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SERI/MR-251-1471 February/March

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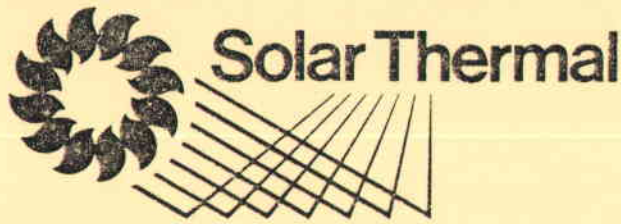
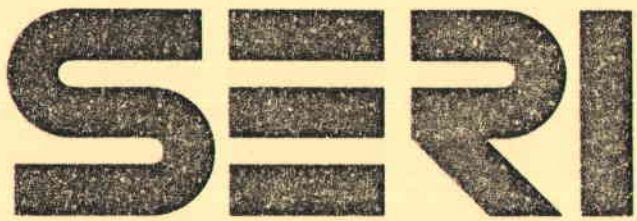


Solar Thermal Research Program

Status Report

February 1985
March 1985

Issued April 18, 1985



Solar Energy Research Institute
A Division of Midwest Research Institute

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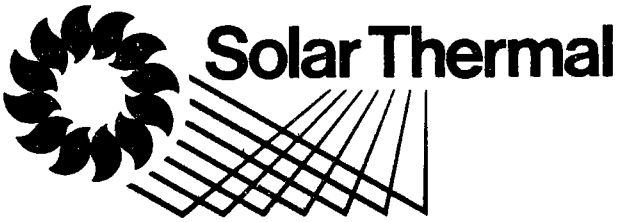
SERI/MR-251-1471 February/March



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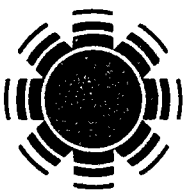

SERI

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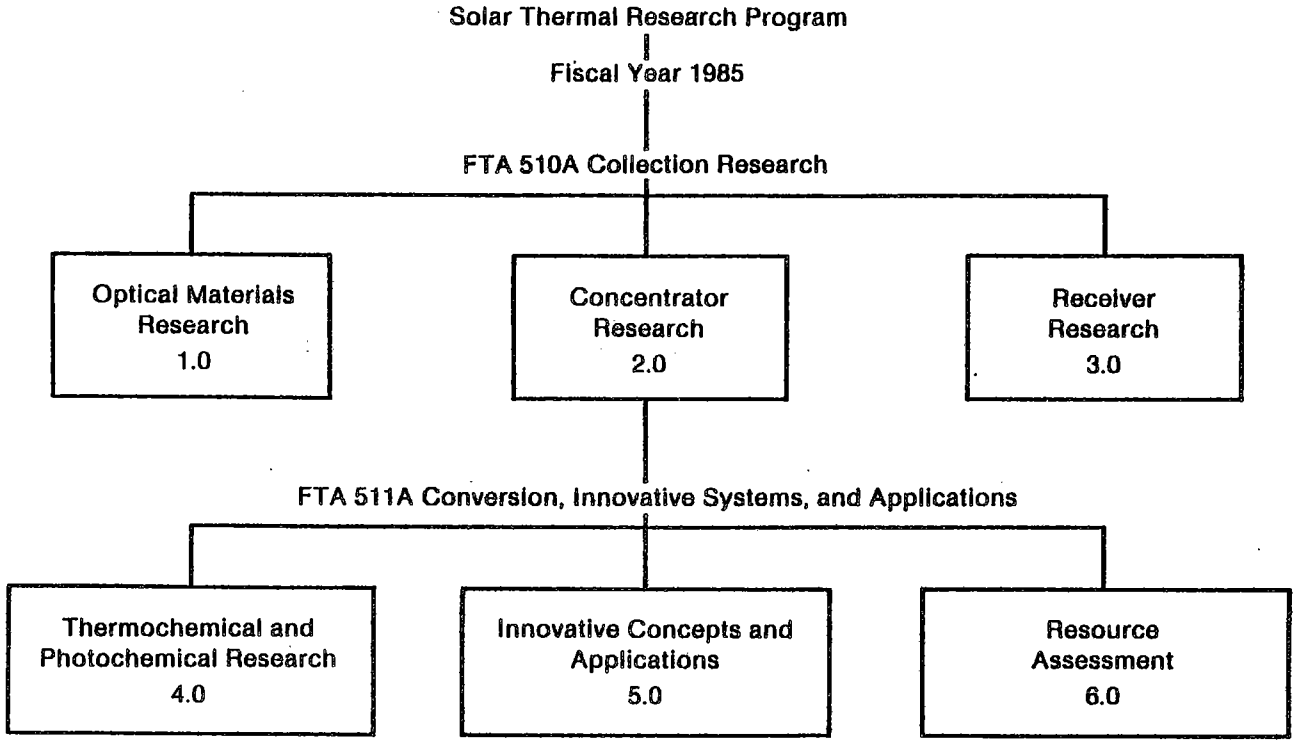


SUMMARY

SIGNIFICANT EVENTS

SERI researchers are performing tests which have the potential to differentiate between initial polymer surface roughness effects and metallization-induced roughness effects on the specularity of silvered polymer reflectors. (Page 3)

Solar tests by the Georgia Tech Research Institute (GTRI) indicate that borosilicate glass coatings will provide some protection from devitrification for fused quartz. (Page 6)

SERI analyses of the stretched membrane heliostat performance indicate that unfocused heliostats have the potential of nearly equaling the performance of focused designs when smaller diameter, lower receiver temperatures, or larger sizes of plants are considered. Otherwise, focusing provides performance advantage. (Page 8)

Representatives from SERI, Georgia Tech Research Institute, and Industrial Welding and Supply have initiated meetings and activities to ensure the direct absorption receiver test at GTRI in August through October, 1985 happens according to plan. (Page 12)

Research at the University of Houston on techniques for absorber coating formation by ion implantation has been completed. Good absorber optical properties were achieved, but lifetimes were too short to be practical. (Page 14)

Lawrence Berkeley Laboratory achieved a milestone in the definition of concentrated flux effects on surface reactions. (Page 17)

A technical assessment by the University of New Hampshire indicates that it is feasible to manufacture caprolactam, a nylon intermediate chemical, by using solar energy. Economics are being defined. (Page 19)

The University of Hawaii has conceived, constructed, and proven a unique unit for photo-thermogravimetric analysis. Early data indicate that the reaction pathway for zinc sulfate decomposition depends on heating rate. (Page 19)

The University of Houston has devised a laboratory technique which will enhance the search for a compatible molten salt to serve as a working fluid in the ammonium hydrogen sulfate energy storage system. (Page 20)

TECHNICAL DESCRIPTION

A. FIELD TASK AGREEMENT 510A COLLECTION RESEARCH

This research encompasses optical materials, concentrators, and receivers. Optical materials research centers on improving reflector materials and obtaining better absorber coatings. Concentrator concept research is focused on light-weight, low-cost innovative collector designs. Receiver concept research is focused on low-cost and high-efficiency configurations with good durability, and on extending the temperature range beyond the current technology.

PROGRAM ELEMENT 1.0 OPTICAL MATERIALS RESEARCH

Optical materials research is directed at three areas: mirrors, absorbers, and windows. The objective of mirrors research is to obtain reflecting surfaces which meet high performance requirements in specularity and which satisfactorily operate in the solar environment. Absorber coatings improve the thermal performance of receivers by increased absorptance. Some receiver concepts require a closed cavity with a window to contain reactants. Research on windows aims at understanding the unique effects of high solar flux on specific candidates for window materials capable of sustained operation at elevated temperatures.

Mirror research in this fiscal year amplifies research from fiscal year 1984 on silver/polymers. During fiscal year 1985, it is anticipated that SERI will identify silver/polymer combinations which show no short-term ultraviolet degradation, will produce and test silicon nitride film deposits on both sides of a silver mirror, and will identify the sources of optical irregularities inside, as well as on the surface of commercially available polymers. SERI expects to identify the controlling factors determining metallic surface roughness, and will produce and test metallic substrates with polymeric leveling layers. SERI expects to identify the factors affecting black chrome performance when deposited on stainless steel. In research on windows, SERI, in conjunction with Georgia Institute of Technology, expects experimentally to characterize at least one coating material and to understand mechanisms in devitrification.

PROGRESS

Silver Polymer Reflectors-SERI

It may be possible to separate the effects of two factors that may limit the specularity of a metallized polymer. First, are the bulk and the surface optical properties of the unsilvered polymer sufficiently good to result in quality mirrors? Second, even if the polymer prior to metallization is good, does the process metallization degrade the silver/polymer interface? The following observation suggests a means to answer these questions.

Preliminary measurements of the reflectivity of thick, cast, polymethylmethacrylate (PMMA)-based polymer sheets that have not been silvered yielded a highly specular reflectance approximating the theoretical value for such material. The specularities at 25 milliradians and 15 milliradians are essentially the same, while the specularity at 7 milliradians is only slightly lower. This important observation indicates that the polymer has excellent intrinsic bulk and surface properties, perhaps better than the

present ability to make specular measurements. These measurements are continuing. Subsequently the polymers will be silvered to learn if the initial specularity is degraded.

A draft report (also a Deliverable) on "Evaluation of Surface Preparation Effects and Identification of a Definitive Approach for UV Protection" was completed by the research staff and was submitted for review by Management at SERI.

The following work has been accomplished toward the goal of covalently bonding stabilizers to the PMMA in order to increase the effective life of the stabilizer. The purified, monomeric ultraviolet-stabilizer 4-methacryloxy-2-hydroxy-benzophenone (MHB) has been homopolymerized, and the dissolution characteristic of the product has been determined. A purification procedure for the MHB-MMA copolymer has been accomplished. It was observed that the formation of a viscous precipitate could be avoided by substituting ethanol for methanol as a non-solvent. Polymethylmethacrylate has been purified for new mirror preparations. A new dip-coating apparatus has been designed, and the parts for it have been ordered. New chemicals for the electroless wet mirroring process have also been ordered.
After 12 weeks of outdoor testing on four glass samples (PAN/sputtered Silver/7809 Glass—B2-167-15 through 18), the samples showed extensive edge corrosion and debonding at the silver/glass interface. However, where these solvable problems had not occurred, researchers were able to measure 95.3 percent and 95.9 percent hemispherical reflectance on two mirrors and 88.5 percent and 91.2 percent specular reflectance at 7 milliradians. To take better advantage of these encouraging results, an improved method of bonding the deposited silver film to glass is required, and better techniques for sealing the edges should be devised.

