SERI/MR-251-1471 June/July

Agate

Solar Thermal

Solar Thermal Research Program

Status Report

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Solar Thermal Research Program

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SUMMARY

SIGNIFICANT EVENTS

Research at the University of Denver (under subcontract to SERI) has identified γ-$LiAlO_2$ as one of the major phases in the passivating layer that forms when molten eutectic lithium-sodium-potassium carbonate (LINAK) reacts with sapphire or Coors AD 998 alumina. (Page 3)

Preliminary cost and performance estimates for all subsystem components of a direct absorption receiver system are nearly complete. The methodology for combining these costs into an estimate of delivered energy cost is being developed. A draft of the briefing package is being prepared for internal review. (Page 8)

Recommendations regarding proposals for the three-meter-diameter stretched membrane test module were made and approved. Finalization and signing of the contract are expected shortly. (Page 14)

A small-scale model of a novel, air-inflated heliostat drive has been fabricated and is being evaluated. (Page 15)

SERI's modifications to the GIT design of the direct absorption molten carbonate salt loop were completed. These modifications were necessary to incorporate recommendations from the initial design review. The loop will be employed first in ground tests and later for experiments on direct absorption on the ACTF tower. (Page 17)

The fabrication of the MARK I fast TGA at the University of Hawaii is now almost complete, and the system is under preliminary evaluation. This instrument will be used to measure rapidly the weight change of decomposing solids in order to provide data from which the kinetics and mechanisms can be determined. (Page 21)

A workshop on Instrumentation and Measurement (I&M) Needs of the Solar Thermal Technology (STT) Program was held at SERI on June 21 and 22. Major needs were identified and prioritized. (Page 23)

A glass-coating Milestone scheduled for June was met by demonstrating that devitrification of fused quartz specimens is inhibited by borosilicate glass coatings. (Page 25)

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

Research at the University of Denver (under subcontract to SERI) has identified one of the major phases in the passivating layer that forms when molten eutectic lithium-sodium-potassium carbonate (LINAK) reacts with sapphire or Coors AD 998 alumina. It is γ-$LiAlO_2$ and has been confirmed by generating the x-ray diffraction pattern for a sample of γ-$LiAlO_2$ and by comparing it to patterns obtained from samples of sapphire and Coors AD 998 that had been reacted with the molten salt. Other reflections in the diffraction patterns for both materials have yet to be identified. An x-ray diffraction pattern was done on the passivating layer on Monofrax M; this pattern showed distinct differences from the patterns for the passivating layer on sapphire and Coors AD 998.

Scanning Electron Microscopy (SEM) of the passivating layer on sapphire showed densely packed columnar grains growing up from the surface of sapphire. These grains appear to form a tight coating that may be difficult for the salt to penetrate as the coating thickens; the decreasing rate of weight gain observed for this material at longer times in the earlier corrosion experiments up to 67 days supports this idea. This sample was reacted in eutectic LINAK at 900°C. SEM photographs of Coors AD 995 alumina samples tested in eutectic LINAK showed passivating layer grains that were much larger and more equiaxial than the grains on sapphire. This observation coupled with the larger weight change during corrosion experiments that were observed for the AD 998 compared to sapphire suggests that the layer is less protective on AD 998 than on sapphire. SEM photographs of the passivating layer on Coors AD 998 that had been in corrosion tests for 21 days in eutectic sodium-potassium carbonate showed a layer that had been cracked and partially removed. This occurred because the coupon was washed in water prior to weighing, and without lithium carbonate in the melt, the passivating layer was susceptible to attack by the water. The lithium aluminate is stable in water.

A professor from the University of Louisville has started work under the ASEE program. He is working on determining the liquidus behavior in the quarternary system Li_2CO_3-Na_2CO_3-K_2CO_3-$BaCO_3$. Previous studies have shown that partial replacement of the lithium component of the alkali metal carbonate ternary system by small (1 percent to 3 percent) amounts of alkaline earth carbonates, especially $BaCO_3$, has little effect on the melting characteristics of the mixture. It is the purpose of the present study to investigate the effect on the molten salt mixture of larger replacement of the lithium component.

The theory of phase diagrams shows that helpful insight into the behavior of complex mixtures can be obtained by diagrams of simpler mixtures of the components. The eutectic seen with large amounts of Li_2CO_3 added is lost at low Li_2CO_3 concentrations. The point at which the eutectic disappears is of interest, since the low melting temperature then increases rapidly upon further reduction of the lithium fraction. Studies of K_2CO_3-$BaCO_3$ and Na_2CO_3-$BaCO_3$ binary system may also be conducted to approach the ternary system, K-Na-Ba carbonate. A literature search has been conducted and has shown that such information is not readily available in the existing literature. As a preliminary step to better understanding of DTA data taken above the eutectic melting temperature, a theoretical expression for the heat of melting of the continuous transition near the liquidus of a simple binary system has been derived.

Coupons of Coors AD 998 and Monofrax M that had been tested up to 67 days in LINAK at 900°C with 20 percent CO_2 are being continued for longer times in LINAK at 900°C with 19 percent O_2 and 10 percent CO_2. The purpose is to determine if the passivating layer flakes off during successive testing of the same coupons.

Coupons of sapphire were exposed to LINAK for times of 1.5 minutes, 15 minutes, and 2.5 hours to evaluate the initial formation of the passivating lithium aluminate film at 900°C. Coupons of Monofrax M were gold-coated for SEM analysis of the passivating layer formed at 900°C in LINAK. A coupon of Coors AD 998 that had been exposed to sodium hydroxide at 900°C is being prepared for metallography and has been gold-plated for SEM examination. The coupon experienced severe attack and will be examined for signs of intergranular corrosion. The data from previous studies were used to convert the corrosion rate values into terms of weight change per unit surface area.

A series of samples of ternary mixtures of the alkali carbonates were studied in melting runs conducted on the Perkin-Elmer DTA/DSC equipment. The data were taken in the

DSC mode. It aids in interpretation of observed ternary features to identify features of the bounding binary mixture and watch these alter as the amount of the third component is increased. One series was run with the mole ratio of Na_2CO_3 to K_2CO at 30 percent, with Li_2CO_3 varying from 0 to 30 mole percent. In order to correlate with earlier work on the ternary and the quarternary with $BaCO_3$ added, a second series was run with the mole ratio of Na_2CO_3 to K_2CO_3 at 44 percent, Li_2CO_3 varying from 0 to 20 mole percent. The data were in good agreement with standard data, and better identification of features aided in interpretation of the complicated paths of the melts through the ternary diagram.

The binary mixture of K_2CO_3 and $BaCO_3$ was studied at various concentrations ranging from pure K_2CO_3 to a 50:50 molar mixture. At low $BaCO_3$ concentrations, ($X_{BaCO_3} < 25\%$), the data suggest that a solid solution is formed, and that at very low $BaCO_3$ concentrations ($X_{BaCO_3} < 10\%$), the melting temperature may be above that of pure K_2CO_3. A eutectic melting accompanied by a slower continuous melt was observed at higher concentrations (X_{BaCO_3} from 25% to 50%). The data are consistent with a eutectic temperature of 779°C at a X_{BaCO_3} of about 45 percent, with a latent heat of fusion of 25 cal/gm.

The binary mixture of Na_2CO_3 and $BaCO_3$ was studied at various concentrations ranging from pure $NaCO_3$ to $BaCO_3$ slightly above 50 percent. The data are consistent with a normal eutectic of 701°C at a X_{BaCO_3} of about 40 percent, with a latent heat of fusion of 46 cal/gm. There appears to be possible incongruent melting for X_{BaCO_3} above 50 percent.

In mechanical measurement the objective of the project has been to determine a true plane strain fracture toughness value, K_{IC}, for 99.5 percent alumina. Compliance measurements are needed in conjunction with the K_{IC} determination. Tests are to be conducted with a four-point bending arrangement. This arrangement offers a greater amount of volume (under a high stress) than with three-point bend testing. The main problem with four-point testing is the potential error due to the load points not making contact with the sample at the same time. This error is minimized through the use of roller pins. Also, the stresses due to friction at the load and support points are minimized through the use of freely pivoting roller pins secured with rubber bands.

With four-point bent testing the samples should be square, and the sample sides that are normal to the load line should be parallel to less than 0.003 inch. This can be accomplished by carefully cutting samples from slices that are well aligned to the diamond saw or by surface grinding. The "Lapmaster" has been examined to see if it can achieve parallelism. The weight on the sample must be kept level; unfortunately, shims placed around the weight could not hold it level while lapping took place. Alternative procedures are being planned.

A Chevron notch will be cut into each sample with the newly acquired diamond wire saw. The wire saw has been chosen because small thicknesses of the Chevron notch are possible. Thickness of the Chevron notch is one of the variables in fracture toughness testing. The wire saw has been partially assembled and will be operating soon.

The sample displacement is measured with the extensometer attached to two aluminum cylinders, one cylinder of which is attached to a small rod in contact with the top of the sample, and the other cylinder is attached to a tube in which the small rod moves. The tube can be "floating," or it can be pressing against the surface of the top of the test jig. To determine displacement of any parts of the test jig, a six-inch high alumina block has been used as a sample. It is a safe assumption that the displacement of the alumina block is negligible up to 20 kilograms load. With the outer tube floating, the displacement versus load measurements were found to be inconsistent. With the outer tube pressed against the top block, the measurements were reasonably consistent. The spring force on the small rod was adjusted for the greatest consistency.

The slope of the load displacement curve has been determined with a Nicolet oscilloscope and computer. Both the electronic and mechanical arrangements will be confirmed by making modulus measurements on Plexiglas, alumina, and possibly glass.

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

Gas Phase Measurements

A new design for a sealed crucible was completed, and the parts were ordered. The final design has an 0-ring sealed stainless steel cover for the crucible having four Teflon sealed ports in the top: (1) gas inlet port; (2) gas outlet port; (3) gas sampling port; and (4) a thermocouple port. The seals were ordered having the ports pre-drilled and tapped so that installation will entail little effort. A second furnace was used to determine the effectiveness of the new 0-ring seals when used with the present design for the furnace top. The addition of the 0-rings and a wire compression set-up does seal the crucibles. However, other aspects of the present design require the more complete redesign discussed above.

Since the new set of corrosion experiments was started, the quadrupole gas analysis system has been in continuous operation and has been sampling the gases above the crucibles once every hour. The gas probe has been moved to all six crucibles sequentially, the air background has been measured, and steps were made to minimize the air background. Calculations were performed for the approximate percentage of air background in each crucible. These calculations were documented and distributed along with a description of the procedure used to obtain the results.

Work continues on understanding the differences between the chemistry of alloys and ceramics in molten carbonate melts. The dominating factors seem to be red/ox and acid/base equilibria, and the volatility of some of the corrosion products such as $Na_2(g)$ and H_2O at 900°C. From preliminary studies, the corrosive acid/base factors in carbonate melts are controlled by O_2 and CO_2 levels in the purge gas. But redox and volatility factors as well as differential solubility and dendritic precipitation of insoluble samples are not as easily controlled.

Optical Measurements:

The interim-high-temperature cell has been in operation for several weeks, and some data are available. Researchers are having some experimental difficulties that do not relate directly to the optical measurements. The difficulties relate simply to proper containment of the molten salt, and improved experimental arrangements are being implemented that will benefit future installation as well as these immediate results.

The experiment uses sapphire windows spaced at known but variable distances. The intervening space is filled with molten salt (eutectic Na,K,Li carbonate), and the optical transmittance is measured into a forward cone of about 6 degrees. By measuring the transmittance over two optical path lengths and by knowing, or by independently measuring, the optical constants of sapphire, researchers can determine the optical calculations to the five-layered system—air, sapphire, salt, sapphire, air.

Staff researchers have data for one salt thickness. It is possible to look through the cell while it is at a temperature of 475°C (the molten salt visually appears water-clear), to insert the heated unit into the spectrophotometer, and to measure the transmittance between 350 nm and 850 nm (the PbS detector of the spectrophotometer saturates in the near infrared spectral range of 850 nm to 2600 nm). Several pertinent observations result. If the salt is held at temperature (~475°C) for about two hours, it is visually clear. However, during the two-hour interim, there is a distinct decrease in initial cloudiness. Several possible explanations are being considered, and it seems unlikely that it is a simple temperature-lag. For the one thickness of salt, researchers can quantify this transmittance as a function of time. After 10 minutes at 475°C, the solar-weighted transmittance (between .35μ and .85μ, corresponding to 60 percent of the solar spectrum) for a 0.65in.optical path length was approximately 60 percent. At this point the molten salt visually appeared somewhat cloudy. Thirty-five minutes later the transmittance had increased to approximately 75 percent. The transmittance does stabilize at the high value, and it is apparent for experimental conditions that a predominant fraction of the radiation is not reflected. Additional measurements are in progress to quantify the properties of the salt by obtaining data for a second salt thickness.

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

Preliminary cost and performance estimates for all subsystem components of a direct absorption receiver system are nearly complete. The methodology for combining these costs into an estimate of delivered energy cost is being developed. A draft of the briefing package is being prepared for internal review.

A comprehensive internal briefing package on the status of convection modeling has been completed for internal review. This briefing package summarizes both theoretical and experimental research, and it also presents some initial comparisons on system impact as a function of operating temperature to establish the importance of this technical issue in the context of high-temperature solar thermal systems.

Researchers have completed the short interpolation code to analyze the effects of different wind data averaging periods on the stretched membrane heliostat. Minor difficulties in generating focal lengths for an optimized small field exposed to a range of wind speed and directions were experienced but have now been resolved. Receiver radiation losses will be modeled by using an effective emissivity determined empirically from data in The Performance of High-Temperature Central Receiver Systems by De Laquil and Anderson.

For the stretched membrane-glass/metal heliostat comparison study, researchers calculated matrices of focal length in comparison to wind speed and direction for optimized small sectors at the outer edge (worst case) and in the middle (typical case) of the north field of a single membrane heliostat field. Based on these focal lengths, they used DELSOL2 to calculate the design point (noon, March 21) and annual average optical efficiency for each combination of wind speed and direction. The effect of wind was small (see table below), beneficial, and appeared quite linear for winds with a normal component below about 30 miles per hour (middle of field) or 24 miles per hour (edge of field).

Table 1. Range of Wind Effects on Optical Efficiency for Focal Lengths Greater Than Twice the Slant Range

	Design Point	Annual Average
Middle of field (0-30 mph)	0-1 %	0-1 %
Edge of Field (0-24 mph)	0-5 %	0-5 %

For winds with large normal components, the focal length of the heliostat was reduced to less than one-half the slant range, which results in dramatically increased spillage, since the image size exceeds the heliostat size.

