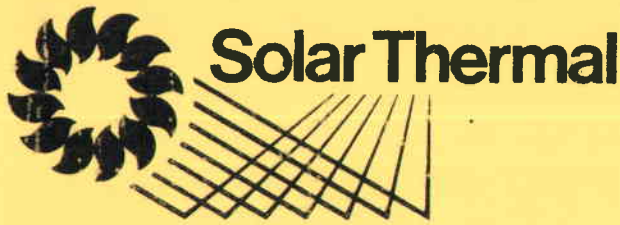
SERI/MR-251-1471 October/November



Solar Thermal Research Program

Status Report

October 1984
November 1984

Issued 18 December 1984

SERI

Solar Energy Research Institute

A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

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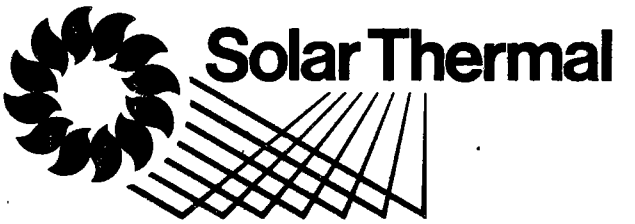

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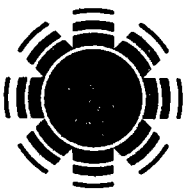

SERI

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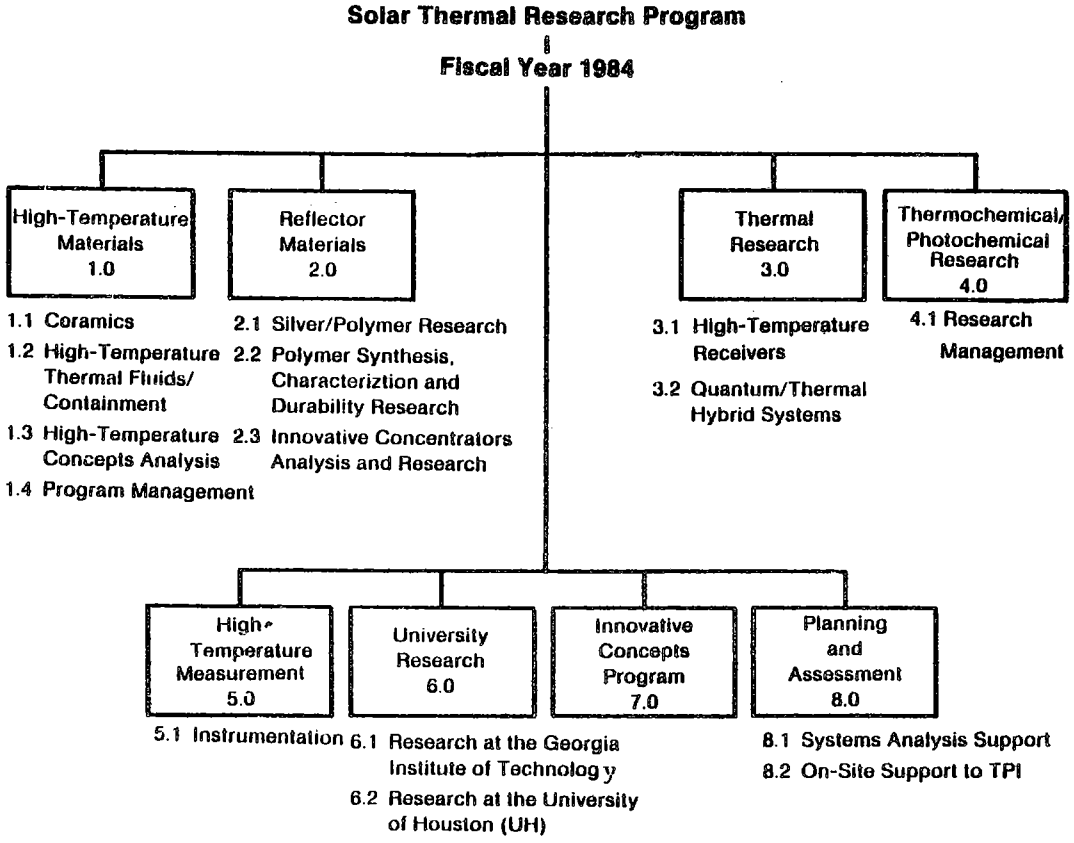
TABLE OF CONTENTS

	Page
Summary	1
Technical Description	
1.0 High-Temperature Materials	3
2.0 Reflector Materials	9
3.0 Thermal Science Research	15
4.0 Thermochemical and Photochemical Research	19
5.0 High-Temperature Measurement	21
6.0 University Research	23
7.0 Innovative Concepts	29
8.0 Planning and Assessment	31
Carryover Tasks/Fiscal Year 1983	33
Subcontracts	A-1
Resource Expenditure	B-1
Publications	C-1
Milestones	D-1

Work Breakdown Structure for the SERI Solar Thermal Research Program



SUMMARY

SIGNIFICANT EVENTS

Significant Events

The Absorber Assembly, an essential part of the Direct Absorber Receiver Test Loop, has been fabricated and has been tested successfully at the maximum test temperature of 900°C. The 500°C test apparatus has been completed, and viscosity measurement calibration runs using water have been successfully completed. (Page 16)

Three proposals were received for fabrication of the 900°C molten salt loop which will be used to test the direct absorption receiver concept at the ACTF in fiscal year 1985. A decision on the fabricator is planned for early December. (Page 16)

Researchers at SERI have completed the assembly and are nearing completion of the shakedown tests on a rather unique instrument. The instrument is designed to measure radiative transfer properties of solids and of some liquids at temperatures up to 900°C. First use of this instrument is planned for obtaining the absorptance of Inconel 600, which is the material of the first absorber plate of the Direct Absorption Receiver Proof-of-Concept Test. The same instrument will then be used to measure the transmittance (extinction coefficient) of molten carbonate salt. Temperature dependent properties are essential in predicting the radiative heat transfer phenomena in a DAR. The capability to measure radiative transfer properties at high temperatures is seen here as a significant capability of use not only to DOE, but to other government programs (e.g., DOD), to industry-at-large, and to university researchers.

C. L. Tien, Vice-Chancellor for Research at the University of California at Berkeley and a professor of Mechanical Engineering with a world-wide reputation in heat and mass transfer, particularly, radiative transfer, visited SERI on Monday, November 26. He spent the day with SERI researchers and reviewed current research in direct absorption, cavity receivers, polymer/silver mirrors, and measurement of radiative transfer properties (the integrating sphere) at high temperatures. At the conclusion of his visit, he was complimentary of the quality of research at SERI. He will continue as a consultant to the program.

Professor E. Sparrow, a world-recognized heat transfer authority, reviewed the work at SERI on thermal convection during his recent visit to SERI. He has been retained as a consultant to review and to comment on several projects-including the issue of convective losses from cavity receivers. He made several suggestions regarding the research in progress and discussed alternative approaches.

Construction of the innovative spiral concentrator is nearing completion at the Georgia Institute of Technology. The spiral concentrator performance will be characterized experimentally in early fiscal year 1985. (Page 24)

The University of Houston's task on chemical storage of energy is doing an engineering evaluation of the ammonium hydrogen sulfate cycle. The research will be reviewed at Houston in early December. (Page 26)

The Acurex Solar Corporation contract for research on holographic solar concentrators was placed during October. This is for Phase 2 research in the Innovative Concepts Research Program Element. Negotiations are proceeding with Hughes Aircraft Company for Phase 2 research on a thermoelectrochemical converter. (Page 29)

Four contracts for Cycle 2, Phase 1, in Innovative Concepts Research, were placed in November:

- o University of Arizona—Spectrally Selective Beam Splitter
- o University of Chicago—Compound Optical Systems with Maximal Concentration for Solar Thermal Conversion
- o Southern Research Institute—Development of Novel Protective Coatings for Solar Reflectors
- o Hughes Aircraft Company—New Ideas for Solar Thermal Conversion (Page 29)

Progress continues on definition of a technique to characterize the optical quality of stretched membrane heliostats. The reflection of a checkerboard test-pattern on the heliostat will be photographed for video-digitization and analysis to define distortion. The test pattern has been created, and the video-digitization system is now available. (Page 12)

The fabrication of the components of the second-generation, rapid-data-acquisition, thermogravometric analysis apparatus nears completion at the University of Hawaii. The device will be used to measure weights of solids which decompose rapidly in a high flux, radiant environment.

NOTE

In the detailed reports that follow, note that the work described is for continued effort during this period funded in FY84. New effort funded in FY85 was authorized to SERI in November, 1984, with plans to begin the work in January, 1985, and hence will be reported in the next bimonthly report.

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

Coupons of transparent single crystalline spinel ($MgAl_2O_2$), supplied by the University of Washington, were exposed to eutectic LiNaK at 900°C for 6 days and 27 days with a purge gas(71% Ar ; 19% O_2; 10% CO_2)bubbled into the salt. The spinel coupons formed a white corrosion product, presumably $LiAlO_2$, with a resulting weight gain for the coupon. Coupons with (111) and (100) orientations were evaluated, and the coupons with the (100) orientation showed the least weight gain after 27 days (1.6 mg/cm^2). This weight gain was about 10 times larger than the gain for sapphire coupons. This result suggests that the $LiAlO_2$ coating on spinel is not protective to the extent that it is on sapphire.

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

Metallographic sections were prepared on coupons of alloys exposed to eutectic LiNaK at 900° C in a 1.4 percent CO_2 in nitrogen atmosphere. Several experiments have indicated a peculiar melting behavior for LiNaK. Researchers have observed an accumulation of white powder on the cooling unit above the melt which may indicate selective loss from the salt with a concurrent change in the melt composition and in the melting point. A sample of the white powder was sent to Coors Spectrochemical for analysis.

A source for calibrating gas mixtures traceable to NBS was found. All of the gas mixtures are standardized against nitrogen or helium. Ar mixtures traceable to NBS are not available; so researchers plan for calibration to use primary, standard-grade, gas mixtures which are known to better than ±0.1 percent. Once the ratios of Ar, N_2, CO_2, CO, etc., are known (ratio to N_2, i.e., $N_2 = 1$), the old data on gas analysis and subsequent data can be interpreted with higher accuracy. All subsequent experiments will also have higher accuracy in the mass-flow rates and compositions provided to the crucibles.

Coupons of graphite-graphite composites supplied by SAI were tested for 12 hours in molten eutectic lithium-sodium-potassium (LiNaK) carbonate at 900° C. The gas above the salt was 10 percent CO_2, 19 percent O_2, and 71 percent Ar which was introduced into the air space above the salt. The result is what researchers estimate to be moderate-to-low oxidation potential in the salt as compared to the oxidation potential of atmospheric air. Under these conditions the mass change rates of the coupons in the twelve-hour test were -2.8 ± 0.3 mg/cm^2 and -4.2 ± 1.2 mg/cm^2 for a composite of Thornell film in an isotropic graphite matrix and a glassy carbon matrix. The densities of the composites were measured at 1.81 gm/cc and 1.79 gm/cc. If one assumes that all weight changes are due to the oxidation of carbon and that the weight loss is linear with time, their densities allow one to calculate that thickness changes of 31 μ m/day and 47 μm/day would occur.

Tests of SAI graphite-graphite composites were continued with the purge gas (71 percent AR; 19 percent O_2; 10 percent CO_2) bubbling into the molten salt for 55 hours at 900° C. If one assumes that weight changes are due to oxidation of the graphite to gaseous products and that the weight changes are linear with time, the corrosion rates would be 250 μm/day and 190 μm/day for Thornell 300 fibers in an isotropic graphite matrix and in an amorphous carbon matrix. This is more than three times the loss rate for experiments where the purge gas was not bubbled.

SEM micrographs of the Thornell 300 fibers in an isotropic graphite matrix show that the fibers are attacked by the eutectic LiNaK at 900°C even when the purge gas is not bubbled. However, the matrix was attacked more readily, and fibers sticking up from the matrix remained after exposure to the molten salt.

Optical Measurements

Thermal characterization of the high-temperature, reflectometer-integrating-sphere furnace was carried out to 500°C. The coating on the sphere has been instrumented, and a precision-optical pyrometer has been identified and ordered to extend the characterization beyond this temperature. Plans for a nitrogen-gas purge of the ambient environment inside the sphere have been formulated and are being implemented to assure protection of the coating of the sphere at elevated temperatures in the furnace.

An in-house assembly of a chopper motor has been modified and installed to allow light source chopped at a frequency appropriate for the detector and amplifier system. Optical alignment of the high-temperature reflectometer has been completed, and a calibration curve has been generated for the monochrometer (to relate drum setting to wavelength). The detector and the amplifier components have been checked and are operational. In general, integration of the system is proceeding on schedule.

An Inconel 600 sample holder and Inconel 600 samples capable of in situ molten-salt containment have been designed and are being fabricated. These will allow optical characterization of configurations of salt/alloy and only alloy at high temperatures. Containment vessels for measurements of salt only have been received (an all-sapphire design and an alumina tube-sapphire, window-frit-bonded design).

TASK 1.3 HIGH-TEMPERATURE CONCEPTS ANALYSIS

Objectives

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

Progress

A review of costs for other storage designs for molten salt was conducted for a perspective on the current costs on carbonate salt utilized in the electric power DAR* system study just completed. The survey of storage costs includes the current carbonate salt storage in two configurations (cylindrical and conical), three nitrate salt designs (two from the repowering studies), and a sodium storage (also from the repowering studies). These estimates indicate that costs for nitrate salt range from $9,000/MWh to $17,000/MWh for temperatures up to 566°C. The carbonate storage for temperatures up to 900°C was estimated to be $18,000/MWh to $24,000/MWh, and the cost for sodium

*DAR = Direct Absorption Receiver

storage was about $41,000/MWh. An internal memorandum on the storage work has been prepared.

