solar Pond Mixed Layer-Gradient Layer	Purdue University Interface Studies	70	4/83
Solar Pond Surface Mixed Layer Studies	Wind Mixing in Salt Gradient Solar Pond	Massachusetts Institute	62	6/83

TABLE
Planned Major Procurement Funded from FY 1983

Research Area	Subject	Subcontractor	FY83 (K$)	Award Date
Optical Materials Research	Materials Outdoor Exposure	DSET, Inc.	50	12/83
	Polymers Synthesis and Modification	JPL	150	2/83
Thermal Materials Research	Investigation of Improved Properties in Densified Ceramics	Terra Tek	65	2/83
	Structural Integrity of High Temperature Ceramic Components	To be determined	85	1/83
	High Temperature Heat Transfer Fluid Thermal Diffusivity Techniques	To be determined	100	
	Thermal Science Research	To be determined	100	10/83
	Leakage through Seal Material	Barber-Nichols	15	2/83
Innovative Concepts	Multiple Subjects	To be determined	300	9/83

APPENDIX B

RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

3. Program Identification: SOLAR THERMAL TECHNOLOGY

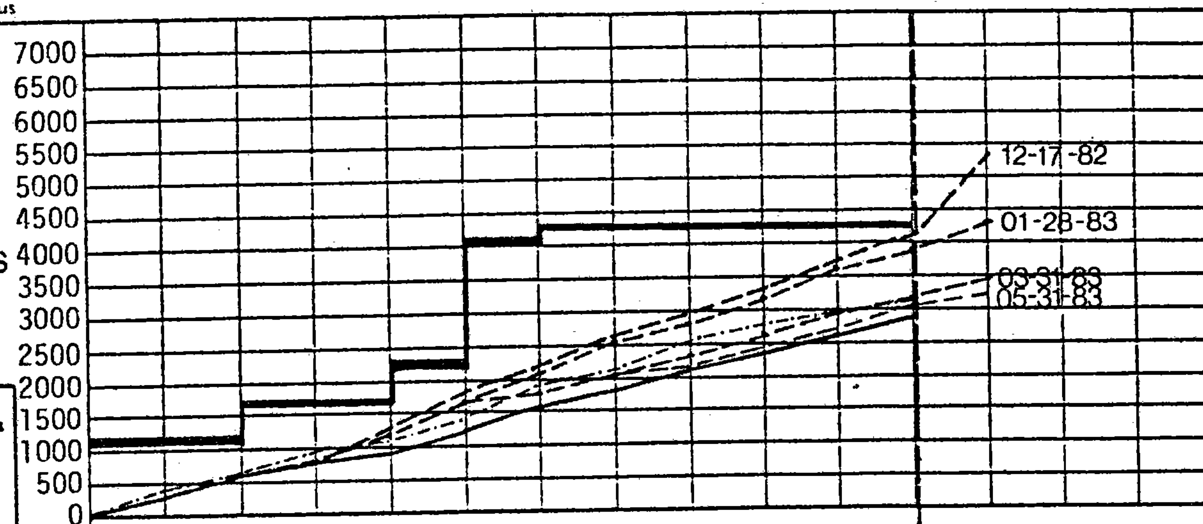
4. WPA/Task: PROGRAM TOTAL

7. Months: Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec.

8. FY 83

9. Cost Status

a. THOUSANDS OF DOLLARS



b. B&R Numbers: EB0201, EB0202

Accrued Costs	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
c. Planned	241	508	779	1277	1770	1819	2065	2187	2464	2733	3016	3280			
d. Actual	241	508	750	892	1212	1527	1788	2077	2342	2585	2761				
e. Variance	0	0	29	356	173	(266)	(15)	(167)	12	26	107				
f. Cum. Variance	0	0	29	385	558	292	277	110	122	148	255				