Averaging 7200 typical wind speed and direction, data points yielded a 0.4 percent over-estimate of energy collected by a sector in the middle of the north field as compared to summing the energy collected at each of the 7200 data points. Other parts of the field would be affected by approximately +.3 percent, -0.5 percent, and -0.3 percent for an overall field average of approximately 1 percent. This finding is very significant because it means that researchers do not have to modify DELSOL2 to incorporate wind effects; they can use an annual average wind speed and direction to set the heliostat focal lengths for an annual simulation. This is a consequence of the fact that 98 percent of the insolation (at Daggett) occurs when the wind speed is less than 30 miles per hour.

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 through subcontracts with industry and universities.

Progress

On July 30, 31, and August 1, Dr. Howard S. Coleman, Division Director of the DOE 's Division of Solar Thermal Technology, visited SERI. While at SERI, Dr. Coleman received formal and informal briefings on:

- The FY84 STT Research Program;
- The recommended FY85 Program;
- Program accomplishments;
- The future thrust of the Program.

SERI continued to provide support for the Solar Thermal Technology Five-Year Plan and for the SERI Research Program Plan.

For the follow-on phase of the first cycle of the Innovative Concepts Research Program, the proposals were evaluated technically, and a presentation was made to the Source Selection Board. The competitive range was determined, and clarifying questions were asked of those in the competitive range. The Source Selection Official will make recommendations in early August with contract placement by the end of September.

Technical evaluation of the numerous proposals for the second cycle "New Ideas for Solar Thermal Conversion" was accomplished. The Source Selection Board will meet on August 9 and 10 with the goal of having the contracts in place by the end of September.

During July SERI, as requested by DOE/HQ, submitted the first drafts of the WPP and FTPs for the FY85 STT Research Program. Using DOE's critique of the first drafts and revised budgetary guidance, SERI initiated preparation of revised WPPs and FTPs.

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

Twenty-six weeks of real-time outdoor testing of silvered polymers made in fiscal year 1983 have been completed. The silvered polymers consist of polymer/sputter-deposited silver/backing material/adhesive/316 stainless steel, where the polymers are Acrylar, Flexigard, and Barex. While hemispherical reflectance data are not yet available, specularity measurements (15 mrad) and visual observations are as follows: Barex samples are all milky in appearance and have specularities of about 10 percent. Flexigard samples have not yet exhibited marked changes in specularity from the initial values of 54 percent to 74 percent, except where delamination or severe blistering occurred. The latter most likely results from the adhesive backing used. The Acrylar samples revealed marked increases in specularity after exposure from initial values of 53 percent to 63 percent to a range from 69 percent to 83 percent, again after excepting three samples that delaminated or blistered severely. Since the low initial specularity values are related to the polymer film itself, the specularity increases in Acrylar possibly result from aging processes in the polymer that either smooth the interface or decrease the scattering centers in the commercially processed polymer. After the reflectance data are obtained, a ranking of the 15 combinations will be made. Based on visual observations and the specularity data, no dramatic differences in ranking are expected between the degradation observed in the Weather-Ometer and that obtained in outdoor testing.

Long-term testing of silvered polymers was continued under QUV accelerated exposures and real-time outdoor conditions. During the period, a devices and services instrument became available for measuring specularity at 7 mrad rather than 15 mrad. This more stringent measurement has revealed additional metallization work will be necessary to meet the long-term goals for reflectance, specularity, and durability. The specularity (7 mrad) of vacuum-deposited silver on both glass and polymeric substrates is markedly decreased when Inconel backings are used and on polymers without Inconel backings. It is also seen that some specularity loss is measurable for a silver/glass mirror made by the wet electroless chemical process and for FEK-244 (an aluminum/polymer reflector). A possible explanation is to attribute some specularity losses from Inconel-imposed stresses on the silver/glass or polymer interface that result in irregularities and an enhanced diffuse component.

After 8 weeks of QUV accelerated testing, three samples of evaporated silver on Flexigard exhibited hemispherical reflectances of 90.5 percent, 90.7 percent, and 91.1 percent (compared to 90.6 percent, 90.4 percent and 90.6 percent initially) and specularities (15 mrad) of 97.96 percent and 95 percent (compared to 96.95 percent and 90 percent initially).

After four weeks of QUV testing, a 7809 glass/Ag_E/No-Inconel-backed mirror maintained 100 percent specularity (15 mrad) but similar glass/silver mirrors with 35 nm and 75 nm of Inconel had changes from 95 percent and 98 percent to 97 percent and 72 percent, respectively. The large decrease in one specularity resulted from visible corrosion.

After the same QUV exposures, three ECP-300P/Ag_E/Inconel-backed mirrors yielded specularities (15 mrad) of 91 percent, 40 percent (delaminated), and 80 percent compared with initial values of 100 percent, 96 percent, and 99 percent. The hemispherical reflectance also decreased from over 90 percent to 87 percent to 88 percent for the Inconel backed mirrors but was even lower at 85 percent for a mirror without Inconel.

The Milestone, "Identify sputtered silver polymers showing long life potential," was met by letter report.

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

Extraction experiments under different temperature conditions have been performed on stabilized PMMA-silver-mirrors over a time period of 13 days in distilled water. In the first series, mirrors were exposed to a constant volume of water at room temperture in Erlenmeyer vessels. After one week it was observed that the unstablilized PMMA film lifted completely off the mirror surface with the silver staying attached to the glass substrate. All the stabilized PMMA films were still attached to the silver glass with only the edges of the films lifting. Corrosion of the silver started from the edges. After 13 days all stabilized films, except the one with Tinuvin-P, had lifted off the glass substrate with the corroded silver layer attached to the polymer film. The corroded silver dissolved subsequently in the water. Transmission measurements of the polymer films provided some evidence on the permanence of the stablilizer: Tinuvin-P $>$ National Starch $>$ Uvinul 400 $>$ Givsorb.

In the second series, mirrors were exposed to a continuously repeating extraction cycle in a Soxhlet extractor with hot water ($T \sim 80°C$). These samples showed much less corrosion than the ones from series one: all the polymer films stayed attached to the mirrors. Unfortunately, grease used to lubricate the glass joints of the extractor leached onto the samples and plasticized the polymer layer in addition to being deposited on them as a "junk layer." Thus, these samples could not be analyzed, and this experiment must be repeated.

Research indicated that corrosion is more rapid in cold water. One possibility is that the higher solubility of oxygen in cold water is responsible for the increased corrosion of the silver layer in series one. The presence of the stabilizers in the PMMA-layer could have slowed down this corrosion process at the polymer-silver interface, so that the silver stayed attached longer to the polymer interface.

In work subcontracted at the University of Denver observations of photodegradation of PAN films of varying thickness (4.4μ, 650Å) on silver and of the effects of the metallic substrate on photodegradation have been obtained. Observations have been initiated on the effects of benzotriazoles and Tinuvin-P on the photodegradation of PAN/silver films.

Additional data from accelerated testing in a QUV and Weather-Ometer have been accumulated on stabilized PMMA-coated silver mirrors and are being compared to data obtained from mirror samples exposed outdoors. Results obtained from measurements of the variation of the effective ultraviolet-absorber concentration in the polymer glazing with time indicate that the permanence of the stablilizer in the glazing is dependent on the weathering mode. The concentration of the selected ultraviolet absorbers (Tinuvin-P, Uvinul 400, National Starch, Givsorb) in the polymer glazing does not change during 16 weeks testing in the Weather-Ometer if the samples are shielded from the ultraviolet light source. If exposed to ultraviolet light during these tests, researchers observed a complete loss of the Givsorb stabilizer (based on ultraviolet-vis absorption spectra), whereas the other stabilizers show no or negligible loss from the polymer matrix during this time interval. The outdoor test data confirm a similar trend during a thirty-week exposure period. Quite different results are obtained with the QUV-exposure mode which includes a repetitive condensation of water on the mirror samples. Severe stabilizer losses, probably due to a "washing out" effect, are observed here already after eight weeks exposure, with Givsorb and Uvinul 400 showing the strongest decrease in absorber concentration, followed by National Starch. Tinuvin P demonstrates the best performance and reveals a higher permanence than the polymeric National Starch stabilizer. This phenomenon is presently not understood, but may be due to different inhomogeneous stabilizer distributions in the polymer matrix due to solubility differences and the preparation technique of the polymer glazings.

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

Recommendations regarding proposals for the three-meter-diameter stretched membrane test module were made and approved. Contract negotiations were also held with the recommended subcontractor and have been finalized. Finalization and signing of the contract are expected shortly.

SERI staff have initiated running NASTRAN with the current consultant to evaluate a broader range of structural response issues on the studies of the stretched membrane reflector.

Construction of two models of a small-scale polymer membrane heliostat (2 ft. or .6 meter diameter) has been completed. Both use a new laminated structural reflector film from the 3M Company. One has a taped joint in the film to illustrate its effects. These modules are about two feet in diameter and weigh only 3.7 pounds. Initial examinations point out a slight delamination and cracking of the reflector material at points where it was wrapped around the frame for attachment.

The two, single-piece, polymer-stretched-membrane modules (two feet in diameter) are holding up well. Splitting and delamination which appeared after the first few days in the structural polymer does not seem to be occurring any longer. The bonded lap joint in the seamed material provided by the 3M Company, however, appears to be creeping. The bond adhesive provided appears very flexible and viscous and, hence, would not be an adequate long-term solution.

Researchers have completed construction of the third reflector module (a conical model). As expected, the construction of the conical reflector was especially difficult in this small size. With this geometry, only, a slight variation in the exact spacing of the butt-seam caused a marked distortion in the desired shape. Because of the difficulty in making a perfectly spaced butt-seam, the rim tension required to pull out all of the wrinkles was enough to distort the conical shape around the rim (most of the load is picked up by circumferential stress at the outer rim). Staff members are studying this model further to learn as much as possible about this shape and plan to build another one when they have studied some of the problems and their solutions. The staff will be running some NASTRAN assessments of the models in the near future.

The optical testing effort is still awaiting resolution of the Hannaway contract (for digitizing the surface quality data). An order for a twenty-foot T-square, mat-white projection screen for the target has been placed. Black or dark red squares will be painted on the screen for use as the target. Researchers are planning implementation of the optical testing in the laboratory area in the Field Test Laboratory Building.

A small-scale model of a novel, air-inflated heliostat drive has been fabricated. It is controlled by restraining cables. A fan inflates a plastic pillow which lifts the heliostat from the ground. Preliminary trials with the experimental model indicate that the major problem may be the selection of a suitable arrangement for the restraining cable pulleys. The selection of proper attachment and anchor points for the restraining cables reduces to a three-dimensional linkage. A consultant in linkage analysis and design has been contacted to assist in the analysis of the linkage. He agreed to assist in evaluating the potential of the concept. Blowers continue to be a problem also with the model. The small-scale models with which researchers are working require a higher static pressure than the full-sized versions will. A way to obtain higher pressures seems to be to use blowers which are disproportionately large and powerful. It will be difficult to demonstrate low-power consumption when the fan for a two-foot-diameter mirror support is itself fourteen inches in diameter, five inches wide, and is driven by a three-quarter-horse-power motor. Smaller blowers are being sought.

A revised draft report investigating wind-loading effects on solar collectors and possible schemes for load reduction has been completed and was sent to SERI's Word Processing Department. Another draft report investigating the potential benefits of RF field control has also been completed. Both reports have been prepared and are based on work performed in 1983 by ASEE summer professor participants.

A rough draft of the next structural report on a concept for a stretched membrane heliostat has been prepared. More in-depth information on stability, initial imperfections in framing, and simple methods to predict the deformation of the single-membrane-frame combination are included. Researchers have also incorporated results from the analysis of two membrane assemblies for inclusion in the report. The purpose of the report is to document findings to date and to focus on the numerous technical issues with this concept for later use in a design optimization.

Laboratory work on a bench-scale reflective module with a segmented-stretched-membrane was begun for study on the technical issues with this concept. The segmented conical membrane can allow focusing without a procedure for vacuum or lamination.

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

During the design review on May 14 and 15, Georgia Institute of Technology (GIT) provided an estimate for the construction of a 900°C (1652°F) molten salt loop. The loop is needed to conduct experiments on molten salt falling films for the Direct Absorption Receiver and Thermal Storage (DARTS) project. Initially, ground tests were to be conducted on film characteristics (that is, dry spots, film thickness) and then heat transfer experiments at the ACTF at Georgia Institute of Technology. The estimated costs were beyond funding levels allocated for this project. SERI performed an in-house estimate and had another source also estimate the construction costs. These estimates were less than those from GIT. The design from GIT for the molten salt loop was reviewed to identify areas in which costs could be reduced. Although GIT could reduce the cost, the scaled-down version also exceeded the available funding. As a result, a decision was made to conduct a competitive procurement for the construction of a 900°C (1652°F) molten salt loop.

Several alternatives were identified and evaluated. SERI resolved to take the following action.

- o SERI will complete construction of the absorber assembly as scheduled.
- o The Thermal Storage Program at SERI is constructing a 700°C molten carbonate salt loop for a heat exchanger experiment. SERI will employ that apparatus for initial ground tests with the absorber assembly.
- o SERI will conduct a competitive procurement for the construction of the 900°C molten salt loop. That loop will be employed to complete the ground tests and the ACTF experiments.

Modifications to the GIT design of the molten carbonate salt loop were completed. These modifications were necessary to incorporate recommendations from the initial design review. The loop will be employed first in ground tests and later for experiments on direct absorption on the ACTF tower.

SERI is fabricating the absorber assembly which is connected to the 900°C molten salt loop. The absorber required heaters to maintain the appropriate temperature for the flowing molten salt. The design incorporates Watlow cartridge heaters operating at design limits. Tests on the heater installation were conducted.

The 900°C molten salt loop delivery is not expected until 1985. A batch operation, 500°C, low salt flow rate device is now being designed. The function of that loop is: (1) to provide a device to check out the SERI absorber assembly; (2) to calibrate the falling film measurement system; (3) later to experiment with designs of a graphite mixer. The 500°C (932°F) apparatus will be fabricated and ready for operation in the Fall of 1984. Any problems with the absorber will be identified and corrected before delivery of the 900°C loop.

Experiments with water-falling films are being conducted to evaluate phenomenon anticipated in molten salt falling films. An ASEE summer professor is conducting experiments with smooth and rough surfaces. He has observed that at some low-flow rates an initially wet channel will form dry spots. Dry spots on the molten salt absorber would cause damage in the solar receiver. Roughened surfaces (screens placed on the smooth surfaces) can both thicken the film and avoid dry spots. Other devices including large (1 cm) diamonds, circles and squares with thickness near that of the molten salt film (0.1 cm) are also being investigated. The large shapes are not as effective as screens in avoiding dry spots but offer better potential in withstanding the corrosion rates expected with molten salt.