In testing commercially silvered polymers, the 15 milliradian specular reflectances of the commercially available polymers YS-94 (Acrylic), polycarbonate, and Teflon FEP (SERI codes AG 509; AG 208 and 209; and AG 128, 129, 408 and 409) all decreased below 50 percent after 65 weeks of outdoor testing. Testing of these samples has been discontinued. The aluminized polymers FEK 244 (AG 108 and 109) also showed declines from values of 85.8 percent (±0.7%) which had been maintained for 52 weeks, to 75.6 percent and 82.1 percent after 65 weeks of outdoor testing. Testing of these two samples is being continued.

A sample (silvered ECP300X) obtained from 3-M and held at SERI as a witness sample was measured for its optical properties. The values are the following: the hemispherical reflectance is 95.2 percent compared to 95.1 percent initially, specularity (15 milliradians) is 94.99 percent compared to 99.9 percent, and specularity (7 milliradians) is 86.0 percent (not measured initially). The decrease in specularity at 15 milliradians over 15 months is similar to the observations from outdoor tests. The reasons for the decrease in indoor conditions is being investigated.

After 12 weeks of outdoor testing on four glass samples (ECP-300XP/evaporated silver/7809 glass—B2-168-4, 5, 15 and 16), specularity at 7 milliradians has changed from initial values of 83 percent, 63 percent, 64 percent, and 76 percent to 80 percent, 72 percent, 62 percent, and 70 percent . The decreases are slight, and the increases in specularity in this polymer are a surprise and are not understood. Testing will determine if further improvements in specularity result with aging.

After eight weeks of outdoor testing, three mirror samples (PAN/sputtered silver/7809 Glass—B-4-13-1, 4, 5), speculiarity values at 7 milliradians for these samples are holding

at 89 percent, 90 percent, and 91 percent compared with initial values of 94 percent, 94 percent, and 96 percent. Hemispherical reflectances measured for the first time are 94.3 percent, 95.4 percent, and 95.8 percent. At present, specularity is at the borderline of 90 percent for a 7 milliradian acceptance angle.

A Barstow silver/glass mirror segment, approximately one foot by one foot, has been evaluated. After cleaning the glass surface, the following values for specular reflectance were obtained. For comparison, an NBS standard aluminum quartz (calibrated at NBS at 4 degrees acceptance angle) and two Glaverbel silver/glass mirrors are also listed. Each tabulated value is the average of five measurements at different locations on the mirror surfaces. The ratios of values at 7 milliradians and 15 milliradians are also tabulated.

REFLECTANCE

Milliradians	BARSTOW	NBS	GLAVERBEL Number 1	GLAVERBEL Number 2
25	85.0	—	—	—
15	84.8	85.3	94.4	94.7
7	83.9	83.5	92.4	92.9
	Ratio 7 mr Reflectance to 15 mr Reflectance			
7/15	0.99	0.98	0.98	0.98

The Barstow values are significantly lower than the Glaverbel mirrors that SERI is using as interim standards. The constancy of the 7/15 values for all the glass mirrors suggests that the specularity of the weathered Barstow mirrors is relatively good; however, additional measurements are needed.

For further comparison, three silver/polymer mirrors have been weathered outdoors for 36 weeks with the following values:

REFLECTANCE

Milliradians	Number 1	Number 2	Number 3
15	95.3	93.9	94.8
7	92.1	81.6	89.6
	Ratio 7mr Reflectance to 15 mr Reflectance		
7/15	0.97	0.87	0.95

The ratio 7/15 suggests that the polymer mirrors will be less specular than glass at smaller acceptance angles. Again measurement with an improved capability for lower acceptance angles is needed to enable more definitive statements to be made.

Other Reflector Materials Research at SERI

Background information was obtained by conducting extensive computer data base searches on the topics of black chrome durability and metal substrate front surface reflectors.

A producer of precision-rolled sheet metal, strip and foil was contacted for information and to obtain samples of 1 F surface finish metal strip (the highest quality of standard surface rolled metal). Such a surface finish typically has an rms roughness of 1 to 2 microinches in the longitudinal direction and 2 to 3 microinches in the transverse direction. Window glass typically has a surface roughness of 1 to 2 microinches (one microinch = 25 nm). Measurements are needed to measure the specularity of the typical, precision-rolled sheet. It is not yet clear that precision metal rolling cannot produce the required surface quality without the addition of levelizing polymers.

Optical Materials Research at Georgia Institute of Technology

Research at Georgia Institute of Technology on window materials is emphasizing inhibition of devitrification of fused quartz and is attempting to understand how to build a mosaic window which will survive in concentrated sunlight. The ACTF test program, begun in late 1984, was completed with solar testing of a coated window specimen. The results suggest that borosilicate glass coatings are giving some degree of protection from devitrification, although researchers are still trying to prepare smooth, pore-free coating films.

The Monte Carlo thermal modeling appears to be a promising method for calculating accurate temperature profiles in window glass. Efforts are underway to ensure the program will give valid solutions over all reasonable values of the run parameters.

PROGRAM ELEMENT 2.0 CONCENTRATOR RESEARCH

Concentrator research at SERI in fiscal year 1985 investigates ways of reducing current support structure requirements. Research on concentrators utilizing silvered polymers aims at development of potentially lightweight, low-cost, durable concentrators with high performance; in particular, the stretched metallic and polymeric membrane heliostat and dish concepts are considered. Demonstration of the technical feasibility of lightweight stretched membrane concepts through experimentally verified analyses of subscale test modules is to be accomplished. Greater durability (at least five years) with retention of optical quality in solar reflector use is to be evaluated and verified by environmental testing. Configurations for the various concepts are to be defined, and cost comparison studies are to be carried out.

During fiscal year 1984, concentrator research focused on the study of the stretched membrane concentrator. Structural analysis, the fabrication of a number of experimental prototypes, and measurements of their structural behavior advanced to the point that the technical feasibility of the membrane concept has been established, and the static structural/optical response of the membrane is predictable with sufficient accuracy. Also during this period, wind-load reduction and abatement studies were initiated at Colorado State University.

During fiscal year 1985, the research effort aimed at understanding and reducing wind loads on collector fields, including heliostats, dishes and troughs, will continue. The possibility of using composite materials for reflector surface backing as well as for structural members is to be studied. Structural and optical testing of the three-meter modules will take place. The definition of the structural response of membranes to static and dynamic loading and the preferred membrane attachment configurations are to be studied. A separate effort is to define the structural requirements for stretched membrane concentrators to be used for higher receiver temperature systems. Effort is to be initiated to define the performance of polymers as possible structural membranes. Finally, a research effort will aim at studying alternative mechanisms and strategies for focusing concentrators. Assessment of the performance and the cost characteristics of selected Fresnel lens concentrators is to be initiated.

PROGRESS

Concentrator Research at SERI

Staff finished the fixture which will be used to test the three-meter-diameter stretched membrane test modules. Observations and measurements on the first of the three-meter-diameter structural test modules have been completed, and the module has been returned to Dan-Ka Products for reconfiguration. Sixty-three video frames were digitized and archived for later analysis; each frame requires a separate floppy disk (5.25 inches). Simulated wind loading was imposed on the module with the membrane under various levels of tension. Researchers took two sets of data with the weight of the module supported first at a single point at the bottom and then by two brackets in positions at "two o'clock" and "ten o'clock". In most cases, three frames were taken for each loading condition, while varying the view angle, so that better coverage of the surface was made. The reconfiguration of the module (changing to a hard attachment) was completed, and the module was picked up. The fairly compliant pneumatic tensioning mechanism on this module has been bypassed with a rigid attachment of the membrane directly to the structural ring-frame. In making the hard attachment, staff

held the ring flat on an external fixture while the pneumatic device was used to tension the membrane. A rigid, but brittle, epoxy adhesive was used to fix the membrane to the frame at this tension. The rigidly attached membrane is expected to make the structure, as a whole, much stiffer to external loads. A brittle epoxy was used so that the bond can be readily broken later for reattachment at a different tension.

Researchers have completed software to illustrate both the direction and the magnitude of the errors in the surface slope on the test modules and to display this information on the monitor screen for quick qualitative optical evaluations. Staff completed a check of the procedure. Also, they continue to develop additional software for the video-digitization equipment to refine and to further define the calibrating procedures which will help to take out nonlinear effects of the camera lens. This new software represents a refinement on the already existing capability to provide a better understanding of the absolute accuracy of the predictions in surface deformation.

The economic effect of convective losses on central receiver plants was further explored. Initial analyses which compared the effect of convective losses on the levelized energy cost for two proposed prediction methods were completed. Theproposed method showed differences in levelized energy-cost attributed to convective losses (the "cost" of convection) which ranged from about \$0.10/GJ at 300°C to \$0.50/GJ at 900°C. Another proposed method indicated the cost of convective losses to be higher and started again at about \$0.20/GJ at 300°C but increased to well over \$1.00/GJ at 900°C. (The average levelized energy cost for these cases was about \$7.00/GJ.)

Effort on the comparisons for stretched-membrane and glass-metal heliostats concentrated on refining the predictions of economic benefit derived from focusing the stretched-membrane heliostats. Earlier results demonstrated that unfocused heliostats have the potential of nearly equaling the performance of focused designs in certain situations (with heliostats of smaller diameter, lower temperatures, or larger sizes of plants).

A problem with the DELSOL optimization procedure has been identified and corrected. A memorandum has been prepared and sent to Sandia, Livermore, developers of the code, to describe the problem and the necessary changes to the code. The problem which does not appear to be serious in most cases led to slightly erroneous results in the final optimized configuration when convection losses were a major loss mechanism. New system designs were developed for several sizes of plants, temperatures, and diameters of stretched membrane heliostats. Generating these system designs involves reoptimizing many of the system characteristics, particularly the aperture dimensions. The performance results which have been generated indicate that the decrease in performance associated with changing from a focused, stretched membrane to a flat, stretched membrane on a heliostat is larger for small plants (75 MW) because of their intrinsically smaller apertures. This decrease in performance is also more pronounced for systems with higher delivery temperatures, again because of the smaller apertures. Much of this decrease, however, can be ameliorated by reducing the size of the flat heliostat. Thus, for some combinations of temperature and size of plant, flat heliostat (50 square meters) will produce results which are within percentage points of those from the focused heliostat. Further, early results indicate that for unfocused heliostats which cost \$50 per square meter used in a 75 MW plant, the allowable cost of focusing will vary from about \$1.00 per square meter to well over \$10.00 per square meter—depending on the temperature and the size of the unfocused heliostat. As the size of the plant increases, the allowable cost of focusing is expected to move to the smaller end of this range, since the intrinsically larger apertures tend to minimize the effect of changing from focused to unfocused heliostats.