A review of transport costs and performance is also underway as a part of the study of the IPH DAR system. Initial efforts are directed at acquiring data from previous studies. Of particular interest is the distributed system transport study (Sandia, Albuquerque) which shows both performance and cost of a carbonate-salt transport system. The amount of piping in a distributed system, however, will be considerably larger than for a central receiver system; and, therefore, researchers expect the costs and the performance for a central receiver system to be more attractive than indicated in the earlier study. Initial contact has been made at Sandia, Albuquerque, to exchange information and to obtain the raw cost and the performance data from the 1500°C carbonate salt transport study. Data from Sandia have been received, and review has begun. The cost and performance of the thermochemical transport system studied by Sandia will also be compared with those for a carbonate-salt, central-receiver system.

Work also has focused on developing a more comprehensive data base on temperature and field-size for the DAR study. This information will allow more accurate definition of the performance of the system for a wider range of conditions without the need for interpolation. Another element being studied is the temperature gradient anticipated from inlet to outlet in the receiver. In establishing this more comprehensive data base, a trio of codes (DELSOL2, RADSOLVER and SHAPEFACTOR) is being implemented in an iterative fashion to arrive at an optimal configuration of a field and receiver for a specific size of a field and operating temperature of a system. The codes to analyze the radiative and convective losses of the receiver are in place, and their operation has been automated to a certain extent. Training of new personnel in the use of these codes is largely complete. Generating the data base is expected to be complete in December, 1984. The research will benefit this Task, the DAR analysis, and the heliostat comparison.

A draft of a document on estimating the benefits of secondary concentrators and focusing of stretched membrane heliostats in central receivers has been completed by using the DELSOL2 analysis. The detailed performance of secondary concentrators was not modeled, and all flux impinging on the secondary-concentrator, intercept aperture is assumed to be absorbed by the receiver. Thus, no losses in reflection or absorption associated with the secondary concentrator are considered. Hence, the benefits predicted will represent an upper bound of what actually might be feasible. Results indicate that secondary concentrators are most effective in high temperature and in small-sized to medium-sized power plants. Furthermore, flat heliostats with secondary concentrators potentially can perform better than focused heliostats without a secondary concentrator for high temperature and large field systems. If a significant portion of this potential benefit as defined in this initial study can be attained, then secondary concentrators deserve further consideration, both as an approach to reducing losses in receivers and as a possible alternative to focusing stretched-membrane heliostats.

For further study, researchers have begun comparing the stretched-membrane heliostat (78 m^2) directly with the heliostats of glass and metal (100 m^2). In particular, the initial sizing for the field configuration for the heliostats (100 m^2) has been completed for a range of field sizes and applications of temperature. These data are now being used in a portion of the process for optimizing the receiver and will subsequently be utilized to optimize again the field in an iterative fashion. Researchers have set this iterative, optimizing process as a benchmark by using the field and receiver codes with the data from the study of high-temperature central receivers.

Reviews have been received, and requested modifications have been made for the conference paper, "A High Temperature Central Receiver Study," submitted for the ASME/ASES conference next spring. Since the personnel (Sandia, Livermore) who were associated with publication of this work as a SAND report are no longer available, SERI has acquired the computer-coded text, and researchers will submit this version to SERI's Editing Department. In accordance with an agreement with Sandia, this publication will not be a SERI document, but the final mats will be sent to Sandia for distribution or publication under Sandia's auspices.

Researchers outlined SERI's work on convection for Professor Sparrow (University of Minnesota) during his visit to SERI. He has been retained as a consultant to review and to comment on several projects, including the issue of convective losses from cavity receivers.

The second of two contracted reports from Professor A. Clausing (University of Illinois) was received. The first report dealt with general program recommendations for work on the problem of convective losses from cavity receivers. His general recommendation was that the most important questions to be answered at this point revolve around the patterns of heat and mass flow within the cavity and the effect of cavity geometry on these flows. This second report deals with the effect of fluid-property variations on convection at ratios of high temperature. It summarizes much of the work that he did while at SERI and was an extension of some of his earlier work. A modified version of the report incorporating the changes recommended by SERI reviewers is being considered for possible publication as a SERI report performed under contract.

TASK 1.4 PROGRAM MANAGEMENT SUPPORT

Objectives

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

Progress

- SERI's Fiscal Year 1985 Annual Operation Plan was accepted by DOE/HQ. The fiscal year 1985 letter of authorization for funding was issued by DOE/HQ.
- Frank Wilkins of DOE visited SERI for an informal review of various program elements.
- SERI participated in the DOE Quarterly Review in Washington, D.C., in October. Georgia Institute of Technology and the University of Houston also made presentations.
- SERI personnel met with Acurex personnel at the Acurex facilities to start properly the Phase II Innovative Research Contract on holographic solar concentrators. Both Acurex and Broadbent (Acurex subcontractor) facilities were toured.
- B. Gupta, G. Nix, and C. England (consultant) visited LBL for a review of its research on solids decomposition in direct concentrated solar flux.

- SERI participated in the workshop at Black and Veatch in Kansas City in late October. That workshop was to generate industry ideas for the SERI Research Plan.
- A working meeting to provide additional ideas for the FY 1986 to FY 1990 Research Plan was held by SERI. Participants included Georgia Tech, University of Houston, Sandia National Laboratory—Livermore, DOE, a SERI consultant, and SERI Personnel.

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

After 20 weeks of accelerated testing in the QUV, the hemispherical reflectance of two control combinations (B1-191-1,-2) of 7809 glass/evaporated silver/Inconel/aluminum or glass/silver/adhesive/aluminum remains at 95.5 percent with specularities of 94.5 percent (15 mrad) and 90 percent (7 mrad). The data on specularity again were slightly better for the sample without Inconel than the one with 35 nm of Inconel. The hemispherical reflectances of the four polymer combinations (B1-191-4,5,11,12) are 94 percent, 83 percent, 85 percent. (The specularities, which were below 10 percent after 13 weeks of testing were not measured.) The latter three samples, which all have Inconel backings, all had hemispherical reflectances over 90 percent after 13 weeks of testing. Thus, the reflectance loss has been dramatic between 13 weeks and 20 weeks. Since there is a suspicion the losses of specularity and now hemispherical reflectance are related to the adhesive used, a new set of samples were to be prepared, characterized, and tested.

The Deliverable (draft, SERI/PR-255-2493), "Identification of Chemical and Physical Phenomena Affecting the Lifetime of Silvered PMMA," was completed.

The intensity distributions of reflected beams can be approximated by Gaussian distributions symmetrically oriented about the specular direction. With this model it can be shown that a required reflectivity of 0.9 at 2 mrad implies that at 7 mrad the reflectivity must be negligibly different from that at 15 mrad. This can be a practical criterion for performance in lieu of more elaborate optical measuring equipment.

Mathematical models used to predict radar reflections can also be used in the optical regime. One model predicts that, if the wavelength, λ, is greater than the standard deviation, σ, of surface height about the mean, then the specularity will depend on σ and not on local (or mean) slope which is a more detailed parameter. This model is being analyzed to determine whether predictions can be made about specularity as a function of wavelength.

Forty-eight silvered specimens were prepared by vacuum deposition at rates of 0.1 nm/s to 7 nm/s onto 7809 glass or ECP-300-XP polymeric substrates at room temperature. A WO_3 backing material was also deposited onto eight of the polymeric substrates. Specularities were measured at 15 mr and 7 mr, and the following conclusions were obtained concerning the influence of the rate of deposition and WO_3. (1) The specularity of the silver side of a silver/glass sample is better than that of glass/silver (98 percent compared to 96 percent at 15 mr and 96 percent compared to 94 percent at 7 mr). (2) Specularity does not depend significantly on the deposition rate from 0.1 nm/s to 7 nm/s. (3) The specularity of ECP-300-XP/silver is less than 90 percent and ranged from 61 percent to 88 percent at 7 mr. The specularity was about 96 percent for this configuration at 15 mr. Efforts are planned for December to determine possible causes, which might be dust or deposition rate effects, for the low and variable specularities. (4) Specularities of 96 percent (15 mr) and 94 percent (7 mr) were obtained by coating PAN onto silver/7809 glass substrates and by measuring the specularity through the polymer. (5) The 100 nm-thick WO_3 backing reduces the ultraviolet transmittance at 320 nm from 20 percent to 5 percent. This is not as effective as Inconel. Furthermore, the WO_3 backing adversely reduces the specularity at 7 mr to unacceptably low values (58 percent).

A surface analysis of the silver on the silver/glass specimens before and after coating with PAN (number 4 above) revealed the films as deposited were virtually pure silver with only minor C and O signals. After standing for several days in a desiccator, a contamination layer of hydrocarbons was present, and several monolayers of Cl and S impurities were present underneath the contamination layer. It is not known if the Cl contamination is thick enough to result in accelerated degradation in ultraviolet, as has been found for 10 nm-thick layers of Cl on Ag.

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

Data on hemispherical and specular reflectance were obtained on relatively thin (3,000 A°), stabilized, PMMA-coated, silver mirrors (sputtered and wet processed) after 6 months of QUV exposure (ultraviolet and no ultraviolet). Results confirm more rapid degradation due to ultraviolet for the sputtered silver mirrors. Losses of stabilizer were noted for all samples based on the decrease in the characteristic stabilizer absorption band. Tinuvin P has performed best in this regard.

Corrosion on these mirror samples starts predominantly at imperfections (pinholes) and produces a characteristic spherulitic pattern of silver corrosion. Profile measurements with the TENCOR instrument indicate a vertical growth of about 2,000 A° for the corrosion spots, which cause the overlying polymer film to crack and to wash away together with the corroded silver area in the dew cycles of the QUV. The result is a transparent spot on the mirror. This corrosion can be avoided or diminished by the use of thicker polymer films as used on other mirror samples presently under testing.

A draft of the annual progress report on the synthesis and characterization of polymers (a deliverable) has been prepared and submitted to SERI's Word Processing Department.

After 26 weeks of outdoor weathering, the hemispherical reflectance of 3-M Flexigard polymer/sputtered Ag/DS/7809 glass (B1-161-X) has changed from 89 percent to 90 percent; the specularity (15 mrad) declined from 93 percent to 92 percent. The specularity (7 mrad), which was not measured prior to testing, is 69 percent.

After 20 weeks of weathering in the QUV, the hemispherical reflectance of two specimens of 7809 glass/evaporated Ag/-DS/aluminum (B1-191-1, 2) has declined from 96.1 percent to 95.4 percent. The specularity (15 mr) has declined from 100 percent to 95 percent and 95 percent to 94 percent. The specularity (7 mr), which was not measured initially, is 90 percent.

The specularity (7 mr) of three witness samples of ECP-300-XP polymer/sputtered Ag/Inconel/DS/7809 glass (B2-21-13, 25, 37), which have been stored in the laboratory since May 10, 1984, were 92 percent, 94 percent, and 84 percent. The December test matrix will again include sputter deposition of silver onto polymers.

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

The checkerboard, test pattern (6.5 meters high) for the three-meter, stretched-membrane, test modules has been painted on the wall of the Concentrator Laboratory. The center line of the optical test range is 4.75 meters above the laboratory floor so that a minimum of floor space is used. The checkerboard consists of dark red and white squares with a fifty-centimeter spacing.

All of the major parts for the video/digitization system have arrived and have been turned over to the subcontractor, Advanced Technology Applications (ATA), for assembly. ATA will be checking all the hardware and will write the specialized software that will produce information from the digitized video image for the slope and the deformation. Researchers met with the ATA engineers and decided on an architecture for the data reduction system and specified the forms of output needed.

Most material for construction of the mirror support and loading structure has arrived, and construction is about half complete. The loading structure acts as the support spider for the heliostat test modules, allows the weight of the heliostat to be carried in different ways, and provides means for imposing various other loads on the heliostat. A shroud on the back of the fixture will allow pulling a slight vacuum in order to simulate a wind load on the heliostat. The support structure is a scaffold platform onto which the test modules will be raised into their testing position. An A-frame for a lifting structure with a winch is currently being fabricated on the support structure.

Staff visited Dan-Ka Products and reviewed progress on the construction of the three-meter test modules and the various fixtures. The design report and briefing package were delivered on schedule. The 0.012-inch-thick, stainless-steel sheet was improperly shipped and is no longer flat. Dan-Ka has been forced to build a special fixture for stretching the sheets flat before assembly. Another delay occurred in bending the ring-frame from a straight box-beam. Although the same vendor who had successfully rolled the ring for a two-meter model was used, the three-meter rings which were delivered were badly warped. To alleviate this problem, Dan-Ka has had short sections rolled and will assemble them by welding at the shop. Researchers also requested some changes to Dan-Ka's double-membrane design; the calculations indicate a potential problem in stability and mounting with the original approach.

Staff visited Sandia, Livermore, to present information on SERI's analysis and testing of stretched membrane heliostats. SERI also plans to support Sandia's contract by presenting findings which impact designs at the meetings with contractors.

Analyses of structures for stretched membrane heliostats have assumed the membrane to be uniform and homogenous. Since metal sheeting is not available in great widths, mirror membranes will be made by joining relatively narrow sheets. The nature of these joints and their effect on the behavior of the membrane (especially on out-of-plane wind loading) are of concern. The two-meter-diameter, laminated mirror which was previously produced for SERI by Dan-Ka Products had exhibited faceting, with slope discon-

tinuities on the surface along the joint. Researchers again examined this mirror in detail for the probable cause of the faceting, if the joint was at fault and how to correct it in the three-meter design. Researchers think that the joint itself was not the cause. The Lexan layer had been added with large gaps where the joints are, and the gaps were later filled with a plastic resin. Rather, it appears that differential conditions in temperature during assembly had caused the slight faceting which was trapped permanently when the metal backing was applied. Researchers concluded that major changes in the joint itself were probably not necessary but that the procedure for fabricating the laminated model requires further study.