In summary, the request for proposal package for the 900°C has been prepared and will be sent out in August. The absorber assembly design has been completed and fabrication has started. A 500°C batch loop is being designed to allow testing of the absorber in the fall of 1984. The water falling film experiments are developing techniques to avoid dry spots in a molten salt receiver.

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

A consultant reviewed SERI's thermodynamic analysis of combined Quantum/Thermal Conversion. SERI's current results were confirmed, and certain questions about approach were resolved.

The details of fitting a beam splitter to a heliostat were worked out. It was determined that it is not necessary to move the beam splitter relative to the heliostat in order to hold the focal point on the receiver while tracking the sun.

Data on the cost of producing hydrogen by the General Atomic sulpheric acid decomposition thermochemical reaction were collected. This process has been chosen as the thermal part of the tandem quantum/thermal conversion system that researchers are analyzing and also as the baseline pure thermal system to which the tandem system will be compared.

The properties which a plastic impregnated with a photochemical should have in order simultaneously to serve as protection for a heliostat or a flat-plate collector, and as an absorber of the ultraviolet portion of the sun's spectrum through a reaction of the photochemical to produce a useful product were determined.

A search was conducted to identify chemical processes which have a step that can be either photochemically or thermally driven. One possible reaction of interest is the conversion of ergosterol to vitamin D_2, which has a photochemical step that can be activated with radiation in the range of 300 nm to 350 nm.

A detailed concept for producing hydrogen using photoelectrochemical and high-temperature thermally driven water decomposition reactions was developed. The system features a dual receiver central to (a high-temperature thermal receiver and a low-temperature quantum receiver) and a field of heliostats of which 10 percent or more are fitted with beam splitters which direct that portion of the solar spectrum with wave lengths below 350 nm to the quantum receiver on the tower.

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

Research at the University of Hawaii on radiant decomposition of solids has concentrated the design and fabrication of the high-heating-rate Thermogravametric Analysis Instruments (TGA). These instruments will be used to measure rapidly the weight change of decomposing solids in order to provide data from which the kinetics and mechanisms can be determined. The fabrication of the MARK I fast TGA is now almost complete, and the system is under preliminary evaluation. Several new developments regarding the MARK I system are worthy of note. Much time and effort were spent on finding a suitable approach to attach thermocouple wires to the suspension rod which connects to the sample holders. Different schemes were tried—including an approach similar to one used in the conventional TGA system (SETARAM). Finally, an arrangement using suspension leads and teflon O-rings resolved the situation.

Another development is concerned with on-line measurement of SO_2/SO_3 gases evolving during the experiments. Discussions were held with a member of the Chemistry Department at the University of Houston; the best approach for analysis of SO_2/SO_3 gas mixtures at very low concentrations seems to be the use of a three-inch long, three-eighth-inch-diameter trap packed with glass beads as support material over which a layer of calcium oxalate is deposited. Using this column at temperatures of about 325°C results in a reaction which consumes sulfur trioxide component of the mixture through reaction involving calcium. The carbon dioxide liberated from this reaction can be continuously monitored by use of an IR absorption spectrometer at 280mm. For this particular case, a collection system and subsequent analysis by a GC system will be used due to unavailability of in-house IR and UV absorption spectrometers.

The design of the MARK II fast TGA system continues, and most of the system components have already been ordered. The MARK II system incorporates a state-of-the-art concept for measuring sample temperature during decomposition. This design uses a micron-thin-film of platinum and rhodium for ulta-high response.

A Beckman model 2400 spectrophotometer was obtained and modified; it is ready to be used to characterize the arc image furnace. An experimental plan has been devised in order to measure fractional spectral distribution of the radiant flux from the xenon bulb. These experiments will soon be conducted on arrival of several pieces of missing information from the Beckman Company regarding calibration of this particular model of spectrophotometer. Extensive modifications of the Friedman kinetics data analysis package have been completed, and the code seems to be free of problems. The code requires weight-loss data for at least three heating rates which will be completed by using the Setaram instrument during the month of August. Once completed, the data will be entered into the code, and the analysis will commence.

Research continued to make progress at the Lawrence Berkeley Laboratory on characterizing heat transfer and optical phenomena for reacting solids. A survey of the literature was made to identify chemical reactions that may be paricularly well-suited to a small particle, direct flux, radiant reactor such as the Solar Thermally Activated Radiant Reactor (STARR). Special attention was given to finding particle materials that would act as solar absorbers and/or catalysts for the reactions. The reactions identified as having potential for STARR were grouped into five categories for convenience: (1) hydrogen production by water splitting; (2) synthetic fuel production by methods other than water splitting; (3) thermal storage; (4) chemical processes not involving fuel production; (5) the detoxification of hazardous waste. Thermochemical data for the compounds involved in the reactions were obtained and were tabulated with calculated enthalpy and entropy change for each reaction. Optical data were located for several of the potential absorber materials, and an effort to locate data for additional materials is continuing. The band gap energy of all the potential semiconductor catalytic materials has been found in the literature.

A new and more efficient computer program for performing Mie calculations was obtained and adapted for use in the LBL system. This program was modified to handle wavelength-dependent dielectric functions and particle-size distribution.

In order to study the effect of particle size, flux density, and gas conditions on the equilibrium temperatures reached by directly heated particles, a new approach was formulated to calculate heat transfer rates from particles to gas. The object was to develop expressions for the heat transfer for intermediate Knudsen numbers (ratio of molecular mean free path to particle diameter) because no such treatment could be located in the literature. An expression was developed to utilize the concept of a surface at intermediate temperature between the particle and the bulk of the surrounding gas. The expression predicts the correct result for small particles (molecular mass transfer heat flow) and for large particles (classical heat flow) and smoothly connects the two regimes.

Work was completed on a mechanical shaker and cyclone chamber for entraining small particles in a gas stream. Screens with differing mesh zones were inserted in the chamber in order to control the particle-size distribution in the gas stream. Two types of iron oxide, magnetite and hematite, were successfully entrained, and optical extinction measurements were made for both oxides as a function of screen mesh size. Particles of hematite and magnetite were collected from the gas-particle suspension of filters, and scanning electron micrographs were made of these samples. The size distribution of the particles was determined from micrographs for each screen mesh size.

Spatial measurements of the radiant flux density from the arc lamp were made in the vicinity of the focus of the ellipsoidal reflector. A spatial integration of these measurements was carried out in order to determine the total power available within the reactor zone. Signficiant variations of the peak fluxes from run to run were noted. The cause of the variation was identified as insufficient mounting and translational facilities to hold the reflector. New mounting rings and an x-y translational stage are being designed to improve the reproducibility of the results.

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

A workshop on Instrumentation and Measurement (I&M) Needs of the Solar Thermal Technology (STT) Program was held at SERI on June 21 and 22. Sixteen scientists from five universities and six research laboratories participated in the identification of needs. The five needs which were identified as having the highest overall priority (consensus of all attendees) are:

- o Improvement of the solar radiation network and resources data base;
- o Flux measurements/instrumentation, including a primary standard;
- o Temperature measurements/instrumentation in a high flux environment;
- o Optical property measurements/instrumentation at high temperatures;
- o Ultraviolet spectral measurements/instrumentation for solar and artificial sources.

These items were defined as generic needs and represented varied aspects of solar thermal research and development. The last two items were given equal ratings.

A summary report on the Workshop has been written and distributed to participants and other interested parties. Another major effort has been preparation for the field measurements at Solar One. Equipment preparations have been completed, and the measurements will begin on schedule.

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

The ACTF test program on window materials has demonstrated signficant devitrification of the inner surface of a new fused quartz window specimen, after a few hours of operation at 1200°C to 1300°C in air. This result agrees with behavior expected under these operating conditions, based on previous testing and the technical literature. Tests are now continuing with a 96-percent silica glass window in air, and future work will include equivalent measurements in steam atmospheres.

A glass-coating Milestone scheduled for June was met by demonstrating that devitrification of fused quartz specimens is inhibited by borosilicate glass coatings. This result was obtained in furnace-test atmospheres of air and steam. Additional work remains to place high-quality coatings on flat-window substrates, to control coating properties, and to conduct solar tests; but the coatings appear to accomplish their intended purpose. Thermal modeling of windows and ceramic materials is yielding agreement with ACTF test data under certain conditions. This work is receiving increased emphasis in order to develop fundamental understanding of damage mechanisms.

The ACTF test program on ceramic structural materials has included tests on two types of firebrick, two types of zirconia composites, and two refractory castable compositions.

The test instrumentation and procedure have been altered to emphasize acquisition of data to support modeling.

Four-color pyrometer data were collected over a broader temperature range than previously collected. This was made possible due to the recently calibrated attenuators. The last set of data was collected over the temperature range of 975°C to 1000°C; the current set was from 500° to 1000°C. The results from these data indicate an effective low-temperature range of 600°C. This limitation was imposed primarily by the detector response at 1.4mm. These data reveal that the resultant error in the measured temperature decreases with temperature. A typical error of 10 percent is obtained at 600°C and less than 5 percent at 1000°C. These accuracies were obtained with artificial samples which deviated from grey conditions very strongly. Due to the sensitivity of the instrument to variations in the environmental temperature, the measurement procedure has been modified to perform real-time calibrations.

Investigation of the particle scattering/absorption mechanism continues in order to characterize performance of the direct flux entrainment reactor. Staff completed modification of MIE scattering computer codes to the current reactor configuration and converted these codes for execution on the computer of the Geophysical Sciences Laboratory. This activity was judged worthwhile because program runs will not now incur cost center charges. The code has been checked with absorption in comparison to particle size calculations and will be used to calculate temperature in comparison to residence time.

The existing entrainment reactor hardware has been modified for cold flow tests by adding a blank base plate penetrated by 2, one-quarter-inch tangential nozzles. Initial tests revealed that particle entrainment was restricted to the lower quarter of the reactor. Only the finest particle components (approximately 10μ) were swirled through and carried out the reactor exhaust. Introduction of feeder tubes with increasing diameters revealed increased entrainment and decreased residence time. Attempts are underway to control entrained particle cloud location by combining lengths of varying feeder tube in the cross-sectional area.

In work on the finite element entrainment reactor model development container, difficulty has been experienced in bringing the MITAS—II finite element computer code to an operational status. Particle-steam temperature profiles have been obtained; however, the results are viewed with a low level of confidence. The problem is not viewed as basic to the MITAS code, but in gaining experience in its use. The problem will be overcome by increasing manpower in this area. The current 16 node model assigns 11 nodes to the fluid-particle cloud, one node each to the inner and outer tubes, two nodes to ambient and one node to space.

A computer program was used to generate and to plot the pattern for the spiral concentrator and mounting points. The theoretical concentration ratio is in excess of 2,000, and the mounting points are on radial lines from the center. Initial concepts for the structural mount were considered and include tensioned wires in a "bicycle spoke" configuration and a simple radial bar bracing.

University of Houston

The high-pressure elements of the liquid jet receiver test system are being tack-welded into place prior to final welding. The pump has been provided with vibration-insulation from both the building and the rest of the loop.

The LEED apparatus for researching photodegradation of materials has been received from the vendor and has been set up for system check-out. Coatings of VN and ZrN have been generated by ion-bombardment. Photdesorption studies of nickel have been initiated.

A finite difference solution was undertaken to confirm the unusual results observed from the analytical model for latent heat storage with simultaneous conduction and natural convection in different regions of the phase change material. The agreement between the two sets of results was excellent, and researchers are now confident of the model. Researchers are seeking to extend the analytical model to a time-dependent coolant flow rate. The user code for heat recovery is nearly complete. There only remains conversion into a pure subroutine package, so that it can be called by the solar simulation program to which it will be attached. A dummy main program will be used in place of the solar system program in the program development to check out all aspects of the code.

Heat-pipe, reactor-receiver research has focused on catalyst deactivation. The PDU was operated for three weeks in a steady-state mode; flow-rates and temperature remained constant for several days. Cyclic operation was then initiated to simulate the daily solar cycle. A given feed-gas flow-rate is used over a period of ten days or more. No significant deactivation of the catalyst has been detected to date.

Chemical energy storage research focused on vertical configuration for the exothermic recombination reactors. Two configurations were considered: cocurrent upflow and cocurrent downflow. Flow regimes at the reactor entrance, zone B entrance, and reactor exit were identified by using different flow regime maps. This study indicated the presence of a slug flow pattern in the vertical upflow case; hence, this configuration was not pursued any further. For the downward flow case, liquid film thickness at the reactor exit was calculated by using theory to verify the presence of the annular pattern. Assuming the liquid holdup for this case to be 10 percent less than for the horizontal case, reactor lengths were determined for the three cases. The 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.

In summary, the cyclic operation of the heat pipe reactor-receiver has been initiated. Causes for potential catalyst deactivation are being investigated. Samples have been prepared for photodegradation tests, and the LEED apparatus has been received. Latent heat energy storage research is proceeding at a satisfactory pace. Preliminary results on heat storage model indicate that it is important to consider both storage and recovery in designing the storage unit.

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 the follow-on phase of the first cycle, the proposals were evaluated technically, and a presentation was made to the Source Selection Board. The competitive range was determined, and clarifying questions were asked of those in the competitive range. The Source Selection Official will make recommendations in early August with contract placement by the end of September.

Technical evaluation of the numerous proposals for the second cycle "New Ideas for Solar Thermal Conversion" was accomplished. The Source Selection Board will meet on August 9 and 10 with the goal of having the contracts in place by the end of September.

Research in the first phase of the first cycle is beginning to wind down. A final report was received from HMJ Corporation on "Performance of Solar Thermal Systems with Liquid Metal MHD Conversion." This is the first contract to reach completion. Other contractors (Southwest Research Institute and Babcock and Wilcox) indicate that the contracted research is essentially complete and that draft final reports are either complete or nearing completion.

Other contracts are still active; Acurex Corporation reports that research on holographic concentrators is proceeding accordingly. Hot-cycling environmental tests at temperatures from ambient to 120°F have been initiated for Acurex holograms. Multiplexing experiments are continuing with both point-focus and line-focus reflectors. Emphasis is on sandwiching two holograms to improve the optical efficiency throughout the solar spectrum. Three point-focus reflection holograms with eighteen-inch focal length have been recorded at 488nm. One was swelled slightly into the blue-green spectral region, and the other two were swelled more toward the red region of the spectrum. Efficiency measurements at three wavelengths were performed. The holograms focus to a one-quarter-inch diameter spot. Three line-focus reflection holograms with a twenty-two-inch focal length have been recorded at 488 nm. One was swelled moderately toward the red spectral region, and the other two were swelled more substantially toward the red region of the spectrum. Efficiency measurements at three wavelengths were performed for all three holograms and for the multiplexed combination of two of the holograms.