g. Cost Plan Date: 05-31-83

h. Planned Costs Prior FY82: 4000

i. Actual Costs Prior FY82: 4011

j. Total Estimated Costs for FY83: 3280

k. Total Contract Value: N/A

l. Unfilled Orders Outstanding: 357

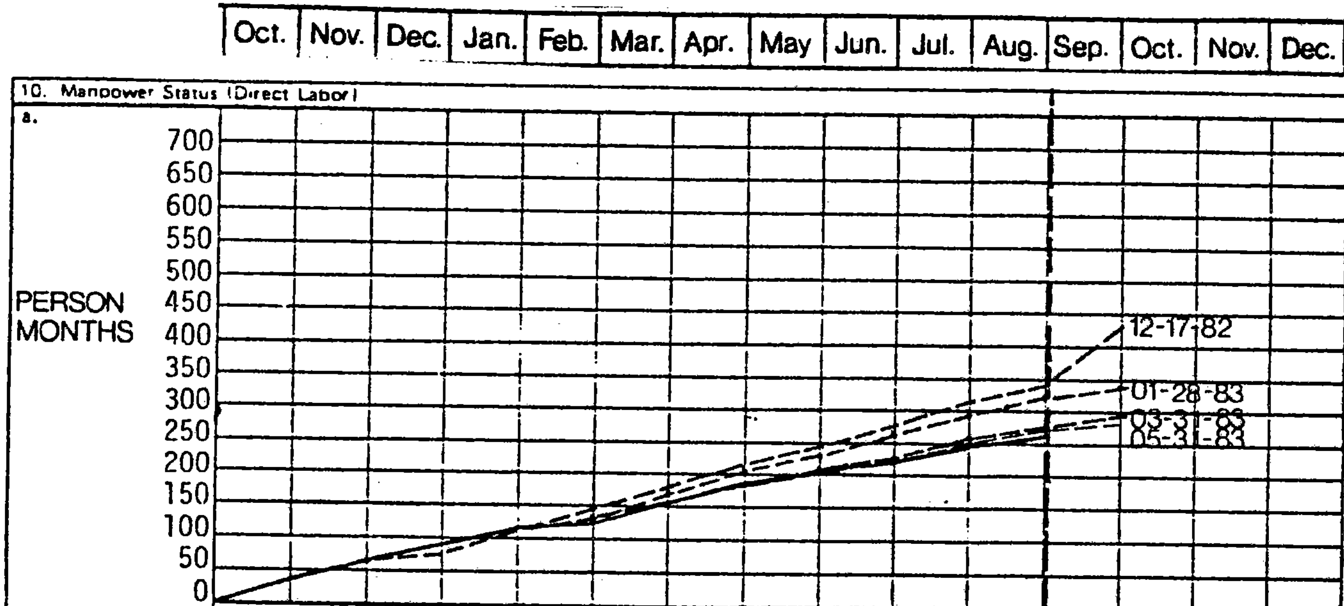
m. Estimate for Subsequent Reporting Period: 232

Obligational Ceiling — Actual
Costs Plus Commitments — Plan

MANPOWER STATUS

10. Manpower Status (Direct Labor)

a.



Manpower		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
	b. Planned	30	59	74	108	141	165	187	208	230	250	270	289			
	c. Actual	30	59	87	113	139	165	189	209	227	246	261				
	d. Variance	0	0	(13)	(5)	2	0	(2)	(1)	3	4	9				