In support of the air-inflated, heliostat-support/drive subsystem, researchers have devised several combinations and arrangements for the restraining cables for trial on the scale models. They constructed two additional test-bed models of the air-inflated heliostat drive/mount so that various restraining arrangements for cables and concepts of bag construction can be examined. In preliminary trials, the new arranagement in the cables seems to overcome all the shortcomings of the original design with a minimum of complications in the mechanism for adjusting cables. Tests will be performed to measure stability and repeatability. Larger scale models are expected to be even more stable. The internal lifting pressure will go down with increased radius to keep the bag's tension within practical limits, but the area that the pressure acts against will increase with the square of the radius. Total lifting force and, therefore, cable tension will increase with the radius and thus make friction and random forces proportionately less important. Dr. Soni (Oklahoma State University) made his first visit to SERI in October to work on the air-inflated heliostat drive. Researchers reviewed the problems associated with the general design in central receiver systems and the heliostat drive/mount, in particular. Researchers studied the concept of the inflated drive/mount and looked at several of the proposed arrangements for restraining cables. They selected the inverted tripod for detailed study, and Dr. Soni made a videotape of the working scale-model in operation for reference at his offices in Oklahoma. A plan for the next stage of work was made, whereby Dr. Soni will analyze the mechanism, will formulate a general mathematical model, will attempt to characterize the control and the stability of the drive, and will suggest improvements. Journal and/or conference papers are anticipated.

Work continued on the SERI report entitled "The Optics of Flat-Mirror Vee-Troughs and of Right Circular Conical Reflectors." Most of the artwork has been done. The briefing package, "Assessment of Tensioned Membrane Technology for Solar Concentrators," has been printed for in-house distribution. An overview article, "Stretched Membrane Technology," giving the status of research and development on the stretched-membrane concept has been drafted. Artwork is currently being developed. This paper will eventually be submitted to the Journal of Solar Energy Engineering for publication and will serve as a current update on the technology for the program.

A preliminary work statement was negotiated with the University of Arizona supported by SAI for the innovative work on stretched membranes. Modules with polymer structural membranes and composite (wood/graphite fiber) support frames are being planned. These and other approaches may offer further significant reduction in cost/performance for the stretched membrane heliostats. Researchers will be evaluating the engineering and cost benefits of these approaches in the next year.

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

A conceptual design of a Direct Absorption Receiver and Thermal Storage System is being prepared for a cogeneration application. The receiver design is based upon a detailed computer run of the fluxes inside a typical cavity. The specific design for a 900° receiver was slightly less efficient (89 percent annual) than a 566° C nitrate salt receiver (91 percent annual) for a similarly sized field and slightly lower temperature. Analyses on the air-to-molten-salt heat exchanger indicates that a direct contact heat exchanger may be desirable.

Criteria for film stability were reviewed. Based on the expected size of DAR commercial applications and on published correlations, the falling molten carbonate salt film is anticipated to be stable for the larger receivers. There remains some question of stability in film for the smaller receivers—especially at high turn-down ratios (sunrise and sunset).

Three proposals were received for the fabrication of the 900°C molten salt loop. One proposal was acceptable, one proposal was unacceptable, and one proposal needed clarification to complete the evaluation. Questions to clarify one proposal and to give the unacceptable proposal an opportunity to rectify problems have been transmitted.

Bids on the long-lead items for the 900°C loop were received. While slightly higher than an original estimate, the bids are at expected levels. Placement of the orders for the long-lead items were held until selection of the subcontractor for the 900°C loop.

A leak check of the 500°C apparatus with water was performed at SERI's Field Test Laboratory Building (FTLB). No leaks were observed and plans are to make measurements of the flowing water film. A Safe Operating Plan for the 500°C apparatus has been prepared and approved by SERI's management. Detailed testing procedures are being prepared.

An in-tank valve design has been prepared for use with molten salt. The valve avoids problems of external leakage and has the potential to be less expensive and easier to repair than bellows valves. A prototype valve has been fabricated and will be tried on the 500°C molten salt apparatus. The in-tank valve design evolved from a delivery problem with a bellows valve. When the bellows valve is received, it will operate in series with the in-tank valve. The in-tank valve was tested with water. Although the valve and seat were lapped together, internal leakage was observed. The leakage was minor, and the valve performed well.

The stability of molten salt films to dry out conditions was calculated and was based on correlations in the literature and the available property data. For medium-to-large receivers (greater than 50 MW_t) no dry-out problems were indicated. For small receivers (10 MW_t) dry spots may occur when operating at turn down ratios of 3 to 1 or more (when operating at one-third to one-tenth the solar-noon, flow rate). The solution to the problem of dry-out may be to restrict the size of the receiver or to implement changes in design for small receivers. The available data are not reliable; the correlations show that scatter and property data (particularly the viscosity and the wetting angle) are not well known. Experimental measurements of flowing salt are needed and will be conducted with the 700°C loop. Following those experiments, additional studies will be needed.

The manifold assembly was welded to the finished Inconel 600 absorber. Water was flowed down the absorber surface and a smooth film was observed. Entrance region effects were observed, but did not extend beyond the predicted four-inch region.

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 con-

cept 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

The draft of a report entitled "Engineering Systems Analysis of a Hybrid Quantum/Thermal Process for Fuels and Chemicals Production" was completed and submitted to DOE Headquarters. The final deliverable on this task (FTP 463-84, program element 3, deliverable d) was thus met.

A draft of a paper entitled "Thermally Decoupled Combined Quantum Thermal Conversion of Solar Energy to Useful Work" was submitted for presentation at the 1985 Congress of the International Solar Energy Society.

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

Emphasis at both the Lawrence Berkeley Laboratory and the University of Hawaii is on collection of experimental data to characterize the decomposition of solids in direct flux. The following information summarizes current status on this research.

At the University of Hawaii, the experimental data collection for low-heating-rate decomposition concluded. The last series of low-heating-rate, experimental runs included experiments at 12.5°K/minute and 17.5°K/minute with a mixture of $ZnSO_4$/Avicel cellulose (1 to 1.85, mass ratio, dry basis). Preliminary evaluation of data shows a pronounced effect on thermal decomposition of zinc sulfate due to presence of cellulose char. Further analysis of data is needed in order precisely to quantify the effects of added char at low-heating rates.

The fabrication of the components of the MARK II Fast-TGA system is near completion. Data collection on rapid heating-rate decomposition will be starting in December.

At Lawrence Berkeley Laboratory, major emphasis is on continued data collection to characterize the optical and heat transfer phenomena occurring in the process of direct-radiant heating of particle suspensions. Status of the program was reviewed for SERI. A survey of reactions and products has been completed, although work will continue as needed to update and to refine information. Chemical emphasis has shifted to a study of the mechanisms to induce reactions. Researchers developed an analysis of heat transfer from particles to gas to arbitrary Knudsen numbers. Research has been initiated to define temperatures as a function of particle size, particle loading and gas flow rate in both cocurrent and countercurrent flow. That research is both experimental and theoretical. In addition, a basis has been formulated for the interaction of process subsystems to characterize the system performance for direct-radiant heating of reacting-particle suspensions.

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

Outlines for the two reports, "An Assessment of Instrumentation and Measurement Needs of the Solar Thermal Technology Program" and "Spectral Measurements at the Solar One Power Plant," were prepared with a schedule for their processing. Procedures for analyzing the data collected at Solar One were developed, and the data analyses were initiated. The analysis of the data collected at Solar One is nearly three-quarters complete. The extraction of spectral reflectance and spectral attenuation information has been achieved.

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

Ceramic Materials for High Temperature Receivers

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

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

good progress during this reporting period, and a semi-transparent solid can now be modeled successfully.

High-Temperature Window Materials

The ACTF test program on window materials produced several sets of thermal data useful for modeling. Since the emphasis in the program includes acquisition of fundamental understanding of the processes governing interaction of radiation and window materials, it was decided that time could be more productively spent in modeling than in testing during the hazy and cloudy period of the summer. The ACTF test program and thermal modeling activity have yielded data needed for definition of the service limits of Vycor, in accordance with program goals. The Monte Carlo modeling is considered to be particularly promising.

It has been demonstrated that borosilicate glass coatings on fused quartz windows give some degree of protection from devitrification. This meets a Milestone rescheduled for June as reported previously and justifies effort to optimize coatings on real windows. The coating development has produced a series of test coatings on flat window specimens, but optimization has not yet been achieved. The work is continuing with the objective of solar-testing a coated window during the current ACTF test program. Such a test will be conducted, although perhaps with a test window having less than optimum quality. Work on mosaic windows has resumed and will be closely coordinated with coating work in order to take advantage of common technology.

Direct-Flux Reactor

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

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

Spiral Concentrator

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

Surface Temperature Measurements in a High Solar Flux Environment

The draft of the topical report on "Performance Evaluation of Four-Wavelength Pyrometer" was completed.

Additional pyrometric observations were made on stainless steel and Inconel coupons to further assess the performance of the four-wavelength pyrometer. Coupons of aluminum, copper, Inconel, and stainless steel were instrumented with thermocouples for data collection with the four-wavelength pyrometer. Initial data sets have been acquired with these materials. These materials were chosen because corroborating thermocouple measurements can be obtained to assess the pyrometer performance.

The data acquisition and pyrometer control program was made more efficient. Data for one temperature estimate (four color) are now acquired in approximately 20 seconds. Furthermore, the sequence used to acquire the data was altered to provide better real-time, baseline corrections to the pyrometer readings.

ACTF Operations and Maintenance

The design of the declination counters has been completed, and 575 units are on order. The first re-aiming of the ACTF mirror field since late 1979 was undertaken and was completed. A modified aiming tool was used to accommodate the systematic error that exists in the location of the kinematic-motion moving point. It is theorized that this technique will reduce the westward drift of the two and one-half inches per hour for the system focus and thus will allow reduced dependence on the empirical tracking curve.

Summary

Emphasis has been on experimental research, especially using the ACTF. Activities have focused on materials behavior and on diagnostic instrumentation. The Direct Entrainment Reactor Task is phasing out. Most research is on or near schedule. The window research has resulted in a coating which inhibits fused quartz devitrification. Ceramics research is demonstrating an understanding of degradation mechanisms. The multispectral pyrometer has been shown to be an accurate instrument. Research will consolidate, refine, and expand these accomplishments. The Key Milestone "verify the temperature measurement accuracy of the multispectral (4 wavelength) solar blind pyrometric" was accomplished. A rescheduling of the Control Milestone "define the service limits for silica-based structural materials with respect to performance as a function of incident solar flux, temperature and atmospheric pressure" to December was submitted to DOE and was based on weather-imposed limitations on data collection at the ACTF.

University of Houston

Central Receiver Systems Analysis

Current work is aimed at optimizing the combined collector-receiver for Central Receiver Systems. A more efficient use of the data on shading and blocking makes it possible to find energy or power constrained optima in reasonable CPU time. Interception data are interpolated from two node files for two different heights of the tower. Approach is currently limited to flat panel or aperture receivers.

Liquid Jet Cooled Receiver

The construction of the liquid jet cooled receiver is nearing completion. The final elements of low-pressure welding of joints in the experimental apparatus have been completed. Researchers await the final hookup of the pump.

Chemical Storage of Energy

The exploration of vertical configurations for energy input Reactors I and II in the ammonium hydrogen sulfate system was carried out. Upward configuration tended to give slug flow; so the preferred configuration is downward, cocurrent flow. Results from Reactor I indicate that if space is an important consideration, a definite advantage exists in going to either a vertical-downflow configuration or a combination of horizontal and vertical down-flow configurations. Results from Reactor II indicate that the difference in lengths between the corresponding horizontal and vertical configurations is negligible. If space is an important factor, then the use of either a combination of horizontal and vertical downflow configurations or a vertical downflow configuration is possible. A combined Reactor I and II was also investigated. Work was started on the economics and the cost estimates by using Guthrie's method and cost indices of chemical engineering plant for three storage system sizes. For purposes of the cost estimates, the following cases have been selected.

Case	Energy Storage Capacity MW_th	Energy Withdrawal Rate MW_t
A	1000	125
B	300	30
C	2800	233.3

Quantitites of $SO_3(1)$, $NH_3(1) + H_2O(1)$ and AHS(1) in storage, the flow rates in the system, and the number of "Case B" recombination units have been determined. Prices of the chemicals used in the system have been obtained. Sizing calculations are in progress.

Photodegradation of Materials

Tests have been run at the GIT solar furnace on six separate material samples exposed to from 2 MW/m^2 to 5 MW/m^2 at 400°C and 500°C. Samples of nickel, diamond-like-coated Zr absorber, metallic decorated anodically oxidized aluminum absorber, and pure aluminum oxide ceramic were tested under exposures of up to three hours each. Significant photodegradation was observed in every sample tested as compared to equivalent samples tested in an infrared furnace. Preliminary analysis indicates an enhanced rate of oxidation for irradiated nickel, solar-induced fracture in Al_2O_3, and severe absorption degradation in the absorber coatings. Detailed analysis requiring further testing is in progress.

CO photodesorption has been observed from oxidized silicon with the spectral response of the desorption measured. The photodesorption threshold is observed at 2.6 eV, well below the band gap of SiO_2. Mechanisms are being proposed for this effort.

Photo-enhancement of the oxidation of nickel has been observed. An increase of 350 percent in the oxidation rate over that for oven-heated samples has been measured for nickel samples exposed to approximately 3.4 MW/m^2 solar irradiation at 400°C. The mechanism responsible is believed to be photo-enhanced dissociation of oxygen molecules. This is another strong example of the possibility of detrimental photo-effect under high-flux solar irradiation. Proposed new research on photo-enhanced catalysis will attempt to turn this detrimental effect into a beneficial enhancement of the rate of important chemical processes.