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

A first draft of the section on research results in the IPH study documentation was completed. Other supporting sections are in various stages of completion. The technical work on this study was completed over two years ago. This current effort is aimed at archiving these results which form an important data base sequence corresponding to moderate temperature Solar Thermal IPH Systems.

Progress to date on the final report for the "Comparative Evaluation of Solar Thermal Systems for Thermal Applications" includes completion of a detailed outline of the paper and about half of one of the major sections.

Two technology inserts were prepared for the MYPP at the request of the TPI based on reviewers' comments made at the semi-annual meeting. Additional modifications on one of the inserts were also provided.

A review of the ceramic materials technology data base continues. State-of-the-art findings on particulate and fiber ceramic composites indicate significnatly improved material choices may be possible from both a performance and cost perspective. These new findings include the following results.

- Enhanced fracture toughness properties are exhibited by both particulate and fiber ceramic composites. Ceramic particulate composites are typified by boron nitride composites in a matrix of Al_2O_3, mullite, or Si_3N_4. Silicon carbide fiber reinforced glass-ceramic matrix composites also show high strength and toughness.
- Partially stabilized zirconia (PSZ) composites (for example, Al_2O_3-ZrO_2) exhibit enhanced flexural strengths and lower rates of slow crack growth compared to conventional ceramic materials.

- Some fiber composites may allow processing that partially compensates for higher material costs. This is because larger and more complex parts can be potentially fabricated as less shrinkage and less support are needed in the molding of these elements into the appropriate shapes. Further, because of the potentially simple fabrication, the processes, and the potentially enhanced performance properties, these materials appear to be more amenable to standard engineering practice and design than conventional ceramics.
- One negative aspect found was that there is a potential of fiber "pull-out" or separation from the matrix, which then will result in reduced structural (expecially flexural) properties. This problem can be caused by severe mechanical or thermally induced differential straining or by poor adhesion of the fiber to the matrix as a result of incomplete wetting during fabrication.

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

The final deliverable was met, and the subcontract was completed.

Purdue University

The final version of the Purdue report, "Solar Pond Gradient Layer Interface Dynamics" was received. This completes the formal requirements for this subcontract. During July two papers based on the work funded by this subcontract were submitted for publication, one to the ASME Journal of Heat Transfer ("Correlation of Mixed Layer Growth in a Double-Diffusive, Salt-Stratified System Heated from Below"), and the other to the Journal of Fluid Mechanics ("Experimental Observations of Convective Layer Dynamics and Entrainment Mechanisms in Salt-Stratified Systems Destabilized from Below by a Small Heat Flux").

A draft final report detailing the bottom heating and combined bottom heating/horizontal flow results was submitted to SERI for review. These results extend existing correlations to parameter ranges applicable to solar ponds and complement SERI work on the combined effect of bottom heat and lateral shear.

University of Utah

The request to postpone the University of Utah's final deliverable and contract termination date from June 30 to September 30 has been approved by the Department of Energy. The test loop is operational and tests have been conducted at a water flowrate of 12kg/s and pentane to water flow ratios between 0.1 and 0.5.

Massachusetts Institute of Technology

Another set of experiments in the wind/wave tunnel were completed. These experiments were performed with an interface present, and mean velocity measurements were taken with a laser anemometer to within 1 cm to 1 1/2 cm of the interface. The mean velocity data will be used to characterize wind-driven entrainment at the interface.

Wind tests with surface protective covers were continued. Photographs of dye-streaks and measurements with a laser anemometer confirmed that nets perform better than pipes and that they ahve an effect up to wind speeds of about 10m/s. Both nets and pipes cause greater mixing directly underneath them, but the turbulence between the net grids is reduced as compared to the uncovered case, while with the pipes the turbulence level is always greater. Results obtained were analyzed and were scaled by the fluctuating velocity at the interface. With this scaling, a fetch effect was identified, but further tests are necessary to quantify the dependence of the entrainment velocity on fetch.

In summary, Milestone status is the following:

- At Purdue, the final milestone (FTP 279, Milestone F, to complete solar pond gradient layer interace dynamics studies) due June 30, 1984, has been completed. An associated deliverable, report entitled "Solar Pond Gradient Layer Interface Dynamics" has been received.
- At MIT, the final Milestone (FTP 279, Milestone I), due August 31, 1984, should be met on time. This will be in the form of a copy of a thesis and an updated version of the users manual for MIT's wind-driven stratified fluid mixing computer program.
- At the University of Utah, the final Milestone (FTP 279, Milestone H), for this subcontract has been approved for August 30, 1984, with the associated deliverable for September 30, 1984. The University of Utah is on schedule for meeting these dates.

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 (Concluded)

	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

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

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(1)	To Be Determined	1.0	Degradation mechanisms in ceramics exposed to thermal fluids at high temperatures	50.0	To Be Determined
(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)	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

PLANNED FY84 PROCUREMENTS: STT RESEARCH PROGRAM
PLANNED SUBCONTRACTS USING FY84 FUNDS (Concluded)

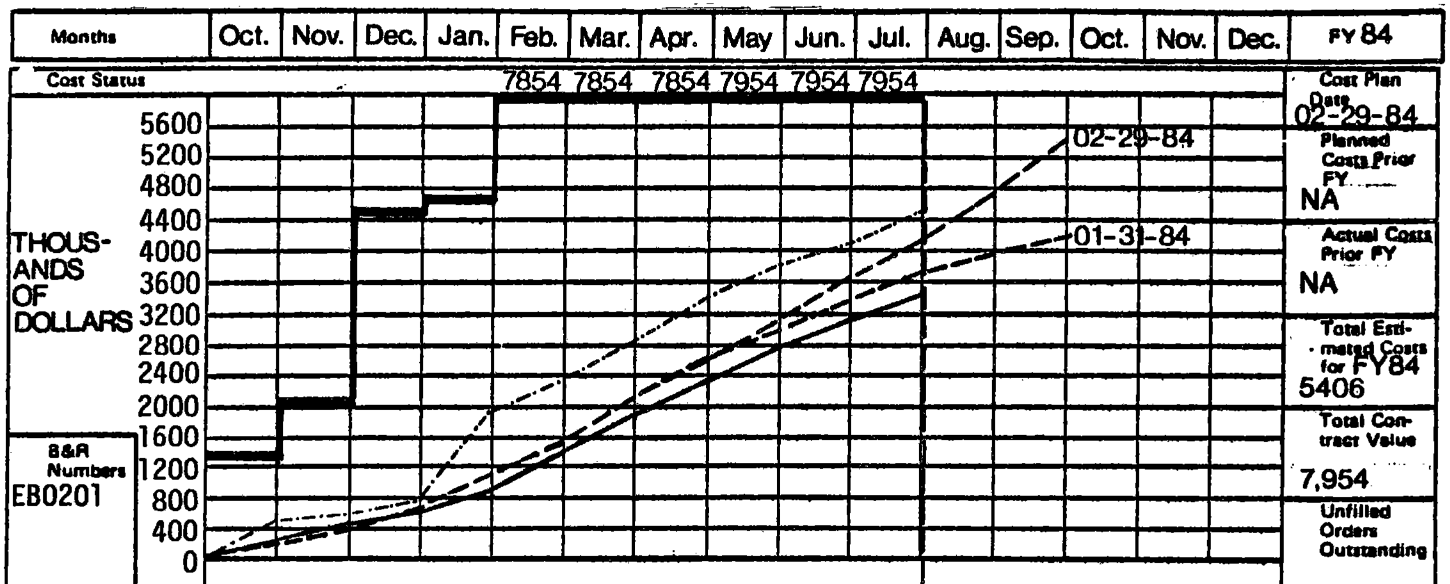
	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(8)	Consulting Agreement with Mr. Conrad M. Vineyard	1.0	Solar thermal technology cost estimation technical support	10.0	Consulting Agreement
(9)	To Be Determined by a Competitive Procurement	1.0	Design and fabrication of an apparatus for measuring the mechanical properties of containment materials used to contain thermal fluids at high temperature	50.0	Industrial Firm to Be Selected by a Competitive Procurement Process
(10)	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
(11)	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

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	



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	
Estimate for Subsequent Reporting Period	

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

Obligational Ceiling — Actual

Costs Plus Commitments — 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	O	N	D	J	F	M	A	M	J	J	A	S

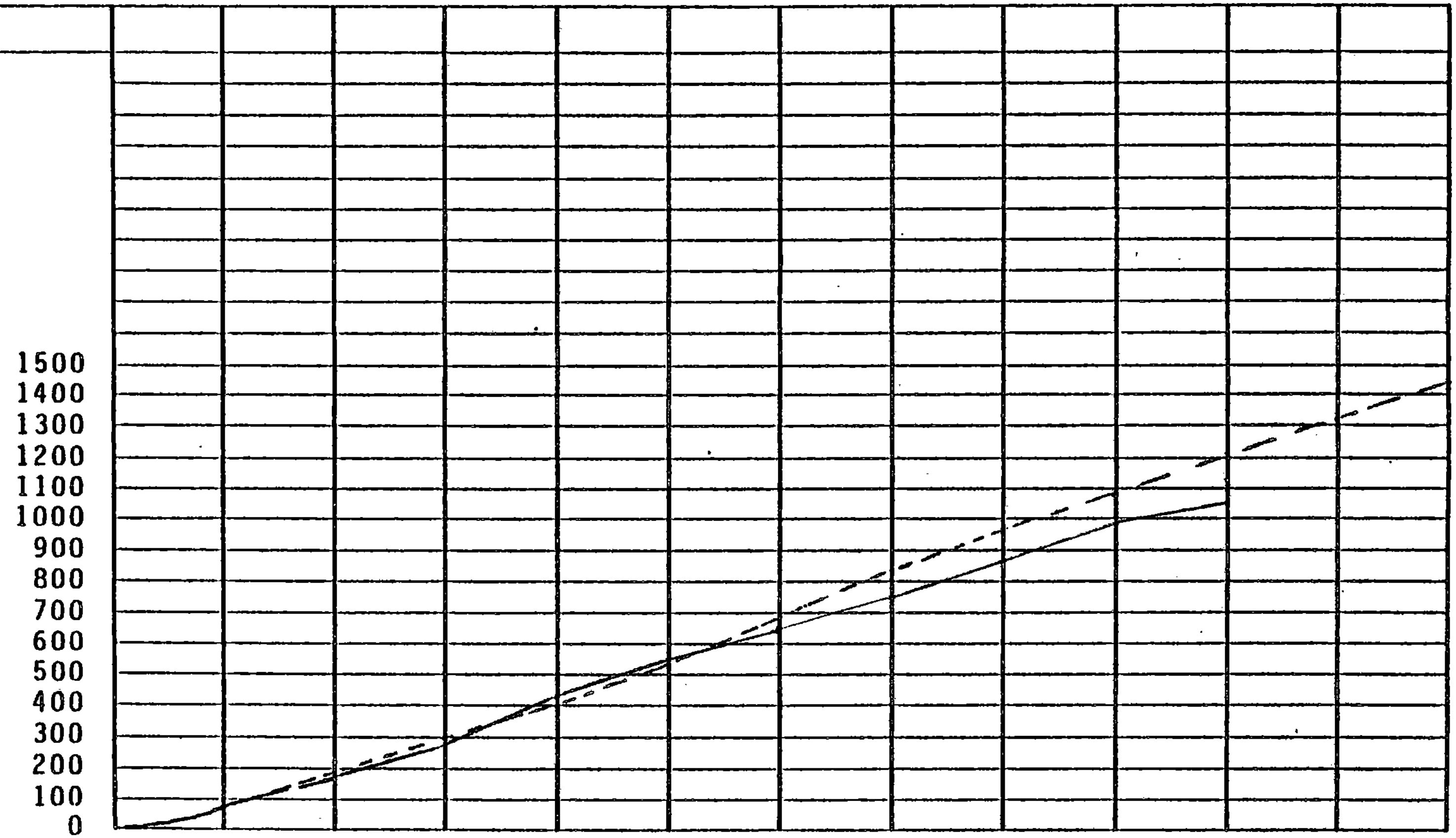
6. Cost Estimate

a. Dollars in Thousands

Legend:

- - - - - Planned

——— Actual



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	Total
	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			c. Actual
	d. Variance	-1.9	14.7	-14.2	-19.7	9.8	52.1	52.2	-22.4	11.1	55.6			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: O N D J F M A M J J A S