e. Manpower Plan Date
05-31-83

f. Planned Manpower Prior FY82
395

g. Actual Manpower Prior FY82
386

h. Total Estimated Manpower for FY83
289

i. Total Contract Manpower
N/A

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

3. Program Identification: SOLAR THERMAL TECHNOLOGY

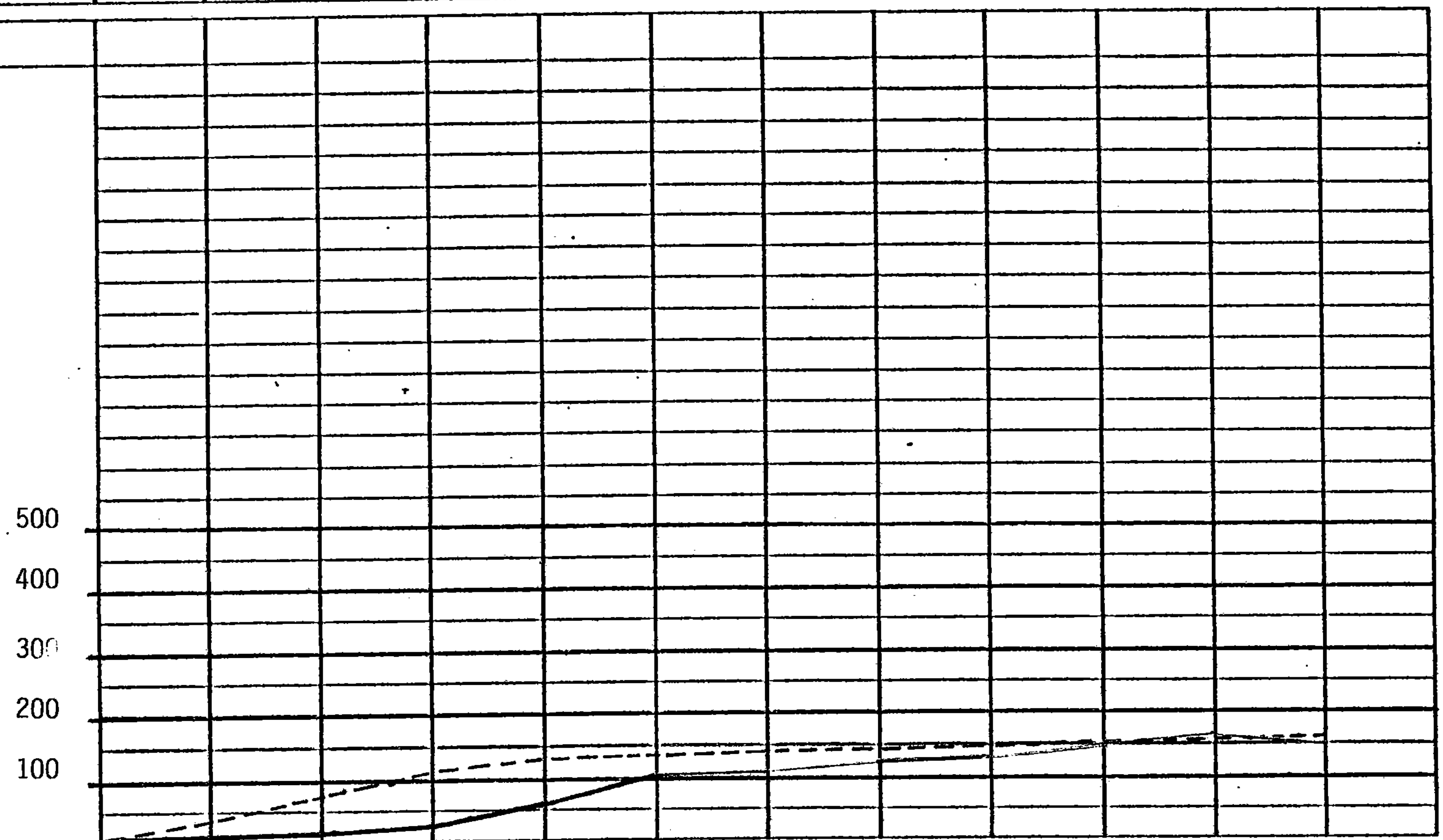
4. WPA/Task: 401 / ADVANCED RESEARCH

5. Months: O N D J F M A M J J A S

6. Cost Estimate

a. Dollars in Thousands

Legend:
- - - - - Planned
——— Actual



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	31	72	117	127	134	142	146	150	154	157	159	
c. Actual	5	17	43	65	107	109	126	138	154	163	152	
d. Variance	26	55	74	62	27	33	20	12	-	-6	7	

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/01/82
To: 9/30/83

3. Program Identification: SOLAR THERMAL TECHNOLOGY

4. WPA/Task: 416 / Concentrator Advanced Development

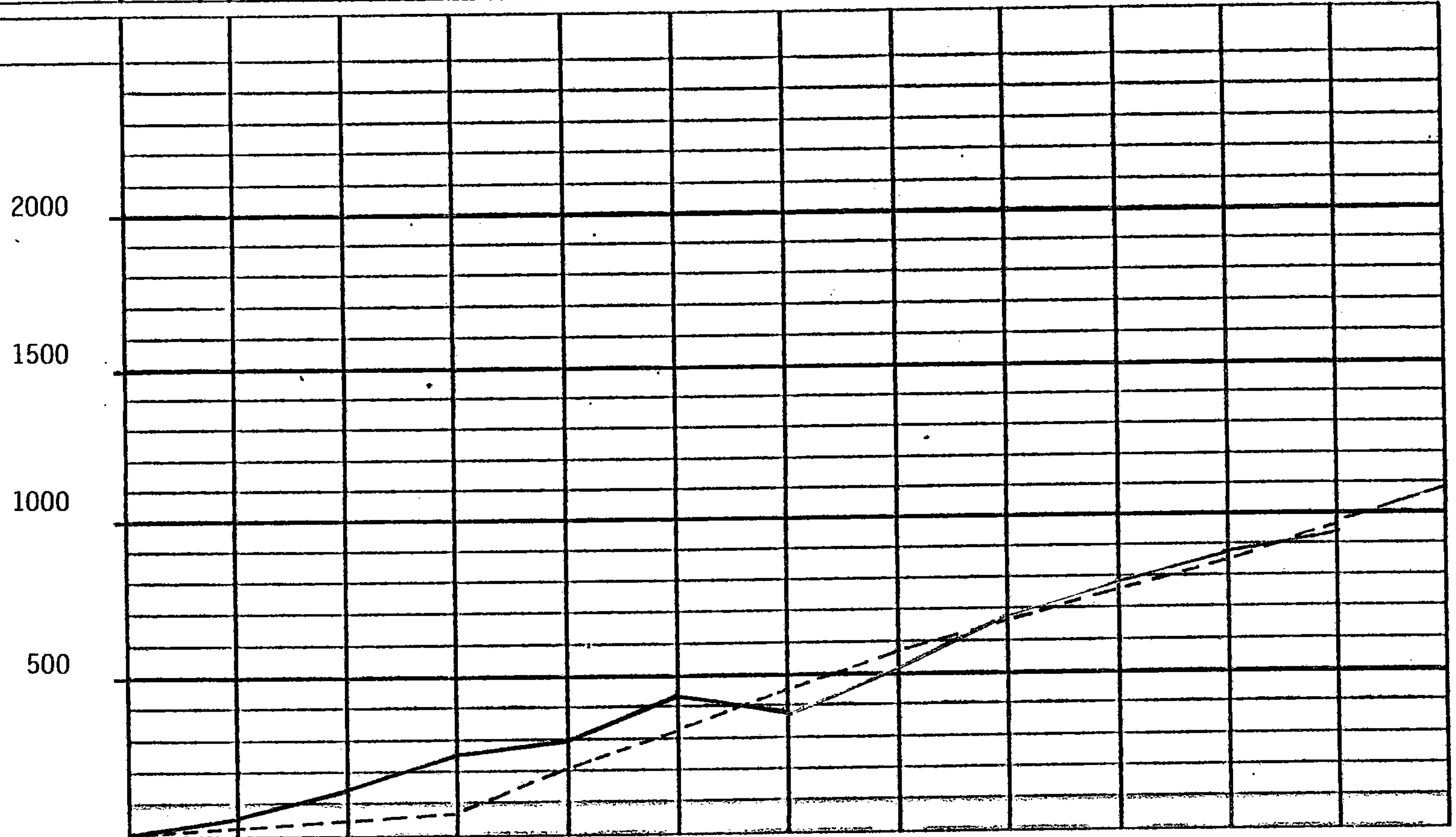
5. Months: O N D J F M A M J J A S

6. Cost Estimate

a. Dollars in Thousands

Legend:
----- Planned
——— Actual

DOLLARS IN THOUSANDS



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	22	45	77	204	330	435	549	651	753	854	971	
c. Actual	45	137	245	295	443	395	524	694	795	888	947	
d. Variance	-23	-92	-168	-91	-113	40	25	-43	-42	-34	24	