System studies on the stretched-membrane, central-receiver systems were expanded to examine the effects of off-optimum aperture designs on both spillage and thermal losses. Results show that the thermal losses from cavity receivers are very linear with aperture area over a range of aperture sizes (plus or minus 25 percent) relative to the optimum area. The results for spillage losses are expected to show significantly larger non-linearities with aperture area because of the shape of the distribution of the solar flux on the aperture plane. Staff also began a comparison of design-point performance to performance at other times of the year.

Concentrator Research at Georgia Institute of Technology

Georgia Institute of Technology has constructed a second spiral concentrator of dimensions similar to the first one which was constructed. Unlike the first spiral this concentrator pattern is not a photographic enlargement but a full-sized computer plot. Great care is being taken to assure that mounting points are located accurately. The concentration ratio, the peak thermal flux in the focal zone, and the flux pattern will be measured by using calorimeters and optical techniques. The first spiral concentrator was tested, and it measured a concentration of 250 suns compared with the design for 1000 suns. Improved spiral cutting and mounting points are being examined. The capability of full-sized computer plots has been implemented. This work eliminates the time and the inaccuracies associated with photographic enlargement.

PROGRAM ELEMENT 3.0 RECEIVER RESEARCH

Receiver research at SERI in fiscal year 1985 primarily is directed at defining durable configurations for metal and ceramic tube receivers as well as direct absorption concepts. Analytical and experimental studies will be used to define the performance drivers corresponding to various receiver concepts and approaches to enhance their performance. Materials research which is of primary importance is directed at developing high performance and long-life absorber surfaces and containment tubes. Metal or ceramic tubes for receivers are to face higher temperatures and more aggressive fluids such as molten salts or liquid sodium. Metal tubes for external receivers to about 600 C are not identified as research targets, but there is a need for diagnostic instruments to measure these and advanced receiver surface temperatures in operation. Research on solar blind pyrometry continues to produce the basis for needed instruments. Studies on cavity configuration and phenomenology have broad application to dish and central receivers and correspond to fluid in tube and direct absorption concepts for a wide range of temperature applications up to 900 C. These investigations include detailed descriptions of loss mechanisms and techniques to reduce these losses, research leading to the development of secondary concentrators, and instrumentation to measure the thermal transport and structural performance parameters in situ during operation.

It is expected that the test loop for conducting the ACTF tests of the direct absorption concept will be constructed and checked out, and some early experiments will have been completed during fiscal year 1985. Also during fiscal year 1985, preliminary experimental data and analysis of sufficient quality are to be available for an initial evaluation of the direct absorption receiver concept. Historical data on failures of cavity tubes are to be collected. Analysis leading to modeling is to begin. Also, it is expected that quantitative correlations of the degradation of absorber coating as a function of impinging solar flux will be completed. It is expected that needs for diagnostic instrumentation will have been specified. An assessment of current errors in estimating convective losses from cavity receivers, including recommendations and a preliminary evaluation of the benefits of secondary concentrators, is also to be completed.

PROGRESS

Receiver Research at SERI

Researchers have completed absorber tests on the 500° C apparatus and are preparing to begin viscosity tests. The latest absorber tests gave measurements of film thickness as a function of salt flow at the 5° angle from horizontal orientation. The data were exceptionally reproducible but show significantly larger film thickness (0.090 inches compared to .060 inches) than would be predicted from existing correlations. Researchers are trying to determine whether variations in viscosity would produce these discrepancies. The tests showed that the technique of measuring film thickness is all right. Using the orifice plate distributor did not materially affect the thickness of the film but did seem to lead to film waviness earlier than the weir distributor.

In research on heat transfer, accurate measurement of salt flow rate is a requirement for all planned experiments and is a difficult measurement to perform. Members of the staff have installed the capability to calibrate the Taylor wedge flowmeter. The method is to allow salt to flow from the flowmeter through the radiant heated section into a heated tank and to measure the rate of level increase with a bubbler. By using the hoist and the

scaffolding, the direct contact heat exchanger was removed, and salt flow calibration equipment was installed.

Experiments on salt flow on the 500° C apparatus established operational stability at low flow, behavior at full flow, and dryout at zero flow. Observing the flow for the 500° C apparatus has shown the following features. (A) Starting at very low flow rates (approximately 0.1 gpm) will create a wide rivulet on the plate which gradually becomes wider and wets the entire plate. It seems that the more times the salt runs the easier the salt wets the plate. This result could be due to adsorption of salt into the plate surface irregularities as more salt flows on the plate with time. (B) The same hysteresis observed with water is seen with salt. That is, while the plate is first being wetted by a low flow, an increase in flow will quickly wet the plate (in a few seconds). The required increase in flow with salt is not as large as observed with water. (C) After the plate is wetted, exceptionally low flows are possible and produce stable film. (D) After wetting the plate during the first two runs and then turning off the flow, researchers observed a gradual dry-out of the plate. This dry-out after the third run seems to be much slower. Again, this could be due to surface adsorption of the salt.

Installation of the 480 volt power at the laboratory was completed by the subcontractors for the 700° C test loop. This installation allowed a check of the radiant heaters which appear to operate as designed. The radiant heaters have been operated in the percent-power mode up to 600° C for two days to oxidize the outer surface of the salt pipe and thereby improve the heat transfer from the radiant heaters. The constant temperature mode must be tested with salt flow because a heat load is needed for proper operation of the feedback loop. The tank heaters which also operate from 480 volts tested correctly and have been used subsequently to melt the full salt charge in the salt tank (approximately 3700 pounds).

The cooling system has been partially installed, and the remaining parts are on order or are ready for installation. The parts which have been installed include thermocouples and cooling coils welded to the outside of the salt tank. It was necessary to get these first parts installed because they involve access to the interior and the exposed exterior of the tank. The remaining parts can be installed when time permits and before high-temperature tests begin.

Industrial Welding and Supply, the contractor fabricating the 900° C test loop, suggested modifications to the pump and valves which the company thought would be necessary at the high-temperature operation planned for the loop. The changes have been forwarded to the firms fabricating the equipment.

SERI and Industrial Welding representatives met with the Advanced Components Test Facility staff in Atlanta, Georgia, to initiate the interfacing discussions. SERI personnel were given a tour of the ACTF facilities including the tower itself, the computer/control room, and the assembly building where the ground tests will be carried out. Researchers reviewed the drawings of the test loop and the changes implemented to the drawings by Industrial Welding. SERI agreed to keep ACTF personnel up-to-date on these changes by forwarding Industrial's monthly reports to the ACTF.

A modified absorber manifold design was developed. Before committing the design to metal, researchers fabricated it from lucite and tested it at 85° from horizontal and at the full 10 gpm (water) flow required for the test loop. In the redesign researchers were careful to allow full damping of the velocity head from the inlet salt flow so that flow

with water indicate that the manifold works very well. In addition, it allows full access to the face of the absorber for flux mapping at the ACTF.

In cyclic corrosion studies, tests have been started at SERI on the influence of thermal cycling between 500° C and 900° C on the corrosion rate of three materials in eutectic lithium-sodium-potassium carbonate. Coupons of Inconel 600, Coors AD-998 alumina, and sapphire have been prepared, weighed, mounted on holders and were introduced into separate crucibles for cycling tests. The cycling consists of repeatedly heating from 500° C to 900° C at a rate of 100° C per hour, then holding for four hours at 900° C, and then cooling at 100° C per hour. The cycle was chosen to provide an approximation to the operating cycle for a receiver, but with a slower heating rate, because of the possibility of thermal stress causing failure of the alumina crucibles if greater rates were employed. The purge gas (71 percent AR, 19 percent O_2, and 10 percent CO_2) is bubbled into the molten eutectic Li-Na-K carbonate salt. Ten test cycles have been completed, and metallographic techniques are being used to determine the depth of the affected metal. It was found that 0.041 ± 0.016 mm/side (where the mean and standard deviation are given for three data points) was the metal loss and that a dense oxide protective layer was found on the metal surface. This metal loss is less than that observed between 12 days and 62 days of continuous exposure to 900° C molten salt in the same high-oxygen-potential environment. If similar results for 30 cycles and 100 cycles are obtained as the experiments continue, then it can be concluded that the corrosion rate of Inconel 600 is not dramatically increased by cycling between 500° C and 900° C, and that such cycling does not cause dramatic spalling of the protective layer. Such spalling would lead to higher corrosion rates for these materials and could render them less attractive candidates for use in advanced receivers that use the molten carbonate working fluid. The materials to be tested have shown good corrosion resistance under static high temperature salt conditions. The cycling tests on Inconel 600 are of special interest, since that alloy will be used in pilot scale studies on the Direct Absorption Receiver at the ACTF in Georgia.

Receiver Research at Georgia Institute of Technology

The ACTF test program, begun in October, was completed in February. One important test in this campaign was the evaluation of aggregate-cast fused silica in direct comparison with slip-cast fused silica. A third type of fused silica, a castable composition, had been tested previously and had exhibited performance in solar flux which was clearly inferior to the slip-cast material. Aggregate casting offers a fairly economical method of producing large refractory shapes. The aggregate-cast material performed as well as slip-cast fused silica in the solar test and, thereby, demonstrated that large silica refractories can be made economically for solar thermal applications. If the application requirement exceeds the capabilitites of slip casting, it has now been established that aggregate casting is a substitute method of fabrication and yields material equivalent to slip-cast fused silica. Solar testing of aggregate-cast fused silica alongside the slip-cast material met a milestone. Transmittance data were obtained for support of modeling studies.

Initial research on cyclic behavior of materials will concentrate on defining a suitable experimental apparatus that can be used to apply adequate radiant flux levels to study the performance of materials under simulated solar heating environments. In order to carry out these investigations in a controlled environment on an un-interrupted basis, it was decided to design a xenon lamp facility. This facility will provide independence of insolation levels. An important aspect of this task is the identification of a suitable test

was decided to design a xenon lamp facility. This facility will provide independence of insolation levels. An important aspect of this task is the identification of a suitable test module that will utilize available commercial lamps and will at the same time provide for expansion of the module so that higher flux levels can be accommodated in future years. Equally important will be early considerations in design to accommodate required diagnostics including those presently contemplated and those for future expansion in instrumentation.

A planning meeting was held in which details of the test apparatus and diagnostic instrumentation were discussed. It was concluded that a modular approach for the lamp chamber would be advantageous in order to increase the versatility of the test configuration. By modular approach it is meant that the lamp housing will be separable from the main enclosure that will contain the solar-like beam. Further, it is anticipated that at least one other separation plan be provided so that the location of the specimen test can be easily interchanged to facilitate a non-interference test set up during on-going testing. The test lamp module will contain most of the parts and access for instrumentation. Preliminary plans call for accommodation of at least he following instrumentation: spectrometer, multicolor pyrometer and scanning calorimeter. It is also possible to include access for FTIR capability.