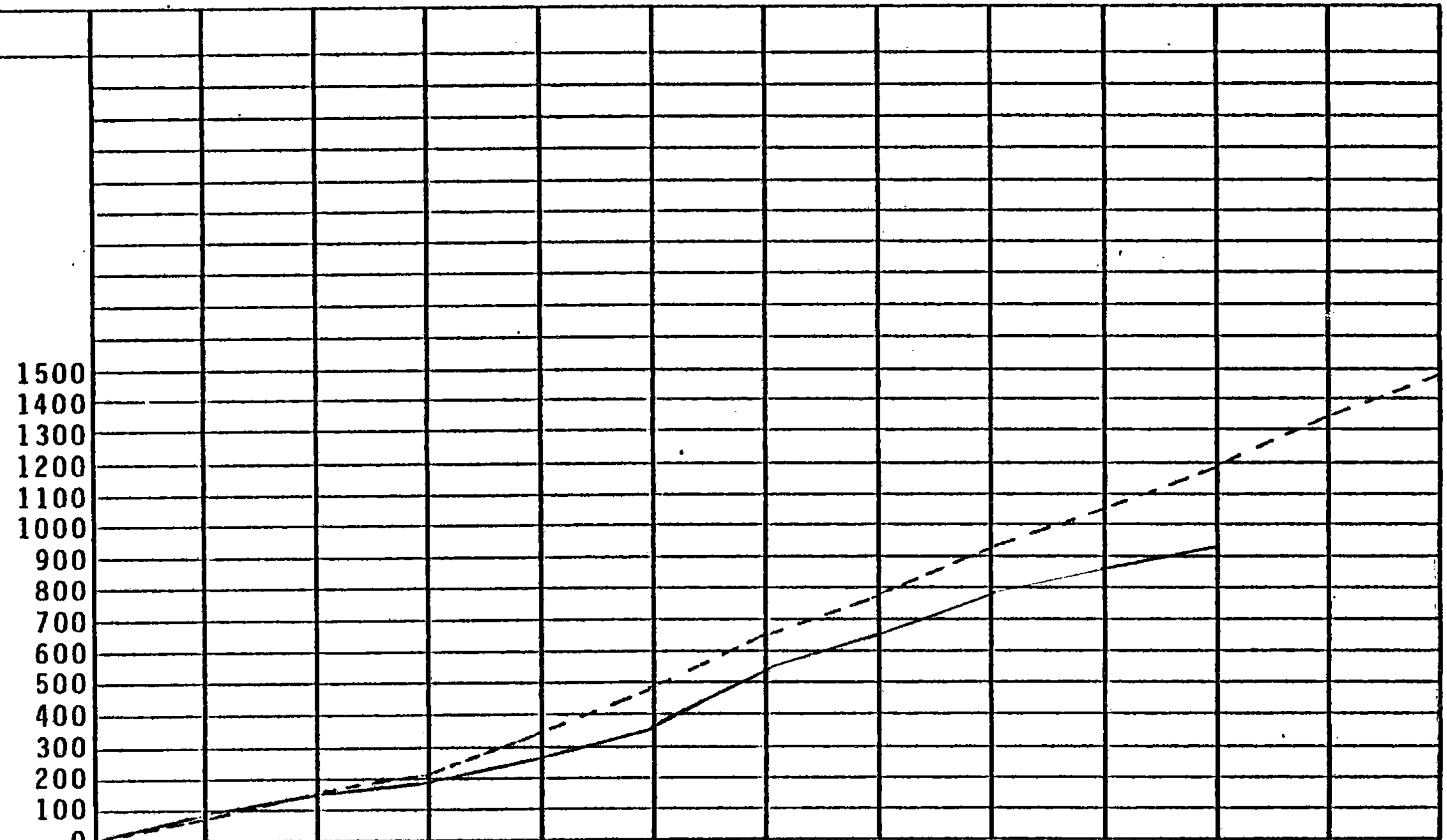
6. Cost Estimate

a. Dollars in Thousands

Legend:

----- Planned

——— Actual



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	Total
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	1479.5
c. Actual	80.5	57.3	54.9	68.9	101.1	189.1	113.1	124.3	78.4	55.2			
d. Variance	-22.8	1.0	36.0	73.4	41.7	-45.3	27.7	9.8	61.5	87.0			

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	

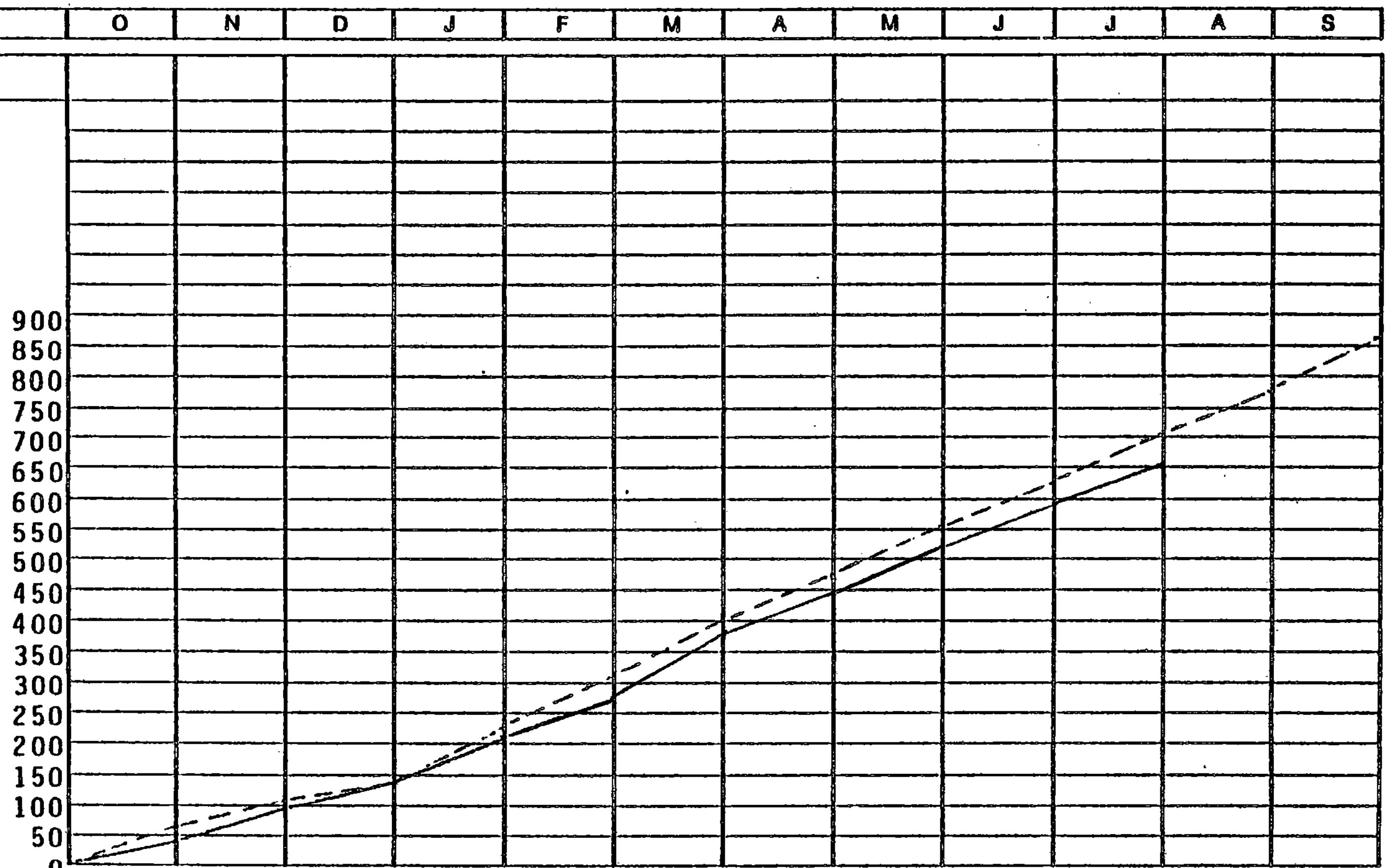
6. Cost Estimate

a. Dollars in Thousands

Legend:

----- Planned

——— Actual



Accrued Costs	O	N	D	J	F	M	A	M	J	J	A	S	
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			c. Actual
d. Variance	12.9	-9.0	3.6	6.0	18.9	-6.8	-2.3	9.5	-3.4	18.4			d. Variance

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	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

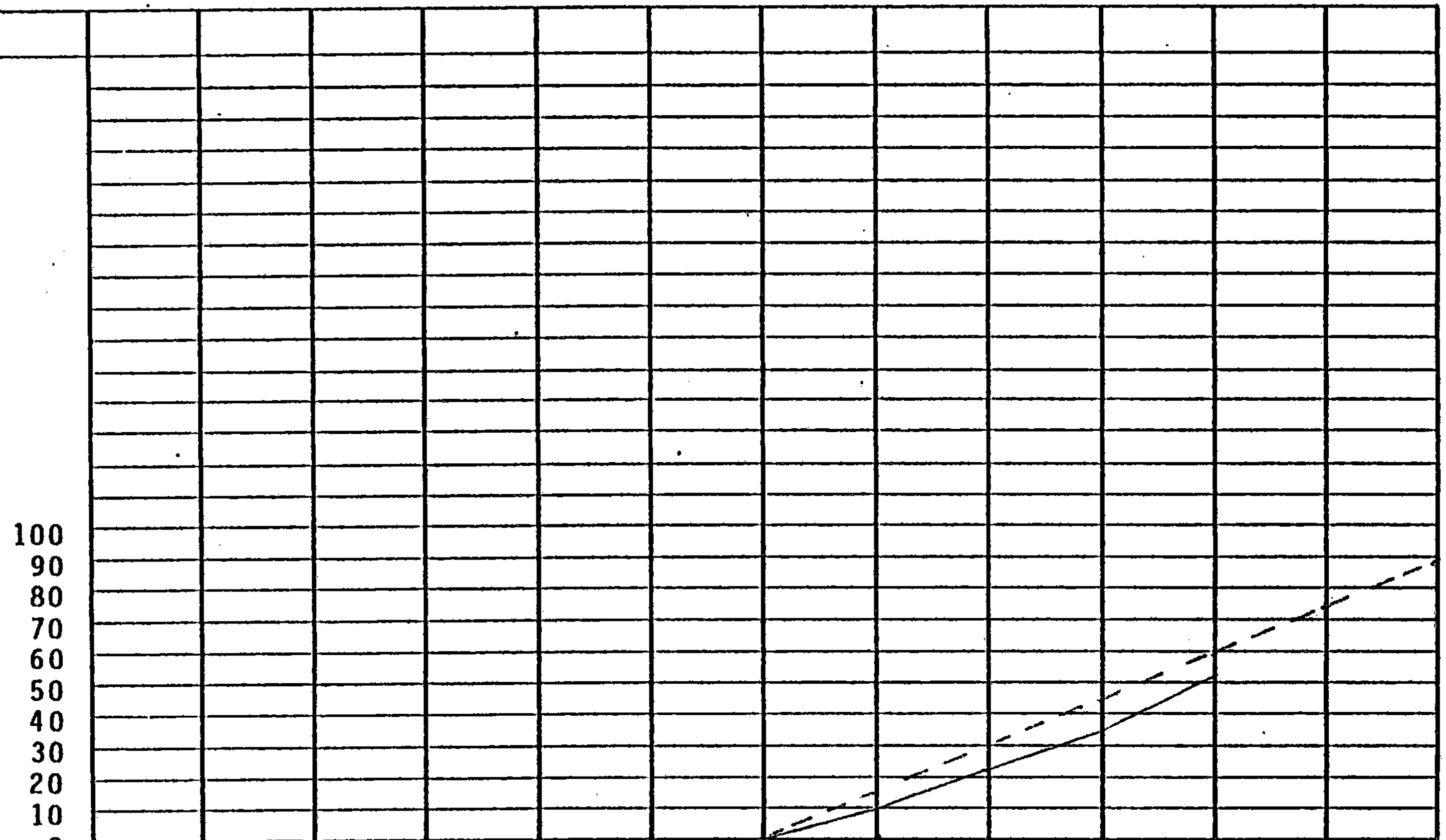
6. Cost Estimate

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	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			c. Actual
	d. Variance	0	0	0	0	0	0	4.5	2.0	2.6	-3.9			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 5.0: Instrumentation and Measurement	

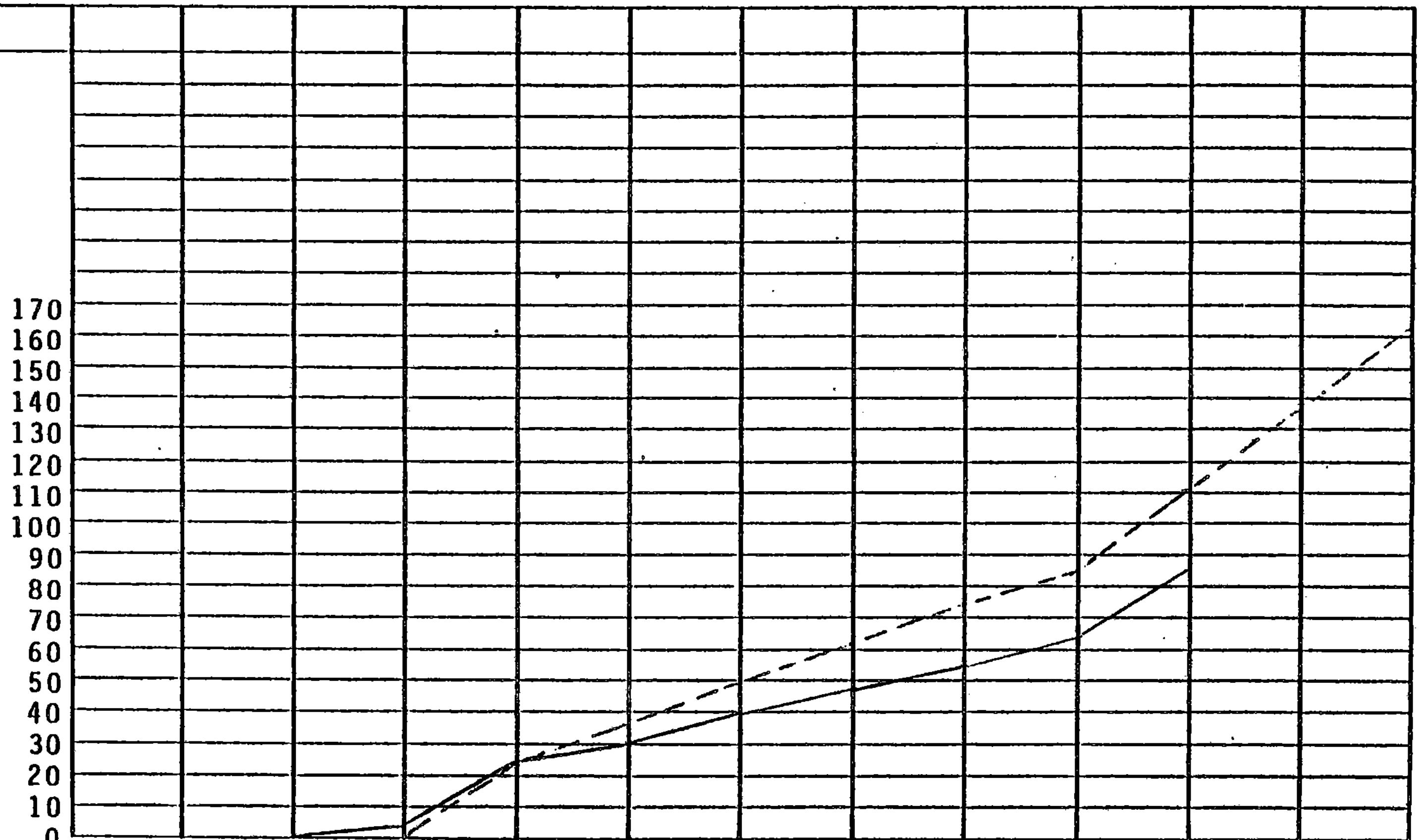
6. Cost Estimate

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	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			c. Actual
	d. Variance	0	0	-4.2	1.4	9.4	2.7	4.7	4.6	2.1	4.4			d. Variance

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/83 To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