Heat Pipe Reactor Receiver

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

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

The schedule of Milestones required contracts for Cycle 1, Phase 2, to be placed in October. Contracts for Cycle 2, Phase 1, were to be placed in November. All negotiations continued on schedule with only a possible delay with Hughes Aircraft. The contract with Acurex for Cycle 1, Phase 2, was placed. It appears the Hughes Aircraft/ Company Contract will be placed in December; a rescheduling of the October milestone has been requested.

Four contracts for Cycle 2, Phase 1, research were placed in November:

- University of Arizona-Spectrally Selective Beam Splitters
- University of Chicago-Compound Optical Systems with Maximal Concentration for Solar Thermal Conversion.
- Southern Research Institute-Development of Novel Protective Coatings for Solar Reflectors
- Hughes Aircraft Company-New Ideas for Solar Thermal Conversion (Spectral Shifting Using Welsbach Effect)

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 second draft of the briefing package on "High-Temperature Materials for Solar Thermal Energy Systems Applications" has been completed and submitted to SERI's Solar Thermal Program Office. In addition, another extensive set of reviewers' comments and recommended changes was incorporated into the document.

Progress continued on the report on IPH ranking. A first draft of portions of Sections 2, 3, 5, and 6 has been completed. A package of the work which has been completed and an outline of the work which is still required (with suggestions for the content of the missing sections) have been prepared and given to a key SERI participant to aid in writing. Another former SERI staff member who was involved in the IPH ranking project has completed his review of the "System Description," and comments are being forwarded. He is also willing to help review the other sections.

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

Work continued on publishing the final report.

Purdue University

Work is progressing on publishing the final report.

Massachusetts Institute of Technology

A draft copy of the thesis for this work has been received and was forwarded to the DOE; that report completed the final deliverable on this subcontract. A process to close out the subcontract was initiated.

University of Utah

A final report was received. This report completed the Deliverables on this contract. Actions to close out the subcontract were initiated. The final report was submitted to SERI's Editing Department for publication and distribution as a SERI report.

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

ACTIVE FY84 SUBCONTRACTS USING FY83 FUNDS (Concluded)

	Subcontract	WBS Number	Procurement Title/Activity	Value (000$)	Type Business
(8)	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
(9)	University of Arizona	2.0	Fabrication and evaluation of graphite fiber composite solar concentrators	30.0	University
(10)	Georgia Institute of Technology	2.0	Spiral concentrating collector	10.0	University
(11)	Acurex Solar, Inc.	2.0	Low-cost, lightweight silver/ metal reflector module development	11.0	Solar thermal industrial firm
(12)	DAN-KA Products	2.0	Design and fabrication of two scale-model stretched membrane reflector modules	110.0	Solar thermal industrial firm

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS

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

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS

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

ACTIVE FY84 SUBCONTRACTS USING FY84 FUNDS (Concluded)

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(15)	Consulting Agreement with Mr. Conrad M. Vineyard	1.0	Solar thermal technology cost estimation technical support	10.0	Consulting Agreement
(16)	Consulting Agreement with Mr. George M. Kaplan	1.0	STT Research Program planning, technical review of reports, and identification, evaluation and exploitation of R&D funded by other Federal agencies	10.0	Consulting Agreement
(17)	Consulting Agreement with Dr. A. H. Soni (Oklahoma State University)	2.0	Analysis and design of adjustable cable restraints for air-inflated heliostat drive/support	10.0	Consulting Agreement
(18)	Acurex Solar Corporation		Holographic Solar Concentrator	205,677	Industrial Firm
(19)	University of Arizona		Spectrally selective beam splitters applied to thermally decoupled combined quantum/thermal conversion in concentrating solar systems	69,474	Educational Institution
(20)	Southern Research Institute		Development of novel, protective coatings for solar reflectors	68,324	Not-for-profit Corporation
(21)	Hughes Aircraft Company		New ideas for solar thermal conversion	58,936	Large business
(22)	University of Chicago		Compound optical systems with maximal concentration for solar thermal conversion	77,127	Educational Institution

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

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

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

	Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business
(6)	Hughes Aircraft Company		Thermoelectrochemical (Tech) Convertor Research-Phase II	221,701	Industrial Firm
(7)	University of New Hamphsire		Solar Photochemical Production of Fuels and Chemicals	56,000	Educational Institution
(8)	To be determined		To be determined	To be determined ($75-100,000)	Historical Black College or University

APPENDIX B

RESOURCE EXPENDITURE

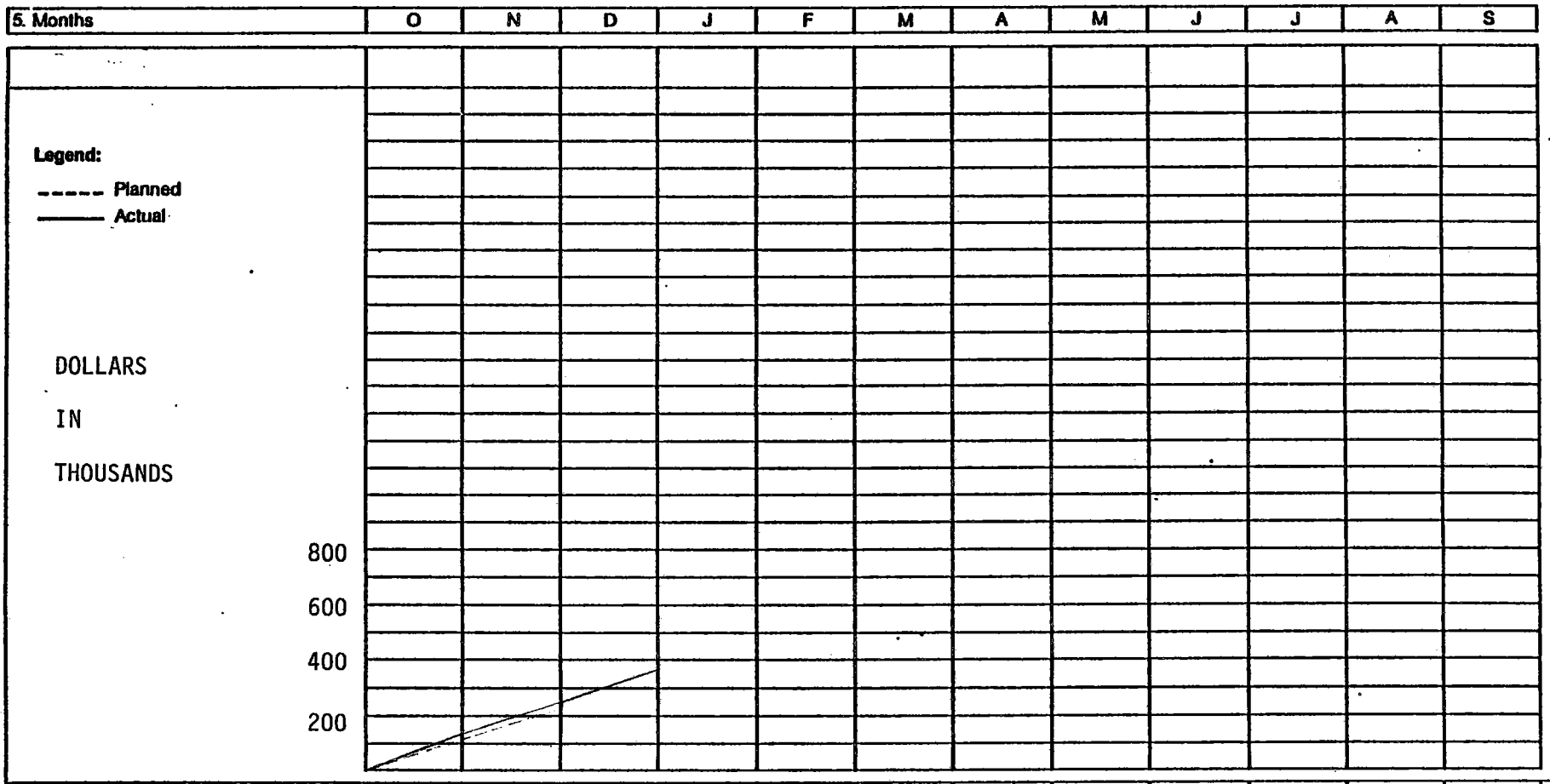
BUDGET STATUS

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: PROGRAM TOTAL	

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	FY 85
Cost Status																Cost Plan Date 12/10/84
THOUSANDS OF DOLLARS (14000 … 0)																Planned Costs Prior FY 84: 5,406
																Actual Costs Prior FY 84: 4,473
																Total Estimated Costs for FY85: 2,829
S&R Numbers EB23																Total Contract Value: 14,987
																Unfilled Orders Outstanding: 571
Accrued Costs — Planned	507	1055	1594	1934	2172	2305	2408	2495	2578	2661	2744	2829				Estimate for Subsequent Reporting Period
Accrued Costs — Actual	458	969														
Accrued Costs — Variance	49	37														
Accrued Costs — Cum. Variance	49	86														

Obligational Ceiling — Actual
Costs Plus Commitments — Plan

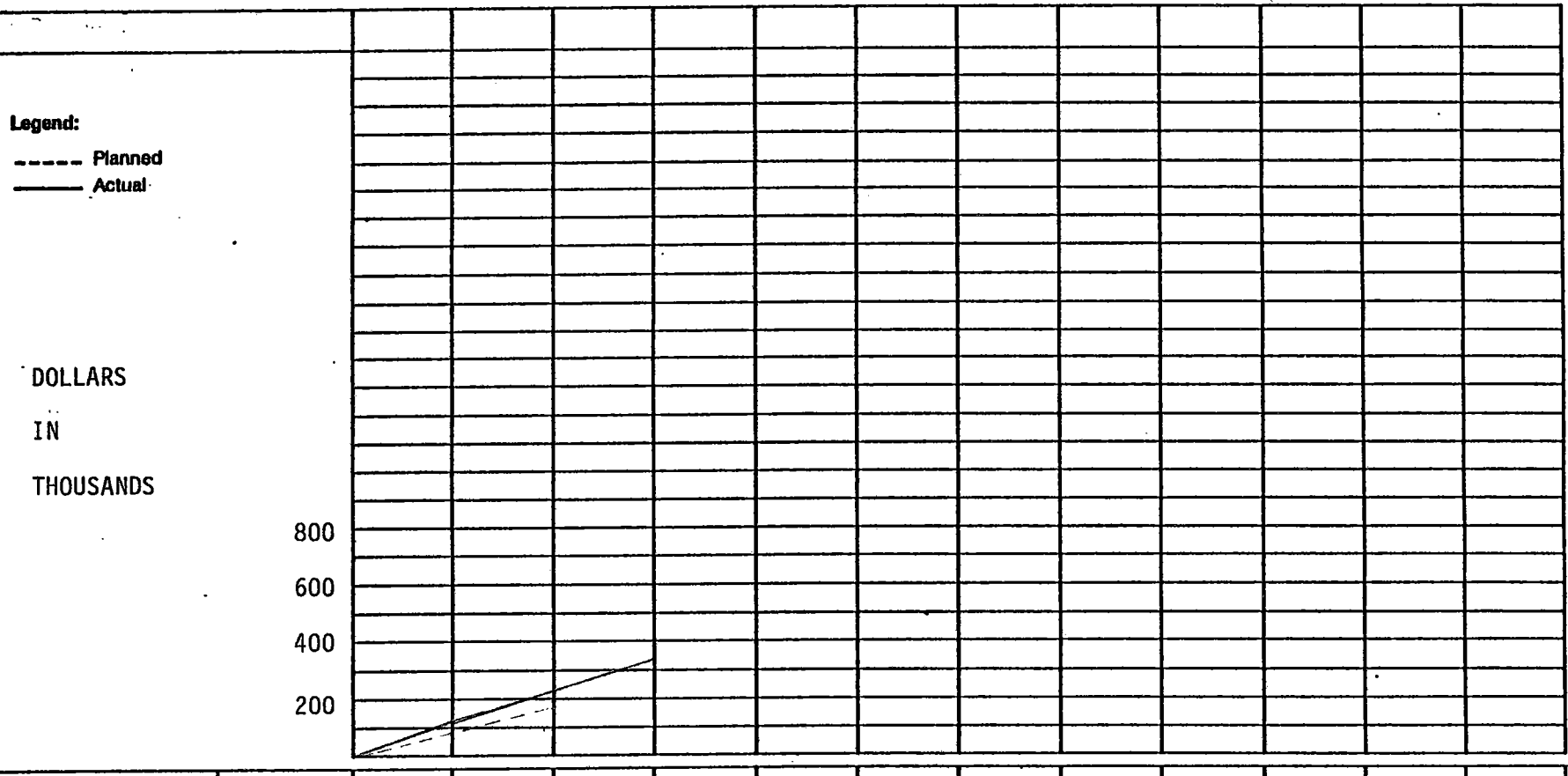
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 1.0 High Temperature Materials	



Accrued Costs	Planned	130.1	137.1	116.6									Planned
	Actual	118.5	132.5										Actual
		11.6	4.6										