A state-of-the-art survey will be conducted to establish the current technology base for measuring intense heat flux. Innovative concepts for making solar flux measurements will be examined for applicability to the solar thermal program. The most promising approach will be carried to the detailed design phase.

C.T. Brown and R. A. Cassanova met with J. Swearengen, C. Pretzel, N. Bergman, and R. Houser of Sandia, Livermore, to discuss flux and temperature measurement. Significant technical exchange occurred. Additionally, it was determined that the efforts at Georgia Tech Research Institute and Sandia in solar flux measurement technology are complementary.

Research on multispectral pyrometry resulted in both the final report on research in fiscal year 1984 and a topical report, "Provisional Performance Evaluation of a Solar-Blind Four-Wavelength Infrared Pyrometer."

A new scheme for calibrating a pyrometer makes use of two reference temperatures and has been tested. This scheme will permit correction of the radiance data for effects of atmospheric absorption. A computer-controlled, two-axis sample stage was built and tested. Precise sample placement in the solar beam is now more easily controlled.

Receiver Research at the University of Houston

Additional data have been gathered at the University of Houston on photo-enhanced oxidation of nickel. Measurements were made at 400° C and 500° C at exposure times of 3 hours and 30 minutes. All show oxidation enhancement from 200 percent to 400 percent.

The work on formation of absorber coatings ion implantation has been completed. Coatings of good solar absorptance have been made on vanadium and zirconium under 10 keV bombardment by N_2+. However, extended air exposure under 400° C (15 hours) results in severe degradation of both the Zr and V implanted samples. The ion

bombardment coatings generated at 10 keV do not have the required high-temperature, high-flux stability. Implantation at energies approaching 50 keV may result in improved stability.

B. FIELD TASK AGREEMENT 511A CONVERSION, INNOVATIVE SYSTEMS, AND APPLICATIONS

This research area encompasses direct conversion from concentrated solar radiation to electricity or chemicals, transport and storage of thermal energy, and generation and assessment of innovative concepts.

PROGRAM ELEMENT 4.0 THERMOCHEMICAL AND PHOTOCHEMICAL RESEARCH

Research on process definition at SERI in fiscal year 1985 is to identify usable adsorption phenomena and processes. The research includes high-flux and high-temperature chemical bond interactions. Reaction research seeks to evaluate side reactions and other major reactions affected by high temperatures, and addresses the unique effects of a large radiant flux on such reactions. The aim of this research is to identify potentially useful conversion reactions and to quantify the effects of high flux and temperature on desired reactions. Research is also to be performed on hybrid processes to use combined solar energy and other fuel sources.

PROGRESS

Solar Incineration of Hazardous Organic Wastes

The University of Dayton is nearing completion of the experimental unit to characterize the solar incineration of hazardous organic wastes. The reactor assembly, the treatment unit, and the chemical analysis unit are complete. The Xenon arc lamp has not yet arrived from the vendor. Experimental characterization of the high-temperature spectra of the test compounds and sensitizers has begun. The experimental apparatus is specifically designed to allow separation of thermal and photolytic effects.

Direct Radiant Heating of Particle Suspension

Researchers at Lawrence Berkeley Laboratory continue to progress in the research on direct-radiant heating of particle suspensions, with emphasis on reacting particles. The survey of the literature to identify chemical reactions that were well-suited to a small particle, direct flux, radiant reactor such as STARR is essentially complete; however, new reactions are added as they are found in the literature. A letter report, "Concentrated Flux Effects on Surface Reactions," was written and submitted to the DOE to complete a key milestone due at the end of March.

LBL programs were used to illustrate the effects of particle size on absorption of light by a suspension. A suspension of large particles can absorb the same fraction of energy from a light beam as a suspension of smaller particles by allowing the beam to traverse a greater distance through the suspension and/or increasing the mass loading of particles. The optimum particle loading per volume of gas depends on the application being considered. Very low particle densities are sufficient for gas phase reactions in which the particles act as the radiant heat exchanger or catalyst for the reaction.

However, if thermal processing of a particulate feedstock is desired, wherein the gas provides only the transport system, much higher loading densities are appropriate. An intermediate particle loading density is more likely when it is desired to initiate

reactions between the gas and particles. One of the goals of this research is to define the range of mass loading for various applications and its effect on receiver size. These calculations are an important step towards that goal.

New samples of particle materials, including CdO, $Co_3O_4MnO_2$, CuO, and Cu_2O, have been purchased in powder form from the manufacturer. All are black or brown/black fine powders except the Cu_2O which is dark burgandy. They are potentially good absorber materials, but they are particularly important because they all have been proposed as reactants in a multi-step, water-splitting cycle. The mass loadings for particle suspensions of these materials obtainable from the cyclone shaker are being determined by drawing a known volume of the particle-gas mixture through a filter and by weighing the filter. Since information about the particle-size distribution was not available from the manufacturer, electron micrographs of samples cut from these filters are being made with a scanning electron microscope. Particle-size distributions for each material will be made from the micrographs.

The transmission of a laser beam through a known distance of the particle-gas suspension is being measured for each of the new materials. Comparison of the results of these measurements will be made with the values calculated by the computer program PDISMIE for materials for which no optical data were available.

One problem in calculating the fraction of the energy absorbed by a given particle suspension has been the poor match between the range of wavelengths for which optical data for the materials are known and the spectrum of the light source. In some cases, as much as 20 percent of the lamp's energy is at wavelengths for which nothing is known about the values of the optical constants. The transmission spectra of particle supsensions of all the particle materials that researchers have on hand are now being measured with the UV/VIS/NIR spectrophotometer available at the laboratory. Recently, this instrument was equipped with an integrating sphere for measuring the scattered light. It is now possible to determine the fraction of the light absorbed by the particle sample over a range of wavelengths from 185 nanometers to 3200 nanometers. Measurements made for a sample of hematite show trends that are consistent with that predicted from calculations made by using the optical data from the literature. This favorable comparison gives some confidence that the absorption measurements from the spectrophotometer will enable reasonable approximations for the optical constants of the materials at wavelengths where no data are now available.

A dichotomous sampler and an x-ray diffractometer are now available for use in the laboratory. The sampler is equipped with a virtual impactor that separates a gas-particle stream into two streams, one containing only large particles and the other containing only small particles. The cutoff in the particle diameter depends on the carrier gas, and in the case of an air-particle suspension, the cutoff diameter is 5.0 microns. Particles from each stream are collected on a filter. The thickness of the particle coating on each filter is measured by a "beta" gauge, and the mass loading is calculated. The filter is then placed in the x-ray diffractometer that scans the filter and records the Bragg diffraction pattern. The diffraction characteristics of all the materials of interest are available for comparison with the results of the scan. These instruments make it possible to identify and to make a quantitative analysis of the particles both before and after they have passed through the radiant flux. They are valuable experimental tools for determining the chemical or physical changes that occur in a particle placed in a concentrated flux environment.

Solar Photochemical Production of Fuels and Chemicals

The University of New Hampshire has completed an initial technical assessment of the feasibility of solar photochemical production of fuels and chemicals, with emphasis on the use of solar energy in the manufacture of caprolactam, a nylon 6-6 intermediate chemical. A preliminary analysis shows that it is feasible to manufacture caprolactam by using solar energy. However, there are technical and economic problems for which solutions will have to be found before any degree of success can be achieved. The major technical difficulties are the development of an efficient beam splitter which can concentrate and decouple short and long wavelength radiation, specification of reactor configurations to transmit the radiation inside the photoreactor to achieve high chemical and energy efficiency, and hybridization of the solar reactor with other energy sources. The University of New Hampshire will experimentally investigate the use of solar energy in manufacturing caprolactam.

Radiant Decomposition of Solids

A unique photothermogravimetric analysis unit was conceived, constructed and used by the Universitiy of Hawaii to collect data on solids decomposition reactions. This instrument is capable of measuring 5 to 10 weights per second for a solid decomposing in a large flux of concentrated sunlight. The data show a potential beneficial effect of direct radiant heating. Zinc sulfate decomposition appears to have multiple reaction pathways of the form:

$$ZnSO_4 \begin{cases} \xrightarrow{A} \text{Products (high heating rate)} \\ \xrightarrow{B} \text{Products (low heating rate)} \end{cases}$$

Additional research will be required to understand the reaction mechanisms and product compositions. Phase I of this research is being completed. A proposal has been submitted for further research.

Solar-Assisted Bond Breaking

Research on solar-assisted bond breaking at the University of Houston has resulted in completion of a literature survey to select the best reaction candidates and construction of an experimental reaction system. Research involving dehalogenation would appear to be most applicable to photo-assisted endothermic reactions. Other, more practical reactions are also being considered for the initial phase of the work.

A fluidized bed reactor has been designed and appears to be satisfactory. The internal diameter of the tube containing the fluidized bed is approximately 0.8 cm. The flow rate required to form a stable fluidized bed is about 100 cm^3 per minute, which corresponds to a linear flowrate of 3.3 cm per second. Al_2O_3 with a bulk density of approximately 0.9 g/cm^3 was ground and sieved for various sizes in the range from 45 microns to 125 microns. The ranges 53 microns to 75 microns and 75 microns to 88 microns proved satisfactory. The xenon lamp has been received and set up by using a micromanipulator for focusing the radiation on the surface of the fluidized bed. The lamp appears to be operating satisfactorily, and the focused beam is of the specified size. The decomposition of methanol into CO and $2H_2$ has been selected to checkout the reactor.

Photoenhancement of Catalytic Processes

The University of Houston research on photoenhancement of catalytic processes is preparing a small scale proof-of-concept test. A pre-test catalytic chamber has been designed by incorporating equipment that could be made temporarily available in the laboratory. The quartz tube chamber will be connected to a quadrupole mass spectrometer for a preliminary test of photo-enhancement of the catalytic reaction:

$$CO + 3H_2 \rightarrow CH4 + H_2O$$

The reaction will be attempted over a polycrystalline nickel catalyst both under high flux (~ 1 mW/m^2) irradiation at $\sim 400°$ C and under infrared oven heat.

Chemical Energy Storage

The review of the research at the University of Houston on chemical energy storage using the ammonium hydrogen sulfate system has resulted in a significant effort to identify the compatible molten salt (CMS). The compatable molten salt is used to carry the ammonium hydrogen sulfate to the decomposition reactor-receivers and as a medium to carry heat to the boiler.