Budget Status

1. Contractor (name and address)	**Solar Energy Research Institute** **1617 Cole Boulevard** **Golden, Colorado 80401**
2. Reporting Period	From: 10/01/82 To: 9/30/83
3. Program Identification	SOLAR THERMAL TECHNOLOGY
4. WPA/Task	417 / Thermal Materials Research

5. Months: O N D J F M A M J J A S

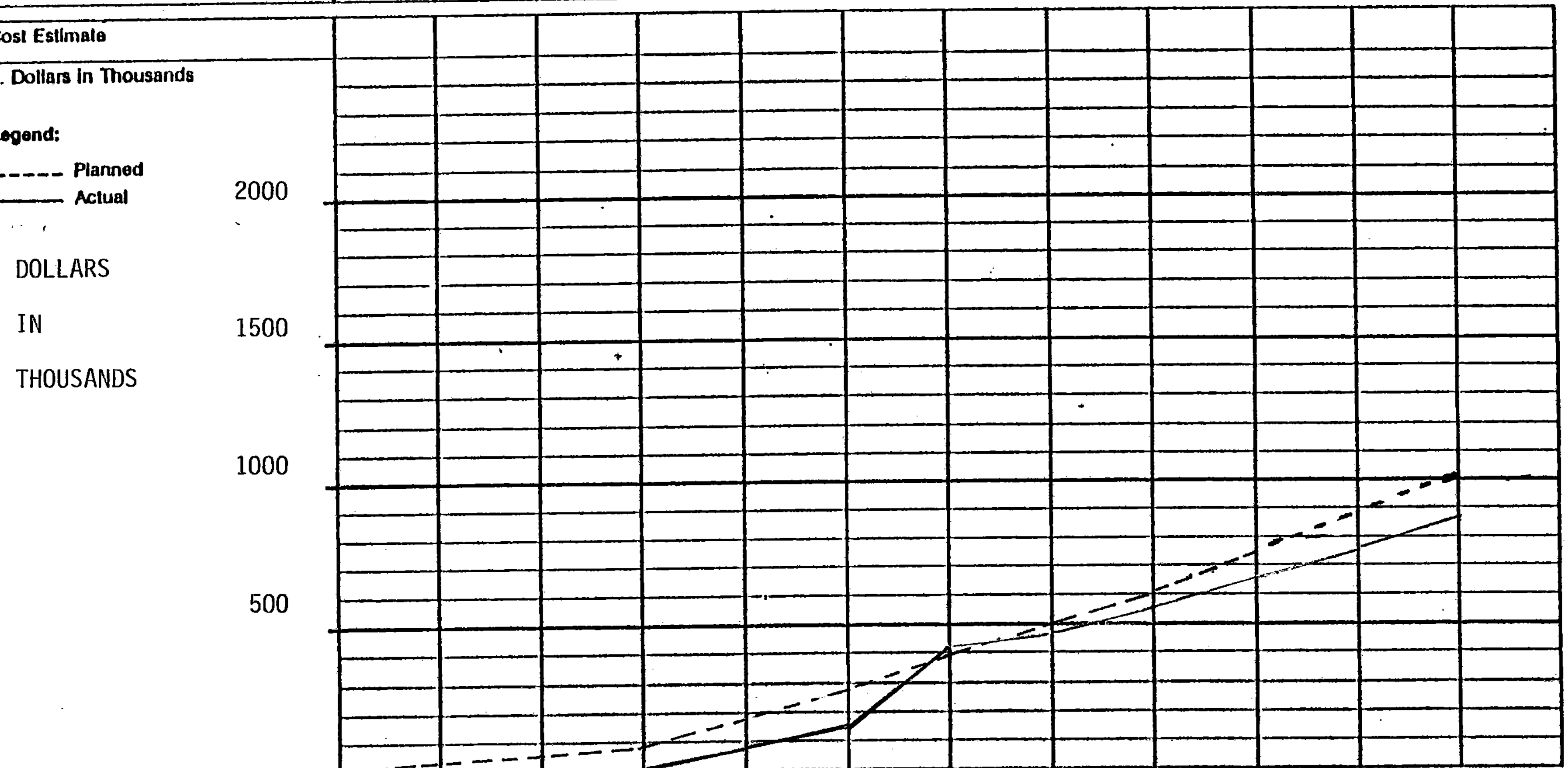
6. Cost Estimate

a. Dollars in Thousands

Legend:

- - - - - Planned

——— Actual



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S
	b. Planned	24	53	81	176	279	414	526	644	768	886	1003	
	c. Actual	–	–	–	88	155	430	491	565	667	787	874	
	d. Variance	24	53	81	88	124	-16	35	79	101	99	129	