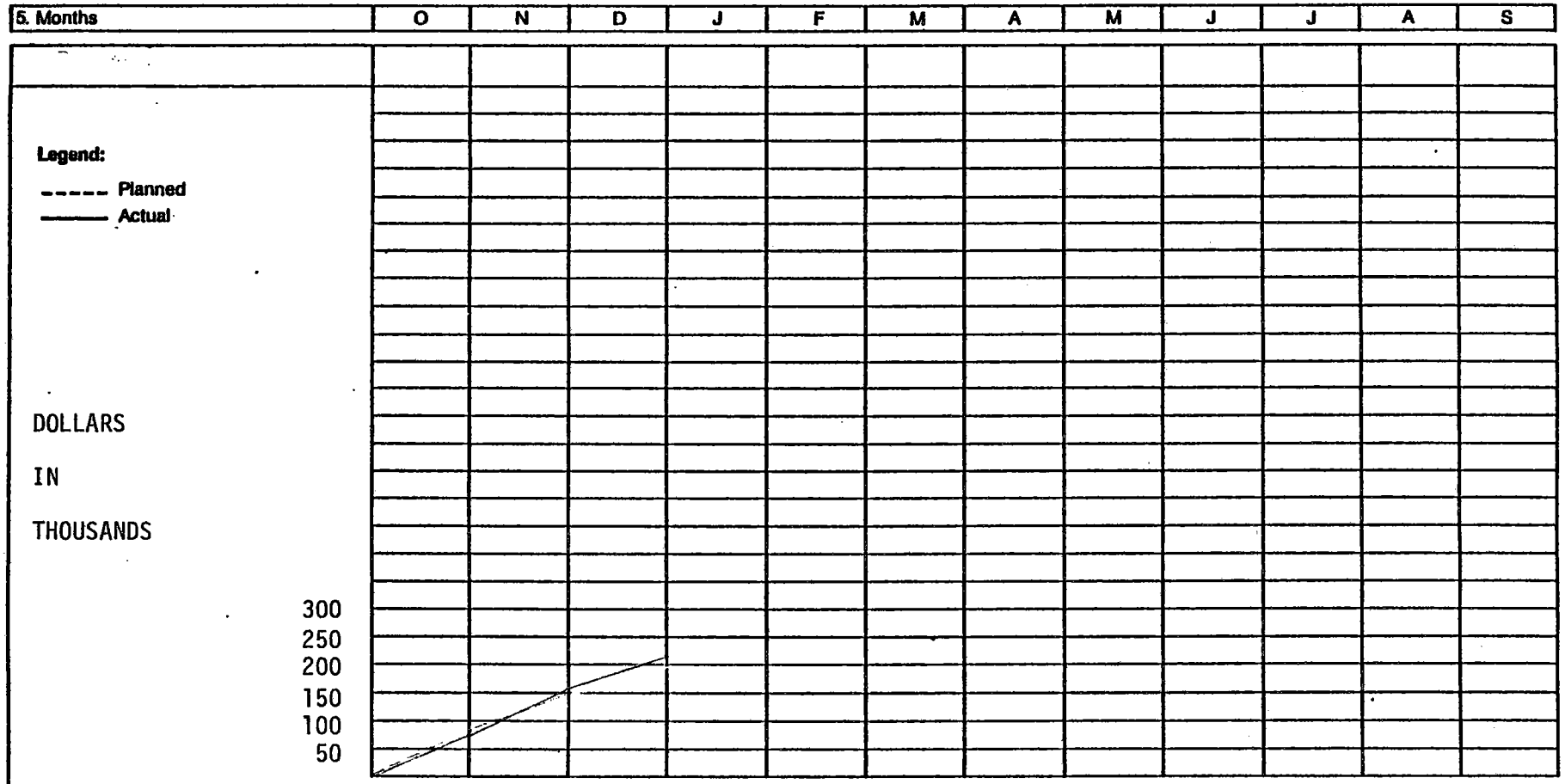
1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 2.0 Reflector Materials	

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



Accrued Costs	Planned	111.7	110.1	104.7										Planned
	Actual	89.6	91.8											Actual
		22.1	18.3											

1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 3.0 Thermal Science Research	



Accrued Costs	Planned	73.4	82.6	61.0										Planned
	Actual	73.8	78.8											Actual
		- .4	3.8											

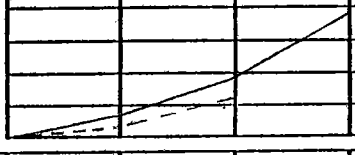
1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 4.0 Photochemical/Thermochemical Research	

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

Legend:
----- Planned
——— Actual

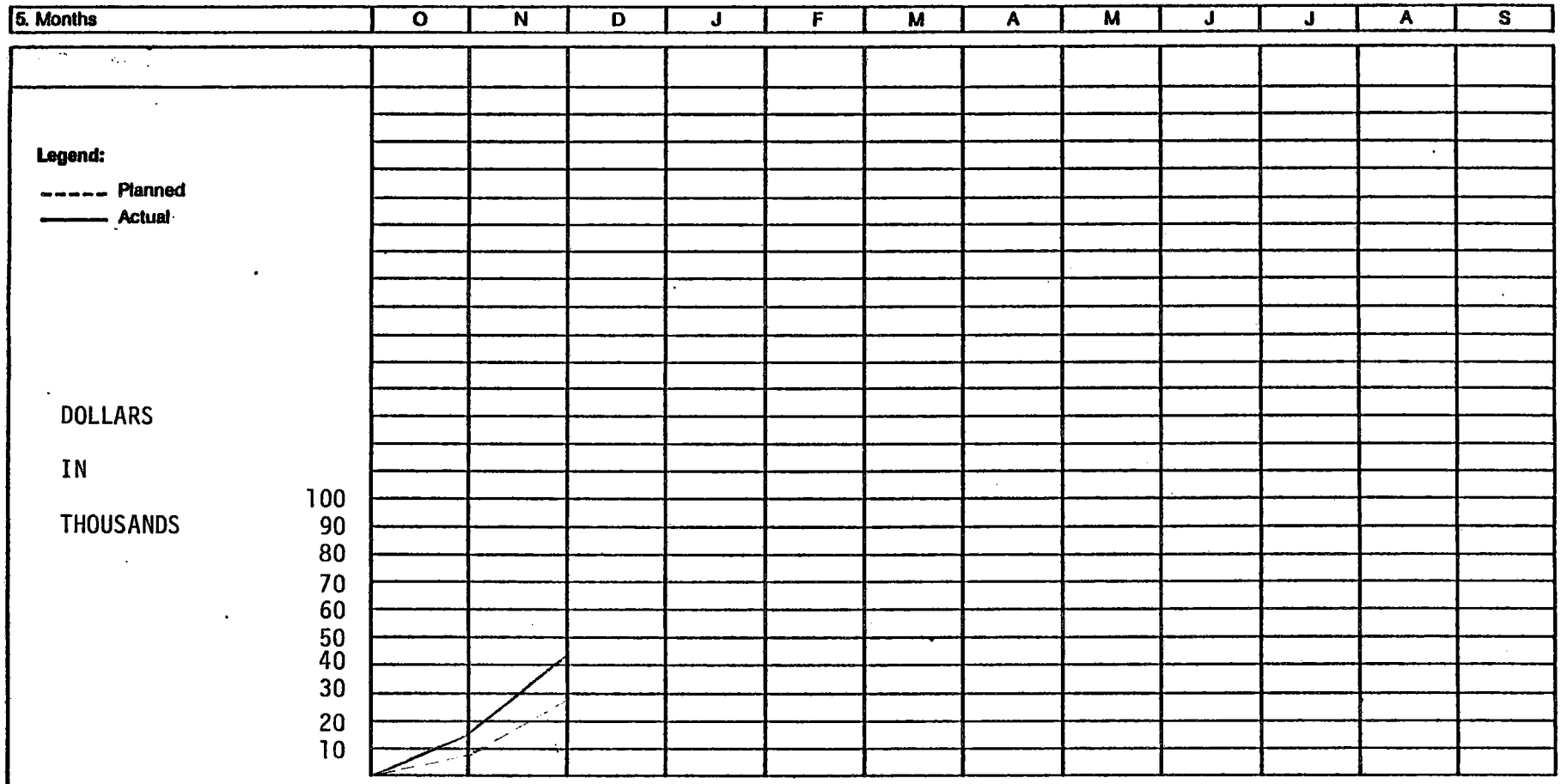
DOLLARS IN THOUSANDS

30
25
20
15
10
5



Accrued Costs	Planned	3.3	6.4	9.9										Planned
	Actual	1.4	4.8											Actual
		1.9	1.6											

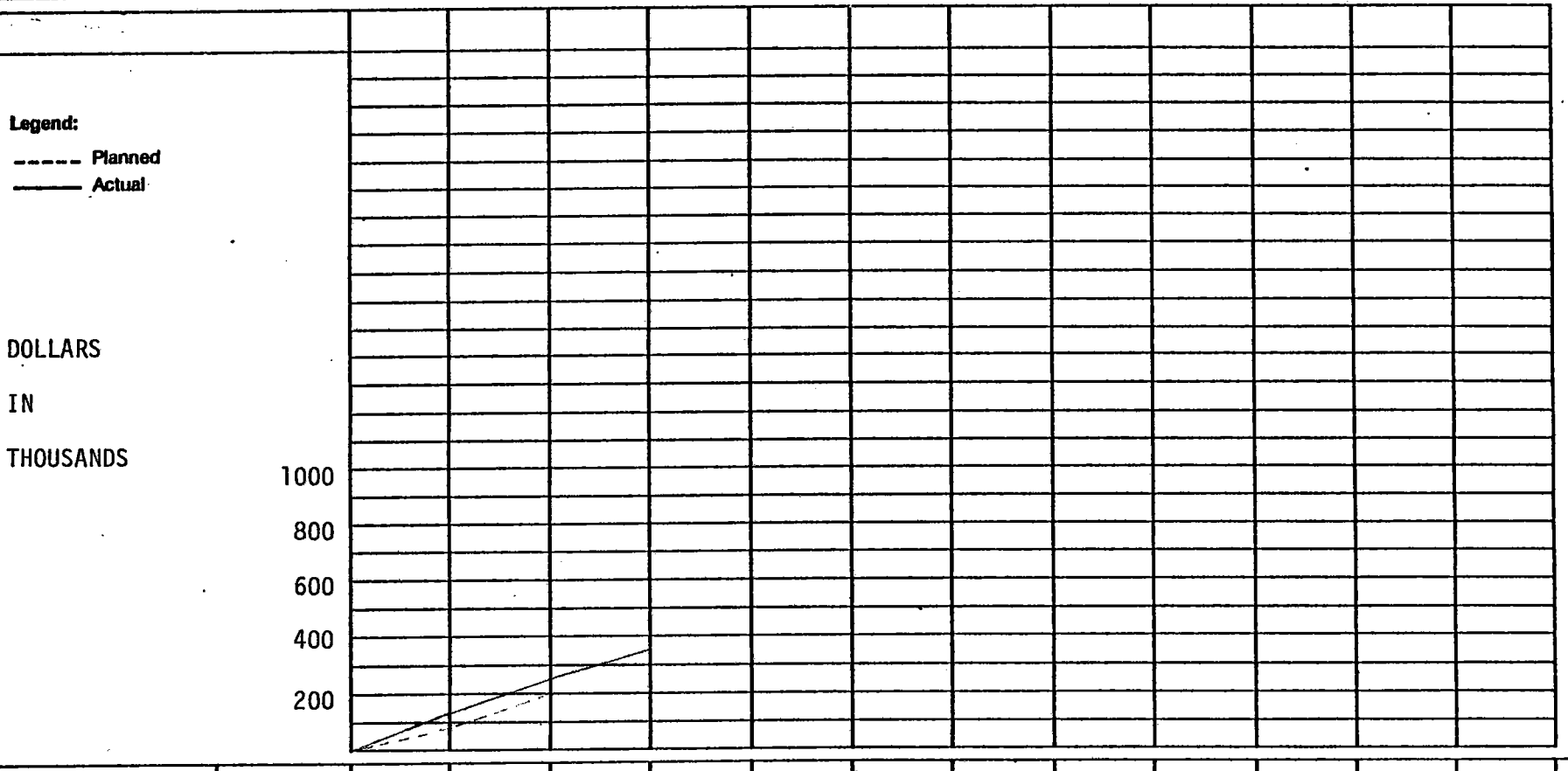
1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 5.0 Instrumentation and Measurement	



Accrued Costs	Planned	15.4	30.1	10.5										Planned
	Actual	8.4	21.0											Actual
		7.0	9.1											

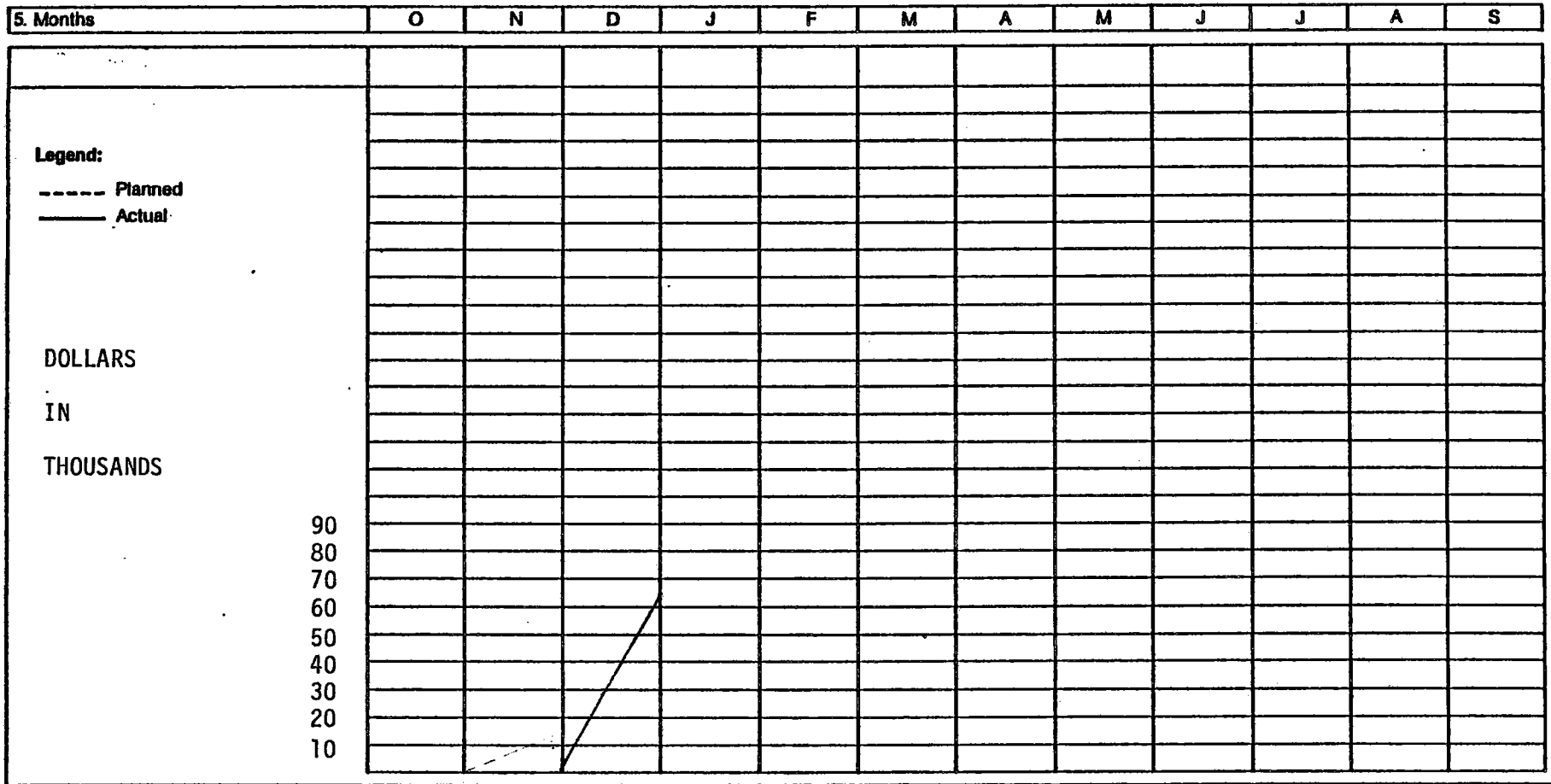
1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 6.0 University Research	