The first step in searching for a compatible molten salt was to make measurement of the melting point on certain selected mixtures. The first mixture had a composition of 15 percent of $ZnSO_4$, and 85 percent of Li_2SO_4, Na_2SO_4, K_2SO_4 eutectic (actually, 15 percent of $ZnSO_4$, 66.3 percent of Li_2SO_4, 7.2 percent of Na_2SO_4, and 11.5 percent of K_2SO_4). Samples were taken by dipping a glass rod into the melt when there was only a small quantity of liquid present. The ion chromatography showed the relative proportions of Li, Na and K were much different in the liquid than in the solid from which it had melted. Liquid composition (excluding $ZnSO_4$) was 63.8 percent of Li_2SO_4, 13.2 percent of Na_2SO_4, 23.0 percent of K_2SO_4. The Zn composition is not directly given by the ion chromatography; so its composition will have to be determined by another method.

The next melt was estimated to be approximately 34.4 of percent $ZnSO_4$. By adding small quantities of $ZnSO_4$ to this melt, it was discovered that the liquidus point (the point that the last solid melts) dropped with increasing $ZnSO_4$ mole fraction until approximately 45 percent to 50 percent of $ZnSO_4$. This melt was analyzed by ion chromatography, and care was taken to weigh each sample so that the Zn composition could be determined by the difference. The composition was 32.3 percent of Li_2SO_4, 10.6 percent of Na_2SO_4, 9.4 percent of K_2SO_4 and 47.7 percent of $ZnSO_4$. The mixture began to melt at 377.5° C and was completely melted by 390° C ($\Delta T = 12.5°$). This technique will greatly enhance the research to select the compatible molten salt.

Hydrocarbon Cracking Using Trigger Reactions

Design of the vapor phase flow reactors was completed. Fabrication of the reactor for the 30 kw arc image furnace was completed at the University of Hawaii. The reactor for the 1 kw furnace is still under fabrication.

The researchers have begun the initial series of acetone photolysis experiments by using the 30 kw arc image furnace. The first set of experiments was aimed at the verification of the ability of radiation from a xenon lamp (with a near solar spectrum), which

possessess a limited amount of ultraviolet, to achieve photolysis. The system was set up to receive the maximum amount of flux and provided no control of the reactor wall temperature. A thirty-centimeter long, 1.2 cm fused silica tube was placed inside a silver-coated reflective cavity, so that two and a half inches of the tube protruded from the top. The reactor was then located so that the top opening of the cavity lay at the focal plane of the furnace, with the protruding reactor passing through the focus. Steam flow of 0.4 g per minute was mixed with an acetone input of 0.035 g per minute and passed thorugh the reactor. After condensation of steam, acetone and other liquid products, the gaseous products were collected via a water displacement vessel. With the furnace set at 18 kw power, the flux at the focus was estimated at 300 w/cm^2.

While detailed analysis of the results is not yet available, gaseous products of CO, CH_4, and C_2H_6 are indicative of the occurrence of photolysis. In the immediate future, the above experiment will be repeated with the addition of an ultraviolet filter to distinguish photolytic and thermal effects. Experiments using another reactor with temperature control capabilities will then follow. This procedure should provide the basis of an experiment to prove the concept of enhanced reaction selectivity and yield.

PROGRAM ELEMENT 5.0 INNOVATIVE CONCEPTS AND APPLICATIONS

Researchers systems and applications technology at SERI in fiscal year 1985 will emphasize generation and characterization of innovative concepts and applications. Innovative concepts and applications are guided by the need to make significant improvements in solar energy cost-effectiveness by providing a much more attractive application or a new concept. The approach is: (A) to identify the concept or application; (B) to do sufficient research to characterize the concept or application; (C) to perform a comparative analysis of alternatives; and (D) if attractive, to integrate any further research into the primary program.

It is planned that during fiscal year 1985 the definition and technical feasibility of various new concentrator concepts will have been completed, with identification of those that show promise for further development. Also, a preliminary assessment of the technical feasibility of the holographic concentrator is to be completed. SERI plans to complete the assessment of non-equilibrium, rapid reactions and to identify the most promising ones. A survey of current scientific developments with relevance to solar thermal systems is to be completed. As a result of planned workshops, new ideas with potential are to be pursued.

PROGRESS

Front-Surface Mirror Protection

Researchers at the Southern Research Institute have selected eight amphiphilic compounds for evaluation as protective coatings on silver surfaces. Because the compounds represent several different chemical classes, researchers hope to identify those classes of compounds that are best suited for deposition on silver. Arachidic acid and stearic acid were selected because they are well-characterized film formers and are known to adhere strongly to metal surfaces such as aluminum. Because previous studies have shown that fluorinated monolayers form extremely inert surfaces that resist soiling, researchers selected perfluoralkyl pyridinium bromide; 1H, 1H, 11H-eicosafluoro-1-undecanyl acrylate; and pentadecafluorooctyl methacrylate as candidate coating materials. Vinyl stearate and methylmethacrylate were selected because they can be polymerized, as can the two fluorinated acrylates. Ethyl stearate was selected as an example of an extremely nonpolar compound.

Researchers are still reviewing literature to pick at least two more compounds. Researchers had selected two additional compounds, but discovered that they are no longer commercially produced and, therefore, are unavailable.

The determination of collapse points for the selected amphiphilic compounds has been delayed because researchers detected a vibration in the laboratory floor. The observed vibrations cause very high errors in the measurement of the surface tension of water, which is the basis for the rest of the work. To eliminate this problem, an isolation table is being built. Once this table is finished, researchers plan to return to schedule on the project.

Thermoelectrochemical Converter

Researchers at Hughes Aircraft operated a small closed loop thermoelectrochemical (TECH) system to demonstrate that no "showstoppers" exist. Emphasis is now on construction of a larger system to demonstrate efficiency and to allow an understanding of the fundamentals of a TECH system. The electrochemical convertor is being emphasized.

Innovative Concentrators

The objective of research at the University of Chicago is to define cost effective innovative concentrators using inexpensive, low optical tolerance, primary concentrators with secondary concentrators in systems with overall concentration ratios of 200 suns to 400 suns. This will allow 500°C to 700°C temperatures to be achieved at 65 percent to 70 percent optical efficiency and with no significant problems in secondary concentrator materials. Researchers have analyzed a collection system with a concentration ratio of 30 for the primary and 5 for the secondary. The secondary concentrator has been specified and will be constructed for testing later in the year at the Advanced Components Test Facility at the Georgia Tech Research Institute.

Holographic Solar Concentrators

Researchers at Acurex Solar Corporation processed eleven line-focus and ten point-focus holograms and measured their diffraction efficiency at 488.0 nm, 514.5 nm and 630.8 nm. Nine line-focus and two point-focus holograms were selected for stacking. The holograms were combined into six line-focus, two-hologram stacks with some of the holograms used in more than one stack, and one point-focus, two hologram stack. The diffraction efficiency of the stacked holograms was measured. The data below illustrate the effect of combining holograms on diffraction efficiency.

Number	Type	Percent Diffraction Efficiency		
		Red 632.8 nm	Green 514.5 nm	Blue 488.0 nm
5/22/3	Point focus	90	35	22
5/22/4		73	95	97
Combined		97	53	54

The data show enhancement of efficiency of red wavelengths, but loss of efficiency resulting from cross-talk at green and blue wavelengths.

The concept of holographic stacking is that each hologram in the stack shall cover a different section of the solar spectrum at high efficiency and shall only minimally, if at all, cover adjoining sections of the solar spectrum. In this manner, holograms in a stack, complement each other in covering the solar spectrum with a minimum of overlap and, hence, a minimum of cross-talk leading to the loss of diffraction efficiency.

This is the basic approach taken for obtaining high efficiency in the solar spectrum region 300 nm to 1300 nm. However, this requires equipment capable of measuring diffraction efficiency other than at currently measure values of 488 nm and 514.5 nm with an argon laser, and of 632.8 nm with a helium-neon laser. Some of the instrumentation is available at Acurex or is being currently obtained, and the balance is under consideration for purchase. With this instrumentation, a maximum of nine points in the diffraction efficiency-wavelength profile of stacked holograms may be obtained. In addition, a reflecting spectrophotometer is being acquired so that diffraction efficiency may be measured quasicontinuously from 300 nm to 1300 nm. In this manner, accurate profiles of efficiency and wavelength can be obtained for the holograms. This will allow researchers to alter both the holographic processing and the optical parameters for the purpose of improving efficiency in diffraction.

Work has continued on dichromate additives for the purpose of improving diffraction efficiency at longer wavelengths. Green and blue dyes have been added to the dichromate gel for this purpose. The Polaroid Corporation has removed its photopolymers from the market, since it judged them sufficiently deficient to require additional development. Consequently, the photopolymer work has come to a temporary halt. Photopolymers are holographic gels that do not require development. Preparations for life-testing of holograms have continued.

Spectral Splitting

Researchers at the University of Arizona have conceptualized and analyzed three interference beam splitters and a liquid optical filter. The interference beam splitters are: symmetric period stack; an induced transmission stack; a metal dielectric stack. All are capable of passing a selected band width and reflecting the rest of the spectrum. All are constructed of very thin stacked layers. Of the three, only the metal dielectric stack shows any significant absorption and thermal heating. After further analysis, the best method will be chosen for fabrication of a beam splitter for experimental characterization.

The concept of liquid filter is absorption of a selected portion of the spectrum by the liquid and the passage of the rest of the spectrum. The liquid is heated, while the band pass portion of the spectrum is available for direct conversion. Because of the liquid heating, this method will be limited to temperatures below the thermal stability limit of the photoactive species in the liquid.

Spectral Shifting

At Hughes Aircraft researchers are working on spectral shifting by using the Welsbach Effect. Dysprosium-Zirconia mixture was chosen as the initial Welsbach material. A solid solution Dysprosium-Zirconia a sample has been prepared as a disc.

The optical system for testing samples at a solar concentration of 100 times has been designed. The sunlight is incident on an anular Fresnel lens and is focused on the concentrator cell. The noneffective wavelengths are reflected by the selective mirror and focused on the Welsbach material. This material then radiates usable wavelengths which are focused again by an elliptic reflector onto the solar cell. Most parts for the system are off-the-shelf items, except for the selective mirror. A mirror with the requirements in reflection and transmission seems to be very difficult to manufacture.

