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SERI/MR-251-1471 August/September

Solar Thermal

Solar Thermal Research Program

Status Report

August 1984
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SERI

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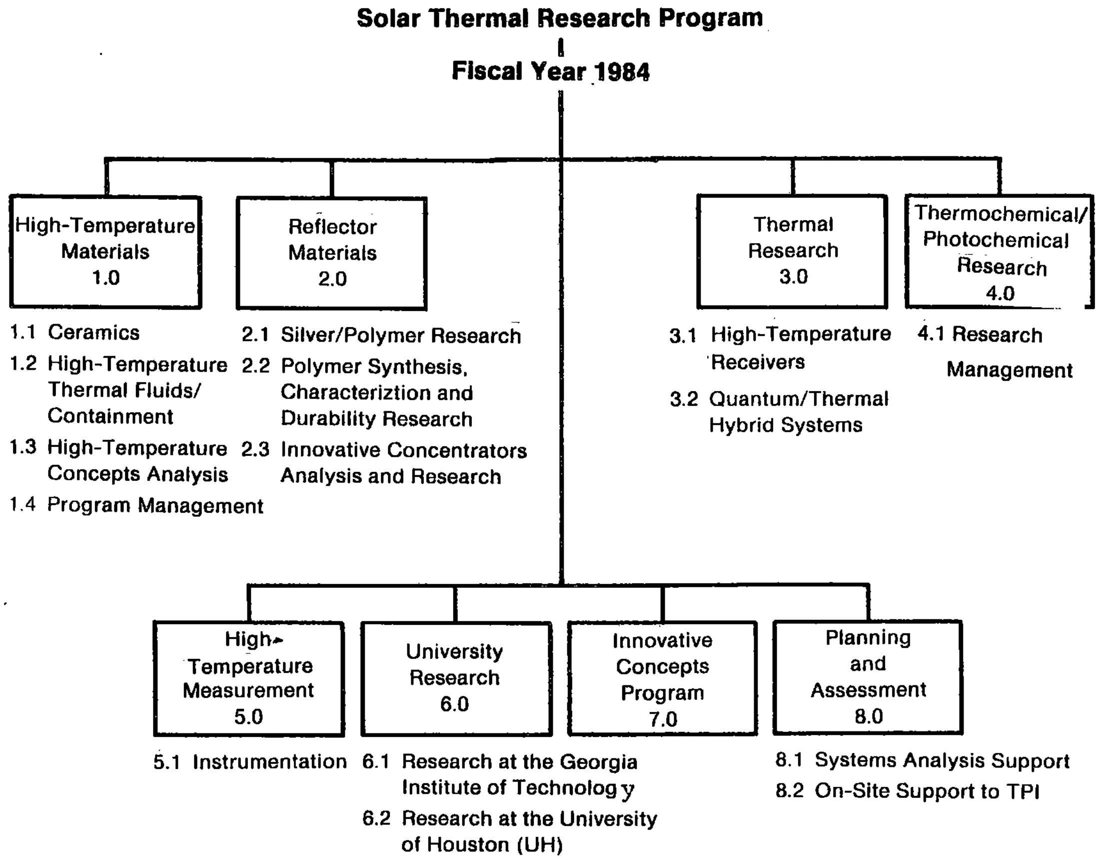


SUMMARY

SIGNIFICANT EVENTS

Significant Events

A preliminary study of the DAR system for electricity production was completed. Overall performance and cost of electricity were found to be similar to those of a nitrate salt system (Saguaro). The direct absorption receiver itself, however, was costed 16 percent below its nitrate salt counterpart. Storage increased availability but did not change substantially the cost of electricity produced. A briefing to DOE/HQ was given on this topic. (Page 8).

The RFP for fabrication of the 900° C molten carbonate test loop was released on September 12, 1984. A well-attended, pre-bid conference held at SERI indicated considerable interest in the RFP. (Page 17).

A study of the performance and possible product costs of a combined photo/thermal process for the production of hydrogen was completed - indicating that this process may be competitive with current estimates of conventional systems only when very optimistic assumptions are made on the eventual performance of two critical elements of the system: the holographic beam-splitter and the photoelectrochemical cell. (Page 19).

Research program plans for fiscal year 1985 were nearing completion with progress made toward the integration of research efforts by different organizations, and their restructure into a simple, consistent functional structure. The SERI Solar Thermal Research Plan was revised and submitted to DOE/HQ. The plan formed the basis for the SERI Solar Thermal Fiscal Year 1985 Annual Operating Plan, which was submitted to DOE at the end of September. (Page 9).

Both cycles of the Innovative Concepts Research Program Element are in the stage of contract negotiation. Goals are to have Cycle 1 contracts in place by the end of October and to have Cycle 2 contracts in place by the end of November. (Page 29).

The contracts resulting from the SAN/PRDA, "Indentification of Solar Unique/Solar Beneficial Phenomena," are in place. Contracts are:
1) University of Hawaii - "Exploratory Studies of the Use of Concentrated Sunlight to Enhance the Selectivity of Hydrocarbon Cracking by the Photolytic Formation of Foreign Free Radical Initiations and Chain Carriers", and
2) University of Dayton - "A Laboratory Evaluation of the Solar Incinerability of Hazardous Organic Wastes".

LBL has been funded by an FTP to DOE/SAN for fiscal year 1985 research to continue investigating radiant heating of reacting solids and to initiate research on "excited state phenomena."

A proposal has been received for fiscal year 1985 research at the Georgia Tech research Institute, with a proposal expected soon from the University of Houston. The goal is to have both contracts in place by December 1. Both contracts are on a calendar-year basis. (Page 25).

SERI, DOE-SAN, and SNLL personnel participated in a Fuels and Chemicals Research Plan Review at DOE/HQ in early August. The Research Plan received a favorable review.

The University of Hawaii continues to make excellent progress in developing an apparatus for fast thermogravimetric analysis; it will allow rapid weight measurements (4 to 5 per second) of solids decomposing in a direct flux field. (Page 22).

TECHNICAL DESCRIPTION

PROGRAM ELEMENT 1.0 HIGH-TEMPERATURE MATERIALS

A number of recent assessments of the direction of the Solar Thermal Program—notably the Energy Research Advisory Board assessment of solar R.&D. priorities completed in September, 1982—recommended that the Federal R.&D. program develop the technology base necessary for the next generation of Solar Thermal Technologies. As the program emphasis shifts to systems designed to operate at temperatures higher than 600° C, the availability of working fluids and their containment becomes a mandatory requirement. At the same time, a parallel effort is required to perform the systems analysis necessary to identify those systems which have the potential for being the most promising from both technical feasibility and cost-effectiveness standpoints and, thus, provide guidance for specific research directions.

The objective of the High-Temperature Materials Program is to provide the Program with the research accomplishments necessary to support the development of high-temperature technology. This includes the development of working fluids and compatible containment materials at temperatures as high as technically feasible, and economically justifiable, in the temperature range of 600° C to 1100° C.

TASK 1.1 CERAMICS

Objectives

The utilization of concentrated solar energy to produce temperatures higher than approximately 900° C depends on the availability of ceramics, either through adaptation of existing technology to the solar environment or through research. This Task has as its long-term objective the development or adaptation of a technology for improving the operating range of ceramics in solar thermal applications above 900° C in the high-flux environment of over 500 suns.

The objectives for fiscal year 1984 are: to determine the radiative and corrosive behavior of ceramics in temperatures above 800° C in high radiant fluxes, in varying temperatures, and in aggressive chemical environments; and to discover, to adapt or to develop several candidate ceramics based on the foregoing objective for further application.

Progress

A report on "The Corrosion of Materials in Molten Alkali Carbonate Salt at 900° C" was completed on schedule in September. R. Coyle, T. Thomas, and P. Schissel authored this letter report that was delivered to the DOE. Coyle and coworkers describe exploratory corrosion tests, where a number of alloys and ceramics were tested for corrosion resistance by submersion in various candidate molten salts under controlled conditions. It was found in this work that molten eutectic lithium-sodium-potassium carbonate (LiNaK) was the most attractive salt to use for the engineering experiments to evaluate these advanced high-temperature concepts. The major focus of the work in this report was on more detailed studies of the corrosion of the high alumina content ceramic materials, which were the most promising materials in the initial exploratory tests, in LiNaK at 900°C. Comparative corrosion results in other molten salts and results on metal corrosion in eutectic LiNaK are also presented, however.

To highlight the important factors that govern the corrosion rates of materials in molten carbonate salts, a brief description of the chemistry of corrosion was included in the report. Corrosion is an intimate combination of acid base reactions, oxidation reduction reactions, and phase change reactions such as dissolution, precipitation, crystallization or evaporation. These reactions vary depending on the particular material and the particular corrosive environment. Although some of the important reactions for a material/environment combination are well known and documented in phase diagrams, this information does not allow researchers to predict the kinetics of the reactions. Also, side reactions may occur and have a significant effect on the corrosion rate. These side reactions are design specific.

The corrosion experiments were conducted on high purity alumina materials in eutectic LiNaK at 900°C for times up to 67 days. Studies were also conducted on the metal loss for alloys after exposure to eutectic LiNaK at 900°C, the corrosion of graphite materials under the same conditions, and the formation of passivation layers on various materials. Results and conclusions included the following details.

- Saphire, Coors AD-998, and Monofrax M, all alumina materials were found to form passivating layers. The layers were identified as γ-$LiAlO_2$ for the first two materials.

- Estimates of the corrosion rates of sapphire, Coors AD-998 and Monofrax M were respectively, 0.005, 0.003, and 0.16 μm per day under highly acidic salt conditions. Under less acidic conditions, the rate for Coors AD-998 increased to 0.057 m per day, the rate for Monofrax M was unchanged, and the sapphire was not tested under these conditions. These estimtates should be considered to be preliminary and dependent on the conditions where the salt and material are in contact.

- The corrosion rate for graphite materials was found to be high and dependent on the oxidation potential in the molten salt. A relatively insoluble layer was observed in one of the experiments.

- The corrosion rates for alloys were found to be lowered by oxidizing conditions in the molten salt. Under these conditions the corrosion rates for Inconel 7600, Hastelloy N and Cabot 201 could be substantially below 1 mm per year per side. This possibility should be investigated in more detailed studies.

- Researchers found that important factors in the corrosion performance of ceramic materials are the purity of the material, the amount of glass phase on the surface, the presence of lithium in the salt, and the acidity of the salt. For alloys and graphite materials the oxidation potential was found to be important, although further study may reveal the importance of other factors.

TASK 1.2 HIGH-TEMPERATURE THERMAL FLUIDS/CONTAINMENT

Objectives

The overall objective of this Task is to obtain a salt with desirable chemical and physical properties for the absorption, transfer, and storage of concentrated solar flux at high temperatures and in combination with suitable containment materials. The objectives for fiscal year 1984 are: to complete the initial phases of studies of the rate of oxidation or corrosion of salts containing chromophores (darkening agents) and of the absorptance, both as a function of temperature; to complete initial studies of the chemistry and stability of high-temperature fluids which are reasonable candidates for such systems; and experimentally to verify the utility of at least one stable thermal fluid/containment system at 900°C.

Progress

Interim optical measurements of specular transmittance (into a 6° cone angle) of molten salt (Li_2CO_3-Na_2 CO_3-K_2CO_3 ternary eutectic) at 495°C were completed for three different path lengths. Based upon an extrapolation of measured transmittance (solar weighted between .35μ to .85μ) to zero optical path length, an index of refraction slightly greater than water was calculated (ignoring multiple reflectances between the air-sapphire-salt-sapphire-air interfaces) for the molten salt. This results in an estimate of the reflectance loss at an air/molten salt interface of less than 5 percent.

Work on the high temperature reflectometer resumed following the intermediate temperature (495°C) optical characterization of molten salts. Fabrication of the furnace element of the high-temperature reflectometer was completed. When completed, this instrument will enable the measurement of radiative transfer properties for both solids and liquids at very high temperatures. An adaptable furnace mounting was designed and implemented to allow easy coupling of the furnace with the integrating sphere. A bath recirculation unit was identified as being potentially suitable for cooling the sphere. An in-house optical pyrometer was secured and made operational to allow thermal characterization of the sphere/furnace system. In particular, the reflectance coating on the inside of the integrating sphere must be maintained at a temperature below 60°C during operation. The infrared thermometer, therefore, will be used to monitor the coating temperature while the furnace is on and while a coolant is being circulated through the sphere.

A variety of options for light source were considered as input to the reflectometer. These included an existing 300 W tungsten halogen arrangement, a 1000 W tungsten halogen source, and an in-house 1000W xenon arc lamp. On the basis of power level, spectral distribution, and focusing requirements, it was decided to use the xenon arc lamp. This equipment has been operationally readied. The 300 W tungsten halogen system will be used for optical alignment. Further optical and mechanical design to accommodate the light source and integrating sphere interface necessitated a modification to the structural support of the reflectometer. Machining of the required light ports was required. Final mechanical alignment also has been completed.

Analytical expression for both the reflectance and the transmittance of an air-sapphire-salt-air system was derived and was based on principles of energy balance. This result will allow accurate reduction of data gathered by using the high-temperature reflectometer. All multiple reflections were included in this calculation.

Prof. R. Mikesell completed his work on the fracture of ceramics this summer under an Associated Western Universities Grant and in cooperation with the Solar Thermal Program. He developed fabrication techniques for chevron-notched, four-point flexure specimens; and he developed the techniques for testing these specimens with SERI's room-temperature, four-point flexure apparatus. This flexure apparatus was fabricated at SERI in accordance with the recent MIL-STD-1942 (MR), "Flexural Strength of High Performance Ceramics at Ambient Temperature," which was issued in November, 1983.

Metallographic sections have been prepared and analyzed for coupons of Hastelloy N and coupons of Inconel 600. These coupons were immersed in molten eutectic lithium-sodium-potassium carbonate at 900°C for as long as 62 days. The purge gas that was bubbled into the molten salt was 80 percent argon and 20 percent CO_2 for some of the experiments and was 71 percent argon, 10 percent CO_2 and 19 percent O_2 for the other experiments. These coupons were tested for corrosion and were monitored for changes in weight.

The results of this metallographic examination for Inconel 600 and Hastelloy N are shown in Tables 1 and 2. In the tables the immersion times are given for the coupons, and the metal loss in millimeters per side is given. This change is determined with an optical micrograph by measuring the thickness of metal remaining after corrosion. The depth of intergranular oxidation in the metal is counted as part of the corrosion product and is given separately in the tables.

The composition of the gas that was bubbled into the molten salt is also given in the table. However, researchers using quadrupole mass spectrometric analysis of the gas above the molten salt have found that some air gets into the gas space. This occurrence is probably due to circulation of cold air that is entrained near the mouth of the crucible and is carried down by thermal convection currents to contact the hot molten salts. The result is that some oxygen is in contact with the salt even for experiments with 80 percent Ar and 20 percent CO_2 (oxygen was excluded from the purge gas). Thus, staff can best characterize the oxidation potential in the two experiments as high (19 percent O_2 was bubbled into the salt) and low (some entrained air was in contact with the surface of the salt).

The tables show that with the potential of low oxidation the rates of corrosion are clearly higher for both the Inconel 600 and the Hastelloy N. It is also seen in the tables that the amount of corrosion in the high oxidation potential experiments did not increase linearly with time for either alloy, although this conclusion is speculative on the basis of the limited data that is available. Thus, if the corrosion rates per side are determined from the figures on loss for 60 days and 62 days for the experiments with high oxidation potential (assuming linear corrosion), the rates are 1 millimeter per year and 1.5 millimeters per year for Inconel 600 and Hastelloy N. To the extent that the corrosion products are protective and the corrosion rates are nonlinear, the rates would be down. This detail contrasts with corrosion rates that were several times as large for both alloys in the experiments with low oxidation potential.

Prof. R. Mills of the University of Louisville completed his work on studying the liquidus of the Li-Na-K-Ba carbonate system. He constructed phase diagrams in the Na-Ba carbonate, K-Ba carbonate, Na-K-Ba carbonate systems and explored briefly the Li-Na-K-Ba system. The work suggested that low-melting eutectics exist in the quarternary system that may allow significant reduction in the amount of lithium (an expensive ingredient) in the molten salt without increasing the liquidus temperature above 500°C.

Table 1 Corrosion Results from Metallography on Inconel 600 Immersed in Ternary Eutectic LiNaK Carbonate at 900°C for Two Atmospheres Bubbled into the Molten Salt

Immersion Time (days)	Oxidation Potential (Purge Gas)	Metal Loss (mm/side)	IGO[a] (mm/side)
21	Low $(0.8Ar:0.2CO_2)$	0.56	0.14
64	Low $(0.8Ar:0.2\ CO_2)$	> 0.59	> 0.14
17	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.12	0.08
30	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.08	0.05
62	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.17	0.09

[a] IGO is intergranular oxidation.

Table 2 Corrosion Results from Metallography on Hastelloy N Immersed in Ternary Eutectic LiNaK Carbonate at 900°C for Two Atmospheres Bubbled into the Molten Salt

Immersion Time (days)	Oxidation Potential (Purge Gas)	Metal Loss (mm/side)	IGO[a] (mm/side)
21	Low $(0.8Ar:0.2CO_2)$	0.31	
67	Low $(0.8Ar:0.2CO_2)$	> 0.62	
17	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.12	
30	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.22	0.02
60	High $(0.71Ar:0.1CO_2:0.19O_2)$	0.25	0.02

[a] IGO is Intergranular Oxidation

TASK 1.3 HIGH-TEMPERATURE CONCEPTS ANALYSIS

Objectives

The objectives of this Task are to conduct research, engineering, and economic feasibility studies designed to identify the most promising concepts for the next generation of Solar Thermal Systems, and to help establish the research agenda necessary to bring these to the proof-of-concept stage. There are three objectives for fiscal year 1984: to conduct a comparative analysis of the stretched-membrane heliostat with the second-generation glass/metal heliostat; to evaluate a baseline direct-absorption, high-temperature receiver system; and to conduct studies of selected components in high-temperature/high-flux applications.