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



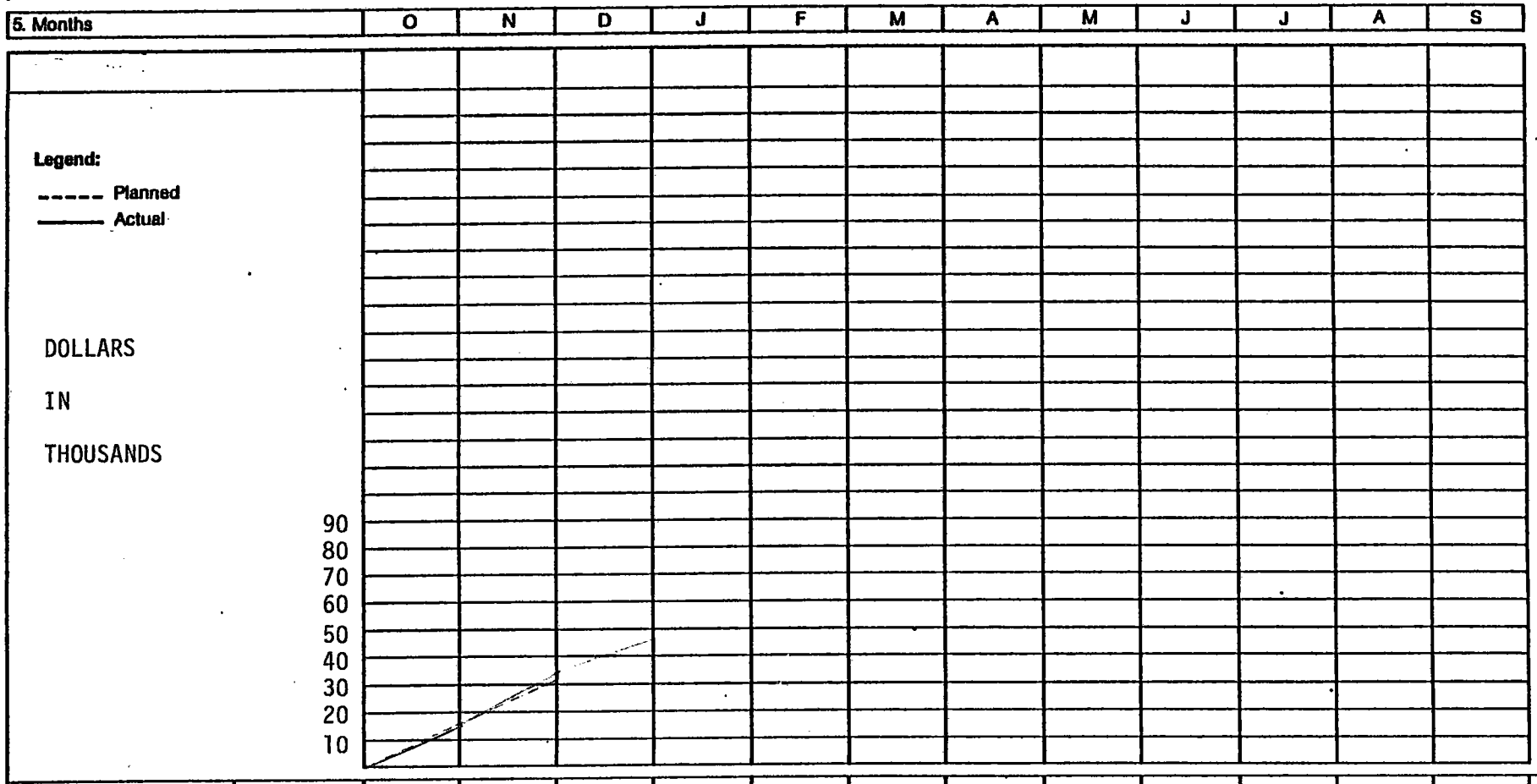
Accrued Costs	Planned	124.2	118.8	110.4									Planned
	Actual	95.1	105.7										Actual
		29.1	13.1										

1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 7.0 Innovative Concepts Research	



		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	Planned	0	0	66.3										Planned
	Actual		16.8											Actual
			-16.8											

1. Contractor (name and address)	Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	2. Reporting Period From: 10/1/84 To: 9/31/85
3. Program Identification	Fiscal Year 1985 STT Research Program	
4. WPA/Task	Program Element 8.0 Planning and Assessment	

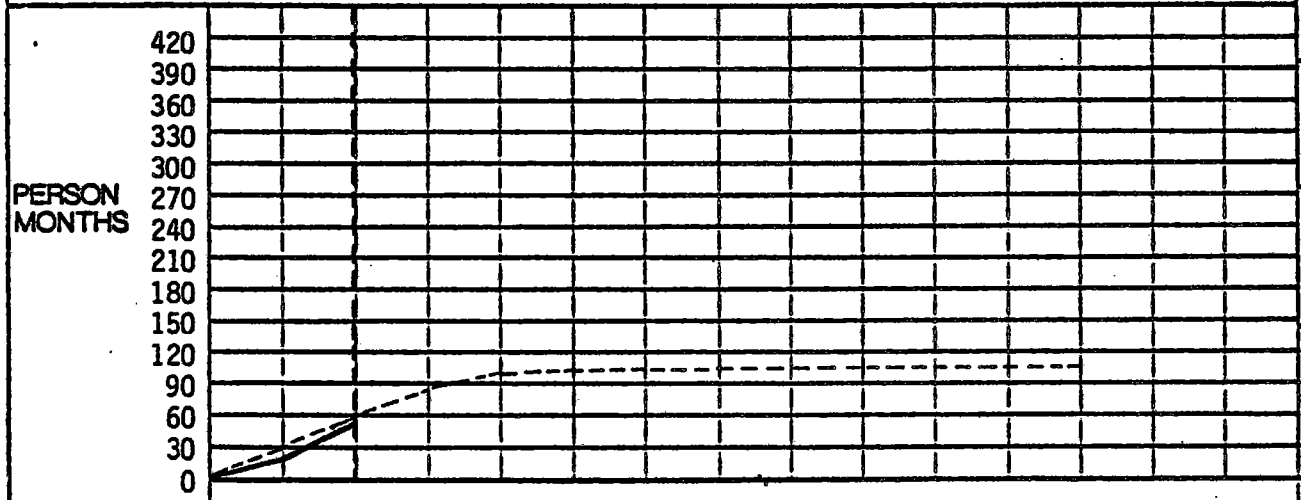


		O	N	D	J	F	M	A	M	J	J	A	S	
Accrued Costs	Planned	15.8	17.7	13.9										Planned
	Actual	16.0	16.1											Actual
		- .2	1.6											

MANPOWER STATUS

FISCAL YEAR 1985

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	FY 85
Manpower Status (Direct Labor)																
Planned	30	60	87	103	108	109	109	109	109	109	109	109				
Actual	27	56														
Variance	3	4														