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

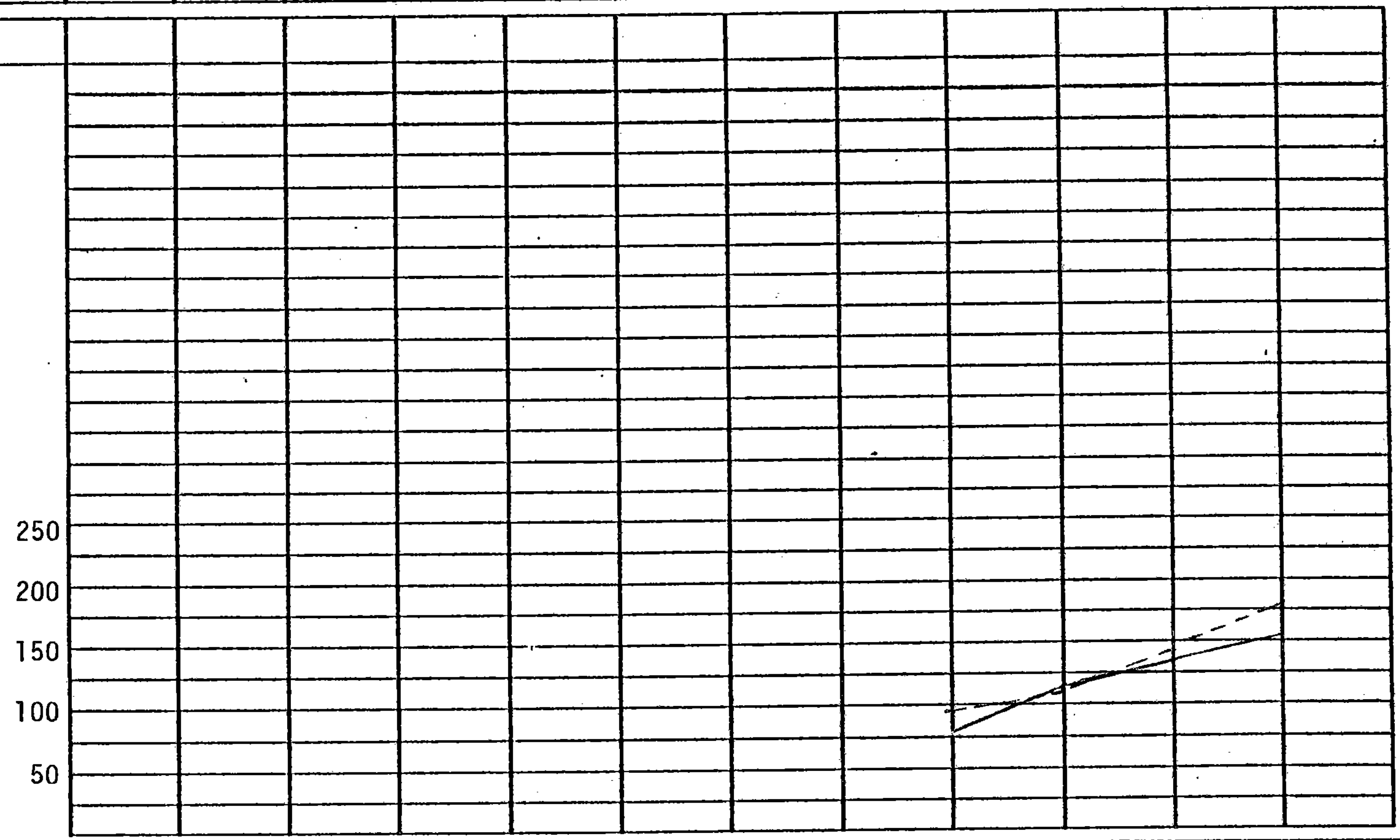
3. Program Identification
SOLAR THERMAL TECHNOLOGY

4. WPA/Task
440 / SUPPORT TO SYSTEMS EVALUATION

6. Cost Estimate

a. Dollars in Thousands

Legend:
------ Planned
——— Actual



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned								77	111	145	179		b. Planned
	c. Actual								96	117	139	156		c. Actual
	d. Variance								-19	-6	6	23		d. Variance