Progress

A presentation of the first phase of the direct absorption receiver system study was given at SERI. The briefing package on the study (SERI/SP-253-2435) has been revised extensively with changes based on the internal critical review. The preliminary assessment of a DAR system for electric power production has shown that the expected cost of electricity from a DAR system was similar to the cost of electricity from a comparably sized nitrate salt system (the Saguaro Plant was used as a base case). The power conversion equipment can operate more efficiently at the high temperatures typical of a DAR system, however, the receiver efficiency at high temperatures is lower. These two opposite effects nearly cancel each other and result in no substantial improvement over the lower-temperature, nitrate-salt systems.

An outline has been formulated and discussed for further study to identify and to analyze alternate applications which can favorably utilize the high-temperature advantages of a DAR system. An initial analysis of the cost of thermal energy from a DAR system, regardless of the application, is currently underway to supplement the electric assessment already performed. These data will provide an assessment of the base-of-the-tower energy costs from a DAR system over a range of temperatures and will include only the cost to deliver energy up to the process interface at the base of the tower. Later activity will focus on identifying and evaluating a preferred DAR system; one preferred candidate for a DAR system is a cogeneration system.

Two letter reports from Dr. A. Clausing from the University of Illinois on Convection Modeling has been received and represents the output from his summer consulting with SERI. The first is a letter report on some of his general findings and recommendations, and the second is a paper on some analytical correlations using variable properties which he has derived from his studies.

The wind-loading effects on the stretched membrane, glass/metal heliostat have been studied, and a draft of this section has been completed. Studies with DELSOL continue to bound the need for focusing of stretched membrane reflectors as a function of temperature, size of the field, and size of the collector.

Work resumed on an initial study comparing secondary concentrators with focused heliostats. DELSOL2 cannot provide performance results for user-specified systems, but a way was devised to obtain the necessary annual energies while keeping the receiver losses constant for increasing sizes of apertures. This will allow a first-order calculation for the value of secondary concentrators.

TASK 1.4 PROGRAM MANAGEMENT SUPPORT

Objectives

The objectives of this Task are to plan, to coordinate, to evaluate, and to report on the activities of the DOE Solar Thermal Research Program assigned to SERI. The Program includes Tasks performed at SERI and subcontracts with industry and universities.

Progress

A major program management effort during the reporting period consisted of the development of the research plan for fiscal year 1985, and its codification into the various working documents, particularly the Annual Operating Plan (AOP). This process was successfully completed in time to meet the program deadline, and a SERI AOP was transmitted to DOE/HQ ahead of schedule.

Efforts were devoted to generating the STT Research Program sections of the DOE report Solar Thermal Technology Annual Evolution Report: FY 1984.

In addition, except for the four sections relating to central receiver research, SERI completed the first draft of the report that documents STT Research Program activities and accomplishments during the period, fiscal year 1977 to fiscal year 1983.

PROGRAM ELEMENT 2.0 REFLECTOR MATERIALS

The low-energy density of the solar flux makes concentrators necessary for thermal systems operating at temperatures higher than about 100° C. At the same time, concentrators continue to present a major opportunity for overall system cost reduction because they typically account for 50 percent of the system cost. The reflector element is a key component for further development in all concepts because a flexible silvered film may be easily mounted and does not impose the stringent rigidity requirement on the structure imposed by glass—allowing lighter, cheaper structures.

The overall objective of the Reflector Materials Program Element is to bring to the proof-of-concept state of development a metalized polymer film which can equal or exceed the radiative transfer performance and the life-cycle cost effectiveness of silvered glass mirrors; to bring to the proof-of-concept state of development, including the theoretical understanding of the structural response, the design, fabrication, and testing of small-scale stretched-membrane/frame heliostats; and to conduct the systems analysis, optimization, and cost analyses for the same.

TASK 2.1 SILVER/POLYMER REFLECTORS

Objectives

The overall objective of this Task is to identify a process or technique for the production of silvered polymeric reflectors with over 90 percent reflectance (integrated over air mass 1.5 solar radiation), with useful lives of over five years, and with a specularity comparable to that of silver/glass reflectors. The service life must be achievable in solar thermal applications where weather, cleaning, and other environmental factors exist.

The objectives for fiscal year 1984 are to identify and to complete the analysis of sputtered-silver polymers showing potential for long life and to complete the identification of the chemical and physical phenomena related to degradation of silvered PMMA.

Progress

Hemispherical reflectance data were obtained on silvered polymers after 26 weeks of outdoor testing. The silvered polymers consist of the following: polymer; sputter deposited silver; backing material; adhesive.

The data are summarized in Table 1. The data from the Weather-Ometer for two weeks, four weeks and eight weeks, initially reported in December, 1983, are repeated for convenience. The changes are +1%, and confirm the visual observations reported. The Weather-Ometer acceleration factor, based on these limited data, is cautiously estimated to be in the range of 6 to 13. The Weather-Ometer data were taken at 60° C, in ultraviolet or without ultraviolet exposure, and at 80 percent relative humidity. The best evaluation of the acceleration can be obtained from the Barex polymeric samples. No evidence has been obtained from the outdoor tests that provide a basis for changing the ranking of these silvered commercially-available polymers made in December, 1983.

Table 1. **Change in Hemispherical Reflectance (%) After Weather-Ometer* and Outdoor Exposures**

	PSBMAC	Weather-Ometer			Outdoors
		2 Weeks*	4 Weeks*	8 Weeks*	26 Weeks
13X	Acrylar	0	0	-1	0
19X	Acrylar	0	0	-1	-2
24X	Acrylar	0	0	-4	0
27X	Acrylar	+1	+1	+2	0 to -1
30X	Acrylar	0	+1	0	0 to -1
15X	Flexigard	+1	0	-1	0
20X	Flexigard	+2	0	0	-1
23X	Flexigard	+1	+1	0	0
26X	Flexigard	0	+1	+2	0 to +1
29X	Flexigard	+1	0	0	0 to +1
17X	Barex	-1	-2	-6	-1
22X	Barex	0	-2	-4	-1
25X	Barex	-2	-4	-2	-2

*Average value for exposed parts of the samples in ultraviolet and no ultraviolet.

The hemispherical reflectance of evaporated and sputtered silver on Flexigard with a 3M Double Stick adhesive on stainless steel substrates remained unchanged at 89.5 percent after 13 weeks of outdoor testing. Even more importantly, the Flexigard/evaporated silver samples did not have a loss in hemispherical reflectance after 12 weeks in the QUV. No specularity data are given for Flexigard for reasons previously discussed for this commercial polymer. After 13 weeks of QUV testing of Inconel-backed, evaporated silver on glass or ECP-300, the hemispherical reflectances are 95.2 percent (silver/glass) and 91.6 percent (silver/ECP-300). The specularity of the silver/glass is 94 percent (15 mr) and 87 percent (7 mr).

Hemispherical reflectance data can again be secured with the PE340 that was repaired. During the repair, the optical alignment was also adjusted; as a result, wavelength throughout has improved the values of hemispherical reflectance by a mean value of 1.6 percent (seven measurements).

Plans have been formulated for resuming the study of the variables that influence the specularity of silvered polymers. In particular, the objectives of the effort will be focused on the goals (fiscal year 1985) of 90 percent reflectance at an acceptance angle of 7 mrad.

After eight weeks of accelerated testing in the QUV, the hemispherical reflectance of sputtered silver on 3-M Flexigard with a 3-M Double Stick (DS) adhesive and a stainless steel substrate is virtually unchanged at 91 percent; the specularity (15 mrad) is also essentially unchanged at 92 percent. The specularity (7 mrad) of the three specimens, which was not measured prior to testing, ranged from 63 percent to 75 percent. These results are quantitatively similar to those reported earlier for similar specimens after 16 weeks of outdoor testing.

After 13 weeks of accelerated testing in the QUV, the hemispherical reflectance of 3-M ECP300XP polymer/evaporated silver/Inconel/DS/7809 glass dropped from 94.8 percent to 91.4 percent (B1-191-12). For a similar combination without Inconel, the loss has been from 94.5 percent to 84.4 percent (B1-191-4). However, the specularities of these samples, which were 80 percent and 40 percent after four weeks of testing, have all dropped below 10 percent after 13 weeks. Control combinations of 7809 glass/-evaporated silver/Inconel or no Inconel/DS/aluminum have hemispherical reflectances of 95 percent, 95 percent, and 90 percent (13 weeks), and two of these have 15 mrad specularities of 94 percent. Of interest is that the two samples with Inconel backing exhibited specularities (7 mrad) of 86 percent and 57 percent, but the sample without Inconel retained a specularity of 90 percent. A preliminary interpretation is that the Inconel backing may be the cause of specularity losses in the control combinations. No similar trend is evident for the similar polymer/silver specimens.

After eight weeks of outdoor weathering, the hemispherical reflectance of 3-M ECP300XP polymer/sputtered or evaporated silver/Inconel/DS/7809 glass (B2-21-XX) declined from 94.3 percent to 93.5 percent; however, the specularity (15 mrad) declined from 99 percent to 96 percent and 95 percent for sputtered and evaporated silver. The specularity (7 mrad), which was not measured prior to testing, is 77 percent with evaporated-silver specimens and 84 percent for those with sputtered silver.

After eight weeks of accelerated testing in the QUV for the combinations 3-M ECP300XP polymer/sputtered or evaporated silver/Inconel/DS/7809 glass (B2-21-XX), the hemispherical reflectance has dropped from about 95 percent to 85 percent for all 15 specimens exposed. Furthermore, the specularity (15 mrad) has also declined from about 100 percent to 78 percent. The specularity (7 mrad) after eight weeks ranges from 34 percent to 50 percent.

The low specularities at 7 mrad after most of the aforementioned testing support strongly the planning decision to emphasize the preparation of highly specular samples and to continue the testing to identify the losses in this optical quantity. It also seems probable that accelerated testing in the QUV for shorter duration can be used because the specularity measurement of 7 mrad is more sensitive to optical degradation than either hemispherical reflectance or specularity measurements of 15 mrad.

TASK 2.2 POLYMER SYNTHESIS, CHARACTERIZATION, AND DURABILITY RESEARCH

Objectives

The overall goal of this work is to identify or to develop polymers that can be used as films, coatings or structural elements and that will serve at full effectiveness for at least five years in solar thermal applications.

This goal establishes the following research objectives for fiscal year 1984: development of chemically bound stabilizers, antioxidants, or quenchers which can interrupt incoming radiation throughout the polymer structure or deactivate free radicals wherever they arise in the structure; development of lightweight, low-cost ultraviolet resistant polymer laminates for use in solar thermal applications; development of test procedures to characterize the durability and to allow projection of service lives of optical polymers in solar thermal applications.

Progress

Measurements for hemispherical (hs) and specular (s) reflectance have been performed on various stabilized PMMA-coated silver mirrors (stabilizer: Tinuvin P, National Starch) which have been weathered for 13 weeks in the QUV. The variables are the stabilizer concentration and the distance that the stabilized layer is from the silver surface. Although hs and s values did not change noticeably for the mirrors, a loss of stabilizer was noted for all samples and was based on the decrease in the characteristic bond of stabilizer absorption.

The following milestones were met by a memorandum dated August 3, 1984:

- August "Complete the identification of chemical and physical phenomena causing the degradation of silvered PMMA"
- September "Draft report documenting the results of the research to identify the chemical and physical phenomena causing the degradation of silvered PMMA"

TASK 2.3 INNOVATIVE CONCENTRATOR ANALYSIS AND RESEARCH

Objectives

The objective of this Task is to identify innovative concentrator configurations and to study the important structural response and design optimization issues associated with stretched-membrane heliostats. This is to be done by analysis and experiments of test hardware to establish the design parameters necessary to bring the development of this concept to the proof-of-concept stage. Two-meter and three-meter diameter test modules will be used experimentally to study the structural responses predicted by analytical techniques.

Progress

SERI developed and signed a contract with Applied Technology Associates (ATA) to develop the video/digitization instrumentation for the measurement of the optical quality of laboratory test modules of the stretched-membrane heliostats. W. Hannaway, an expert in digitization, will be hired by ATA as a consultant. SERI held an initial meeting and visited Hannaway. Work has begun on specifying hardware and on developing software.

The first deliverable on the subcontract for the three-meter-diameter test hardware (design drawings of the ring-frames) arrived from Dan Ka Products. A test location in the Field Test Laboratory Building was chosen for the experiments on the modules of the three-meter-diameter, stretched-membrane heliostats. The high wall and air space over the material staging area which is adjacent to the new laboratory space has been officially reserved for the installation test system for the heliostat figure. The target and heliostat centerline will be about seventeen feet off the floor. Seven feet of working headroom remains in the staging area, and almost twelve feet of headroom remains in the walkway. Design of the target and of the heliostat stand has now begun.

The rigidity of the membrane corresponding to the membrane/frame interface has been identified as a major issue for designing stretched membrane reflectors, since it can significantly affect the limits of stability of the assembly of the frame/membrane. That rigidity can in turn impact the amplification of imperfections and deformations due to lateral loading of the module. An experiment was run to determine the effective spring rate of the pneumatic tensioning attachment to be used on the test hardware. Problems that obscured the information that researchers required in the test fixture were identified. A new fixture was designed and is being built.

A variety of NASTRAN analyses were performed to study the deformation characteristics of various shapes of slightly conical and flat membranes subjected to vacuum loading. Results showed agreement with the anticipated shape and identified some of the advantages and difficulties in using cones and vacuum as focusing methods for heliostats.

Researchers have completed a briefing package on the applicability of tensioned membrane technology for dish and other concentrators. The briefing package corresponds to an analysis Milestone (not a specific Deliverable).

PROGRAM ELEMENT 3.0 THERMAL SCIENCE RESEARCH

The Thermal Science Research Program Element aims at developing the scientific basis necessary for understanding the heat and mass transfer phenomena and the associated material properties needed in order to evaluate the feasibility of candidate high-temperature/high-flux system concepts, and combined quantum (photon)/thermal hybrid system concepts.

The objectives of this research are twofold: to develop the scientific basis necessary for understanding the heat-transfer and mass-transfer phenomena and the associated material properties needed in order to evaluate the technical and economical feasibility of the concept of the high-temperature, molten-salt, direct-absorption system at the proof-of-concept level (and in this way to provide the basis necessary for a decision on its potential for technical development); to complete sufficient theoretical analysis and experimental work to provide the basis for a preliminary assessment of the potential of using the solar flux in a combined quantum/thermal conversion system.

TASK 3.1 HIGH-TEMPERATURE RECEIVERS

Objectives

Economically competitive processes for producing high-temperature fluids for industrial applications and for alternative means for electricity production are needed. In response to this need, the long-term objective of this Task is the development of a high-temperature, direct-absorption receiver system capable of operating efficiently at temperatures in the range of 900° C to 1100° C, for co-generation, high-temperature industrial process heat, bulk electricity, and fuels and chemical applications. The objectives for fiscal year 1984 are: to measure the viscosity of the molten salt, friction factors for smooth and rough surfaces in water and to provide estimates for experiments employing molten salt; to design a molten salt test apparatus to provide both the above data and eventually (future fiscal years) a measurement of heat-transfer rates with direct absorption of solar radiation in the molten salt; to develop a mathematical model of the direct absorption heat transfer and fluid mechanics processes.

Progress

The Request for Proposal for the 900° C molten salt loop was sent out to 30 companies and universities. The proposals are due in October. The loop uses a SERI-produced absorber assembly. The system will be used at the ACTF in 1985 in a direct absorption experiment.

The ground test experiments for flow characteristics will be performed at SERI. These tests provide data on molten salt flows (viscosity, dry-out tendencies, film thickness, and inlet flow distribution). Two apparata will be used in these tests, the 500° C apparatus and the 700° C loop. The 500° C apparatus will provide checks on the absorber assembly and viscosity data. The 700° loop will provide the quantitative data on characteristics of flow.

The 500° C apparatus provides batch flow for small flow rates. This apparatus is nearing completion; parts are being installed and the absorber surface has been reground. Check-out of the loop with water is planned for next month.

Dr. T. Newell has completed his experiments on water falling films. The data for screens indicate substantial thickening of the liquid film, probably better liquid distribution, and better tendency to avoid dry spots. Based upon the current data on corrosion rate of molten salt, metal screens could survive at the inlet (425° C to 500° C), but not at high temperature (900° C). Other devices (1.0 cm holes, 1.0 cm apart, 1 mm deep) will be needed. In very cursory tests, holes seem to do better than the same pattern with pegs. Additional testing is needed on these devices.

Experimental data on the reflectance of molten carbonate salts was received from SERI's Materials Branch. The reflectance in the range 0.35 μm to 0.85 μm is less than 3 percent; the solar-weighted reflectance is expected to be less than 5 percent. These data indicate that salt reflectance is not a barrier to direct absorption receivers.

TASK 3.2 QUANTUM/THERMAL HYBRID SYSTEMS

Objectives

A preliminary thermodynamic analyses of hybrid systems performed in fiscal year 1983 indicated that under certain operating conditions, a hybrid system has a greater efficiency than either a quantum or a thermal conversion system operating alone. Thus, there is a possibility that a hybrid system will produce a cheaper product than either system acting alone. The long-range goal of this work is to determine the technical and economic feasibility of hybrid quantum/thermal solar energy conversion systems. The objectives for fiscal year 1984 are: to complete a thermodynamic analysis of thermally coupled and decoupled hybrid systems; to use this analysis as a guide to select the concept with the greatest potential and to perform a preliminary estimate of the technical feasibility and economic potential of this concept. Another objective is to investigate the feasibility of operating photoelectrochemical reactions at temperatures up to 100° C and solar concentrations up to 50 suns.