Program Element 6.0: University Research

5 Months

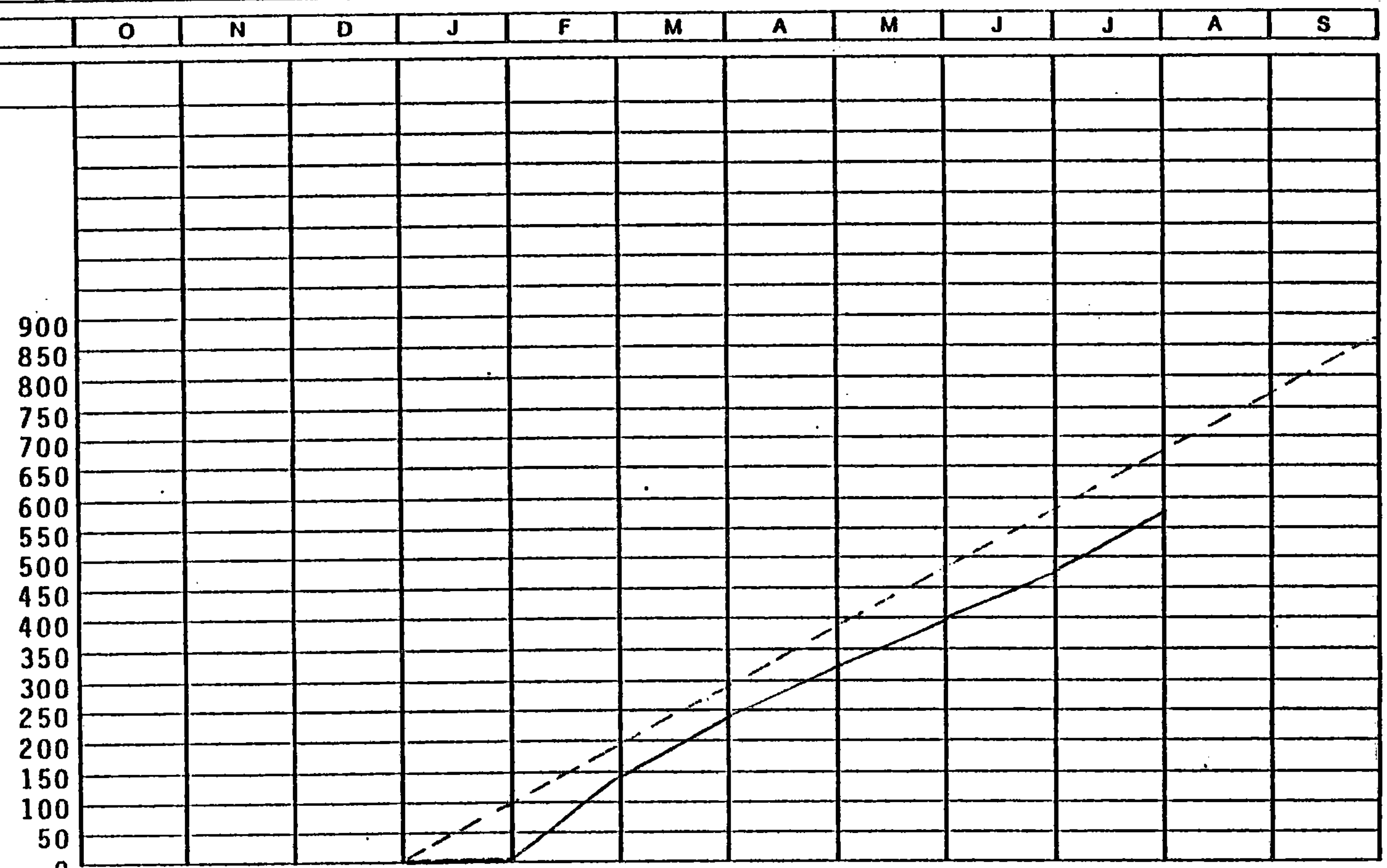
6. Cost Estimate

a. Dollars in Thousands

Legend:

----- Planned

——— Actual



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	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			c. Actual
	d. Variance	0	0	0	94.2	-51.7	1.3	13.5	17.1	23.0	-4.6			d. Variance

Budget Status

1 Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/83 To: 09/31/84

3. Program Identification

FY84 STT Research Program

4. WPA/Task

Program Element 7.0: Innovation Research

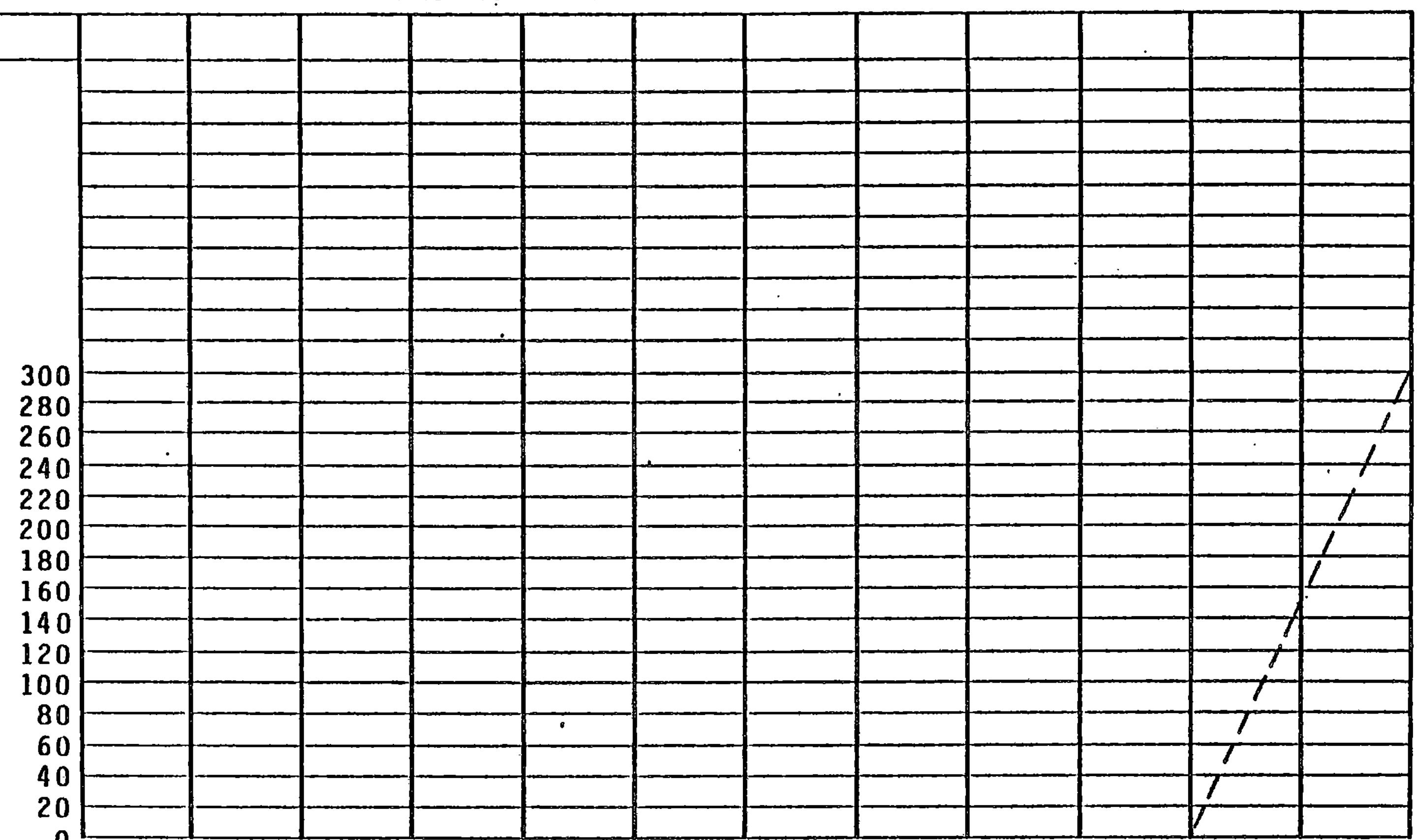
6. Cost Estimate

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	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			c. Actual
	d. Variance	0	0	0	0	0	0	0	0	0	0			d. Variance

Budget Status

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	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

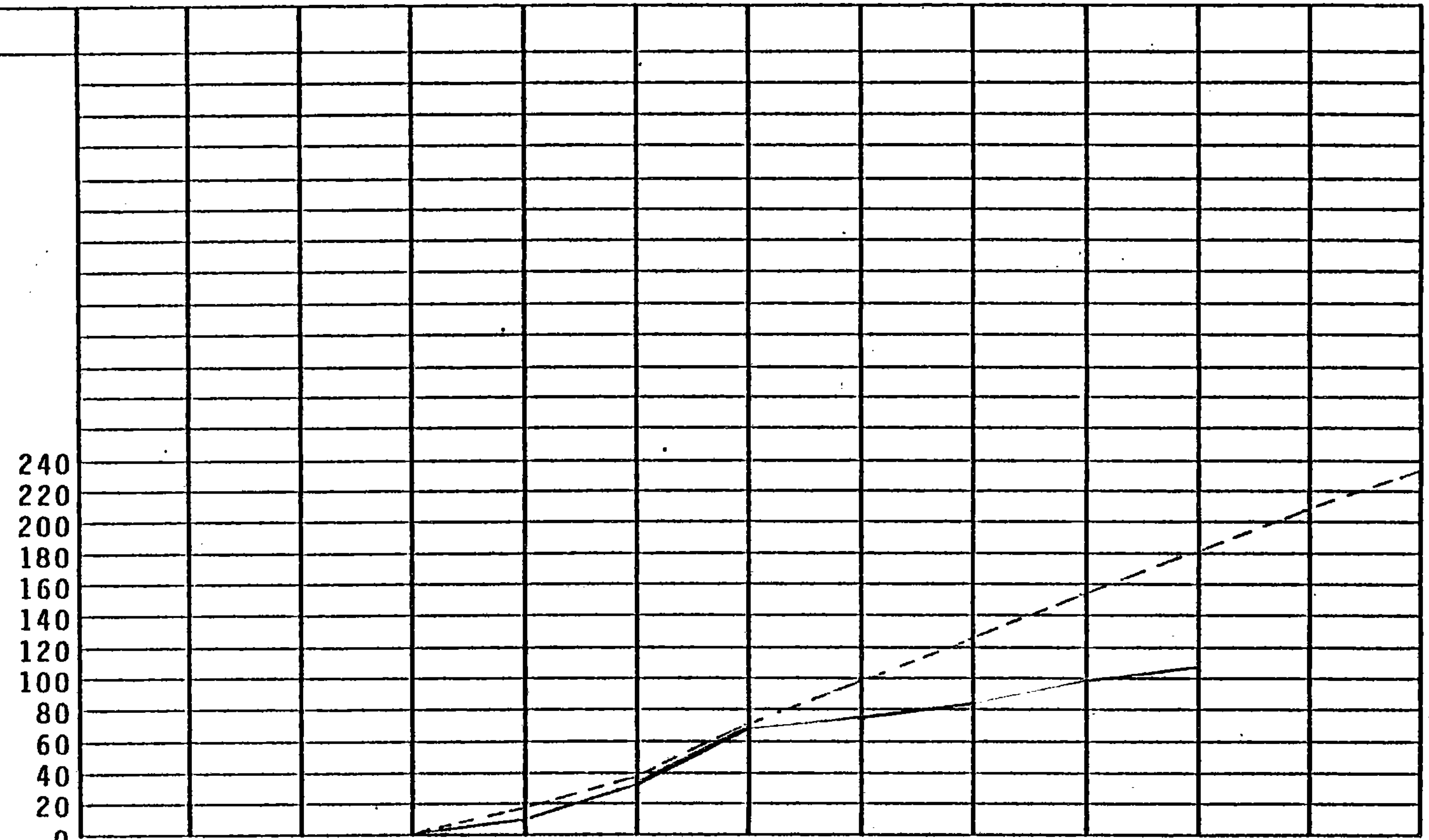
6. Cost Estimate

a. Dollars in Thousands

Legend:

- - - - - Planned

——— Actual

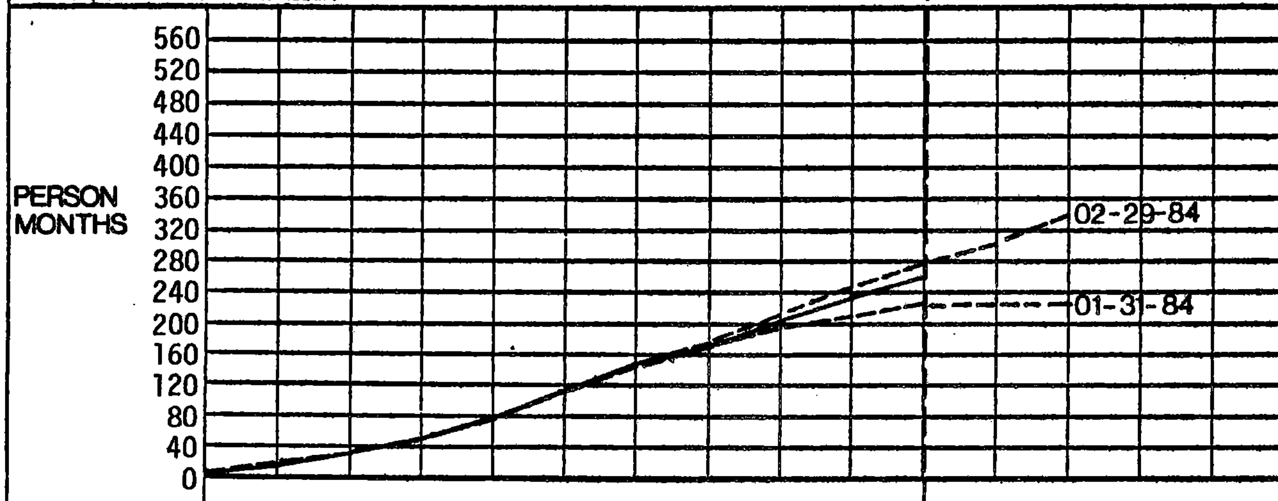


Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	0	0	0	18.7	18.7	33.6	27.5	27.3	27.2	27.1	27.1	26.6	b. Planned 233.8
	c. Actual	0	0	0	10.1	23.2	36.5	3.6	9.8	16.1	6.9			c. Actual
	d. Variance	0	0	0	8.6	-4.5	-2.9	23.9	17.5	11.1	20.2			d. Variance

MANPOWER STATUS

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	FY 84

Manpower Status (Direct Labor)