At this point, Hughes Aircraft decided to review materials to learn if the absorbance in the ultraviolet and visible portions of the spectrum could be increased by the addition of some other element to the Dysprosium-Zirconia mixture. If this is possible, Hughes could use a cold mirror which reflects ultraviolet and visible light and transmits .7 to 2.0 micronmeters. This type of mirror is routinely manufactured and can be easily procured. This question should be resolved during the next reporting period, and will allow data collection to begin.

PROGRAM ELEMENT 6.0 RESOURCE ASSESSMENT INSTRUMENTATION

The objective of Resource Assessment Evaluation is to evaluate, to establish the uncertainty of, the national direct beam insolation data base and monitoring network and to improve it. The Instrumentation and Measurement Workshop in fiscal year 1984 established the improvement of the national direct beam insolation data base and monitoring network as the number one priority for instrumentation and measurements in the Solar Thermal Program. This is due to a very strong need for measured and accurate data on direct-beam insolation and due to the fact that the current national data base (SOLMET/ERSATZ, 1953-1975) comprises data of questionable accuracy (10 percent to 30 percent estimated). In addition, the current monitoring network (National Weather Service, 38 stations, 1976 to present) is unsatisfactory due to poor quality of data and diffculty of data retrieval.

During fiscal year 1985, SERI is to complete the evaluation of a low-cost microprocessor-based solar tracker for direct-beam measurements. Such a tracker will be evaluated by utilizing expertise at historically black colleges and universities in conjunction with the SERI Radiation Research Laboratory. It is anticipated that the microprocessor-based tracker will be suitable and will represent a significant improvement for direct beam measurements. SERI is to work with the National Oceanic and Atmospheric Administration and with participants in solar thermal technology to implement the improved tracker in current monitoring programs.

PROGRESS

Two position sensors for tracker evaluations were completed. Copies of the report in draft form (TR-215-2612), "Spectral Measurements at the Solar One Power Plant," were printed and distributed for review both internally and externally prior to final publication. Orders for data on satellite images and ground observations were placed. Regions covered are the Western United States and the Caribbean. These data will provide improved information on cloud cover for radiative transfer models to be used to estimate direct beam irradiance.

In response to requests from DOE, discussions were initiated with Babcock and Wilcox regarding the assessment of direct beam solar resources in the Dominican Republic. This assessment is needed for the design of a 20 MW central receiver power plant to be built at Monte Cristi. Initial plans for installation of equipment and collection of data for the Dominican Republic and Puerto Rico were made during a visit to Babcock and Wilcox at Barberton, Ohio.

The evaluation of the national direct beam data base is continuing. A summary description of quality control measures employed by the collecting agencies was prepared.

APPENDIX A

SUBCONTRACTS

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
The 3M Company	1.0	Silver/polymer reflector material research	To Be Determined	Industrial Firm	Negotiations in progress	P. Schissel
Jet Propulsion Laboratory	1.0	Stabilization of polymer materials against UV degradation	To Be Determined	Federal Laboratory	Planned for award in April, 1985	P. Schissel
University of Denver	1.0	Stabilization of Silver/ Polymer reflector materials against UV degradation	To Be Determined	University	Planned for award in April, 1985	P. Schissel
To Be Determined	1.0	Protection of front surfaced mirrors from environmental exposure	To Be Determined	To Be Determined	Planned for award in June, 1985	P. Schissel
University of Denver	1.0	Polymer-protected silver mirrors and mirror degradation mechanisms	42.0	University	Awarded in FY 1984 and continuing into FY 1985	P. Schissel
Southern Research Institute	1.0	Development of novel protective coatings for solar reflectors	68.3	Not-for-profit Corporation	Awarded	G. Nix
To Be Determined	1.0	Optically uniform surfaces	To Be Determined	To Be Determined	Planned for award in July, 1985	M. Murphy
To Be Determined	1.0	Polymer laminates for stretched membrane reflectors	To Be Determined	Industrial Firm	Planned for award in July, 1985	M. Murphy

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
DAN/KA Products	2.0	Design and fabrication of five scale-model stretched membrane reflector modules	110.0	Solar Thermal Industrial Firm/Small Business	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
Colorado State University	2.0	Identification and evaluation of wind avoidance/reduction schemes for concentration collectors	70.0	University	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
Consulting Agreement with Dr. Sachin Bhaduri (University of Texas/El Paso)	2.0	Provision of technical support to SERI on wind avoidance/ reduction schemes for concentrating collectors	7.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
Consulting Agreement with Dr. Bing Chen (University of Nebraska/Omaha)	2.0	Design, fabrication and evaluation of experimental RF systems for controlling heliostat fields	7.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
Consulting Agreement with Dr. James Pearson (John Brown University, Siloam Springs, AK)	2.0	Design, fabrication and evaluation of experimental RF systems for controlling heliostat fields	7.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
University of Arizona	2.0	Fabrication and evaluation of graphite fiber composite solar concentrators	30.0	University	Awarded in FY 1984 and continuing into FY 1985	M. Murphy
Acurex Solar, Inc.	2.0	Silver/metal reflector materials evaluation	11.0	Solar Thermal Industrial Firm	Awarded in FY 1984 and continuing into FY 1985	P. Schissel

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
Consulting Agreement with Dr. A. H. Soni (Oklahoma State University)	2.0	Analysis and design of adjustable cable restraints for air-inflated heliostat drive/supports	10.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	R. Wood
Acurex Solar Corporation	2.0	Holographic solar concentrators	205.7	Solar Thermal Industrial Firm	Awarded Follow-on anticipated in November, 1985	G. Nix
University of Nebraska/Omaha	2.0	Stretched membrane reflector dynamic analysis	To Be Determined	University	Planned for award in April, 1985	M. Murphy
Colorado State University	2.0	Wind response on stretched membrane reflectors	To Be Determined	University	Follow-on research planned for award in April 1985	M. Murphy
University of Arizona	2.0	Composite structural materials for stretched membrane reflector modules	78.8	University	Awarded	M. Murphy
To be Determined	2.0	Evaluation of refractive concentrators	To Be Determined	Solar Thermal Industrial Firm/Small Business	Planned for award in March, 1985	M. Murphy
Dan-Ka Products, Inc.	2.0	Stretched membrane reflector structural requirements definition	To Be Determined	Small Business	Follow-on planned for award in May, 1985	M. Murphy

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
Georgia Institute of Technology	1.0 3.0	University research in support of the FY 1985 Solar Thermal Research Program (Thermal materials, direct absorption, etc.)	660.0	University	Awarded	G. Nix
Georgia Institute of Technology	3.0	Operation and maintenance of the Advanced Components Test Facility (ACTF)	235.0	University	Awarded	G. Nix
Consulting Agreement with Dr. Richard Bradt (University of Washington)	3.0	Four-point flexural testing and provision of technical support to SERI on high temperature materials	9.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	T. Coyle
Black & Veatch Consulting Engineers	3.0	Research program planning support to SERI	75.0	Solar Thermal Industrial Firm	Awarded in FY 1984 and continuing into FY 1985	L. Shannon
Consulting Agreement with Mr. Conrad M. Vineyard (Loveland, CO)	3.0	Solar thermal technology cost estimation technical support	10.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	M. Murphy

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
Consulting Agreement with Mr. George M. Kaplan (Reston, VA)	3.0	Solar Thermal Research Program Support	5.0	Consulting Agreement	Awarded in FY 1984 and continuing into FY 1985	B. Gupta
Industrial Welding Supply	3.0	Fabrication of a 900°C molten salt test loop	226.0	Industrial Firm	Awarded	M. Carasso
To Be Determined	3.0	Cyclic heating effects	To Be Determined	To Be Determined	Award Date to Be Determined Later	P. Schissel
To Be Determined	3.0	Acquisition of high flux experiment hardware	To Be Determined	To Be Determined	Planned for award after completion of detailed engineering design	A. Lewandowski
University of Houston	3.0 4.0	University research in support of the FY 1985 Solar Thermal Research Program (Photodegradation research, thermochemical energy storage systems, etc.)	350.0	University	Awarded	G. Nix
Hughes Aircraft Company	4.0	Thermoelectrochemical converter research	221.7	Industrial Firm	Awarded	G. Nix
University of New Hampshire	4.0	Solar photochemical production of fuels and chemicals	56.0	University	Awarded	G. Nix
Lawrence Berkeley Laboratory	4.0	Direct radiant heating of solid suspensions	To Be Determined	Federal Laboratory	Follow-on research	G. Nix

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
University of Hawaii	4.0	Direct flux decomposition of particles	To Be Determined	University	Follow-on research planned for award in May 1985	G. Nix
Hughes Aircraft	4.0	Thermoelectrochemical conversion devices	To Be Determined	Industrial Firm	Follow-on research planned for award in January, 1986	G. Nix
To Be Determined	4.0	Nonequilibrium reactions	To Be Determined	To Be Determined	Award date to be determined Later	D. Johnson
University of Arizona	5.0	Spectrally selective beam splitters for thermally decoupled quantum/thermal hybrid systems	69.5	University	Awarded	G. Nix
Hughes Aircraft Company	5.0	New ideas for solar thermal conversion (Welsback Effect Research)	58.9	Industrial Firm	Awarded	G. Nix
University of Chicago	5.0	Compound optical systems with maximal concentration for solar thermal conversion	77.1	University	Awarded	G. Nix
To Be Determined	5.0	Innovative Concentrators	To Be Determined	To Be Determined	Planned for award in late FY 1985	M. Murphy

SOLAR THERMAL RESEARCH PROGRAM SUBCONTRACTS

Subcontractor	WBS Number	Subcontract Title/Activity	Value (000$)	Type Business	Status	Technical Monitor
Radiation Research Associates	6.0	Generation of Monte Carlo simulation estimates of attenuation and scattering between heliostats and a receiver	25.0	Small Business	Awarded in FY 1984 and continuing into FY 1985	G. Maxwell
Bluefield State University	6.0	Resource data monitoring	To Be Determined	Historically Black University	Planned for award in April, 1985	G. Maxwell
To Be Determined	6.0	UV burst effects	To Be Determined	To Be Determined	Planned for award in June, 1985	G. Maxwell