Progress

Researchers have completed an assessment of the tandem combined quantum/thermal conversion system for producing hydrogen. Because the cost of a dichroic beam splitter appears to be large and the efficiency appears to be low, the use of a holographic beam splitter was investigated. Preliminary data available from NTS indicate that such a beam splitter may have a cost and an efficiency approximately the same as a heliostat. Using this assumption and an optimistic assumption on the conversion efficiency of the electrochemical photochemical cells, the overall conversion efficiency of sunlight to hydrogen is 14 percent for a thermal electric plant producing hydrogen by electrolysis as compared to 15.3 percent for a tandem thermal quantum conversion plant. The cost of hydrogen produced by a thermal electric plant is estimated to be $30 per GJ while it is $28 per GJ for the tandem plant. Based on these optimistic assumptions the tandem plant appears to be marginally better than a pure thermal plant for hydrogen production.

This result is very product-specific. A product which uses ultraviolet light as well as heat in its production process could show greater benefits from the tandem system. Caprolactum, a precursor to Nylon, is such a product. A preliminary analysis shows that using the tandem system to collect ultraviolet photons is an order of magnitude cheaper than producing them with an electric lamp. The overall production cost for Caprolactum could be 10 percent to 20 percent less with the tandem system than by conventional means.

In summary, researchers have completed the technical and economic assessment of the thermally decoupled combined quantum thermal system for hydrogen production . Based on the results of this work, no further effort is planned for the hydrogen production option.

PROGRAM ELEMENT 4.0 THERMOCHEMICAL AND PHOTOCHEMICAL RESEARCH

The Thermochemical and Photochemical Program Element is managed by the U. S. Department of Energy-San Francisco Operations Office (DOE/SAN) with management support provided by SERI for the Research and Advanced Concepts Program, and by Sandia National Laboratories/Livermore (SNLL) for the Solar Applications Program. SERI's objective for fiscal year 1984 is to define and to implement both a 1984 research program and a long-range integrated program plan; to specify the research needed to establish underlying technologies that use concentrated solar energy effectively in either a beneficial or unique fashion; to develop a clearer understanding of the high-flux potential; and to define system and process concepts that can utilize solar radiation in a cost-effective manner.

Progress

The IRI experimental program on direct solar radiant heating of particle suspension is on schedule. Measurements of the flux from the arc lamp solar simulator indicated that the ellipsoidal reflector must be mechanically stabilized to obtain repeatable results. A two-axis translational stage to stabilize and to position the reflector has been completed. In addition, a three-axis translational stage for holding the calorimeter when mapping the spacial distribution of the radiant flux from the lamp solar simulator has been constructed. This translational stage is used also for positioning the reactor vessel at the focus of the reflector. Test runs to observe the heating of a gas-particle mixture in the reactor vessel were made by using commercially obtained carbon particles in the new shaker system and entrainment chamber.

Thermodynamic calculations, to develop methods to calculate the heat flow rates between particles and gas, are progressing. A written paper outlined a new approach to calculate the heat-flow rates for intermediate values of Knudsen numbers (ratio of molecular mean free path to particle size). The treatment provides an analytic expression for particle-gas heat transfer for arbitrary-sized particles. The paper was reviewed and was expanded to include heat transfer in polyatomic gases and is being submitted to the International Journal of Heat and Mass Transfer. A second paper is in preparation to use these results to predict temperature differences between gas and particles for solar heating. Analytical expressions have been developed to predict absorption efficiencies and temperatures as a function of optical depth in a cylindrical reaction chamber both for the case in which the flux and particle flow are in the same direction and for the case in which they are in the opposite direction.

LBL continues to progress in determining optical characteristics of a gas-particle suspension. A survey of useful chemical reactions and their characteristics for solar applications has identified a number of candidate materials for the absorbing particles. The broadband complex refractive indices of these materials were obtained from the literature and were entered as data files. These data files are used with the Mie calculation to ascertain the solar absorptivity of particle suspensions of particular materials. Computer programs were written to calculate the integrated solar absorption of particle suspensions containing a distribution of particle sizes over broad ranges of wavelengths that are weighted to simulate sunlight or artificial solar sources. Graphs of the fraction of total energy absorbed as a function of particle mass-loading and path length of light were produced from these computer programs. The iron oxides were found to be of particular interest because they are catalysts for a number of reactions as well as good absorbers.

Research at the University of Hawaii continues to center on the design, fabrication and operation of a high-heating rate thermogravimetric analysis (TGA) instrument, which will be used to characterize rapid decomposition of solids. Several experiments were conducted in order to calibrate sample temperature at the high-flux temperature environments prevalent within the MARK I Fast-TGA system. The experiment was carried out by using newly obtained Curie point reference materials (Mum, et al) from the National Bureau of Standards. The results from this experiment were not definitive. More experiments have been planned to use five different magnetic alloy reference materials and to cover a temperature range of 250° C to 270° C.

The design of the MARK II Fast-TG system was revised and was finalized; it is in the stage of fabrication. The MARK II system will measure sample temperature by incorporating a Pt-Rh thin film thermocouple in conjunction with a conventional S-type thermocouple, both in direct contact with decomposing sample. The Mettler balance is utilized in a top-loading configuration in this design in order to avoid unnecessary exposure of the hangdown tube to high-flux densities of incoming radiation at the top of the reflective cavity. The completion of fabricating the MARK II Fast-TG system has been scheduled for the end of October.

Another important development is the observed electromagnetic interference between the lamp during ignition and other electronic equipment (including the electromicrobalance). The problem arises when the arc lamp is ignited and results in malfunction and failure of the data collection system. This interference occurs intermittently, and the cause of the problem has been difficult to isolate and to identify completely, although encouraging progress has been made.

In summary, LBL research has provided a strong analytical basis for calculating direct radiant heating of solids suspensions. Experiments will soon begin to provide data. Research at the University of Hawaii is concentrating on an experimental approach with equipment fabrication nearing completion.

PROGRAM ELEMENT 5.0 HIGH-TEMPERATURE MEASUREMENT

As the Solar Thermal Program develops and tests system prototypes on one hand, and conducts research in the direct utilization of high solar fluxes to produce high temperatures on the other hand, there emerge instrumentation and measurement needs which exceed the capability of what is currently available commercially.

The overall objective of High-Temperature Measurement is to identify and to meet these needs in Solar Thermal Program instrumentation and measurement which exceed the capability of current technology and require generic research for attainment. During fiscal year 1984, the objectives consist of systematically identifying these needs and, at the same time, addressing the current, high-priority needs of the Program. Specifically, the objectives include: to assess the near-term (through 1985), mid-term (1985-1990), and long-term (beyond 1990) needs for instrumentation and measurement R.&D. regarding the DOE Solar Thermal Technology Program's major priority area of performing R.&D. to support the needs of industry and utilities with respect to solar thermal central receiver technology development, distributed receiver technology, development and innovative research; to identify one or two high-priority, near-term needs of the DOE Program for specific instrumentation and measurements and to initiate appropriate action; to produce a multiyear plan for the DOE Program (IM-R. & D.) in support of the overall DOE Multiyear Plan.

Progress

Completed in August were the measurements of the spectral characteristics of: (1) direct solar irradiance; (2) reflected irradiance from heliostats (near and far range); and (3) radiance from the receiver at Solar One. All objectives of this measurement were met. The data will be used to extract information on atmospheric attenuation of radiation propagating between the heliostats and the receiver—a key instrumentation and measurement needed at Solar One. Furthermore, these data will be used to extract information on heliostat reflectance, receiver reflectance and emittance, and the radiation environment of system sensors. The analysis of the data and the extraction of information are being undertaken next.

The working standard absolute cavity pyrheliometer at SERI was compared with the two Eppley NIP's used at Solar One to monitor direct normal irradiance. One of the NIPs was found to be 2 percent low; the other one was 4 percent low. These calibration data were given to Sandia, Livermore.

The data collected at Solar One were catalogued and were made ready for the extensive processing required for extracting the information of interest. A plan for the data processing effort was prepared.

PROGRAM ELEMENT 6.0 UNIVERSITY RESEARCH

The University Research Program Element was created within the Solar Thermal Program to enrich the research capability available to the Program with the specific resources which exist in the university system. It is the intent to use these resources to perform applied research within established priorities and to conduct solar-unique innovative experiments on specific critical problems in solar thermal technological development.

One goal of the University Research Program Element is to conduct basic analytical and experimental evaluations in both laboratory and outdoor facilities on materials and processes in order to develop an understanding of the factors affecting the performance of the materials in a solar-application environment. Another goal is to develop innovative concepts for the technology-development programs in the areas of receivers and alternative chemical cycles.

Objectives

Specific objectives for research in fiscal year 1984 at the Georgia Institute of Technology include development and testing of coatings to inhibit receiver-window devitrification, testing of mosaic window designs, experimental definition of the service limits for silica-based structural materials, development and characterization of a direct-flux entrained reactor receiver, and verification testing of the performance of a multispectral solar blind pyrameter. Specific objectives for research in fiscal year 1984 at the University of Houston include development and experimental characterization of a liquid-jet-cooled, high-flux receiver, experimental characterization of the high-flux photodegradation of ceramics, testing of a solar chemical heat pipe, and completion of computer models for latent energy storage and receiver optimization.

Progress

Georgia Institute of Technology

During the modeling of scattering and absorption processes in ceramics, the magnitude of these two coefficients have been estimated from test data acquired in ACTF test programs. For slip-cast fused silica (a white, diffusely reflecting material), the scattering coefficient has a value of 10 to 100 times the absorption coefficient, depending on temperature and other factors. These data will be used to calculate profiles in temperature and flux with thickness of the specimen as the Monte Carlo heat transfer modeling reaches that stage.

The Monte Carlo method was adopted for calculating heat transport because it has the ability to account for complex processes without the need for grossly simplifying assumptions. A program to model heat transport in a one-dimensional slab is operating successfully. It will be extended in the immediate future to model a solid medium with scattering and absorption. It has been observed that optical properties of a ceramic in the visible portion of the spectrum can differ significantly from those in the infrared; modeling must account for these discrepancies.

The ACTF test program on window materials gave several sets of thermal data useful for modeling before the tests were suspended. Since the emphasis in the program now includes acquisition of fundamental understanding of the processes governing interaction of radiation and window materials, it was decided that time could be more productively spent in modeling than in testing during the hazy and cloudy period of the summer.

It has been demonstrated that borosilicate glass coatings on fused quartz windows give some degree of protection from devitrification. This meets a Milestone rescheduled for June as reported previously and justifies effort to optimize coatings on real windows. It is expected that solar testing of one-coated windows will be accomplished in October. Work on mosaic windows has resumed and will be closely coordinated with coating work in order to take advantage of common technology.

Four-wavelength pyrometer data were collected while observing the shadowed side of a solar-heated, stainless-steel sample. The temperature as indicted by a thermocouple was 1283° K, and 1221° K was obtained from the four-wavelength data. The indicated accuracy is 4.8 percent.

Several four-wavelength sets of data were obtained while observing the sunbathed side (∿6000 to 7000 sun concentration) of a stainless steel sample. From these data no evidence of non-solar blindness was detected. The thermocouple temperature was 1154° K, and the four-wavelength temperature was 1180° K. The indicated accuracy is 2.3 percent.

Research in the direct-flux reactor resulted in a series of plots that allow determination of scattering cross-sections for particles of varying size at selected wavelengths. These data will be useful in establishing realistic values for gas and particle emittance for input to the finite-element, reactor-heat-transfer model. In addition, Dr. Grams has completed a study to evaluate the contribution of water band absorption to the reactor-flow, heating mechanism.

The original 16 nodes model of the finite element reactor using a single node for each of the inner and outer tubes was unable to duplicate experimental results. The model did confirm high temperatures of the reactor and feeder tube and the importance of convective heating; however, gas temperatures rose to near maximum at the initial nodal position and little further structure was evident. Accordingly, the model has been modified to incorporate three nodes in each tube as well as seven fluid and particle nodes and one ambient and sky node. Computer code modification is nearly complete and initial runs are being performed. Once operational, this code will be used for parametric studies incorporating the now available valves for gas particle emittance.

All materials for construction of the one-meter diameter spiral concentrator were procured, and reflective material was received from the 3M Company. A photographic process was used to enlarge the computer-generated spiral pattern to a full-scale paper pattern which was then used to cut the spiral pattern from aluminum sheeting. The support structure was designed and fabricated.

University of Houston

Tests have been run at the GIT solar furnace on 6 separate material samples exposed to $2MW/m^2$ to $5\ MW/m^2$ at about 400° C and about 500° C. Samples of nickel, diamond-like coated Zr absorber, metallic decorated anodically oxidized aluminum absorber, and pure aluminum oxide ceramic were tested under exposures of up to three hours each. Significant photodegradation was observed in every sample tested as compared to equivalent samples tested in an infrared furnace. Preliminary analysis indicates an enhanced oxidation rate for irradiated nickel; solar induced fracture in Al_20_3; and severe absorption degradation in the absorber coatings. Detailed analysis requiring further testing is underway.

CO photodesorption has been observed from oxidized silicon with the spectral response of the desorption measured. The photodesorption threshold is observed at about 2.6 eV, well below the band gap of $Si0_2$. Mechanisms are being proposed for this effort.

Exploration of vertical configurations for recombination Reactors I and II in the ammonium hydrogen sulfate system was carried out. Upward configuration tended to give slug flow; so the preferred configuration is downward, cocurrent flow. Reactor I results indicate that if space is an important consideration, then there is a definite advantage in going to either a vertical downflow configuration or a combination of horizontal and vertical downward flow configurations. Reactor II results indicate that the difference in lengths between the corresponding horizontal and vertical configurations is negligible. If space is an important factor, then the use of either a combination of horizontal and vertical downflow configurations or a vertical downflow configuration is possible. A combined Reactor I and II was also investigated.

Cyclic tests of the catalytic heat pipe reactor receiver were performed over a period of two months. No sign of catalyst deactivation or structural degradation was noted. The catalyst appears to be very stable under these operating conditions.

The high-pressure elements of the jet-cooled receiver test loop have been welded by Bechten-Union Carbide at Texas City and have been installed in the laboratory. Researchers are awaiting completion of some final low-pressure welds and the final hook-up of the pump. Then a safety certification is required prior to operation.

PROGRAM ELEMENT 7.0 INNOVATIVE CONCEPTS

The Innovative Concepts Program Element was established in fiscal year 1983 to provide a specific means to encourage ideas in innovative solar thermal technology and to provide a method for the systematic evaluation and the harvesting of those with the highest potential. To accomplish this aim, a Program Research and Development Announcement (PRDA) was distributed during fiscal year 1983 by DOE/SAN. Significant interest was shown by the research community in the program.

Work on Innovative Concepts is specifically designed to encourage, to identify, to evaluate, and to select innovative systems, subsystems, and component concepts having high promise; and by providing limited, but sufficient funds for innovators, to enable researchers to pursue and to document these concepts to the point where the potential and the feasibility may be determined.

Progress

For Cycle 1, Phase 2, the Source Selection Official has issued a directive letter to the SRI Subcontracts Group. The issuance of this letter signals that this action has resulted in active negotiations with those proposers in the competitive range. The objective is to have contracts in place by the end of October.

For Cycle 2, Phase 1, the Source Selection Official has issued a directive letter, and negotiations are underway with those proposers in the competitive range. The objective is to have contracts in place by the end of November.

For Cycle 1, Phase 1, all contracts are complete, and final reports are being received and reviewed. Those contracts are through DOE/SAN.

PROGRAM ELEMENT 8.0 PLANNING AND ASSESSMENT

As new knowledge is acquired, new opportunities are presented for the research and development of new systems concepts with potential for improving the technical and cost performance of solar thermal systems. As systems are installed and as a performance history is generated and indicates opportunities for improvement, the direction, goals, and activities of the program undergo change.

The goal of this element is to provide planning and support in systems analysis to DOE/HQ and the Technical Program Integrator (TPI). As the program direction shifts to the research and development of systems using higher operating temperatures (with the eventual timely selection of one system or a few systems for technological development), this activity plays an interesting and significant role in the analysis of system options and the recommendation, in close coordination with the TPI, of the long-term program for research and development. Once this Task has been accomplished, it is expected that this effort will become more limited in its scope and will become more confined to concept or Task-level system analysis. Two activities were proposed for fiscal year 1984 to achieve the goal: systems analysis support and on-site support to the Technical Program Integrator.

Progress

Work continued on documentation of the IPH study. The first rough draft is over halfway completed. The major elements on which much of the effort has been focused include the system description, the results, and the conclusions. Also, staff has focused on retrieving, defining, and documenting an enhanced data base of selected cases from the numerous ones which were run during the study in 1981.

A first draft of the High-Temperature Materials Briefing Package has been developed. Major revisions and needed refinements have been defined for the next version. The report reviews existing studies on high-temperature materials with potential solar thermal applications. Technical issues, the status of current developments, and the likely candidate materials are described in the survey document. A large bibliography is also identified and presented.

The report (joint with SNLL) "The Performance of High Temperature Central Receiver Systems" (SAND84-8233) was published last month.

CARRYOVER TASKS/FISCAL YEAR 1983

APPLICATION OF SOLAR PONDS TO POWER PRODUCTION

Research on solar ponds has been discontinued. Remaining activity under this title consists solely of progress on four subcontracts.

Progress

Colorado State University

Although this contract has been closed, SERI has received a complete draft of R. Gordon's M.S. thesis, "Observations of Double Diffusive Convection in the Presence of Non-Constant Salinity Gradients," for review. The experiments reported in this thesis were funded by this Task. These experiments verified some aspects of the theoretical work of Zangrando and Bertram.

This final report has been submitted to the Editing Department of SERI for publication and distribution as a SERI report.

Purdue University

All work on this subcontract is completed. All costs have been accrued. Close out procedures have begun. The final report has been submitted to the Editing Department of SERI for publication and distribution as a SERI report.

Massachusetts Institute of Technology

A draft copy of J. Atkinson's thesis was received and was forwarded to the DOE; that report completed the final deliverable on this subcontract. Process to close out the subcontract was initiated.