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

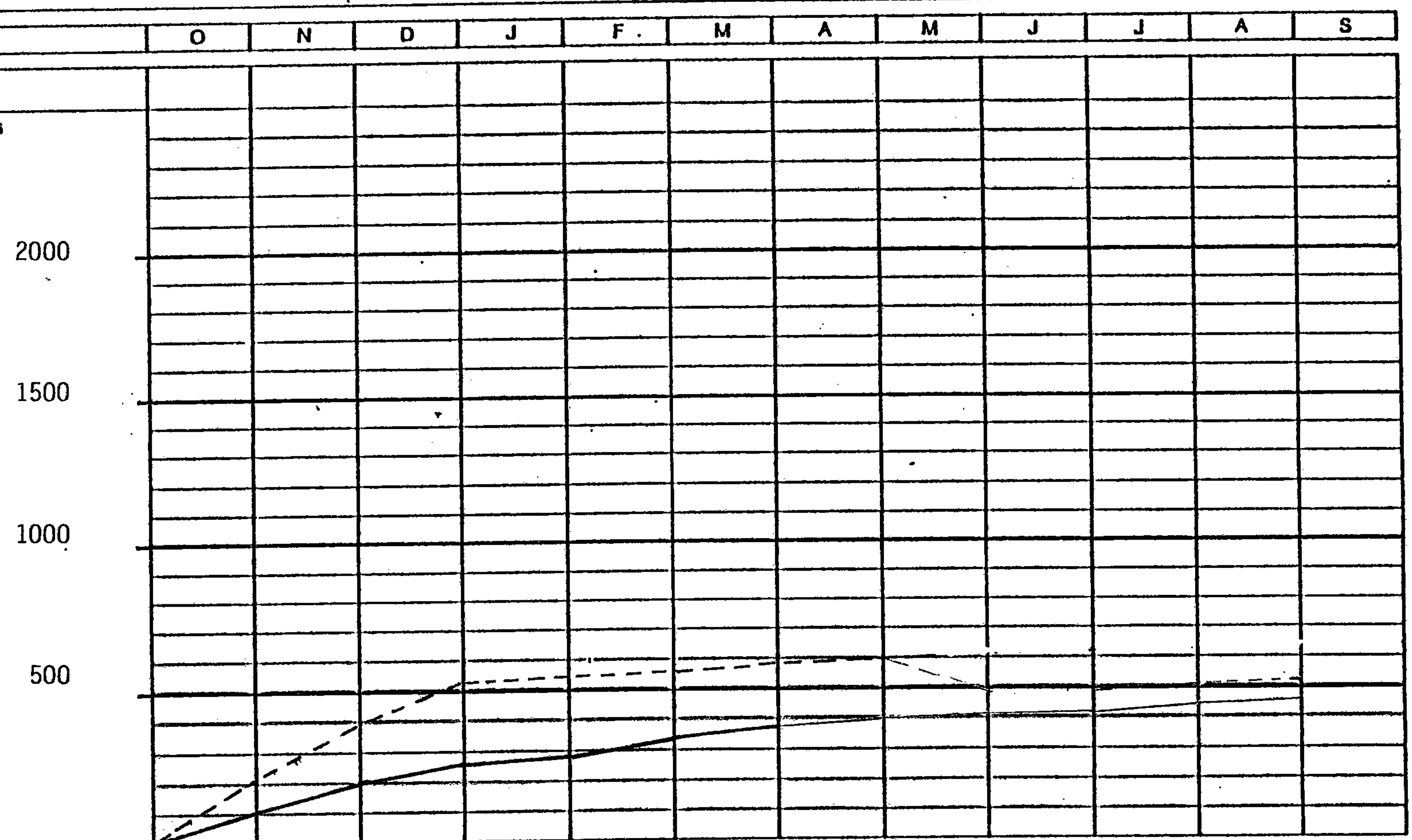
3. Program Identification: SOLAR THERMAL TECHNOLOGY

4. WPA/Task: 279 / APPLIED RESEARCH

5. Months: O N D J F M A M J J A S

6. Cost Estimate

a. Dollars in Thousands



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	210	398	530	543	565	610	618	482	495	508	521	
c. Actual	108	201	262	282	330	375	400	404	427	447	469	
d. Variance	102	197	268	261	235	235	218	78	68	61	52	