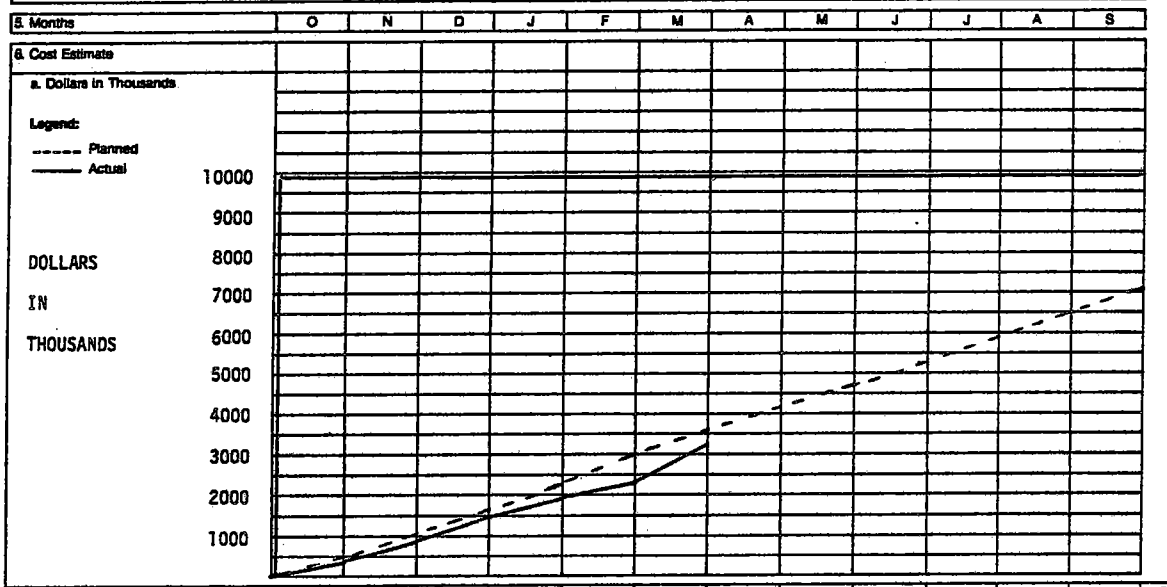
APPENDIX B

RESOURCE EXPENDITURE

RESOURCE EXPENDITURE

Budget Status

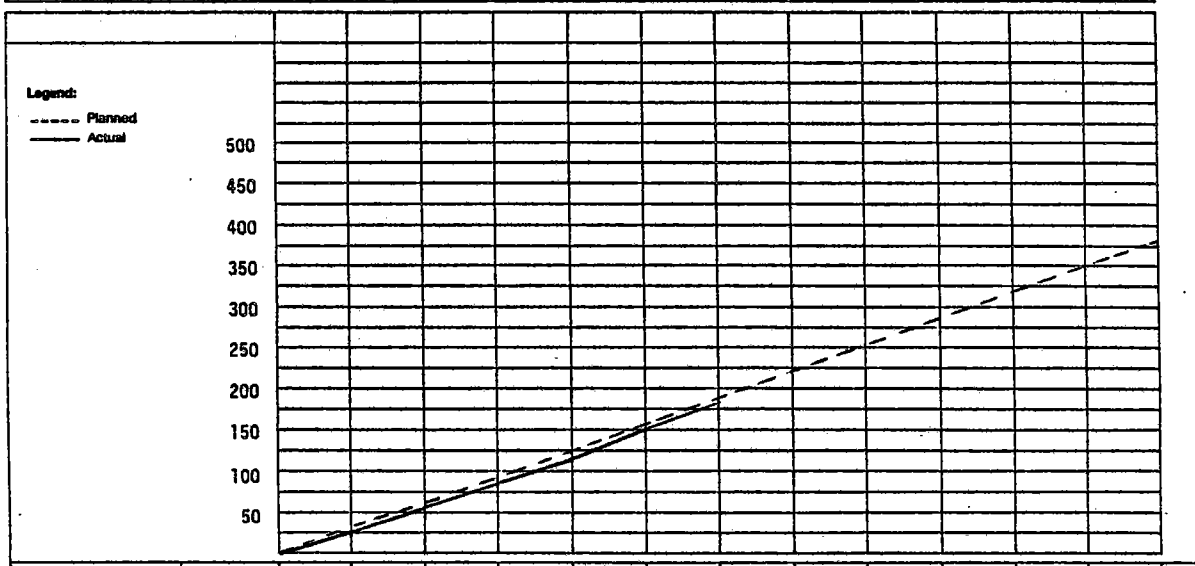
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To: 9/30/85
3. Program Identification: FY1985 Solar Thermal Research Program	
4. WPA/Task: COST SUMMARY: OVERALL PROGRAM TOTALS	



Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	499	1047	1608	2350	3030	3568	4209	4786	5353	5916	6468	7021	b. Planned
	c. Actual	458	969	1517	1936	2398	3231							c. Actual
	d. Variance	41	78	91	414	632	287							d. Variance

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To 09/30/85
3. Program Identification: FY1985 Solar Thermal Research Program	
4. WPA/Task: FTE SUMMARY: OVERALL PROGRAM TOTALS	



		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	29.8	60.1	89.4	126.4	160.9	191.7	226.2	257.0	287.6	318.3	348.9	380.0	Planned
	Actual	26.7	56.3	83.8	119.7	155.4	188.5							Actual
	Variance	3.1	3.8	5.6	6.7	5.5	3.2							

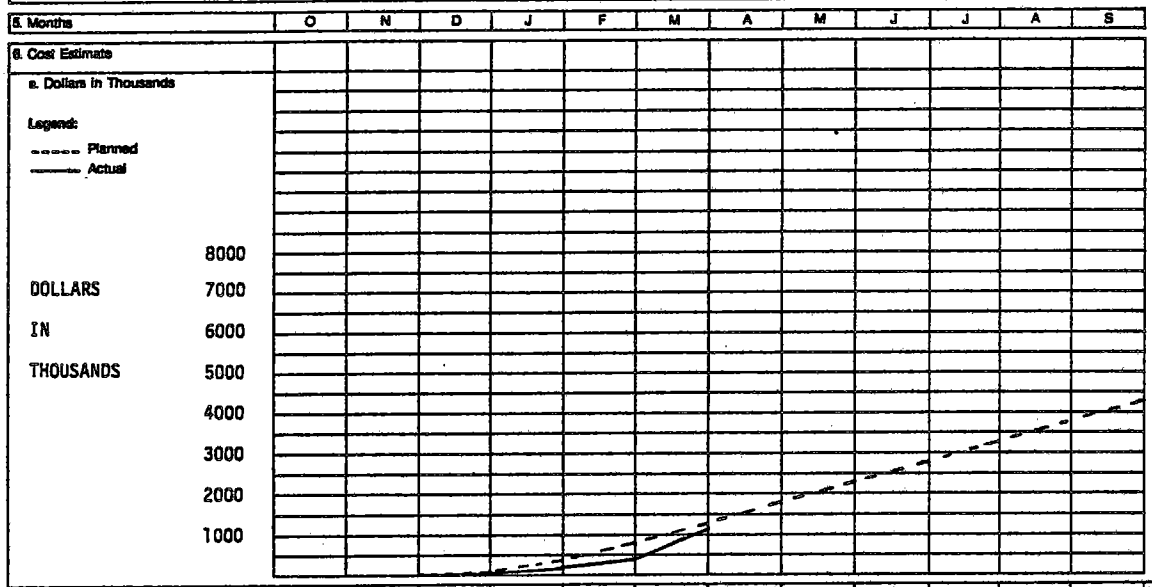
RESOURCE EXPENDITURE

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: 9/30/85

3. Program Identification: FY1985 Solar Thermal Research Program

4. WPA/Task: COST SUMMARY: FY1985 FTA 510 and FTA 511



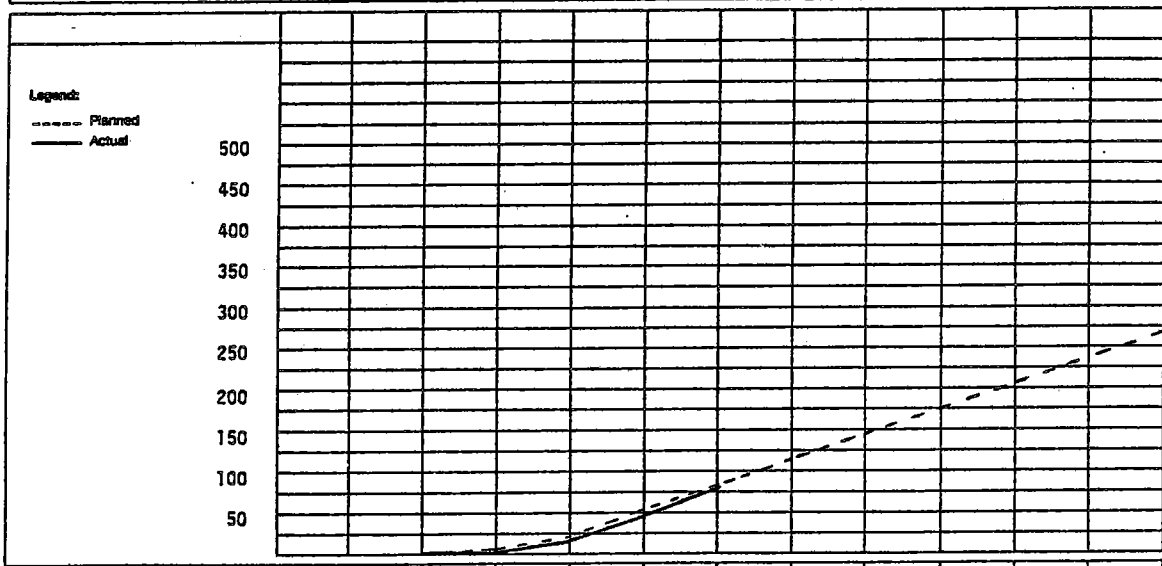
Accrued Costs		O	N	D	J	F	M	A	M	J	J	A	S	
	b. Planned	0	0	22	417	858	1303	1802	2292	2776	3256	3725	4193	b. Planned
	c. Actual	0	0	12	189	469	1202							c. Actual
	d. Variance	0	0	10	228	389	101							d. Variance