University of Utah

Experiments on the performance of a brine-to-pentane Direct Contact Heat Exchanger filled with "egg-crate" packing have been completed. Water inlet temperature was fixed at 85° C, and the pentane inlet temperature was set at 25° C to 30° C. Tests were performed at a variety of column pressures, pentane flows, and water flows. The tests clearly defined when pentane is swept out with the cooled water and allowed an assessment of the heat transfer performance. Less easily defined were the conditions under which pentane may accumulate in the top of the column. Some plots of volumetric heat transfer coefficients compared to mass flow rate ratio for different fixed water flow rates were made. In summary, results indicate that the spray column performs better than the packed column.

APPENDIX A

SUBCONTRACTS

ACTIVE FY84 SUBCONTRACTS USING FY83 FUNDS

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(1)	University of Utah	—	Generation of design data for a direct contact boiler for solar pond power production	100.0	University
(2)	Massachusetts Institute Technology	—	Experiments on wind mixing of a solar pond's surface layer	62.2	University
(3)	Purdue University	—	Experiments on gradient layers erosion in a stratified fluid	75.0	University
(4)	Colorado State University	2.3	Identification and evaluation of wind avoidance/reduction schemes for concentrating collectors	70.0	University
(5)	Consulting Agreement with Dr. Sachin Bhaduri (Univ. of Texas/El Paso)	2.3	Provision of technical support to SERI on wind avoidance/reduction schemes for concentrating collectors	7.0	Consulting Agreement
(6)	Consulting Agreement with Dr. Bing Chen (Univ. of Nebraska at Omaha)	2.3	Design, fabrication and evaluation of experimental RF systems for controlling heliostat fields	7.0	Consulting Agreement
(7)	Consulting Agreement with Dr. James Pearson (John Brown Univ., Siloam Springs, AK)	2.3	Design, fabrication and evaluation of experimental RF systems for controlling heliostat fields	7.0	Consulting Agreement
(8)	Solar Steam, Inc. (Tacoma, WA)	1.3	Fabrication and assessment of a pumpless solar boiler	12.0	Small Business

ACTIVE FY84 SUBCONTRACTS USING FY83 FUNDS (Concluded)

	Subcontract	WBS Number	Procurement Title/Activity	Value (000$)	Type Business
(9)	Denver Research Institute of the University of Denver	1.0	Passivating layers on ceramics and alloys in contact with molten salts at high temperatures	28.0	University
(10)	University of Arizona	2.0	Fabrication and evaluation of graphite fiber composite solar concentrators	30.0	University
(11)	Georgia Institute of Technology	2.0	Spiral concentrating collector	10.0	University
(12)	Acurex Solar, Inc.	2.0	Low-cost, lightweight silver/metal reflector module development	11.0	Solar thermal industrial firm
(13)	DAN-KA Products	2.0	Design and fabrication of two scale-model stretched membrane reflector modules	110.0	Solar thermal industrial firm

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(1)	Consulting Agreement with Mr. Marvin Christensen	4.1	Provision of planning support to SERI and technical monitoring of Solar Fuels and Chemicals Program subcontracts	5.0	Consulting Agreement
(2)	Consulting Agreement with Mr. Christopher England	4.1	Provision of planning support to SERI and technical monitoring of Solar Fuels and Chemical Program subcontracts	25.0	Consulting Agreement
(3)	Georgia Institute of Technology	6.1	University research in support of the STT Program (ceramics, entrainment reactor, etc.)	610.0	University
(4)	University of Houston	6.2	University research and computer model development in support of the Solar Thermal Technology Program	253.5	University
(5)	Consulting Agreement with Dr. Richard Bradt (University of Washington)	1.1	Four-Point Flexural Testing and provision of technical support on ceramics for high temperature solar thermal applications	9.0	Consulting Agreement
(6)	Georgia Institute of Technology	6.0	Operation and maintenance of the Advanced Components Test Facility (ACTF)	235.0	University
(7)	University of Denver	2.0	Polymer-protected silver mirrors and mirror degradation mechanisms	42.0	University

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(8)	Consulting Agreement with Dr. Lorin Vant-Hull (University of Houston)	2.3	Concentrating collector optical performance modeling	10.0	Consulting Agreement
(9)	Black & Veatch	1.0	Provision of solar thermal research program planning support to SERI and generation of a multi-year research program plan	75.0	Solar Thermal Industrial Firm
(10)	Consulting Agreement with Dr. Arthur Clausing (University of Illinois)	1.3	High Temperature Solar Thermal System Central Receiver Convection Analysis	10.0	Consulting Agreement
(11)	Radiation Research Associates	5.0	Generation of Monte Carlo simulation estimates of attenuation and scattering between heliostats and the receiver	25.0	Small Business
(12)	Jet Propulsion Laboratory	2.0	Development of UV stabilizers for polymer film materials	60.0	National Laboratory
(13)	Jet Propulsion Laboratory	8.0	Preliminary engineering designs for and optical analysis of the proposed SERI High Temperature/High Flux Experiment	48.0	National Laboratory
(14)	Consulting Agreement with Dr. Cheng-Lin Tien (University of California/ Berkeley)	3.1	Provision of Planning Support to SERI in high temperature thermal research	10.0	Consulting Agreement

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS (Concluded)

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(15)	Consulting Agreement with Mr. Conrad M. Vineyard	1.0	Solar Thermal Technology cost estimation tehnnical support	10.0	Consulting Agreement
(16)	Consulting Agreement with Mr. George M. Kaplan	1.0	STT Research Program planning, technical review of reports, and identification, evaluation and exploitation of R&D funded by other Federal agencies	10.0	Consulting Agreement
(17)	Consulting Agreement with Dr. A. H. Soni (Oklahoma State University)	2.0	Analysis and design of adjustable cable restraints for air-inflated heliostat drive/support	10.0	Consulting Agreement

PLANNED FY84 PROCUREMENTS: STT RESEARCH PROGRAM
PLANNED SUBCONTRACTS USING FY84 FUNDS

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(1)	Funds for this Planned Subcontract are being Redirected into the FY 1985 Program	1.0	Degradation mechanisms in ceramics exposed to thermal fluids at high temperatures	50.0	
(2)	The 3M Company	2.0	Industrial research for polymer film preparation	50.0	Metallized Polymer Industrial Firm
(3)	To Be Determined	3.0	Acquisition of hardware (e.g. heaters, heater controllers, etc.) and modifications to the FTLB for the 700°C Molten Salt Test Loop (This Subcontract is being cost-shared with the Storage Program)	42.0	To Be Determined
(4)	To Be Determined	3.0	Acquisition of hardware (e.g. Inconel tanks, Inconel pumps, valves, etc.) for the 900°C Molten Salt Test Loop	46.0	To Be Determined
(5)	To Be Determined	7.0	Cycle I Phase II Subcontracts (3 or 4 subcontracts)	641.0	To Be Determined
(6)	To Be Determined	7.0	Cycle II Phase I Subcontracts (8 or 10 subcontracts)	459.0	To Be Determined
(7)	Funds for this Planned Subcontract are being Redirected into the FY 1985 Program	1.0	Design and fabrication of an apparatus for measuring the mechanical properties of containment matrials used to contain thermal fluids at high temperature	50.0	

APPENDIX B

RESOURCE EXPENDITURE

Budget Status

1. Contractor (name and address)

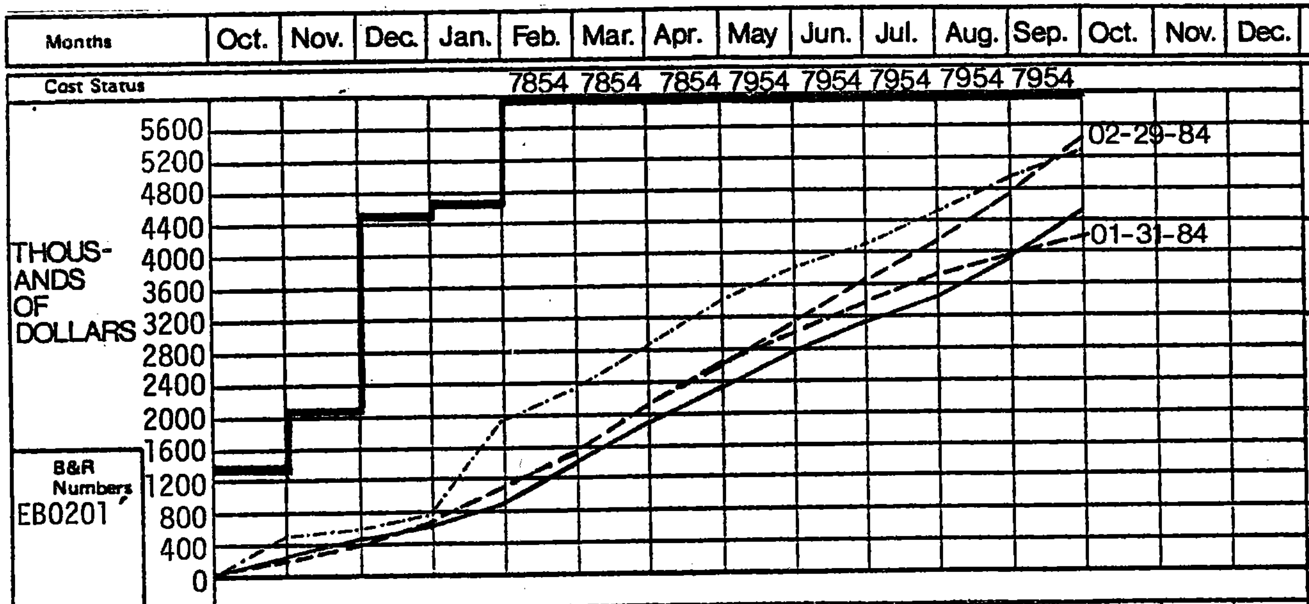
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/01/83
To: 09/30/84

3. Program Identification
SOLAR THERMAL TECHNOLOGY

4. WPA/Task
PROGRAM TOTAL



FY 84

Cost Plan Date 02-29-84

Planned Costs Prior FY NA

Actual Costs Prior FY NA

Total Estimated Costs for FY84 5406

Total Contract Value 7,954

Unfilled Orders Outstanding 783

Estimate for Subsequent Reporting Period

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Accrued Costs	c. Planned	210	405	633	1110	1587	2121	2640	3126	3609	4112	4757	5406			
	d. Actual	222	412	619	932	1383	1909	2281	2736	3108	3458	3937	4473			
	e. Variance	(12)	5	21	164	26	8	147	31	111	153	166	113			
	f. Cum. Variance	(12)	(7)	14	178	204	212	359	390	501	654	820	933			

▬ Obligational Ceiling
-·-·- Costs Plus Commitments
—— Actual
- - - Plan

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To: 09/31/84

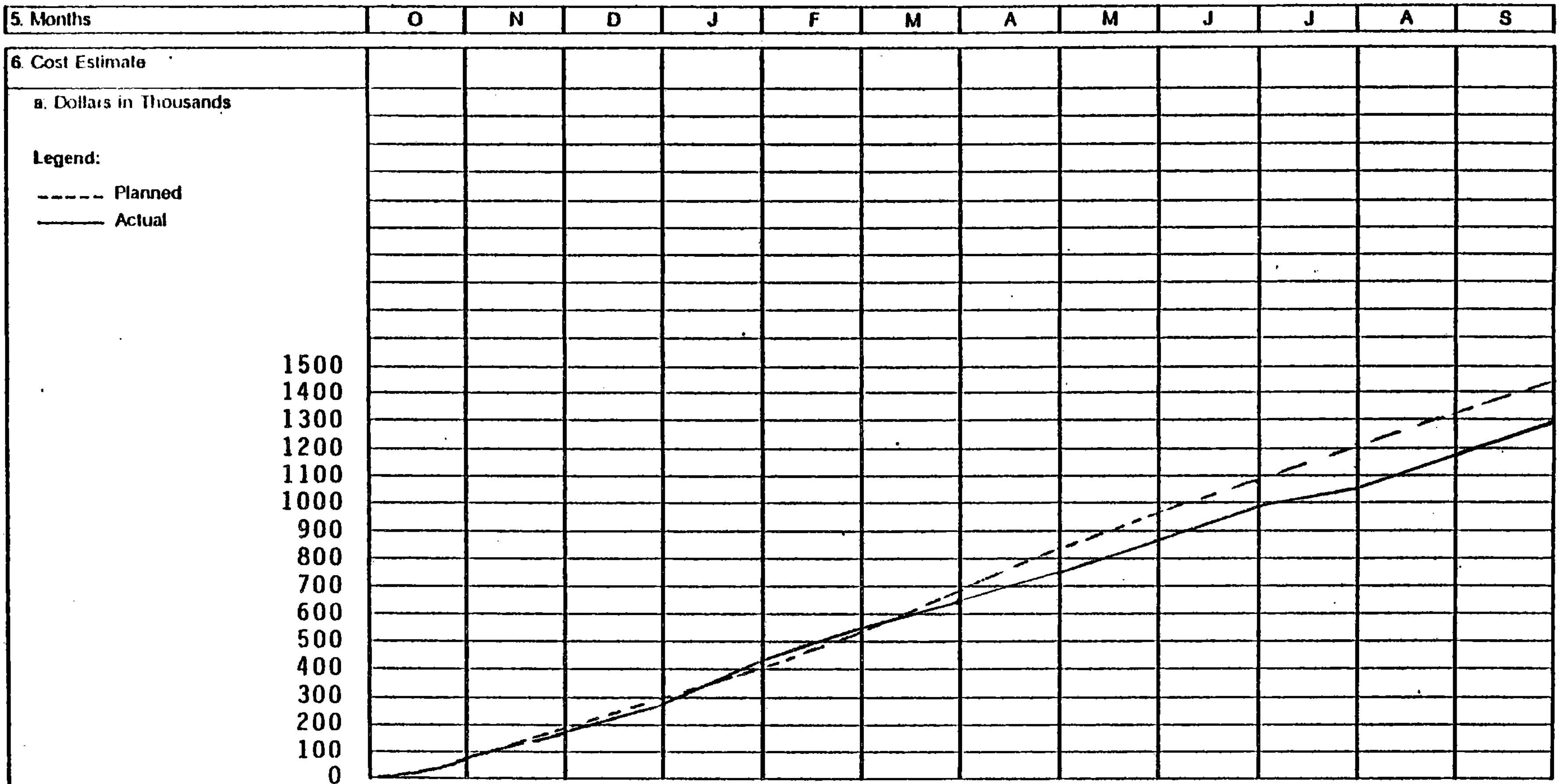
3. Program Identification
FY84 STT Research Program

4. WPA/Task
Program Element 1.0: High Temperature Materials

5. Months

6. Cost Estimate

a. Dollars in Thousands



		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	92.6	97.4	90.7	116.9	128.9	156.0	151.9	121.5	122.6	121.3	117.2	112.0	b. Planned 1429.0
	c. Actual	94.5	82.7	104.9	136.6	119.1	103.9	99.7	143.9	111.5	65.7	120.8	110.3	c. Actual
	d. Variance	-1.9	14.7	-14.2	-19.7	9.8	52.1	52.2	-22.4	11.1	55.6	-3.6	1.7	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To: 09/31/84

3. Program Identification
FY84 STT Research Program

4. WPA/Task
Program Element 2.0: Reflector Materials

5. Months

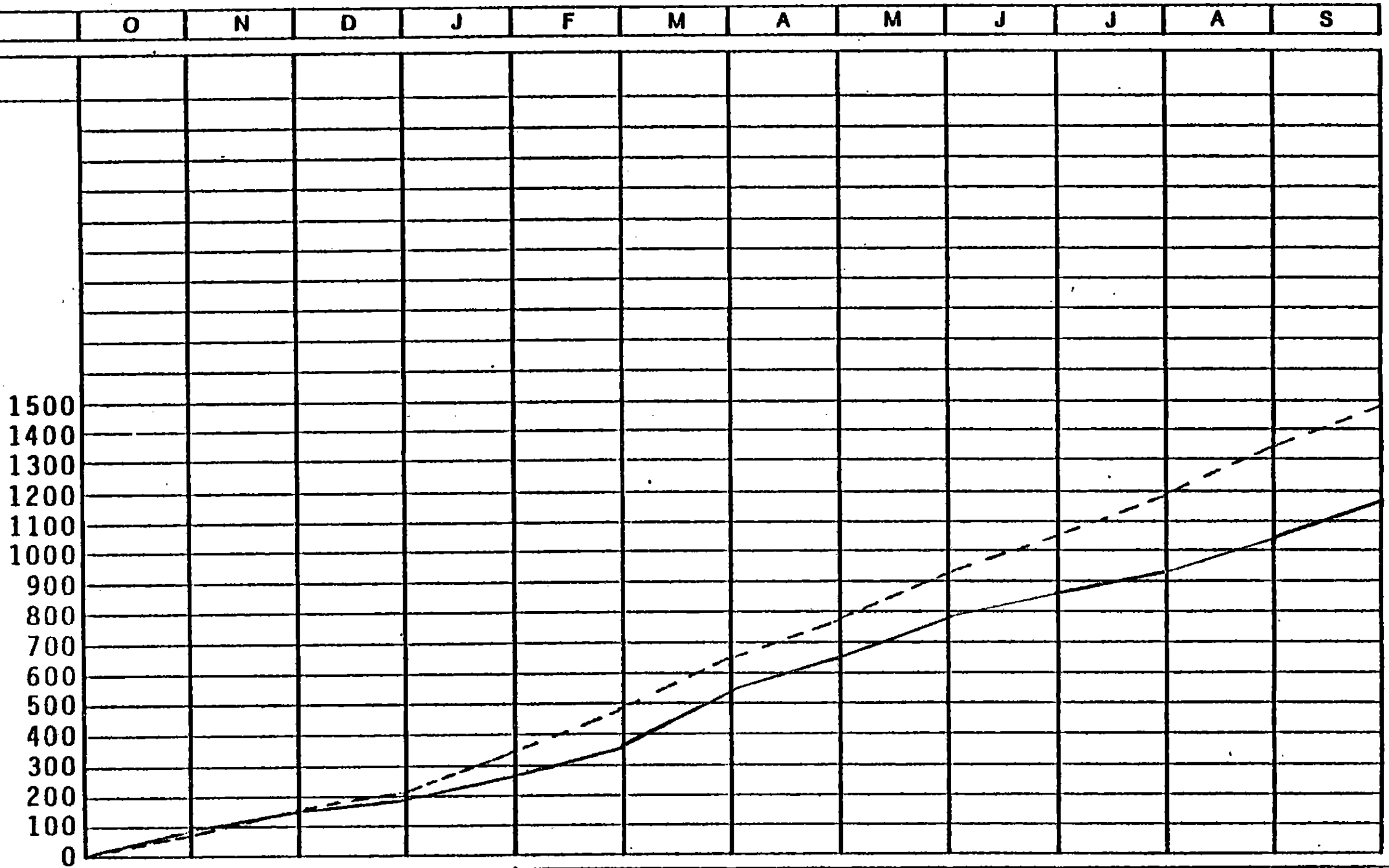
6. Cost Estimate

a. Dollars in Thousands

Legend:

----- Planned

——— Actual



		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	57.7	58.3	90.9	142.3	142.8	143.8	140.8	134.1	139.9	142.2	145.4	141.3	b. Planned 1479.5
	c. Actual	80.5	57.3	54.9	68.9	101.1	189.1	113.1	124.3	78.4	55.2	112.9	139.4	c. Actual
	d. Variance	-22.8	1.0	36.0	73.4	41.7	-45.3	27.7	9.8	61.5	87.0	32.5	1.9	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To: 09/31/84

3. Program Identification

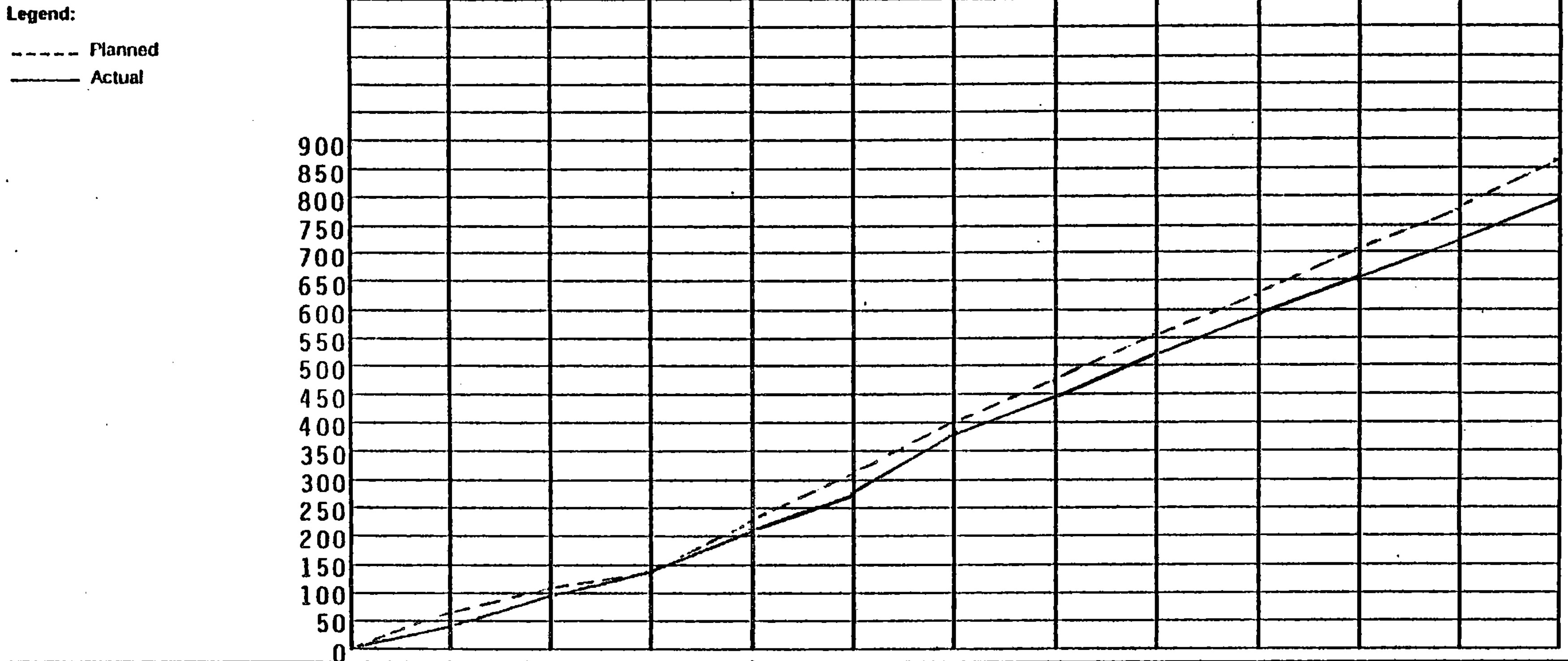
FY84 STT Research Program

4. WPA/Task

Program Element 3.0: Thermal Science Research

6. Cost Estimate

a. Dollars in Thousands



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	60.5	40.3	47.1	79.4	77.2	95.1	77.6	79.7	69.3	77.8	71.7	86.7	b. Planned 862.4
	c. Actual	47.6	49.3	43.5	73.4	58.3	101.9	79.9	70.2	72.7	59.4	66.2	72.4	c. Actual
	d. Variance	12.9	-9.0	3.6	6.0	18.9	-6.8	-2.3	9.5	-3.4	18.4	5.5	14.3	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

Program Element 4.0: Photochemical/Thermochemical Research

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

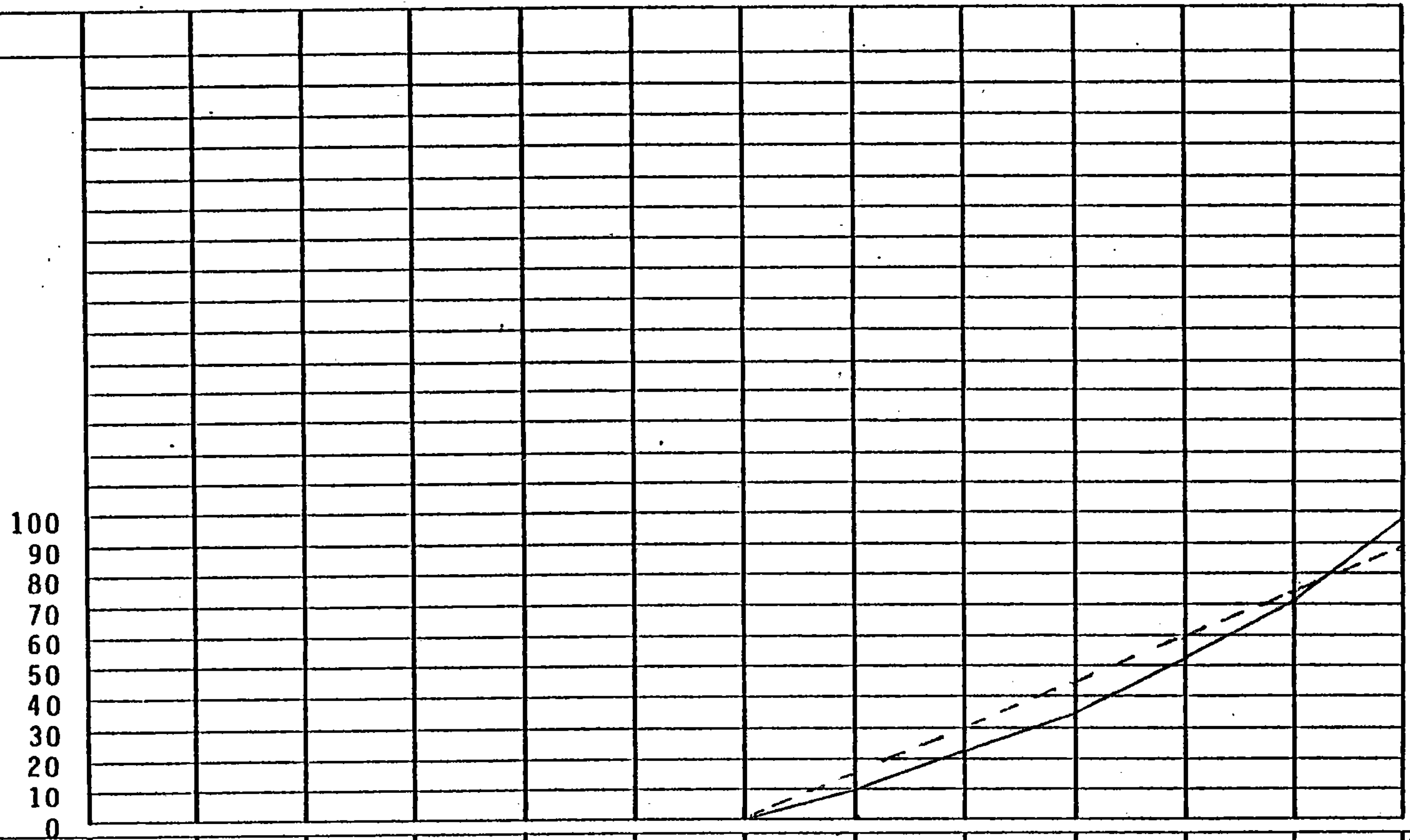
6. Cost Estimate

a. Dollars In Thousands

Legend:

----- Planned

——— Actual



		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	0	0	0	0	0	0	14.7	14.7	14.6	14.6	14.6	14.5	b. Planned 87.7
	c. Actual	0	0	0	0	0	0	10.2	12.7	12.0	18.5	18.3	27.2	c. Actual
	d. Variance	0	0	0	0	0	0	4.5	2.0	2.6	-3.9	-3.7	-12.7	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To: 09/31/84

3. Program Identification

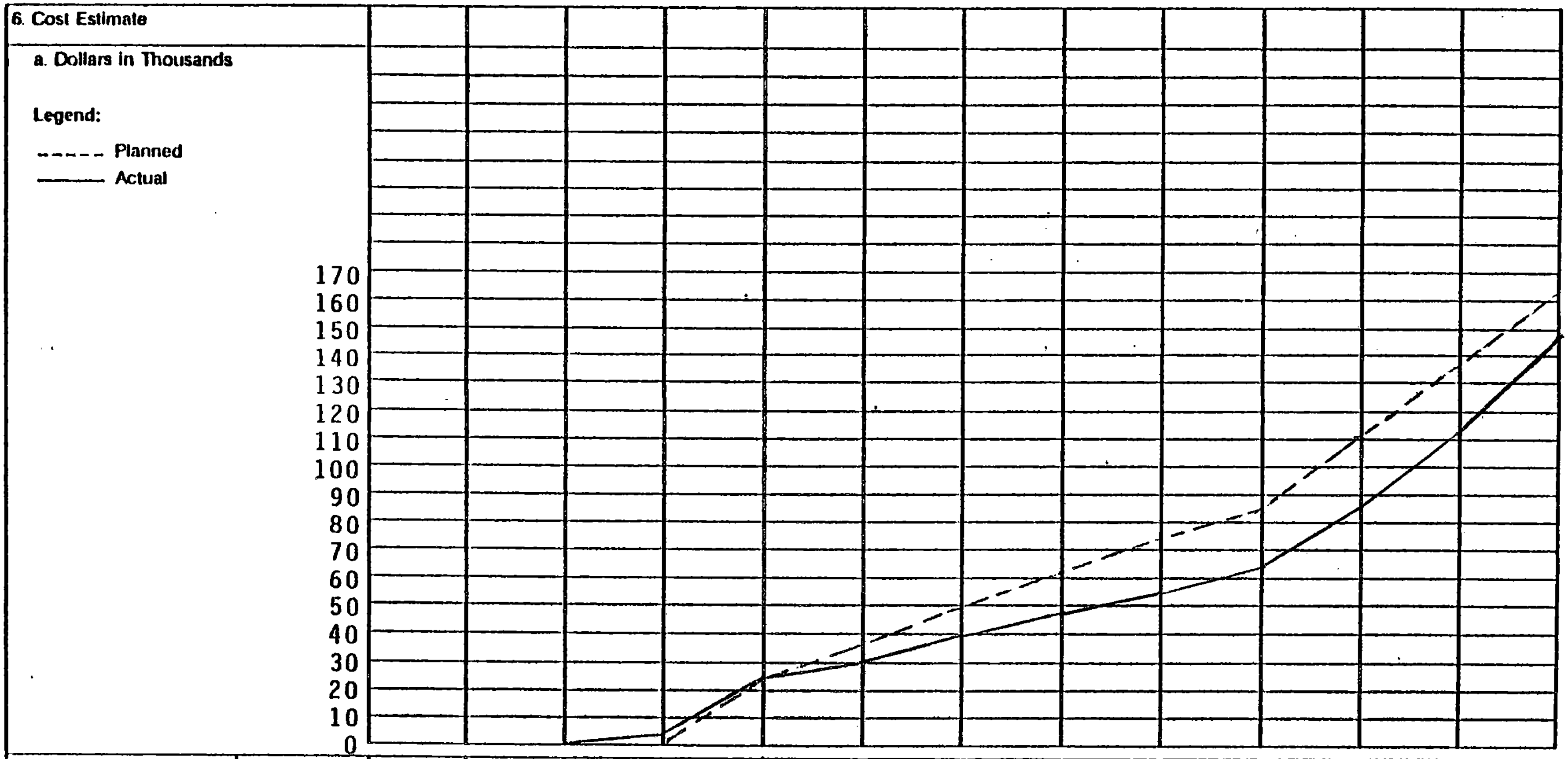
FY84 STT Research Program

4. WPA/Task

Program Element 5.0: Instrumentation and Measurement

6. Cost Estimate

a. Dollars in Thousands



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	0	0	0	24.4	12.4	12.3	12.2	12.1	11.9	25.6	25.6	25.3	b. Planned 161.8
	c. Actual	0	0	4.2	23.0	3.0	9.6	7.5	7.5	9.8	21.2	22.4	31.4	c. Actual
	d. Variance	0	0	-4.2	1.4	9.4	2.7	4.7	4.6	2.1	4.4	3.2	-6.1	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

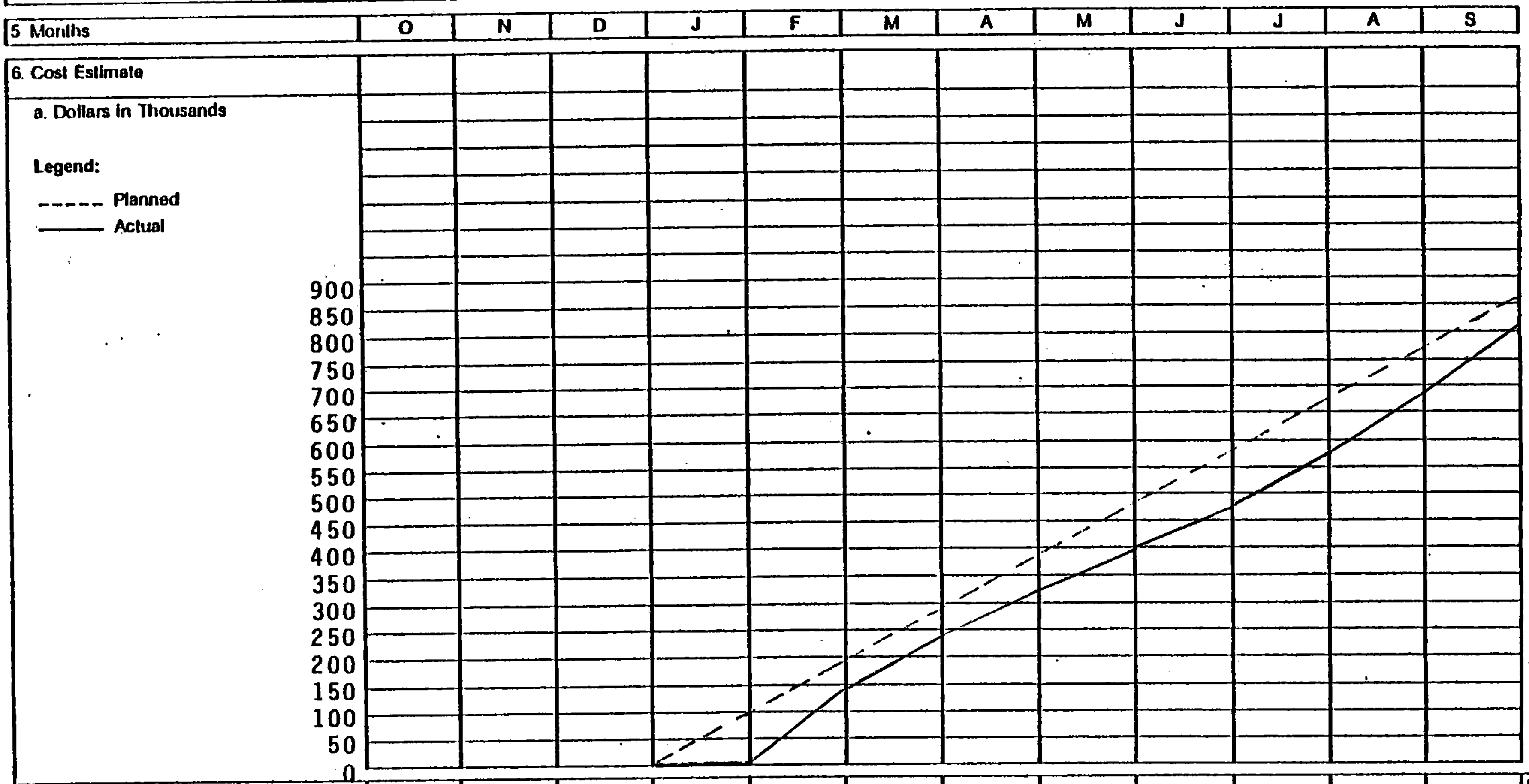
From: 10/1/83
To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

Program Element 6.0: University Research



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	
b. Planned	0	0	0	94.7	94.9	94.9	94.9	94.9	94.9	94.9	94.9	94.9	b. Planned 853.9
c. Actual	0	0	0	0.5	146.6	93.6	81.4	77.8	71.9	99.5	117.4	122.8	c. Actual
d. Variance	0	0	0	94.2	-51.7	1.3	13.5	17.1	23.0	-4.6	-22.5	-27.9	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