Manpower		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					
	Variance	2	0	(1)	(1)	0	2	7	9	12	19					

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

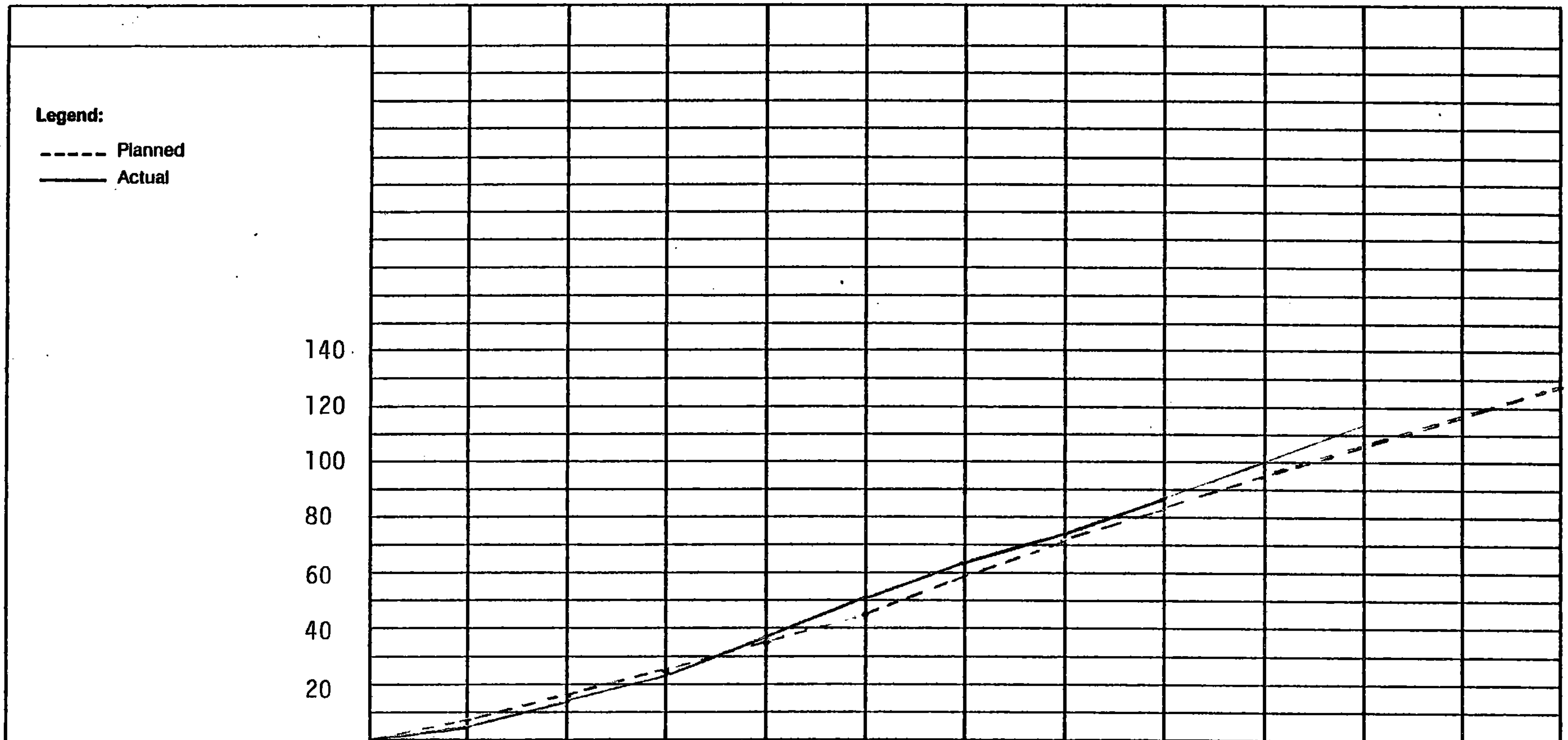
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/83 To 09/31/84

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			Actual

Manpower

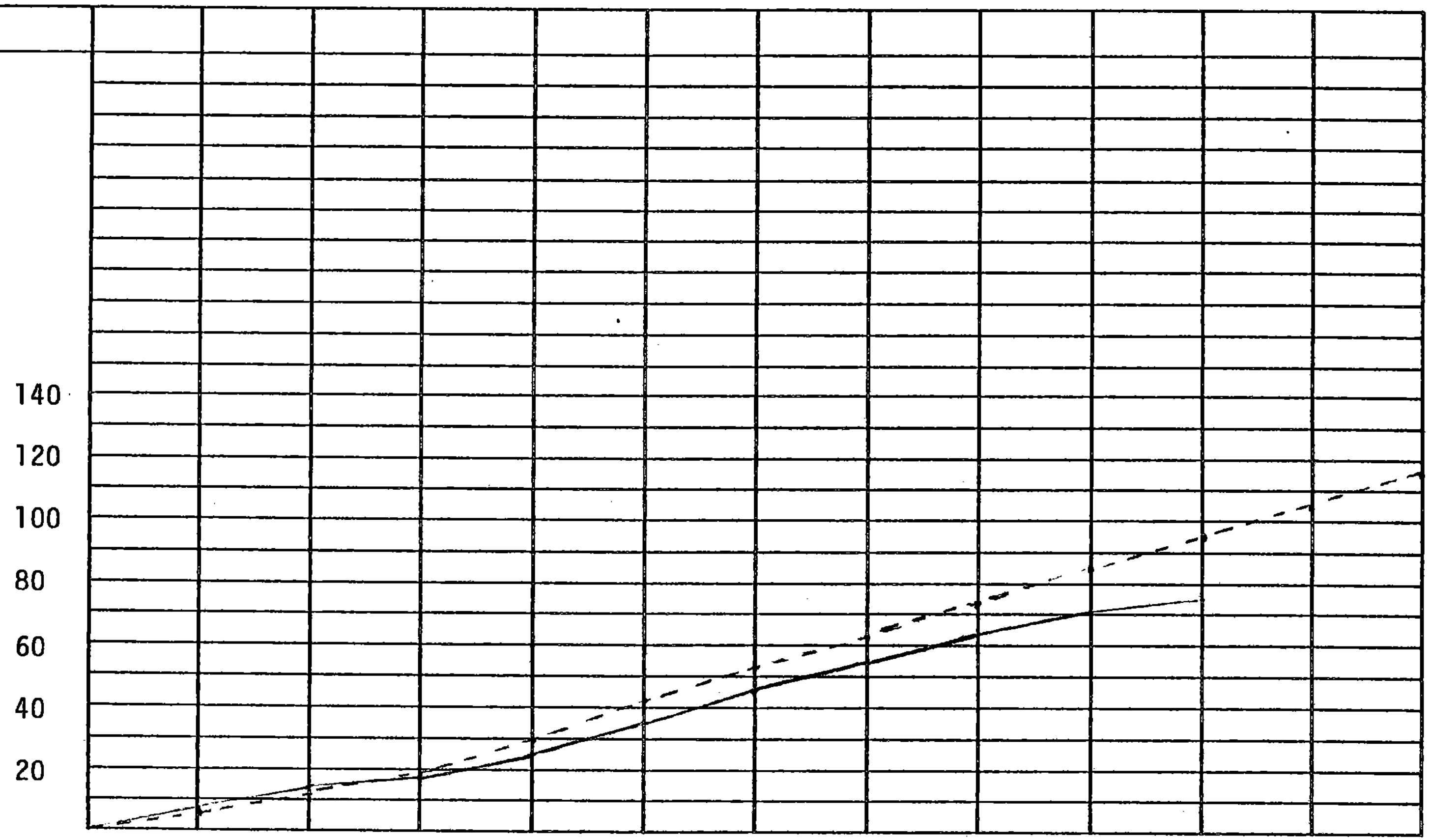
1. Contractor (name and address) Solar Energy Research Institute, 1617 Cole Boulevard, Golden, Colorado 80401	2. Reporting Period From: 10/1/83 To 09/31/84
3. Program Identification FY84 STT Research Program	
4. WPA/Task Program Element 2.0 Reflector Materials	

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

Legend:

----- Planned

——— Actual



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

Manpower

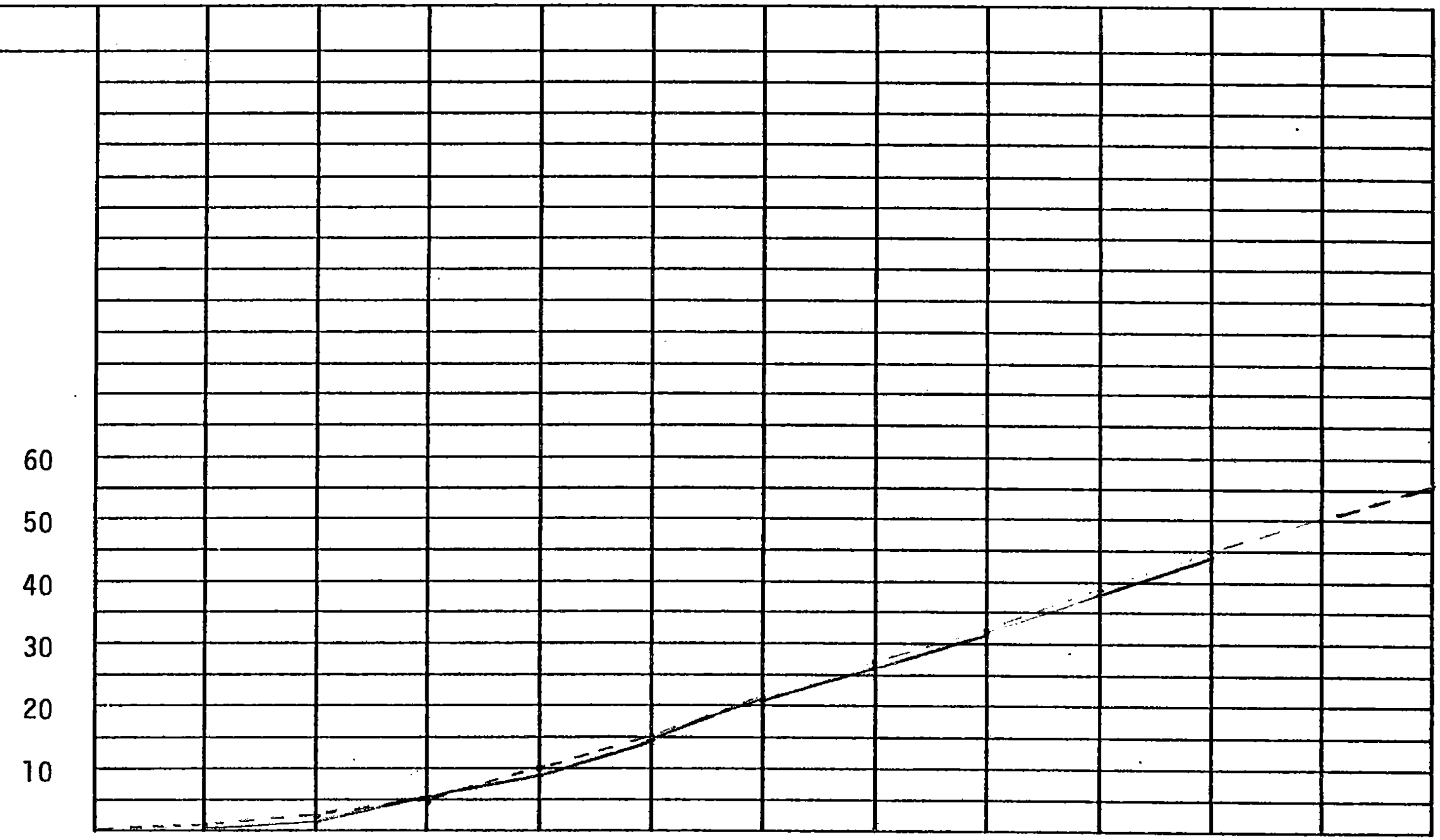
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/83 To 09/31/84

3. Program Identification: FY84 STT Research Program

4. WPA/Task: Program Element 3.0 Thermal Science Research

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

Legend:
- - - - - Planned
——— Actual



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

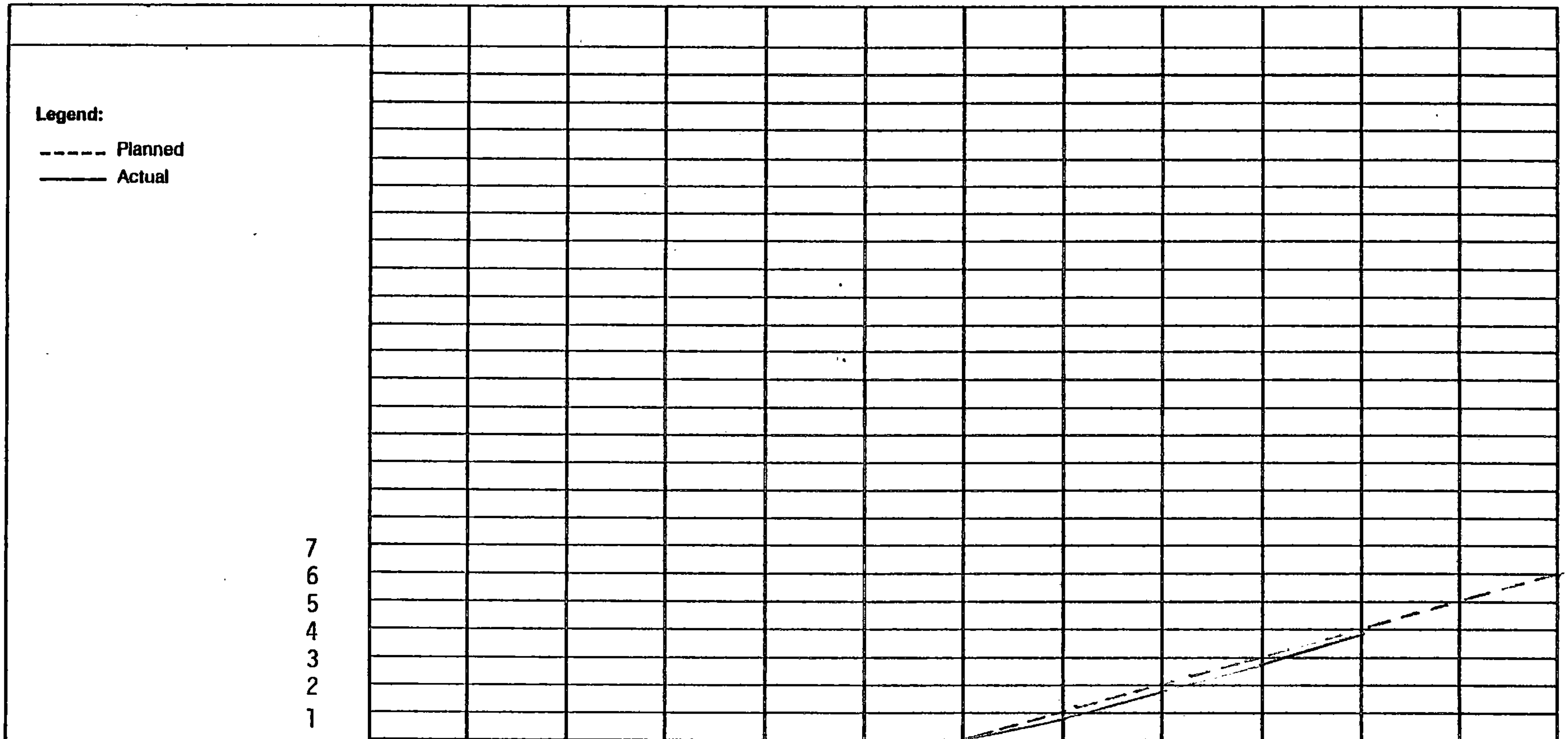
Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	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