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

3. Program Identification: SOLAR THERMAL TECHNOLOGY

4. WPA/Task: 280 / PROGRAM PLANNING AND COORDINATION

5. Months: O N D J F M A M J J A S

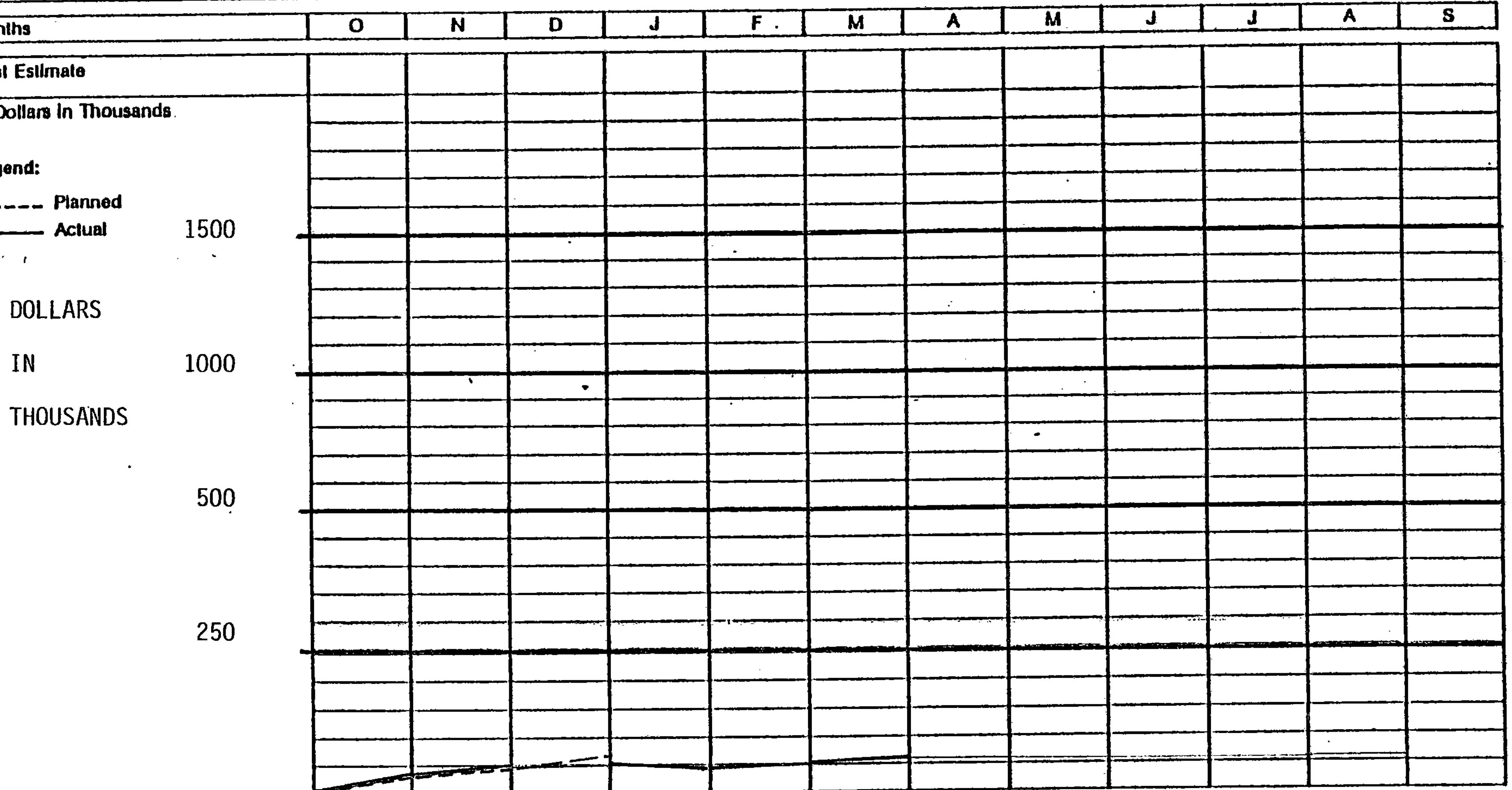
6. Cost Estimate

a. Dollars in Thousands

Legend:

----- Planned

——— Actual



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S
b. Planned	25	47	64	-	-	-	-	-	-	-	-	-
c. Actual	29	46	50	46	53	52	54	54	54	54	54	
d. Variance	-4	1	14									