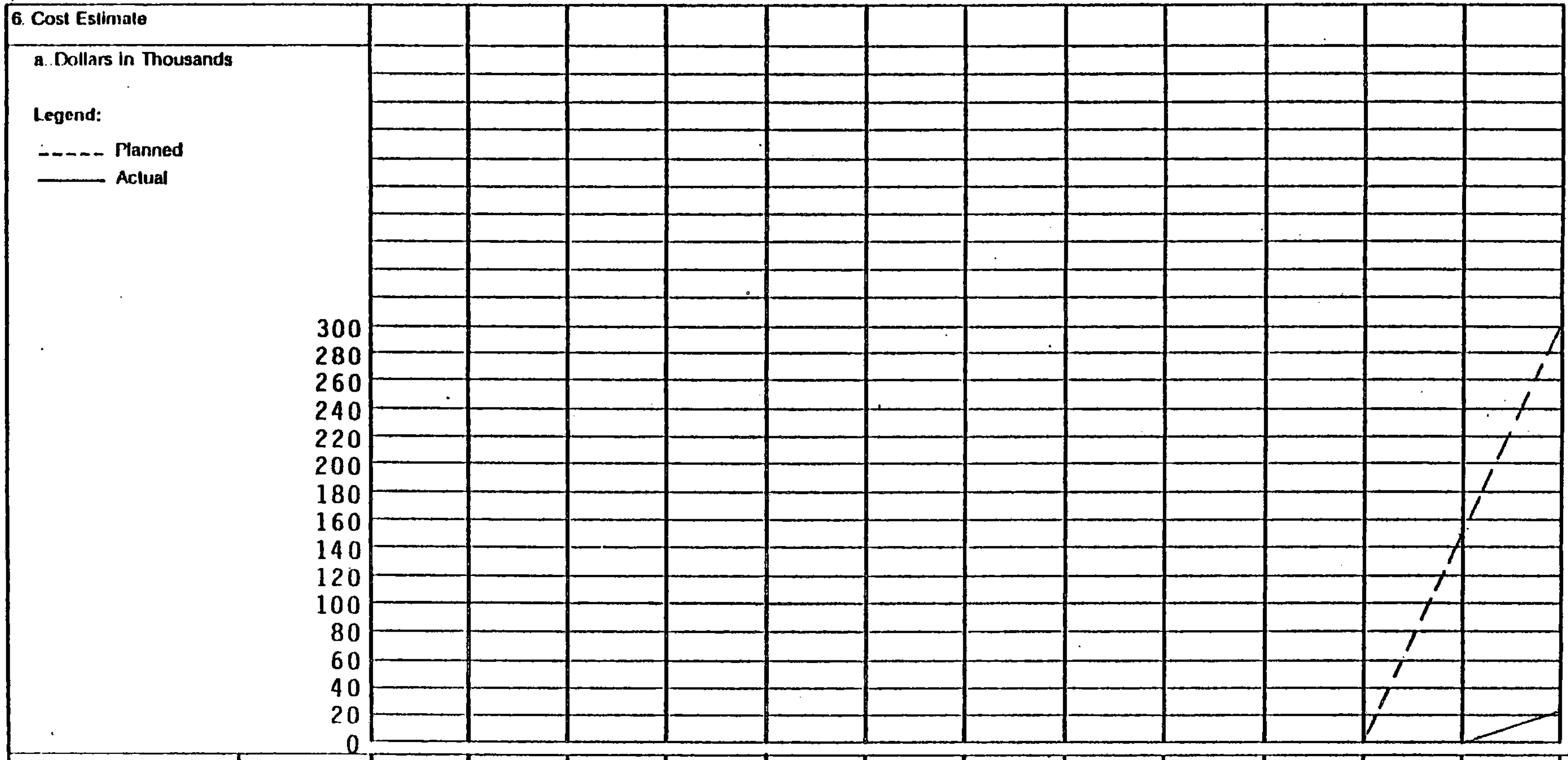
Program Element 7.0: Innovation Research

5. Months

O	N	D	J	F	M	A	M	J	J	A	S

6. Cost Estimate

a. Dollars in Thousands



		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	0	0	0	0	0	0	0	0	0	0	148.8	148.2	b. Planned 297.0
	c. Actual	0	0	0	0	0	0	0	0	0	0	0.0	22.2	c. Actual
	d. Variance	0	0	0	0	0	0	0	0	0	0	148.8	126.0	d. Variance

Budget Status

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

Program Element 8.0: Planning and Assessment

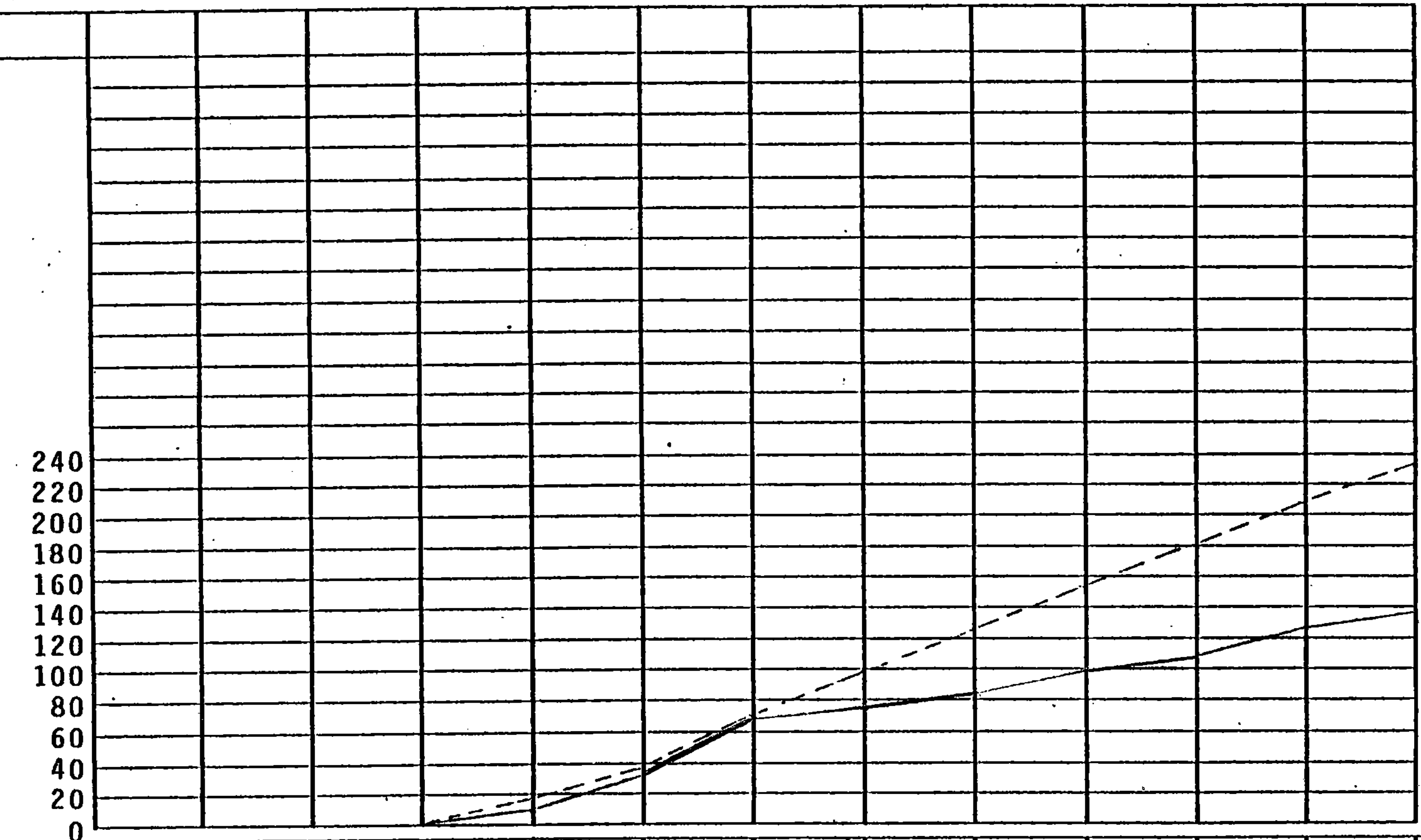
6. Cost Estimate

a. Dollars in Thousands

Legend:

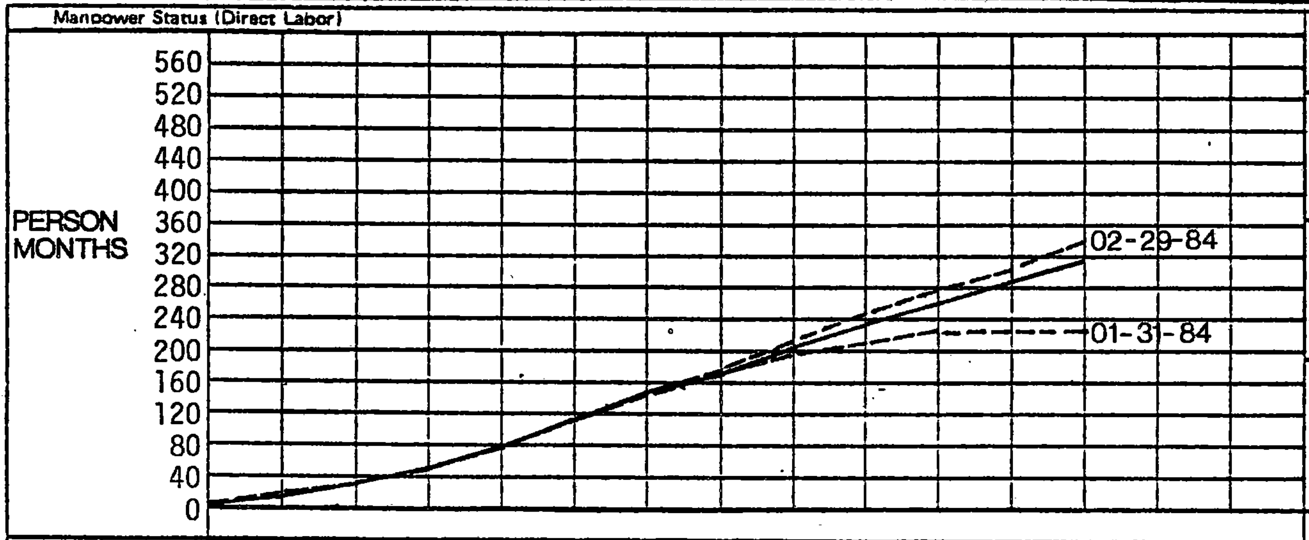
------ Planned

——— Actual



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	b. Planned	0	0	0	18.7	18.7	33.6	27.5	27.3	27.2	27.1	27.1	26.6	b. Planned 233.8
	c. Actual	0	0	0	10.1	23.2	36.5	3.6	9.8	16.1	6.9	20.5	10.3	c. Actual
	d. Variance	0	0	0	8.6	-4.5	-2.9	23.9	17.5	11.1	20.2	6.6	16.3	d. Variance

MANPOWER STATUS



Months		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Man-power	Planned	16	31	49	78	110	145	178	211	243	276	308	339			
	Actual	14	31	50	79	110	143	171	202	231	257	284	309			
	Variance	2	0	(1)	(1)	0	2	7	9	12	19	24	30			

FY 84

Manpower Plan Date
02-29-84

Planned Manpower Prior FY
NA

Actual Manpower Prior FY
NA

Total Estimated Manpower for FY84
339

Total Contract Manpower
339

Manpower

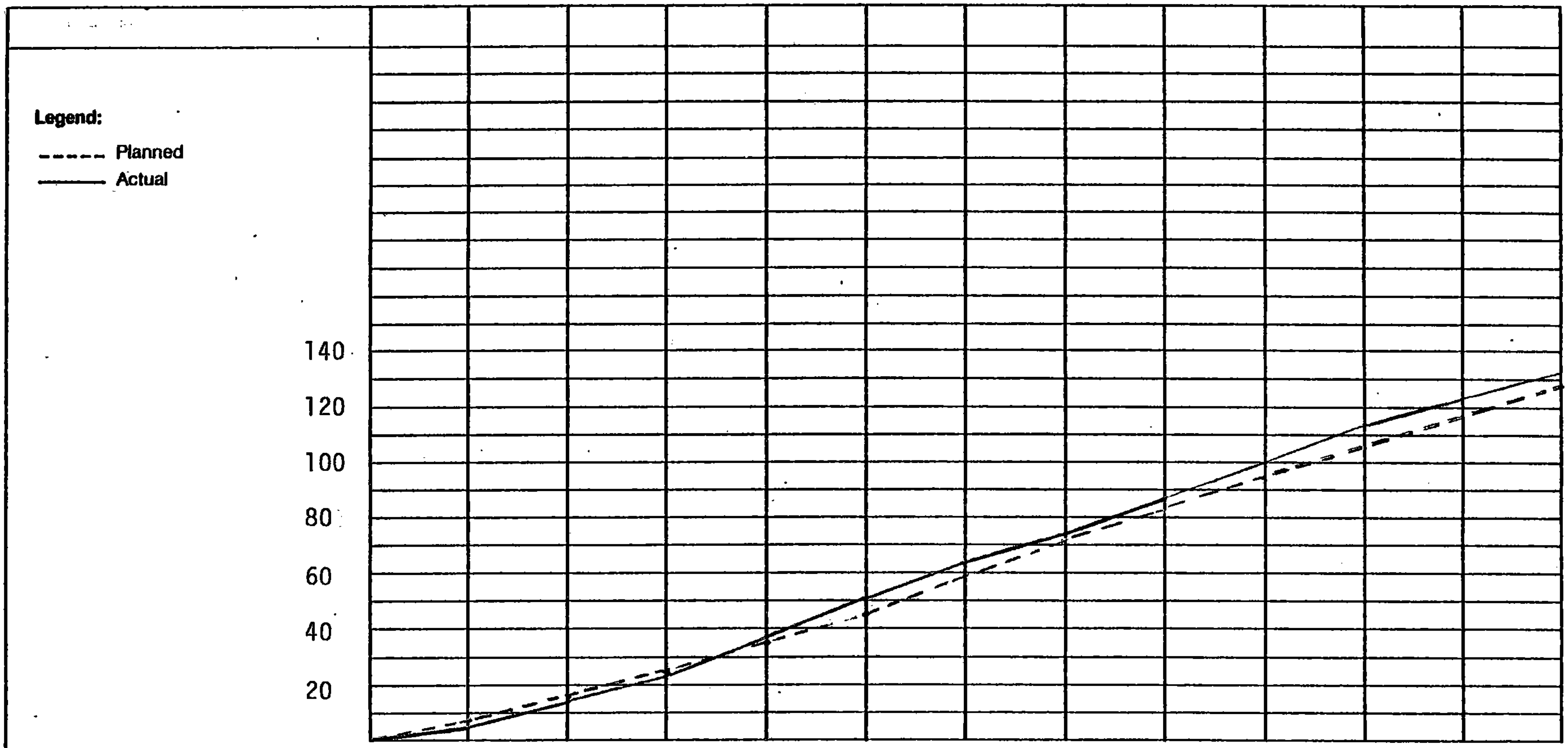
1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification
FY84 STT Research Program

4. WPA/Task
Program Element 1.0 High Temperature Materials



5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	8.3	8.8	8.0	9.3	10.5	13.8	11.9	11.9	11.9	11.9	10.9	10.4	Planned
Actual	6.7	7.7	8.7	15.2	14.0	10.7	11.0	13.57	12.68	12.79	11.67	7,97	Actual

Manpower

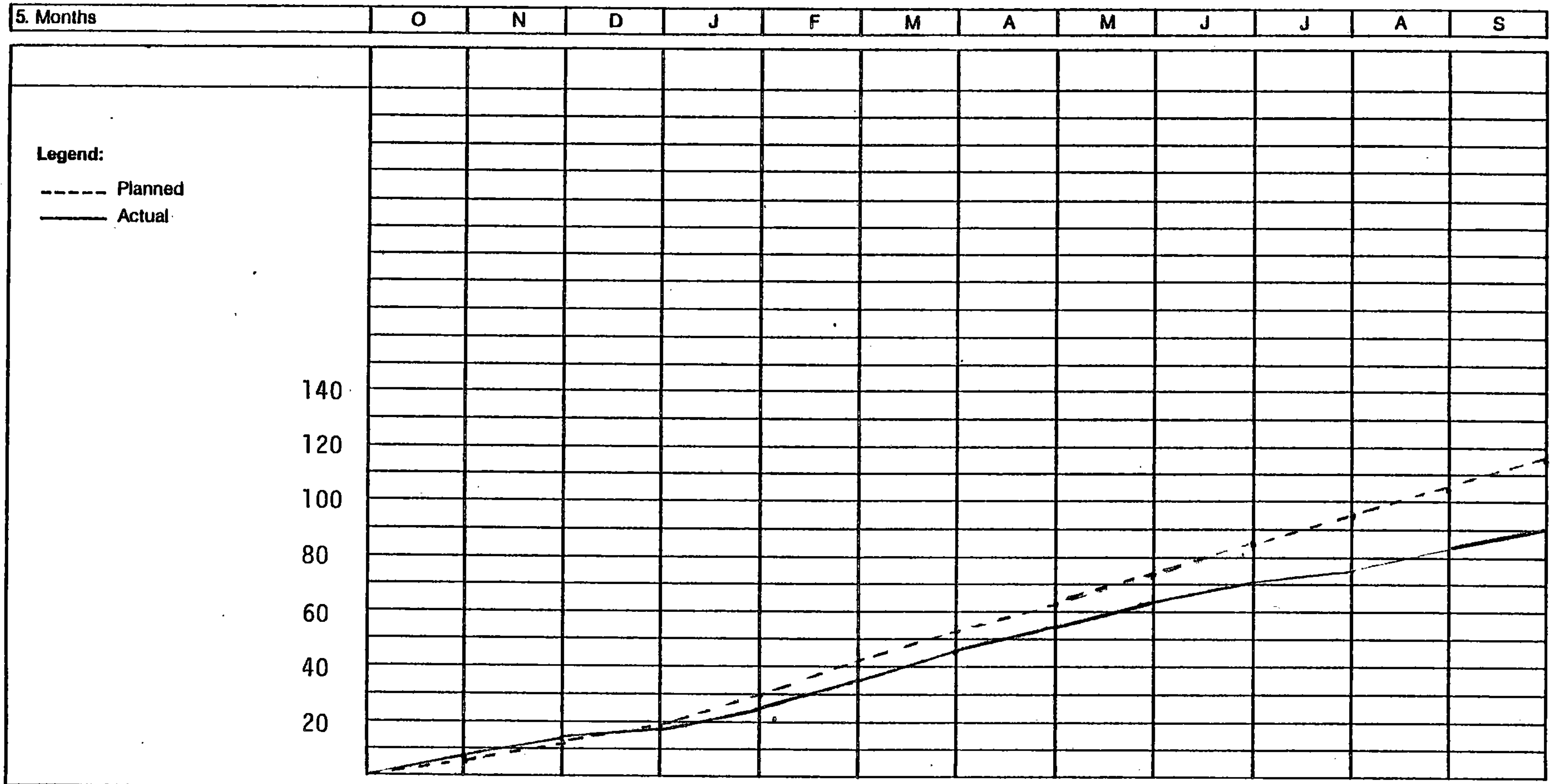
1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification
FY84 STT Research Program