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

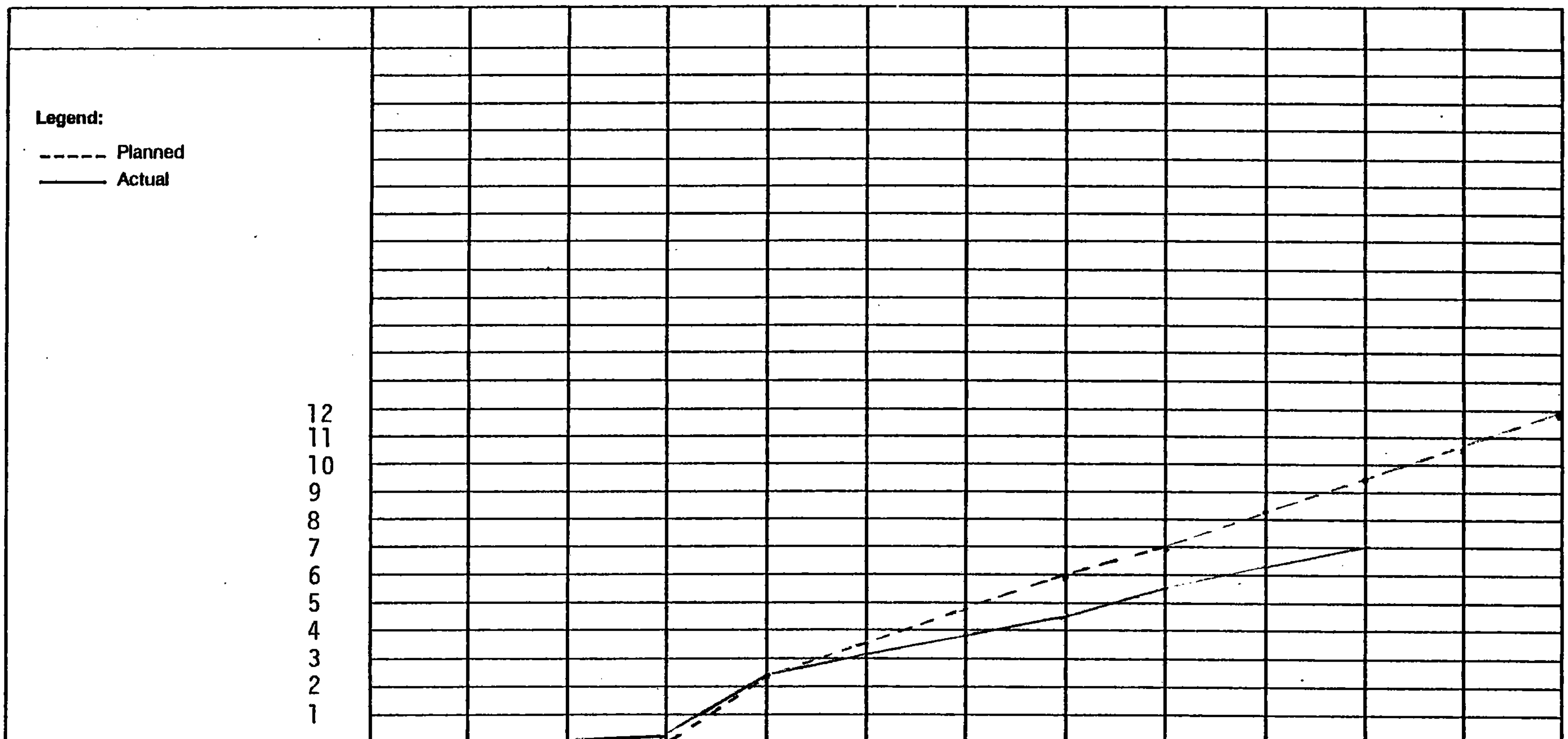
FY84 STT Research Program

4. WPA/Task

Program Element 5.0 Instrumentation and Measurement

5. Months

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



	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			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

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

Legend:

- - - - - Planned

——— Actual

5
4
3
2
1

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			Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	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. Months		O	N	D	J	F	M	A	M	J	J	A	S	
5														
4														
3														
2														
1														
	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			Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/83 To 09/31/84

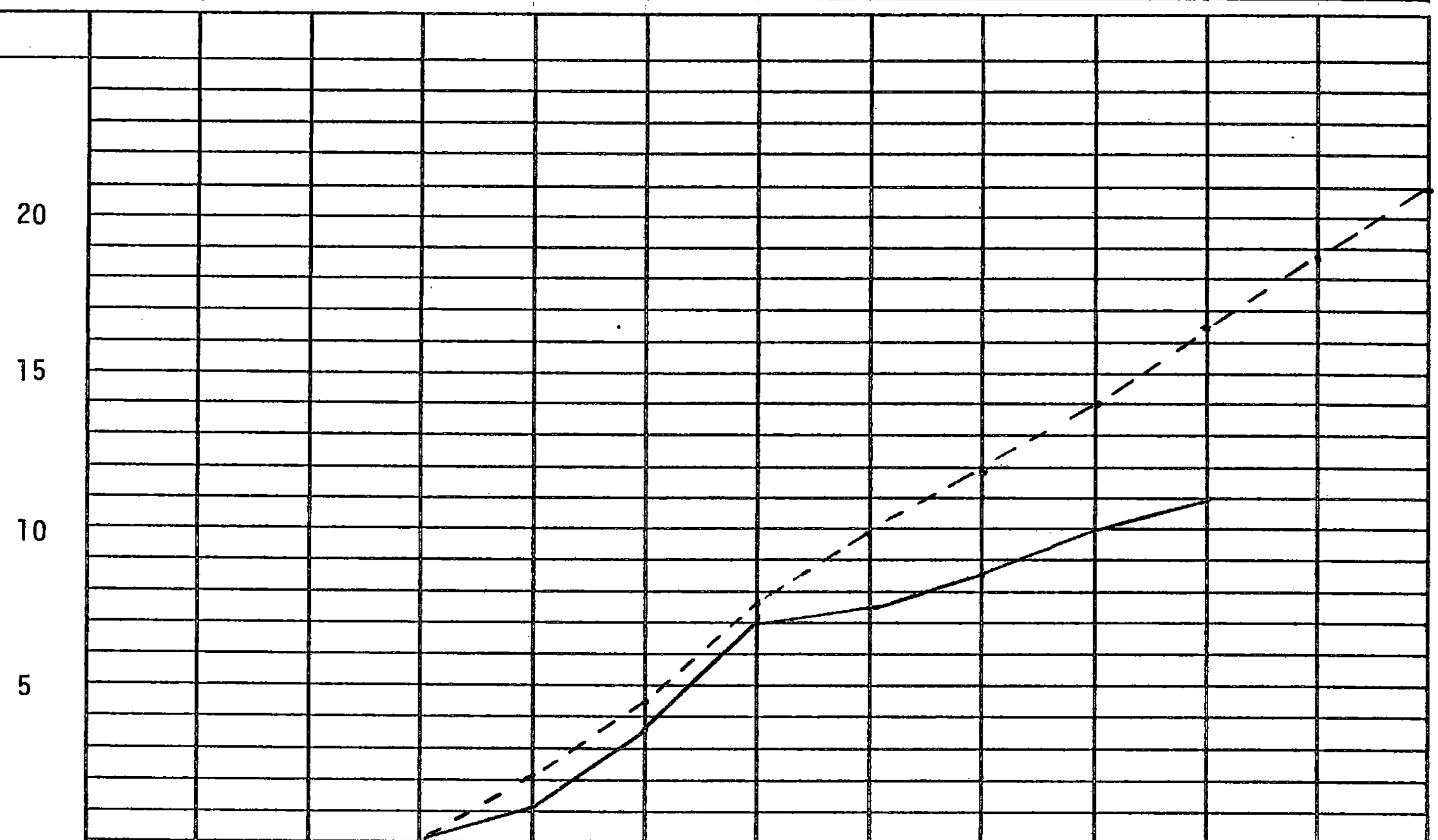
3. Program Identification: FY84 STT Research Program

4. WPA/Task: Program Element 8.0 Planning and Assessment

Legend:

----- Planned

—— Actual



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			Actual

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

1. 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.

2. Bhaduri, S. (In progress). Wind Loading on Solar Collectors. SERI/TR-253-2169. Golden, CO: Solar Energy Research Institute.

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

4. 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.

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

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

7. 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.

8. Murphy, L. M. (In progress). Structural Design Considerations for an Inexpensive Line-Focus Through Reflective Module Prototype. SERI/TR-253-1450. Golden, CO: Solar Energy Research Institute.

9. Murphy, L. M. (In progress). A Simple Analytical Model for Predicting the Static Structural Response and Deformation of a Stretched Membrane Reflective Module. SERI/TR-252-2221. Golden, CO: Solar Energy Research Institute.

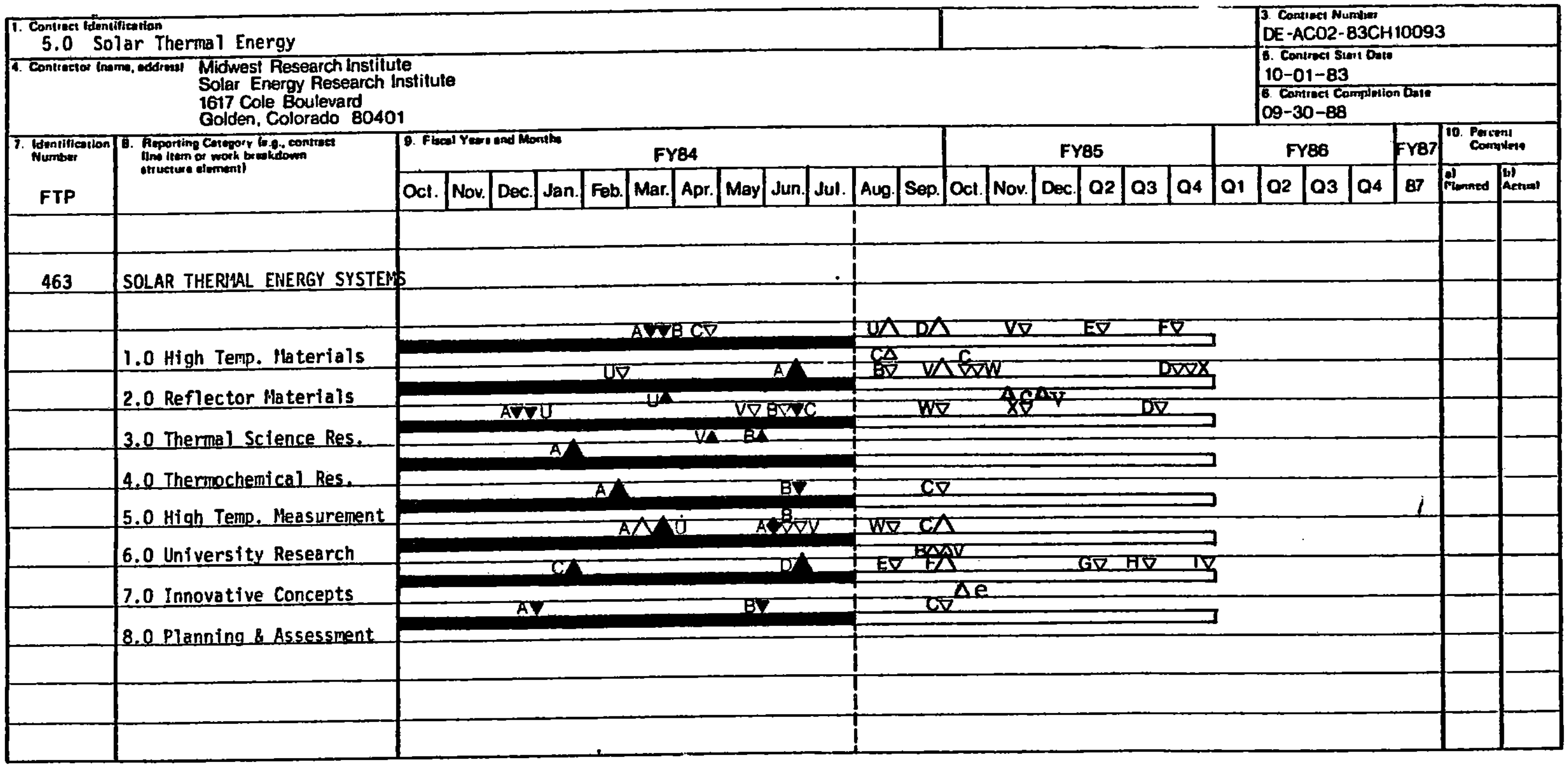
10. Webb, J. (In progress). Photodegradation of Transparent Polymers Measured In Situ Using FTIR-RA Spectroscopy; Vol. I & II. SERI/TR-255-2177. Golden, CO: Solar Energy Research Institute.

11. Thomas, T.; Pitts, J. R.; Jorgensen, G.; Masterson, K.; Czanderna, A. W. (Completed). Advanced Mirrors. SERI/TR-255-1629. Golden, CO: Solar Energy Research Institute.

12. Wright, J., (In progress). Sizing of Direct Contact Preheaters/Boilers for Solar Pond Power Plants. SERI/TR-252-1401. Golden, CO: Solar Energy Research Institute.

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

MILESTONE SCHEDULE



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 recommendd 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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BI-MONTHLY STATUS REPORT

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Wilson, W.