Manpower Plan Date 12/10/84

Planned Manpower Prior FY 84: 339

Actual Manpower Prior FY 84: 309

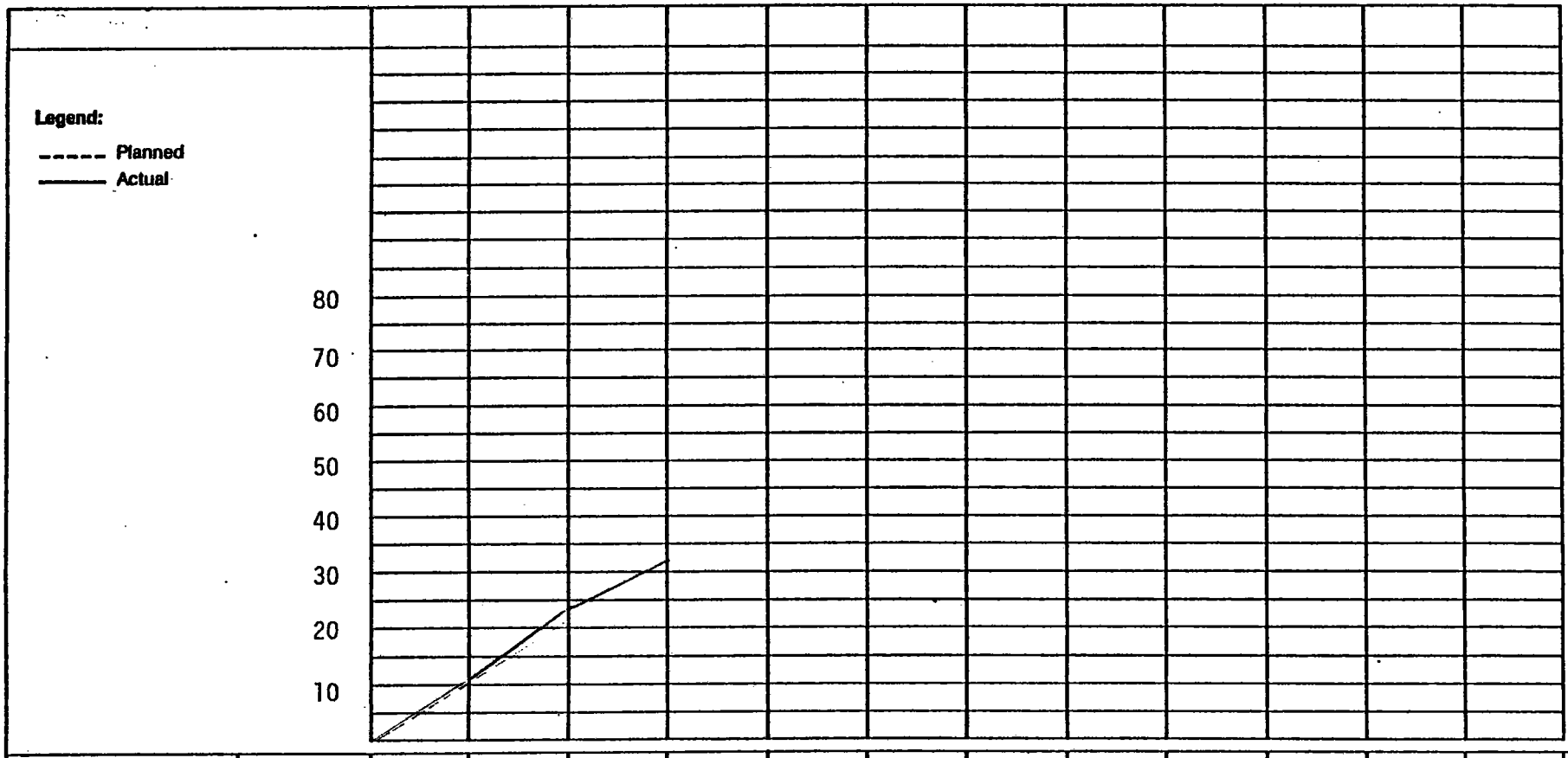
Total Estimated Manpower for FY85: 109

Total Contract Manpower: 365

Obligational Ceiling
Costs Plus Commitments
Actual
Plan

Manpower

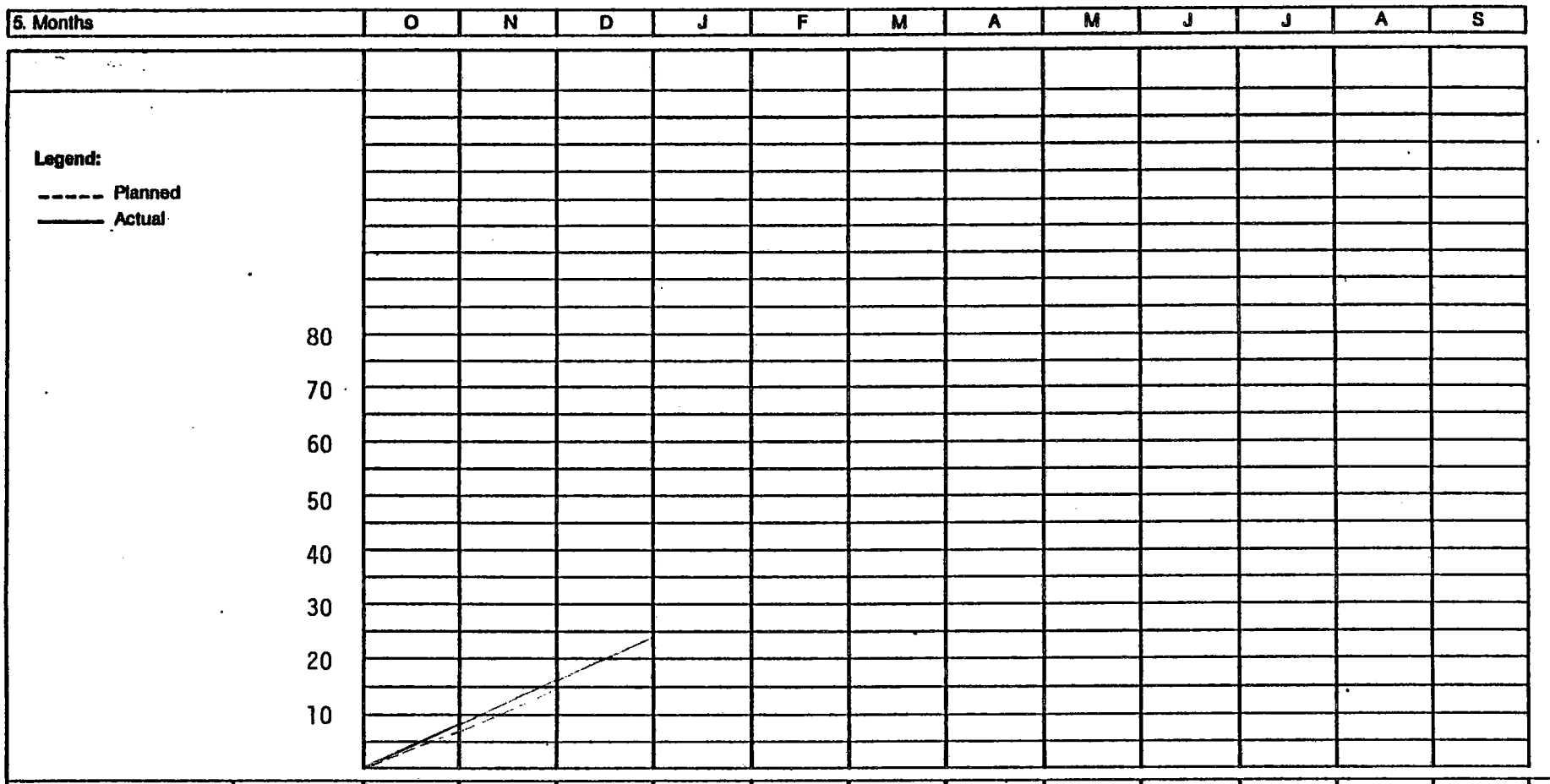
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 1.0 High Temperature Materials	



	O	N	D	J	F	M	A	M	J	J	A	S	
Planned	11.6	12.3	9.5										Planned
Actual	10.73	11.8											Actual

Manpower

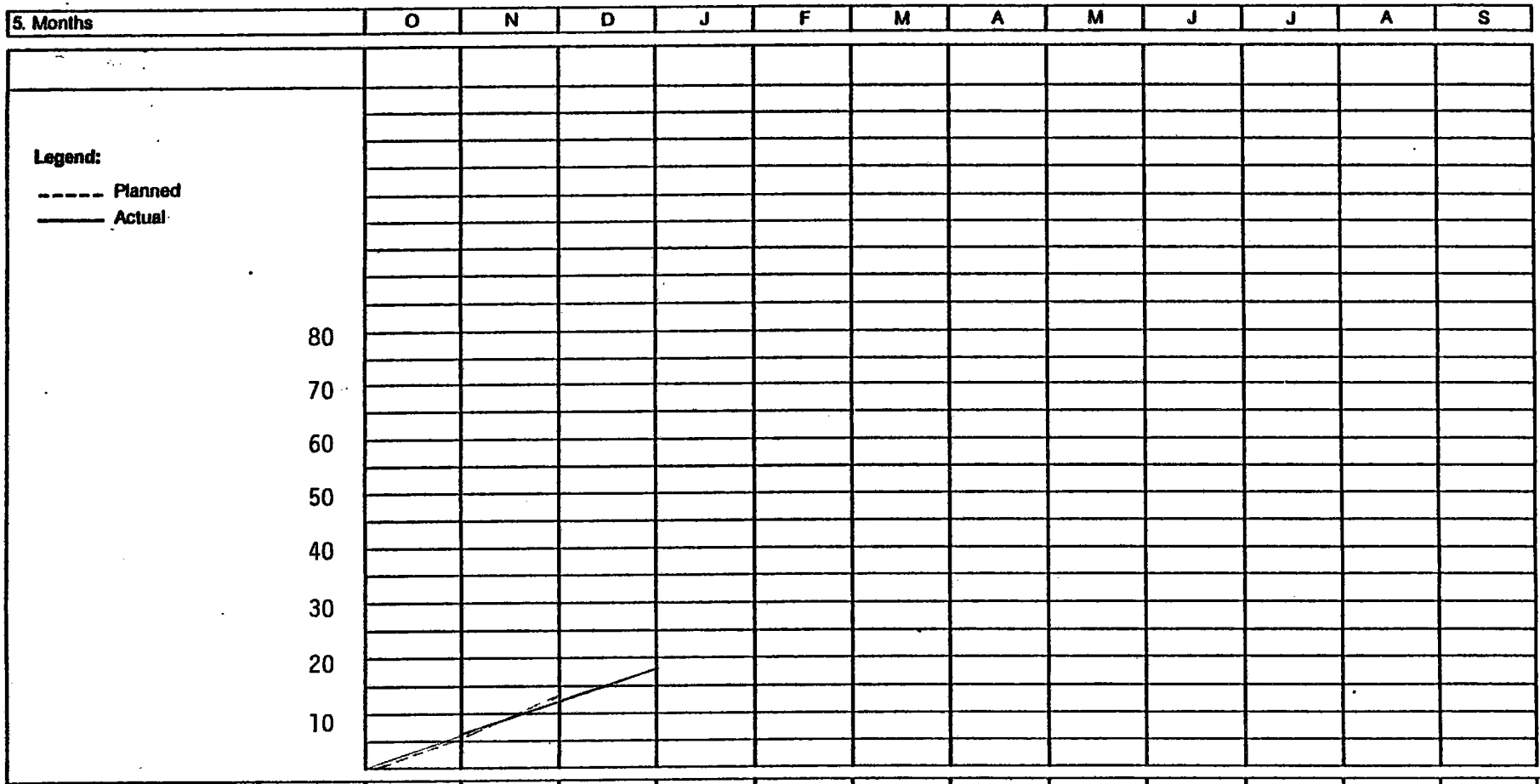
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 2.0 Reflector Materials	



	Planned	8.6	8.3	8.1										Planned
	Actual	7.7	7.8											Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 3.0 Thermal Science Research	



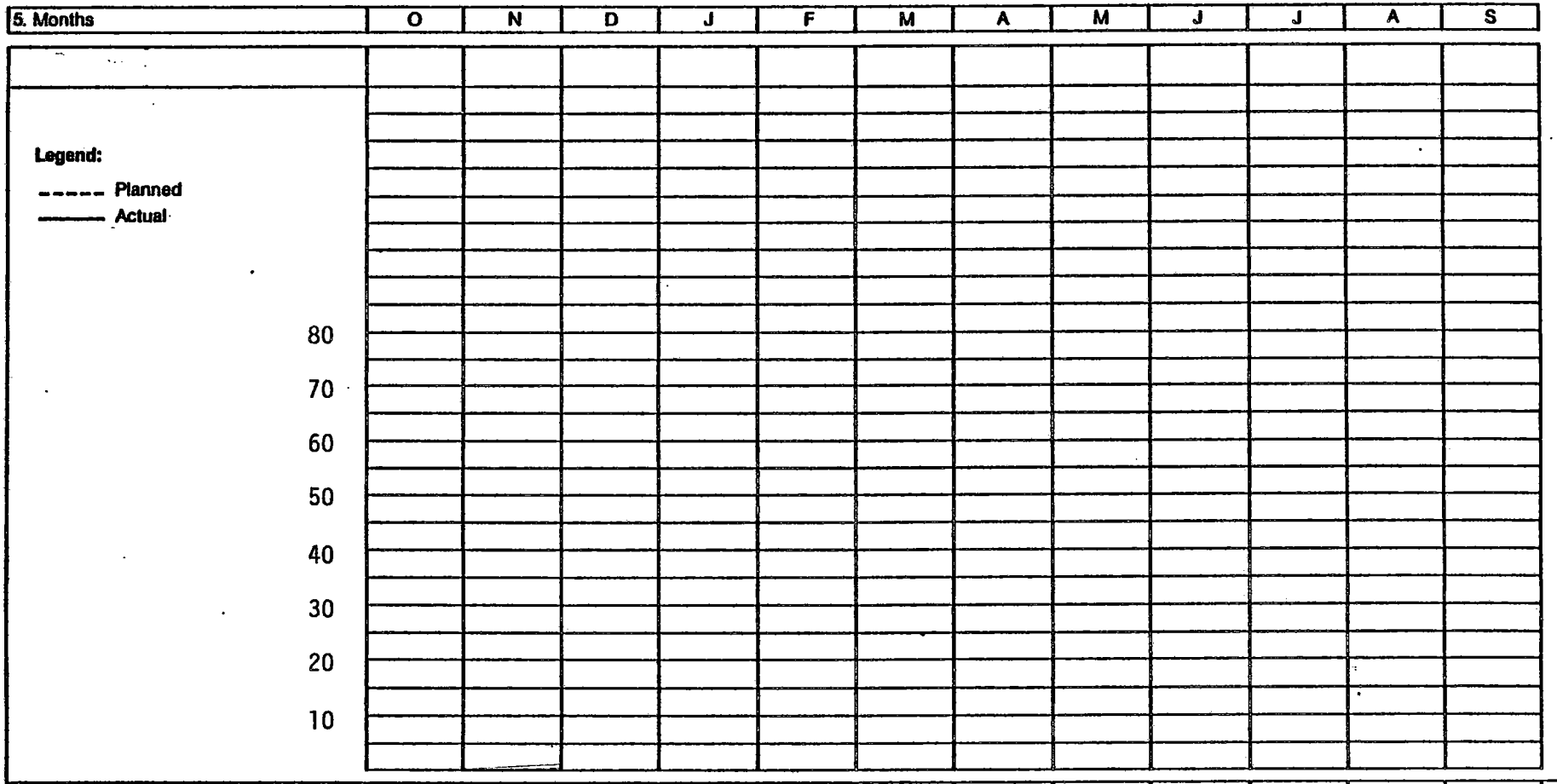
		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	6.9	6.9	6.2										Planned
	Actual	6.9	7.2											Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85

3. Program Identification: Fiscal Year 1985 STT Research Program

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



		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	0	0.5	0										Planned
	Actual	0	0.5											Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 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

Legend:

------ Planned

——— Actual

80

70

60

50

40

30

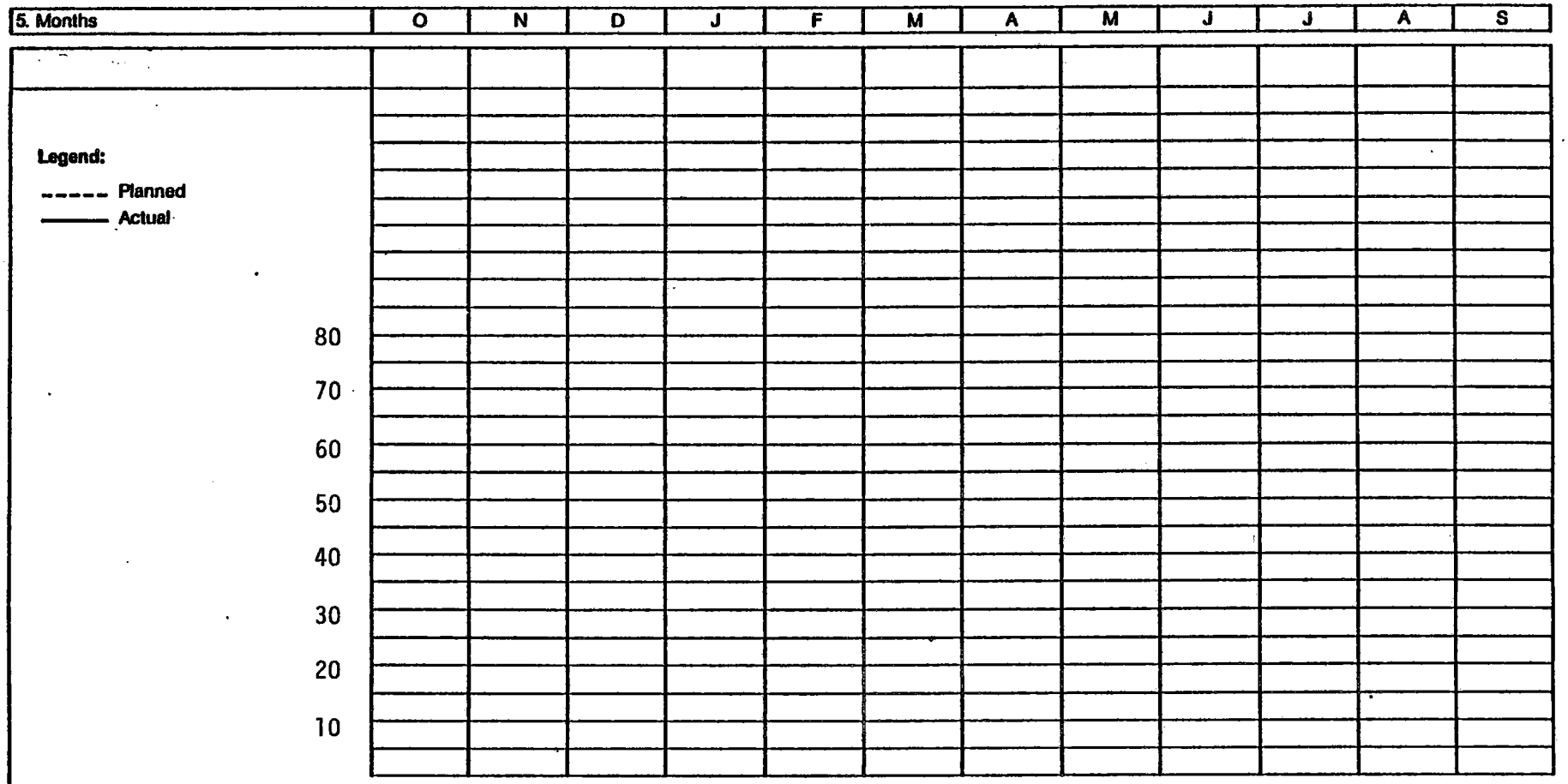
20

10

Planned	1.3	0.8	0										Planned
Actual	.27	.7											Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 6.0 University Research	