4. WPA/Task
Program Element 2.0 Reflector Materials



Planned	5.7	5.8	7.7	10.6	12.2	10.4	10.5	10.5	10.6	10.6	10.5	10.5	Planned
Actual	6.6	6.0	6.1	6.9	8.4	11.5	9.6	8.55	7.24	5.33	6.03	7.78	Actual

Manpower

1. Contractor (name and address)

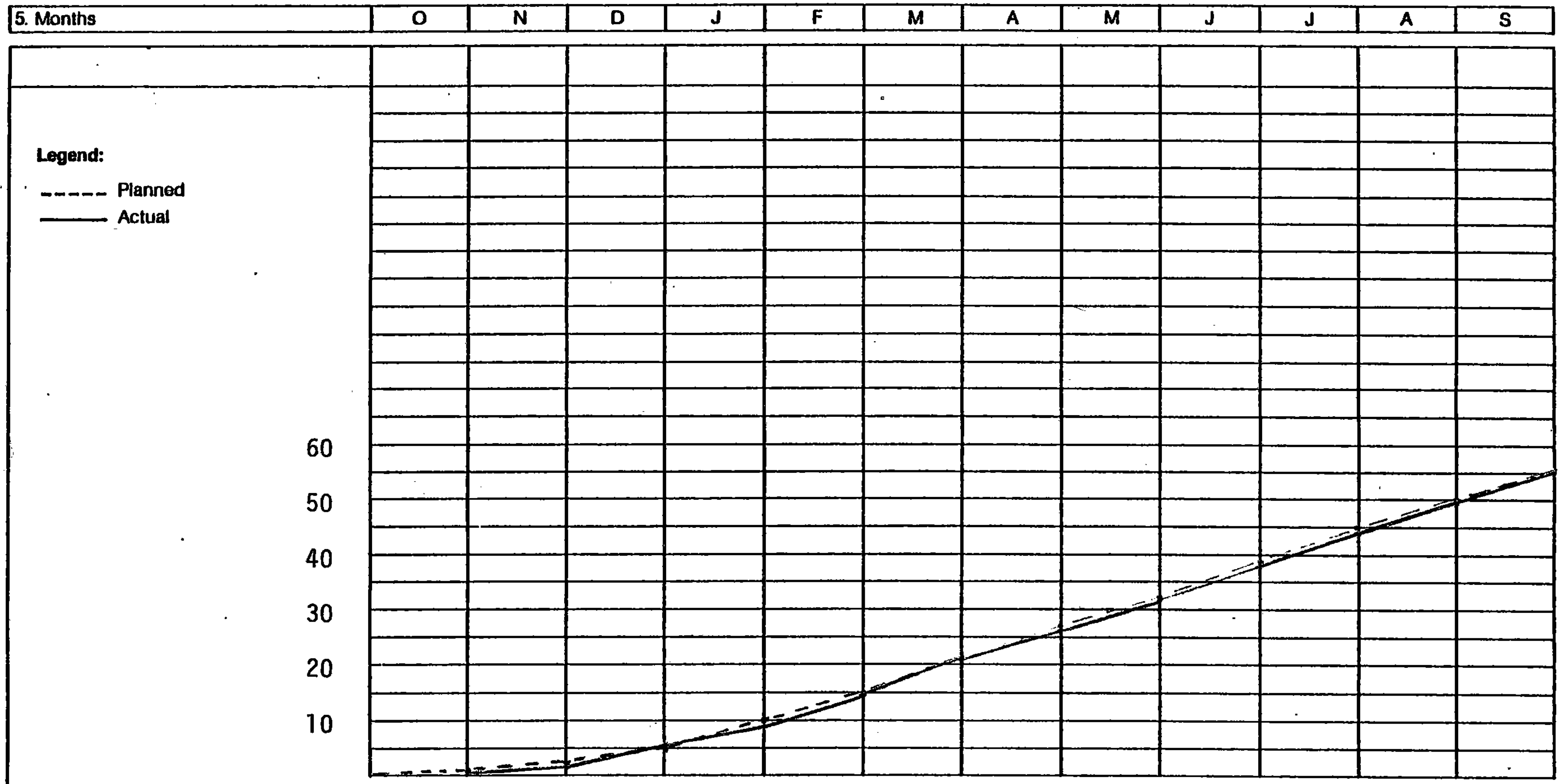
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 3.0 Thermal Science Research

5. Months



	Planned	1.95	1.25	2.25	4.55	5.15	6.85	5.85	5.65	5.55	6.15	5.35	5.85	Planned
	Actual	1.10	1.10	3.70	3.70	5.20	6.39	6.10	5.47	5.43	5.83	5.54	7.31	Actual

Manpower

1. Contractor (name and address)

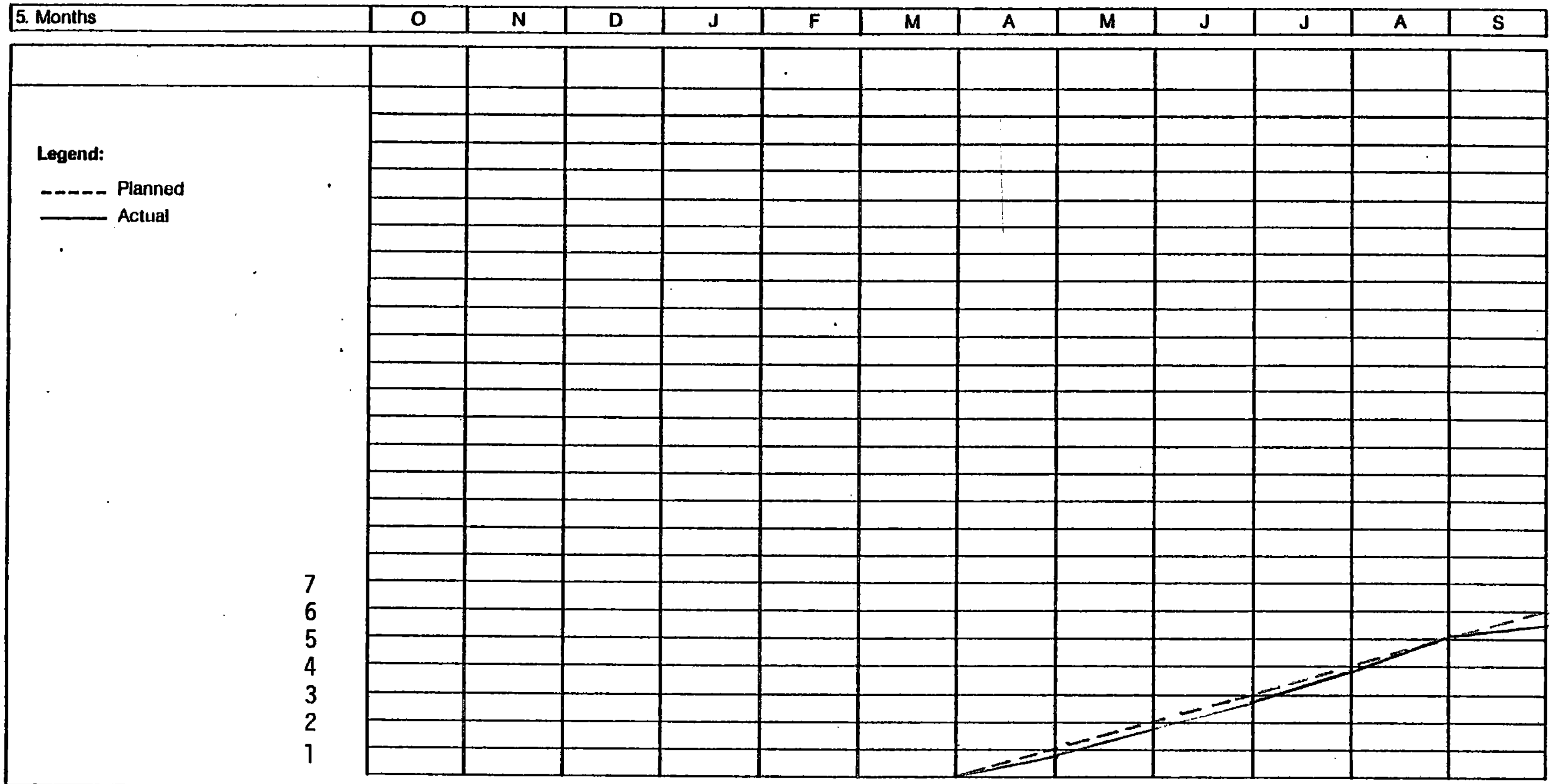
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 4.0 Photochemical/Thermochemical Research



Planned	0	0	0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	Planned
Actual	0	0	0	0	0	0	.89	1.0	1.0	1.08	1.07	.48	Actual

Manpower

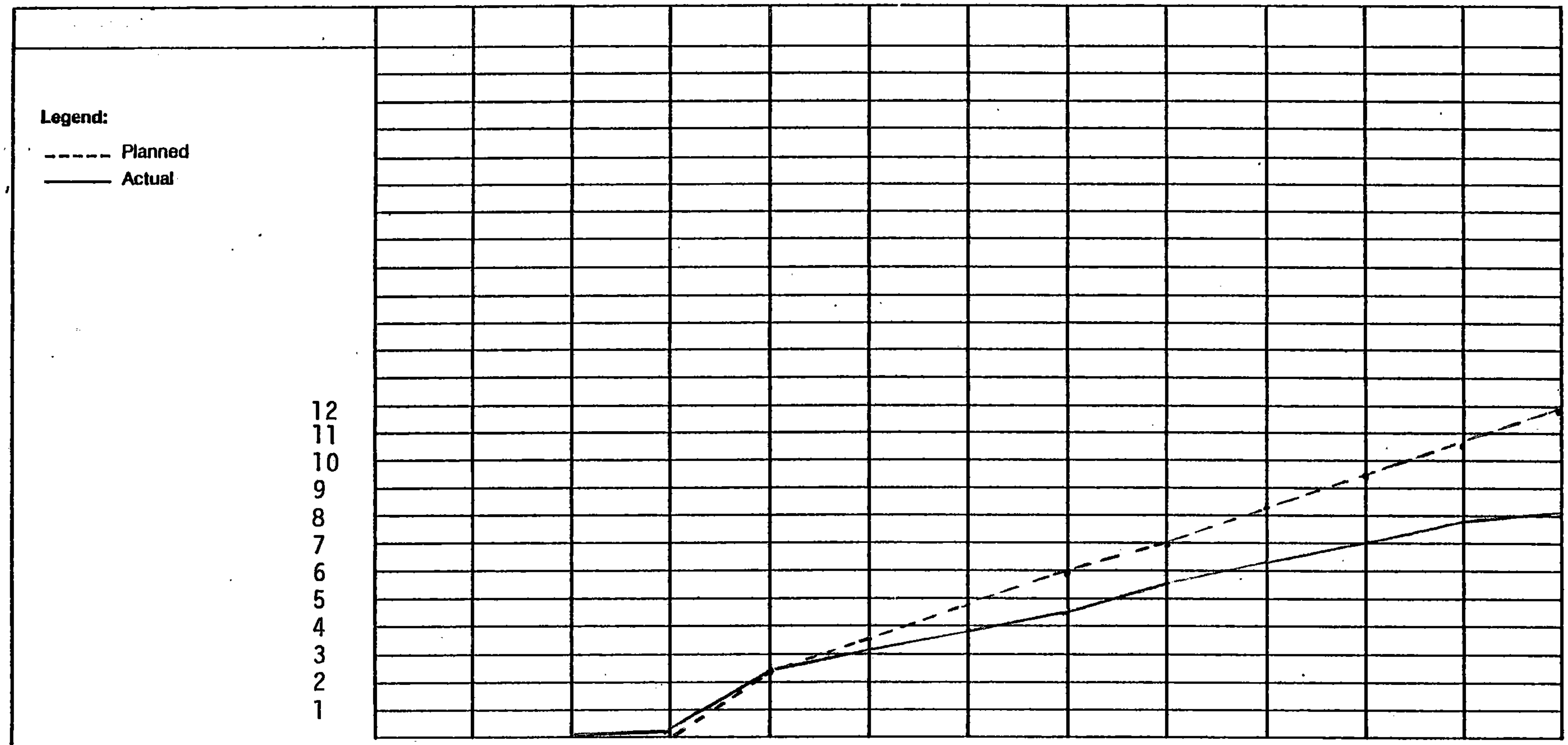
1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 5.0 Instrumentation and Measurement



5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	0	0	0	2.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	Planned
Actual	0	0	0.2	2.2	0.7	0.7	.68	1.01	.79	.76	.80	.27	Actual

Manpower

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 6.0 University Research

Legend:
------ Planned
—— Actual

5
4
3
2
1

5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	0	0	0	0	0	0	0	0	0	0	0	0	Planned
Actual	0	0	0	0	0	0	0	0	0	0	0	0	Actual

Manpower

1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period

From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 7.0 Innovative Concepts

Legend:

----- Planned
—— Actual

5
4
3
2
1

5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	0	0	0	0	0	0	0	0	0	0	0	0	Planned
Actual	0	0	0	0	0	0	0	0	0	0	0	0	Actual

Manpower

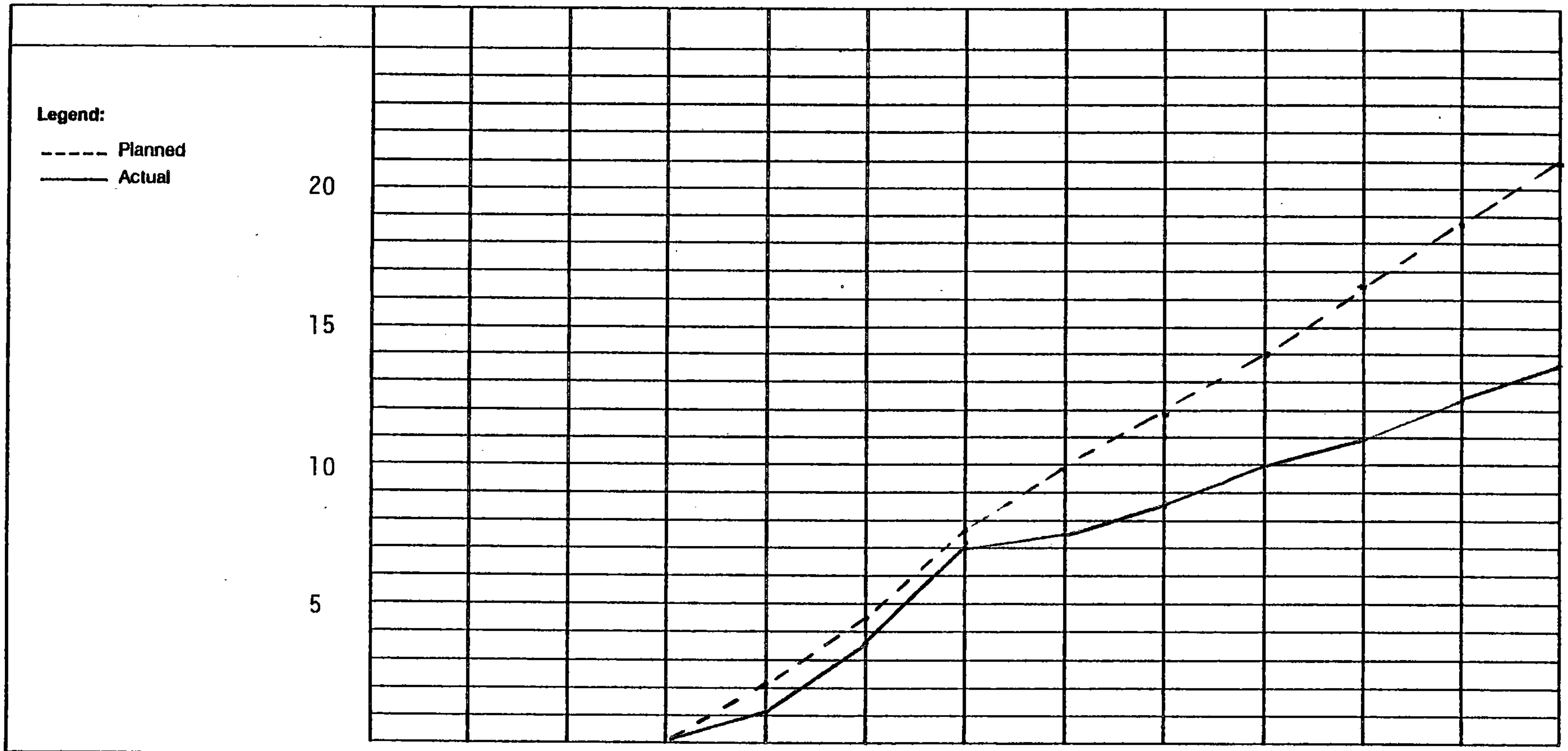
1. Contractor (name and address)

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

2. Reporting Period
From: 10/1/83
To 09/31/84

3. Program Identification FY84 STT Research Program

4. WPA/Task Program Element 8.0 Planning and Assessment



5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	0	0	0	2.2	2.3	3.2	2.2	2.2	2.2	2.2	2.2	2.3	Planned
Actual	0	0	0	1.1	2.6	3.5	.24	.99	1.62	.85	1.53	1.11	Actual

SERI

SOLAR THERMAL ENERGY PROGRAM PUBLICATIONS

Bhaduri, S., Murphy, L. M. (Draft, July, 1984) Wind Loading on Solar Collectors. SERI/TR-253-2169. Golden, CO: Solar Energy Research Institute.