Manpower

1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To 09/30/85

3. Program Identification: FY1985 Solar Thermal Research Program

4. WPA/Task: FTE SUMMARY: FY1985 FTA 510 and FTA 511

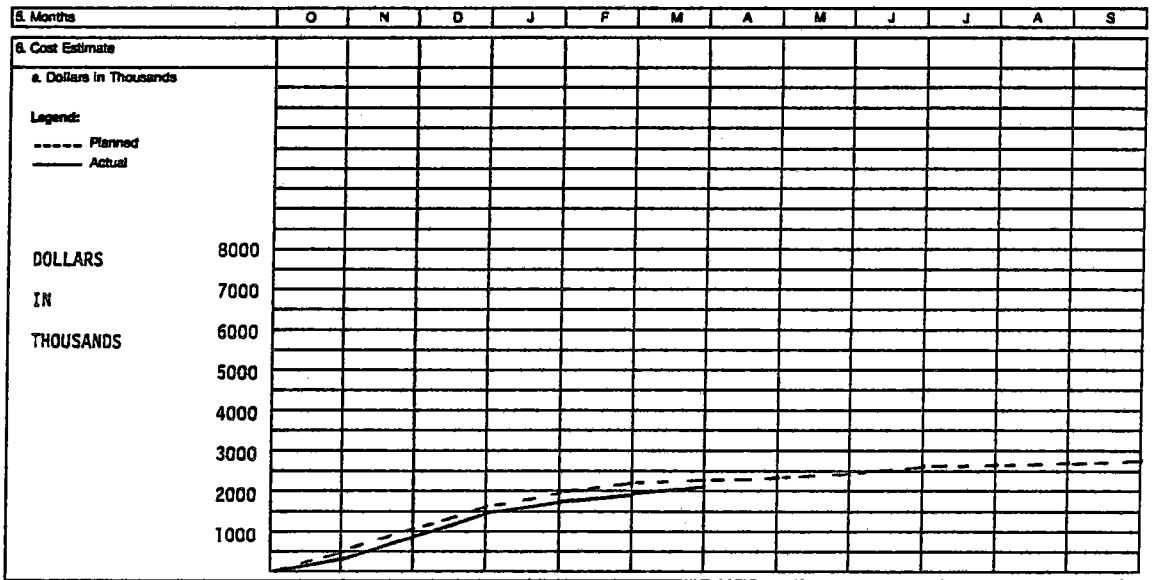


		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	0	0	2.5	23.7	52.8	82.4	116.8	147.6	178.2	208.9	239.5	270.6	Planned
	Actual	0	0	1.1	22.5	49.8	79.8							Actual
	Variance	0	0	1.4	1.2	3.0	2.6							

RESOURCE EXPENDITURE

Budget Status

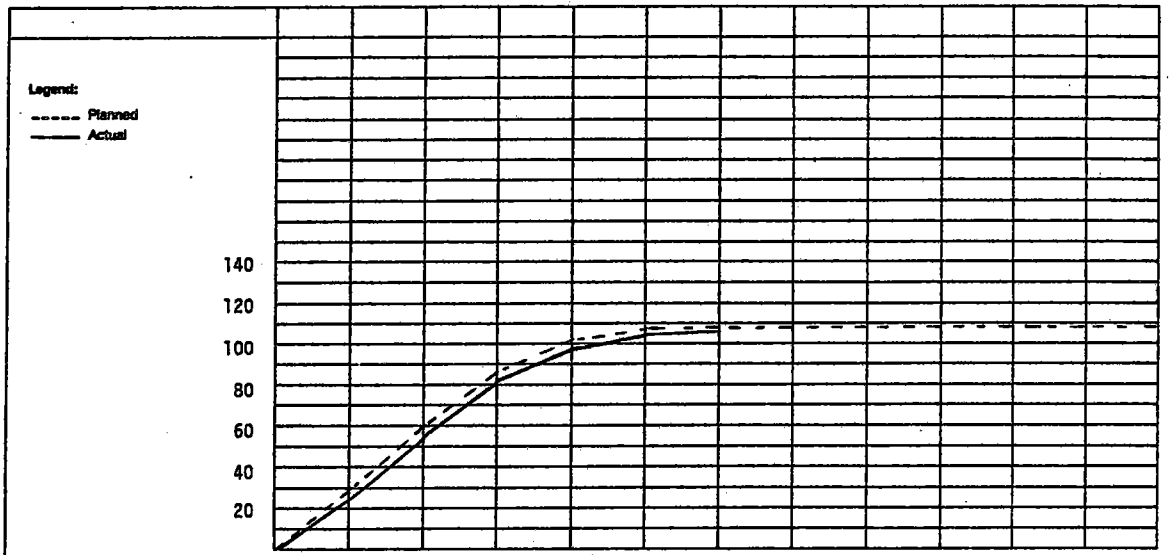
1. Contractor (name and address)	2. Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To: 9/30/85
3. Program Identification: FY1985 Solar Thermal Research Program	
4. WPA/Task: COST SUMMARY: FY1982 - FY1984-FTA 416, FTA 417, FTA 440, FTA 463	



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
6. Cost Estimate														
Accrued Costs	b. Planned	499	1047	1586	1933	2172	2265	2407	2494	2577	2660	2743	2828	b. Planned
	c. Actual	458	369	1505	1747	1929	2079							c. Actual
	d. Variance	41	78	81	186	243	186							d. Variance

Manpower

1. Contractor (name and address)	2 Reporting Period
Solar Energy Research Institute 1617 Cole Boulevard Golden, Colorado 80401	From: 10/1/84 To 09/30/85
3. Program Identification: FY1985 Solar Thermal Research Program	
4. WPA/Task: FTE SUMMARY: FY1982 - FY1984 - FTA 416, FTA 417, FTA 440, FTA 463	



5. Months		O	N	D	J	F	M	A	M	J	J	A	S	
	Planned	29.8	60.1	86.9	102.7	108.1	109.3	109.4	109.4	109.4	109.4	109.4	109.4	Planned
	Actual	26.7	56.3	82.7	97.2	105.6	108.7							Actual
	Variance	3.1	3.8	4.2	5.5	2.5	.6							

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PUBLICATIONS

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

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

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.

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Gordon, 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.

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Murphy, L. M.; Sallis, D. V. Simms, D. (In progress) Structural Design Considerations for Stretched Membrane Heliostat Reflector Modules with Stability and Initial Imperfection Considerations. 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.

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Wood, R. (In progress) The Optics of Flat Mirror Vee-Troughs. SERI/TPJ-253-2447. Golden, CO: Solar Energy Research Institute.

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

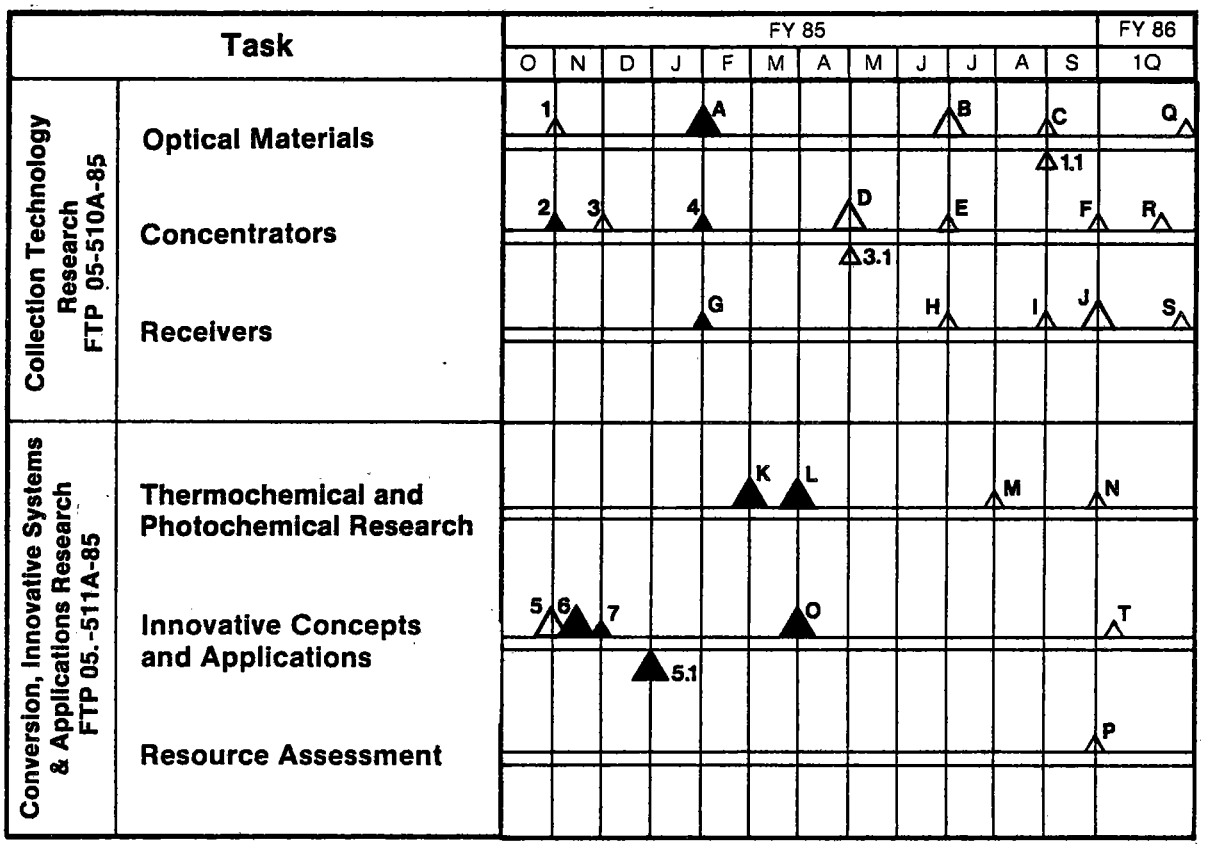
Zangrando, F. (In progress) Survey of Density Measurement Techniques for Application in Stratified Fluids. SERI/TR-252-2221. Golden, CO: Solar Energy Research Institute.

Zangrando, F. and Johnson, D. H. (In progress) Review of SERI Solar Pond Work. SERI/TR-253-2477. Golden, CO: Solar Energy Research Institute.

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

Solar Thermal

Major Milestone Schedule



FY84 Funded Effort (FTP 05-463--84)

1. 3M film surface durability improvement
2. Membrane surface deformation and tension load effects
3. Membrane comparison with glass/metal heliostat
4. Membrane frame coupling concept
5. Award Phase II innovative research contracts
6. Award new innovative research contracts
7. Experimental H yield from 10 sun photoconversion process

FY85 Funded Effort

A. Silver/polymer UV protection approaches
B. Solar test on mosaic windows
C. Silver/polymer film samples with UV protection
D. Steel membrane module performance projection
E. Wind load reduction concepts for concentrators
F. Fresnel lens concept assessment
G. Award 900°C loop fabrication contract
H. Carbonate salt and Inconel optical properties up to 900°C
I. Four wavelength pyrometer experience and data
J. Direct absorption receiver concept feasibility
K. Evaluate research progress in unique and beneficial use of concentrated solar flux
L. Concentrated flux effects on surface reaction
M. Materials effects experiments with concentrated flux
N. High flux experiment support equipment
O. Direct thermal conversion concepts evaluation
P. UV radiation measurement instrumentation
Q. Silver/polymer film useful service life prediction
R. New, innovative concentrator concepts assessment
S. Direct absorption concept benefits assessment
T. Recommend concepts for further evaluation

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