	Planned	0	0	0									Planned
	Actual	0	0										Actual

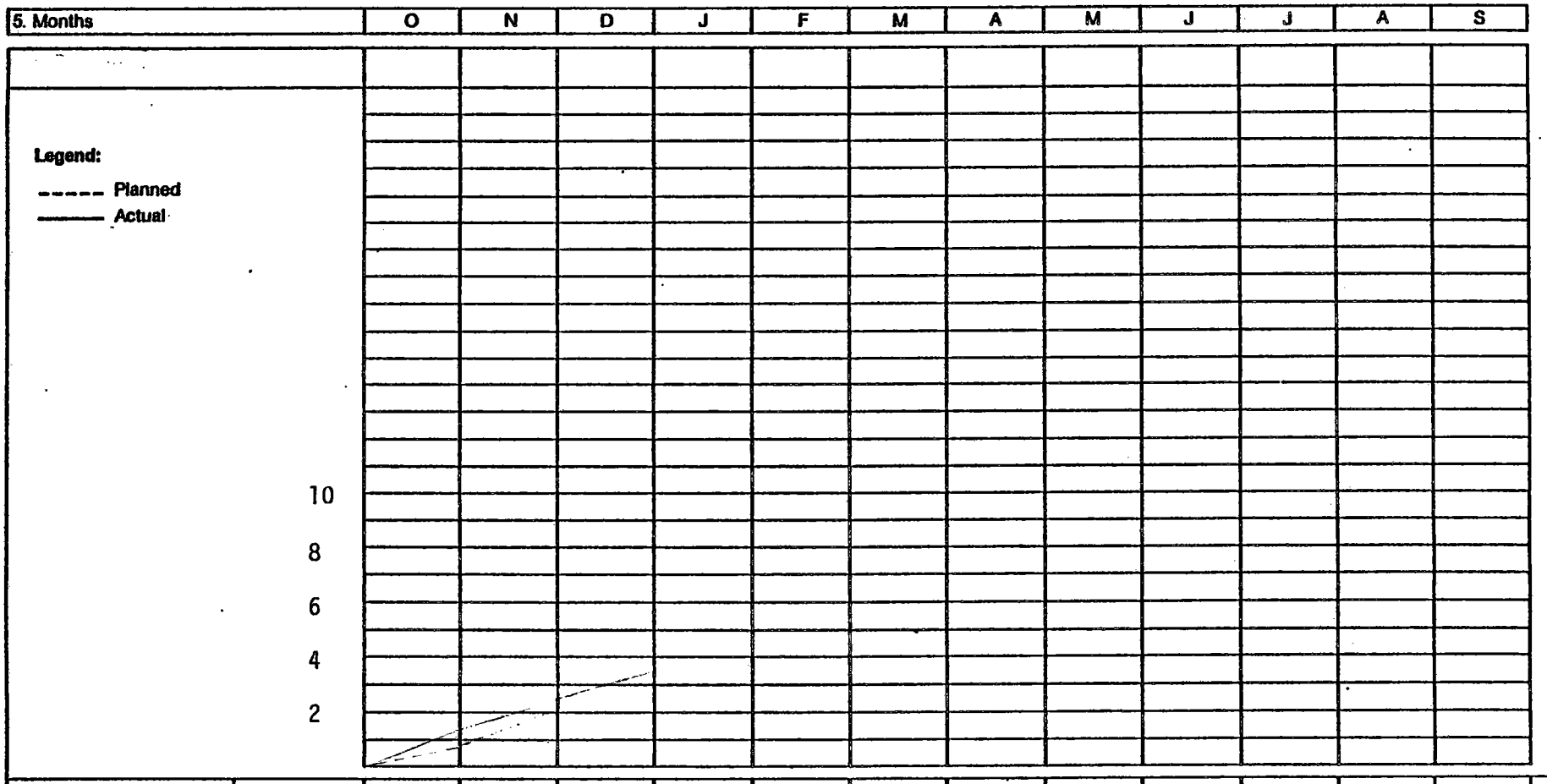
Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute **1617 Cole Boulevard** **Golden, Colorado 80401**	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 7.0 Innovative Concepts	

5. Months	O	N	D	J	F	M	A	M	J	J	A	S	
Legend: ----- Planned ——— Actual													
80													
70													
60													
50													
40													
30													
20													
10													
	Planned	0	0	0									Planned
	Actual	0	0										Actual

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To: 9/31/85
3. Program Identification: Fiscal Year 1985 STT Research Program	
4. WPA/Task: Program Element 8.0 Planning and Assessment	



		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	1.2	1.2	1.1										Planned
	Actual	.89	1.3											Actual

SERI

SOLAR THERMAL ENERGY PROGRAM

PUBLICATIONS

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

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

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

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

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

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

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

Coyle, R. T., Thomas, T. M., and Schissel, P. (In Progress) The Corrosion of Material in Molten Alkali Carbonate Salt at 900°C: FY 1984 Progress Report. SERI/PR-255-2553. Golden, CO: Solar Energy Research Institute.

Coyle, R. T., Thomas, T. M., and Schissel, P. (In Progress). The Corrosion of Selected Alloys in Eutectic Lithium-Sodium-Potassium Carbonate at 900°C. SERI/TR-255-2561. Golden, CO: Solar Energy Research Institute.

DeLaquil, P.; Anderson, J. V. (In Press) The Performance of High-Temperature Central Receiver Systems. SERI/TP-253-2560. (Joint Project: Sandia and SERI) Sandia National Laboratories.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Murphy, L. M. (In Progress) Stretched Membrane Heliostat Technology, SERI/TPJ-253-2500, Golden, CO: Solar Energy Research Institute.

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

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

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

Pearson, J. and Chen, B. (In Progress) An Assessment of Heliostat Control System Methods. SERI/TR-253-2390. Golden, CO: Solar Energy Research Institute.

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MILESTONE SCHEDULE

1. Contract Identification	2. Reporting Period	3. Contract Number
5.0 Solar Thermal Energy	November 1 through 30, 1984	DE-AC02-83CH10093

4. Contractor (name, address)	5. Contract Start Date	6. Contract Completion Date
Midwest Research Institute Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	10-01-83	09-30-88

7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months																						10. Percent Complete	
		FY85												FY86						FY87				FY 88	
FTP		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Q2	Q3	Q4	Q1	Q2	Q3	Q4	88	a) Planned / b) Actual
463	SOLAR THERMAL ENERGY SYSTEMS																								
	1.0 High-Temperature Materials			C V			E V																		
	2.0 Reflector Materials																								
		CW					V																		
				X								C													
	3.0 Thermal Science Research																								
	4.0 Thermochemical and Photochemical Research																								
	5.0 High-Temperature Measurement																								
		C																							
	6.0 University Research																								
						B		V																	
				F																					
	7.0 Innovative Concepts Program																								
		E																							
	8.0 Planning & Assessment																								

MILESTONE SCHEDULE

Task
Program Element 1.0: High Temperature Material
1.A. Complete preparation and check-out of procedures for measuring chemical stability and corrosiveness of thermal fluids at temperature to 900° C. (C)
1.B. Provide a materials data package for the selection of materials to be used in molten salt test-loop apparatus. (C)
1.C. Complete fabrication and check-out of an apparatus for measuring the hemispherical, normal-normal absorptance of ceramics at 700° C. (C)
1.D. Complete weight loss measurement and electron microscopic examination of selected ceramics candidates exposed to carbonate salts at temperatures in the range of 600° C-900° C. (K)
1.E. Complete hemishperical, normal-normal absorptance and transmittance measurements of molten salts with chromophores ("Blackeners") at temperatures up to 700° C. (C)
1.F. Show experimentally the mechanical and chemical stability of a thermal fluid/-containment combination for a period of 30 days at temperatures up to 900° C.
1.U. Complete a preliminary technical performance and economic assessment of a baseline DARTS systems. (K)
1.V. Complete a technical and economic comparison between the stretched membrane and second generation glass/metal heliostat concepts. (C)
Program Element 2.0: Reflector Materials
2.A. Identify sputtered silver polymers showing long life potential. (K)
2.B. Complete the identification of chemical and physical phenomena causing the degradation of silver PMMA. (C)
2.C. Evaluate and improve the surface durability of the 3M Company silver/polymer film at 3M and recommend processes to improve adhesion. (C)
2.D. Complete identification of chemical degradation reactions of silvered polymers, including UV effects to provide basis for specifying composition and process for new products. (C)
2.U. Complete study of lamination processes and complete fabrication of two-meter diameter variable focus stretched membrane module to verify processes chosen. (C)

MILESTONE SCHEDULE (Continued)

Task
Program Element 2.0: Reflector Materials (Continued)
2.V. Complete establishment of membrane/frame coupling concept and complete fabrication of three-meter diameter variable focus stretched membrane module to verify concept selected.(K)
2.W. Complete preliminary surface deformation and tension load characterization of two-meter diameter stretched membrane module at SERI. (C)
2.X. Complete structural response characterization (stability, and surface deformation caused by tension, upper imperfections and simulated lateral loading effects) of the three-meter diameter stretched membrane/frame coupled module at SERI. - (C)
Program Element 3.0: Thermal Science Research
3.A. Complete a preliminary analysis of receiver film temperature profiles based on a mathematical model for both laminar and turbulent flows. (C)
3.B. Complete design review of molten salt test apparatus. (C)
3.C. Complete checkout runs of mathematical model of the molten salt direct absorption process. (C)
3.D. Complete construction and checkout of molten salt test loop. (C)
3.E. Complete tests on heat transfer and flow characteristics of molten salts at ACTF (Second Quarter FY86). (C)
3.F. Complete analysis of experimental data and correlation with mathematical model to establish receiver design criteria (Fourth Quarter FY 86)
3.U Publish proceedings of 1983 conference. (C)
3.V. Complete a thermodynamic assessment of coupled and decoupled systems. (C)
3.W Complete technical and economic assessments of one hybrid system with good potential conversion efficiency. (C)
3.X. Experimentally determine the H_2 yield of two photoconversion systems for water splitting at 10 suns. (C)

MILESTONE SCHEDULE (Continued)

Task
Program Element 4.0: Thermochemical and Photochemical Research
4.A Complete draft program plan for exploring the potential of concentrated solar flux. (K)
Program Element 5.0: High Temperature Measurement
5.A. Complete Preliminary Assessment to identify and rank instrumentation and measurement (I and M) needs to the STT Program. Define two of the highest priority needs and complete recommended action plan to address then. (K)
5.B. Complete study of I and M near-term, intermediate term, and long-term needs of STT Program. Include ranking by priorities and input to the research multiyear program plan. (C)
5.C. Complete initial measurements of one high priority, near-term I and M need at Solar One. (C)
Program Element 6.0: University Research
6.A. Complete the optimization of boron/silicon ratio and laboratory furnace tests for inhibiting window devitrification. (K)
6.B. Define the service limits for silica based structural materials with respect to performance as a function of incident solar flux, temperature, and atmospheric pressure. (C)
6.C. Verify the temperature measurement accuracy of the multispectral (4 wavelength) solar blind pyrometer. (K)
6.U. Complete the photocorrosion studies of Al_2O_3 ceramic. (K)
6.V. Operate the multijet test unit at UH to verify performance meets design specification. (C)
6.W. Operate the solar chemical heat pipe under cyclic conditions to provide data to validate and to improve the mathematical model. (C)
Program Element 7.0: Innovative Concepts Program
7.A. DOE/SAN award of twelve Innovative Research Subcontracts. (C)
7.B. Discussion of selected concepts at Research Workshop. (C)
7.C. Inititate process for "new ideas" solicitation focused on direct solar flux effects. (K)

MILESTONE SCHEDULE (Continued)

Task
Program Element 7.0: Innovative Concepts Program (Continued)
7.D. Complete evaluation of the results of the 12 subcontracts awarded in the FY 1983 Phase I program to identify two or three for additional Phase II support. (K)
7.E. Award of two or three research subcontract recommended in D above. (C)
7.F. Award of "new ideas" subcontract focused on direct concentrated solar flux effects research. (K)
7.G. Initiate process for "new ideas" solicitation repeated in FY85. (C)
7.H. Evaluation and recommendation for future work on few of the research concepts initiated in F above. (C)
7.I. Award of "new ideas" subcontracts as a result of solicitation in G above. (C)
Program Element 8.0: Planning and Assessment
8.A. Complete assessment of technical and economic feasibility of enclosed thermal dishes. (C)
8.B. Complete preliminary assessment of previous SNLL high temperature thermal system studies and other current studies. (C)
8.C. Complete preliminary analysis of high solar flux research needs and value. (C)

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BI-MONTHLY STATUS REPORT

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