Bhaduri, S.; Murphy, L. M. (Completed) "Wind Loading on Solar Collectors." Accepted for presentation and publication in the proceedings of ASME Winter Annual Meeting. New Orleans, LA.

Bohn, M. S. (Completed) Air/Molten Salt Direct-Contact Heat-Transfer Experiment and Economic Analysis. SERI/TR-252-2015. 63 pp. Available NTIS: order no DE84000080.

Buhl, M. L.; Bird, R. E.; Bilchek, R. V.; Connolly, J. S.; Bolton, J. R. (Completed) "Thermodynamic Limits on Conversion of Solar Energy to Work or Stored Energy-Effects of Temperature, Intensity and Atmospheric Conditions." Solar Energy (32:1), pp. 75-84.

Chen, C. F.; Johnson, D. H. (Completed) "Double-Diffusive Convection: A Report on an Engineering Foundation Conference." Journal of Fluid Mechanics (138), pp. 405-416.

Copeland, R. J. (Completed) Benefits from Energy Storage Technologies. SERI/TR-252-2107. 6 pp. Presented at the Energy Sources Technology Conference and Exhibition, New Orleans, LA, February 12-16, 1984. Available NTIS: order no DE84000097.

Copeland, J. J. (Completed) Direct Absorption Receivers. SERI/TP-252-2334. Golden, CO: Solar Energy Research Institute.

Copeland, R. J. (Completed) High Temprature Direct Absorption Research. SERI/TP-252-2105. Available NTIS: order no DE84000019.

DeLaquil, P.; Anderson, J. V. (Completed) The Performance of High-Temperature Central Receiver Systems. SAND84-8233. (Joint Project: Sandia and SERI) Sandia National Laboratories.

Fisher, E. (Completed) Direct Contact Condensers for Solar Pond Power Production. SERI/TR-252-2164. Golden, CO: Solar Energy Research Institute.

Gee, R. (In progress) A Simple Energy Calculation Model for Solar Industrial Process Heat Steam Systems. SERI/TR-253-1871. Golden, CO: Solar Energy Research Institute.

Gee, R. C. (Completed) Low-Temperature IPH Parabolic Troughs: Design Variations and Cost-Reduction Potential. SERI/TR-253-1662. Available NTIS: order no DE84000024.

Gordon, R. (In progress) Observations of Double Diffusive Convection in the Presence of Non-Constant Salinity Gradiants. SERI. Golden, CO: Solar Energy Research Institute.

Hunt, B. (In progress) Solar Thermal Technology: Annual Evaluation Report Fiscal Year 1983. SERI/TR-253-2188. Golden, CO: Solar Energy Research Institute.

Kreith, F.; Davenport, R. L.; Fuestel, J. (Completed) "Status Review and Prospects for Solar Industrial Process Heat (SIPH)." Journal of Solar Energy Engineering (105:4), pp. 385-400.

Kreith, F.; Meyer, R. T. (Completed) "Large-Scale Use of Solar Energy with Central Receivers." American Scientist (71:6), pp. 598-605.

Lazaridis, A.; Copeland, R. J.; Althof, J. (Completed) "A Solar Irradiated Liquid Film Flowing over a Solid Wall." Solar Engineering - 1984: Proceedings of the ASME Solar Energy Division Sixth Annual Conference: Las Vegas, NV; April 8-12, 1984.

Lazaridis, A.; Copeland, R.; 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, CO: Solar Energy Research Institute.

Leboeuf, C. M.; Johnson, D. H. (Completed) Effect of Soil Conditions on Solar Pond Performance. SERI/TP-253-2157. 6 pp. Prepared for Presentation at the American Society of Mechanical Engineers Solar Energy Division Sixth Annual Technical Conference, Las Vegas, NV, April 8-12, 1984. Available NTIS: order no DE84000096.

Leboeuf, C. M.; Johnson, D. H. (Completed) "Effect of Soil Conditions on Solar Pond Performance." Solar Engineering - 1984: Proceedings of the ASME Solar Energy Division Sixth Annual Conference; Las Vegas, NV, April 8-12, 1984, Goswami, D. Y., ed., New York: The American Society of Mechanical Engineers; pp. 12-17.

Lewandowski, A. (Completed) Comparison of Predicted and Reported Performance for DOE Sponsored IPH Field Test Experiments. SERI/TP-253. Presented at the IEA Workshop on Large Solar Thermal Arrays, June 12-15, 1984, San Diego, CA.

Lewandowski, A., et al. (Completed) Direct Absorption Receiver System Study—Phase I. Briefing Package. SERI/SP-253-2438. Golden, CO: Solar Energy Research Institute.

Lewandowski, A.; Gee, R; May, K. (Completed) Industrial Process Heat Data Analysis and Evaluation: Final Report. SERI/TR-253-2161. Golden, CO: Solar Energy Research Institute.

Lewandowski, A. (Completed) Modeling of the DOE-Sponsored IPH Field Test Experiments. SERI/TP-253-2324. Presented at the 1984 Annual Meeting of the American Solar Energy Society, June 5-9, 1984, Anaheim, CA., Available NTIS: order no DE84004501.

Masterson, K.; McFadden, J. (In progress) Directory of Optical Measurement Requirements, Nonemclature, and Facilities for Solar Optical Materials Characterization. SERI/TR-255-988. Golden, CO: Solar Energy Research Institute.

Masterson, K. D.; Gaul, H. W. (Completed) Performance Tests of the Solar Steam, Inc., 9-m Deep-Dish Solar Concentrating Collector. SERI/TR-255-1505. Available NTIS: order no DE84000079.

Meyer, R. T.; Hersch, P., editors (In Progress) Silver/Glass Mirrors for Solar Thermal Systems. SERI/SP-281-2293. Golden, CO: Solar Energy Research Institute.

Murphy, L. M. (Completed) Advanced Concentrator Research: Two Examples. SERI/TP-253-2106. Available NTIS: order no DE84000015.

Murphy, L.M.; Sallis, D. (Completed) Analytical Modeling and Structural Response of a Stretched-Membrane Reflective Module. SERI/TR-253-2101. Golden, CO: Solar Energy Research Institute.

Murphy, L. M., et al. (Completed) Polymer Enclosed Thermal Power Dishes, an Initial Feasibility, Engineering and Cost/Performance Assessment. Briefing Package. SERI/SP-253-2197. Golden, CO: Solar Energy Research Institute.

Murphy, L. M.; Sallis, D. V. (In progress) Stability and Initial Imperfection Considerations for Stretched Membrane Reflector Module. Golden, CO: Solar Energy Research Institute.

Murphy, L. M. (Completed) Technical and Cost Potential for Lightweight, Stretched-Membrane Heliostat Technology. SERI/TP-253-2079. Prepared for Presentation at the ASME Sixth Annual Tehcnical Conference, Las Vegas, NV., April 8-12, 1984. Available NTIS: order no DE84004433.

Pitts, J. R.; Bischke, S. D.; Falconer, J. L.; Czanderna, A. W. (Completed) "Oxide Formation on Aluminum in the Presence of keV Electrons and CO^2." Journal of Vacuum Science and Technology A: Vacuum, Surfaces, and Films (2:2, Part II), pp. 1000-1003. Presented at the 30th National Symposium of the American Vacuum Society, Boston, MA., October 31-November 4, 1983.

Pitts, J. R.; Thomas, T. M.; Czanderna, A. W. (Completed) "Surface Analysis of Silver Mirrors Made from Organometallic Solutions." SERI/TP-255-1793. Accepted in Solar Energy Materials, August, 1984.

Putman, W. J.; Evans, D. L.; Wood, B. D. (Completed) "The Effect of Sky Irradiance Distributions on the Optical Performance of Flat Plate and Stationary Concentrating Collectors." Solar Engineering - 1984: Proceedings of the ASME Solar Energy Division Sixth Annual Conference; Las Vegas, NV., April 8-12, 1984.

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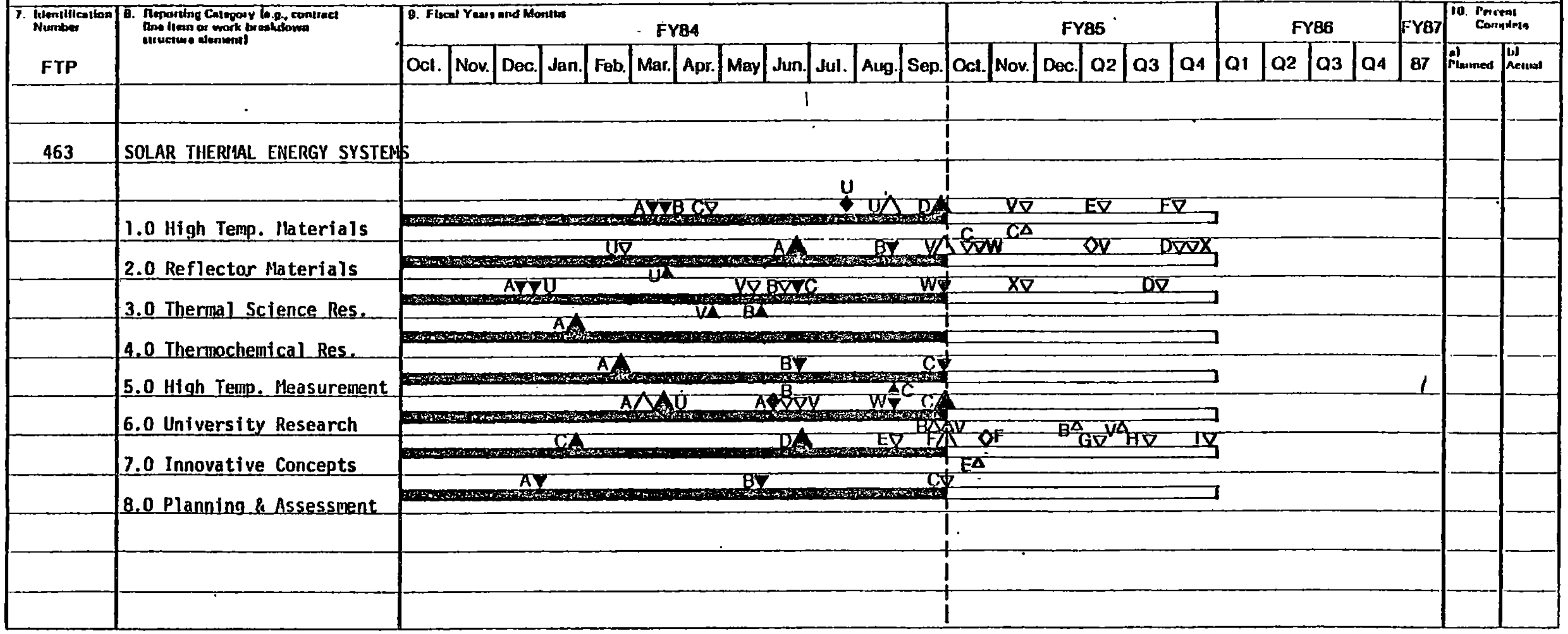
MILESTONE SCHEDULE

1. Contract Identification 5.0 Solar Thermal Energy- Continued		3. Contract Number DE-AC02-83CH10093
4. Contractor (name, address) Midwest Research Institute Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401		5. Contract Start Date 10-01-83 6. Contract Completion Date 09-30-88



MILESTONE SCHEDULE

Task

Program Element 1.0: High Temperature Material

1.A. Complete preparation and check-out of procedures for measuring chemical stability and corrosiveness of thermal fluids at temperature to 900° C. (C)

1.B. Provide a materials data package for the selection of materials to be used in molten salt test-loop apparatus. (C)

1.C. Complete fabrication and check-out of an apparatus for measuring the hemispherical, normal-normal absorptance of ceramics at 700° C. (C)

1.D. Complete weight loss measurement and electron microscopic examination of selected ceramics candidates exposed to carbonate salts at temperatures in the range of 600° C-900° C. (K)

1.E. Complete hemishperical, normal-normal absorptance and transmittance measurements of molten salts with chromophores ("Blackeners") at temperatures up to 700° C. (C)

1.F. Show experimentally the mechanical and chemical stability of a thermal fluid/-containment combination for a period of 30 days at temperatures up to 900° C.

1.U. Complete a preliminary technical performance and economic assessment of a baseline DARTS systems. (K)

1.V. Complete a technical and economic comparison between the stretched membrane and second generation glass/metal heliostat concepts. (C)

Program Element 2.0: Reflector Materials

2.A. Identify sputtered silver polymers showing long life potential. (K)

2.B. Complete the identification of chemical and physical phenomena causing the degradation of silver PMMA. (C)

2.C. Evaluate and improve the surface durability of the 3M Company silver/polymer film at 3M and recommend processes to improve adhesion. (C)

2.D. Complete identification of chemical degradation reactions of silvered polymers, including UV effects to provide basis for specifying composition and process for new products. (C)

2.U. Complete study of lamination processes and complete fabrication of two-meter diameter variable focus stretched membrane module to verify processes chosen. (C)

MILESTONE SCHEDULE (Continued)

Task

Program Element 2.0: Reflector Materials (Continued)

2.V. Complete establishment of membrane/frame coupling concept and complete fabrication of three-meter diameter variable focus stretched membrane module to verify concept selected.(K)

2.W. Complete preliminary surface deformation and tension load characterization of two-meter diameter stretched membrane module at SERI. (C)

2.X. Complete structural response characterization (stability, and surface deformation caused by tension, upper imperfections and simulated lateral loading effects) of the three-meter diameter stretched membrane/frame coupled module at SERI. - (C)

Program Element 3.0: Thermal Science Research

3.A. Complete a preliminary analysis of receiver film temperature profiles based on a mathematical model for both laminar and turbulent flows. (C)

3.B. Complete design review of molten salt test apparatus. (C)

3.C. Complete checkout runs of mathematical model of the molten salt direct absorption process. (C)

3.D. Complete construction and checkout of molten salt test loop. (C)

3.E. Complete tests on heat transfer and flow characteristics of molten salts at ACTF (Second Quarter FY86). (C)

3.F. Complete analysis of experimental data and correlation with mathematical model to establish receiver design criteria (Fourth Quarter FY 86)

3.U Publish proceedings of 1983 conference. (C)

3.V. Complete a thermodynamic assessment of coupled and decoupled systems. (C)

3.W Complete technical and economic assessments of one hybrid system with good potential conversion efficiency. (C)

3.X. Experimentally determine the H_2 yield of two photoconversion systems for water splitting at 10 suns. (C)

MILESTONE SCHEDULE (Continued)

Task

Program Element 4.0: Thermochemical and Photochemical Research

4.A Complete draft program plan for exploring the potential of concentrated solar flux. (K)

Program Element 5.0: High Temperature Measurement

5.A. Complete Preliminary Assessment to identify and rank instrumentation and measurement (I and M) needs to the STT Program. Define two of the highest priority needs and complete recommended action plan to address then. (K)

5.B. Complete study of I and M near-term, intermediate term, and long-term needs of STT Program. Include ranking by priorities and input to the research multiyear program plan. (C)

5.C. Complete initial measurements of one high priority, near-term I and M need at Solar One. (C)

Program Element 6.0: University Research

6.A. Complete the optimization of boron/silicon ratio and laboratory furnace tests for inhibiting window devitrification. (K)

6.B. Define the service limits for silica based structural materials with respect to performance as a function of incident solar flux, temperature, and atmospheric pressure. (C)

6.C. Verify the temperature measurement accuracy of the multispectral (4 wavelength) solar blind pyrometer. (K)

6.U. Complete the photocorrosion studies of Al_2O_3 ceramic. (K)

6.V. Operate the multijet test unit at UH to verify performance meets design specification. (C)

6.W. Operate the solar chemical heat pipe under cyclic conditions to provide data to validate and to improve the mathematical model. (C)

Program Element 7.0: Innovative Concepts Program

7.A. DOE/SAN award of twelve Innovative Research Subcontracts. (C)

7.B. Discussion of selected concepts at Research Workshop. (C)

7.C. Inititate process for "new ideas" solicitation focused on direct solar flux effects. (K)

MILESTONE SCHEDULE (Continued)

Task

Program Element 7.0: Innovative Concepts Program (Continued)

7.D. Complete evaluation of the results of the 12 subcontracts awarded in the FY 1983 Phase I program to identify two or three for additional Phase II support. (K)

7.E. Award of two or three research subcontract recommended in D above. (C)

7.F. Award of "new ideas" subcontract focused on direct concentrated solar flux effects research. (K)

7.G. Initiate process for "new ideas" solicitation repeated in FY85. (C)

7.H. Evaluation and recommendation for future work on few of the research concepts initiated in F above. (C)

7.I. Award of "new ideas" subcontracts as a result of solicitation in G above. (C)

Program Element 8.0: Planning and Assessment

8.A. Complete assessment of technical and economic feasibility of enclosed thermal dishes. (C)

8.B. Complete preliminary assessment of previous SNLL high temperature thermal system studies and other current studies. (C)

8.C. Complete preliminary analysis of high solar flux research needs and value. (C)

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