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/01/82 To: 9/30/83

3. Program Identification: SOLAR THERMAL TECHNOLOGY

4. WPA/Task: 281 / RESEARCH AND ADVANCED DEVELOPMENT

5. Months: O N D J F M A M J J A S

6. Cost Estimate

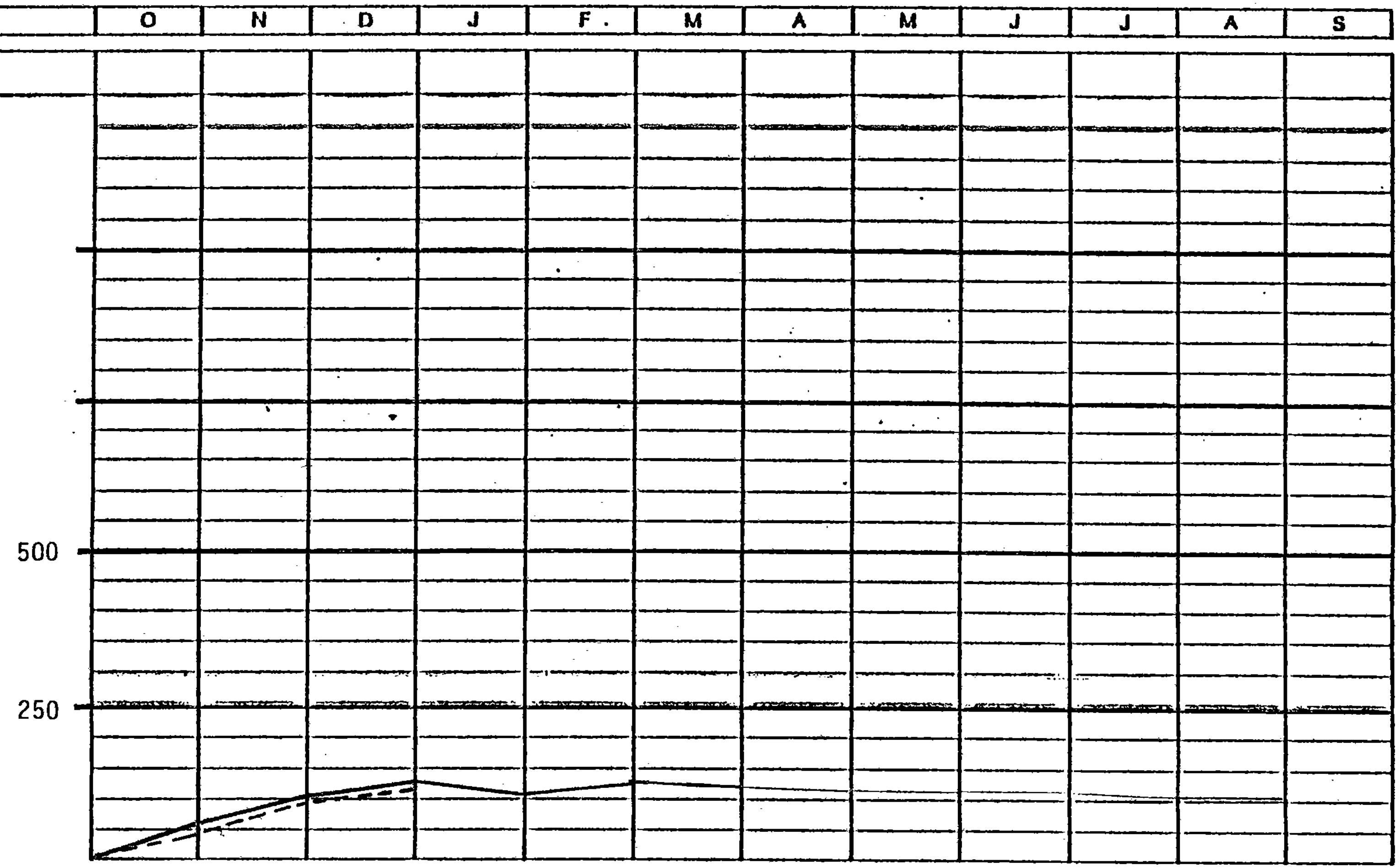
a. Dollars in Thousands

Legend:

------ Planned

——— Actual

DOLLARS IN THOUSANDS



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	
b. Planned	44	89	119	-	-	-	-	-	-	-	-	-	b. Planned
c. Actual	54	107	123	116	124	121	122	126	128	107	109		c. Actual
d. Variance	-10	-18	-4										d. Variance

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

Reports Completed

Heat and Mass Exchange in Solar Ponds: Results of Preliminary Laboratory Tests.

"Performance Benefits of the Direct Generation of Steam in Line-Focus Solar Collectors." Journal of Solar Energy Engineering. K. May and M. Murphy (SERI).

SERI/SP-253-1790. Recommended Subelement Cost Goals for Advanced Generation Heliostats (SERI).

SERI/SP-253-1791. A Systems Study of the Polymer/Enclosed Heliostat Concept and a Comparison with Glass/Metal Heliostats (SERI).

TP-253-1881. A Simple Energy Calculation Method for Solar IPH Steam Systems. R. Gee (SERI).

SERI/TR-255-1641. Surface Analysis of Commercially Made Mirrors. T. M. Thomas, J. R. Pitts, and A. W. Czanderna, (SERI).

Decomposition of Sulphuric Acid in Hydrogen Production Test Equipment-Final Report (General Atomic).

SERI/TR-253-1818. Technical and Cost Benefits of Lightweight Stretched Membrane Heliostats, L. M. Murphy (SERI).

Draft Reports Completed for DOE Internal Use

Solar Ponds Multiyear Research Plan. R. Hewett (SERI).

Solar Thermal Research Multiyear Program Plan. R. Hewett (SERI).

Reports Completed in this Period

SERI/TP-255-2001. High Temperature Molten Salts for Use in Solar Thermal Energy Systems.

Reports in Process

RESEARCH AND ADVANCED DEVELOPMENT - WPA 281A

SERI/TR-255-1504. Matrix Approach for Testing Mirrors - Part 1. June, 1982. K. D. Masterson and M. A. Lind (SERI).

SERI/TR-255-1627. Matrix Approach for Testing Mirrors - Part 2. K. D. Masterson, J. Blea, R. Goggin, M. Gutierrez, G. Jorgensen, and J. McFadden (SERI).

SERI/TR-255-1629. Advanced Mirrors. S. M, Wong, T. M. Thomas, J. R. Pitts, and A. W. Czanderna (SERI).

SERI/TR-255-988. Directory of Optical Measurement Requirements, Nomenclature, and Facilities for Solar Optical Materials Characterization. K. Masterson, J. McFadden (SERI).

Thermal and Optical Performance of Solar Steam, Inc., Deep Dish Concentrating Collector. K. Masterson, H. Gaul (SERI).

Structural and Mechanical Design Considerations for Stretched Membrane Heliostats. L. M. Murphy (SERI).

APPLIED RESEARCH - WPA 279A

SERI/TR-253-1450. Structural Design Considerations for an Inexpensive Line-Focus Trough Reflective Module Prototype. L. Murphy (SERI).

SERI/TR-252-1401. Sizing of Direct Contact Pre-Heaters/Boilers for Solar Pond Power Plants. J. Wright (SERI).

PROGRAM PLANNING AND COORDINATION - WPA 280A

IPH Case Studies Report (SERI).

Solar Thermal Cost and Performance Goals.

MATERIALS RESEARCH - WPA 416

SERI/TR-255-1813. Photodegradation of Polymeric Materials for Glazing.

Applications as Studied Using FTIR-RA Spectrocopy. J. Webb (SERI).

SERI/TR-256-1488. Response Time Testing of Concentrators. A. Lewandowski (SERI).

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MONTHLY STATUS REPORT

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SERI/MR-251-1471 August

Solar Thermal

Solar Thermal Research Program

Status Report

August 1983

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Solar Energy Research Institute

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1617 Cole Boulevard
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