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THE AEROSPACE CORPORATION

Aerospace Report No.
ATR-77(7523-22)-1

SUMMARY REPORT

SOLAR THERMAL POWER SYSTEMS PROGRAM
DISPERSED POWER SYSTEMS PROJECTS
AND
RESEARCH AND DEVELOPMENT PROJECTS

26, 27 JANUARY 1977

ALBUQUERQUE, NEW MEXICO

Sponsored by

Energy Research and Development Administration
Division of Solar Energy
Washington, D.C.

March 1977

Prepared by

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NASA Lewis Research Center
Cleveland, Ohio

Sandia Laboratories
Albuquerque, N.M.

ERDA Contract No. E(04-3)-1101

Project Agreement No. 2

FOREWORD

This report presents a summary of the contracts comprising the ERDA Dispersed Power Systems Projects and R&D Projects. These projects were reviewed by ERDA in Albuquerque, New Mexico on 26 and 27 January 1977.

The Dispersed Power Systems Projects are comprised of Total Energy, Irrigation and Small Community Systems Projects. The objectives of these projects are to demonstrate technical, economical and institutional feasibility of these solar energy applications and to promote within appropriate industrial, agricultural or community sectors, technologies which offer the prospect of being economically competitive with other energy sources.

The Research and Development Projects are designed to explore materials technology, and component and subsystem development in support of the objectives of the entire Solar Thermal Program.

As a result of the general review of these projects and the subsequent deliberations by the Ad Hoc Review Committee, The Aerospace Corporation was asked to update the pre-meeting data package normally prepared for the Ad Hoc Review Committee and to issue it in lieu of the usual Meeting Highlights Report. To assure that the most recent status for each project was objectively recorded, Jet Propulsion Laboratory, Lewis Research Center, and Sandia who provide ERDA with technical management support for the individual projects were requested to review and revise the pre-meeting data package. Aerospace then compiled this information into this Program Summary. The report then represents a joint effort with these organizations. The report contains both programmatic information and brief overviews of technical status and accomplishments of the various projects. This report was compiled by S. J. Fenster, a Member of the Technical Staff of The Aerospace Corporation.

The author wishes to acknowledge the valuable assistance of Micki Lewis, Sandi Herron, Mary Lou Black and Ginny Jackson in preparing this publication.

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1.0 PROGRAM TECHNICAL SUPPORT - The Aerospace Corporation

1.1 Program Summary

Title:	Organization:
Solar Thermal Program Support Systems Engineering and Mission Analysis	The Aerospace Corporation P. O. Box 92957 Los Angeles, California 90009
Amount: $1,085,000	Principal Investigator: Dr. Mason B. Watson (213) 648-5615

Effective Date:	Duration or Ending Date:	Contract No.
12 December 1975	15 December 1976	E(04-3)-1101

Objectives and Tasks

This is a consolidation and continuation of the Solar Thermal Program Support and Mission Analysis efforts underway at The Aerospace Corporation to develop and implement the technology necessary to generate solar thermal power.

In order to achieve these objectives The Aerospace Corporation is involved in the following tasks:

1) Assistance in the development of the overall program plan for the ERDA solar thermal program including the provision of independent technical assessments of program status and prospects.

2) Provision of general systems engineering for the overall identification, development and integration of subsystems; to identify design compromises among those subsystems; to define the interfaces between major subsystems; and to define and assist in developing required test plans.

3) Provision of technical reviews of contractor designs and conduct of independent analyses of key problem areas identified by ERDA or The Aerospace Corporation.

4) Provision of timely technical guidance by alerting ERDA to actions required to assure successful program implementation or to minimize the impact of design changes, cost, schedule and performance on program implementation.

1.2 Program Status

As part of this contract The Aerospace Corporation is conducting mission analyses for three Dispersed Power Systems Projects. These are the Solar Total Energy Project, the Small Community Project, and the Irrigation Systems Project. Approximately 25% of the total contract activity is allocated to these analysis tasks.

Solar Total Energy Systems Project

The purpose of the Solar Total Energy (STE) Systems Project is to:

1. Identify preferred applications for solar total energy systems and the solar concept best suited to this application.
2. Define the system requirements for these preferred applications and systems.
3. Estimate the market capture potential, the degree of penetration of the market and associated costs and benefits.

The following discussion summarizes the work being performed by The Aerospace Corporation in support of these objectives.

A solar total energy system computer simulation program has been completely developed and tested. The program uses a 365 day, hourly insolation and demand input and provides the fossil energy displaced, the makeup fuel required, the solar system costs and the cost of equivalent fossil fuel energy.

A study of an idealized STE application utilizing this computer program has been undertaken to determine if such an application would be economically competitive, and to establish desirable characteristics to be sought in practical applications which are to be supplied by STE systems. In order to operate the STE system turbine at a constant power level, a constant electrical demand was assumed for the analysis, with the thermal demand coincident in time. The level of the thermal demand was assumed to

be 3.67 times electrical in order to maximize the utilization of turbine waste heat.

Simulation results for this application, based on a STE system design having 1/2 hour of high temperature storage yielded an equivalent cost ratio* of 0.95, showing that the STE system was economically viable for this application. Subsequent simulation studies in which the thermal and electrical demand profiles and the amount of low temperature storage were adjusted to optimize system performance have indicated that an equivalent cost ratio as low as 0.84 is achievable. Based on these studies it appears that a range of application parameters are possible (see Figure 1) for which STE systems can be economically attractive, and can provide significant levels of fossil fuel displacement.

Planned activities for CY 1977 involve the definition and application of screening criteria to select preferred applications for performance analysis and market assessment to determine economic feasibility and capture potential.

Small Communities Project

The purpose of the Small Communities Project is to determine the conditions under which solar thermal power plants can be technically and economically feasible sources of electric or combined electric and thermal power for small communities. Aerospace Corporation technical support to the project involves assessment of solar/subsystem performance and costs and the analysis of the economic, institutional, environmental and societal considerations which bear on small community ownership and operation of a solar power plant. To facilitate this assessment, several different scenarios have been identified which involve varying degrees of ownership by a small community of generation and/or transmission and/or distribution equipment. The issues being examined for each of these scenarios include cost of

* Equivalent cost ratio is defined as the cost of producing energy from a solar total energy plant relative to the equivalent cost of that energy as supplied by the utility.

RANGES OF IDEALIZED SYSTEM APPLICATION PARAMETERS FOR ECONOMIC VIABILITY ESTABLISHED

- TURBINE INLET TEMPERATURE (and hence receiver temperature) SHOULD BE ~500°F
- LOAD RATIO (ratio of thermal-to-electrical load of ~2.5 to 5.0 required)
  - SMALLER LOAD RATIOS ASSOCIATED WITH HIGHER INLET TEMPERATURES

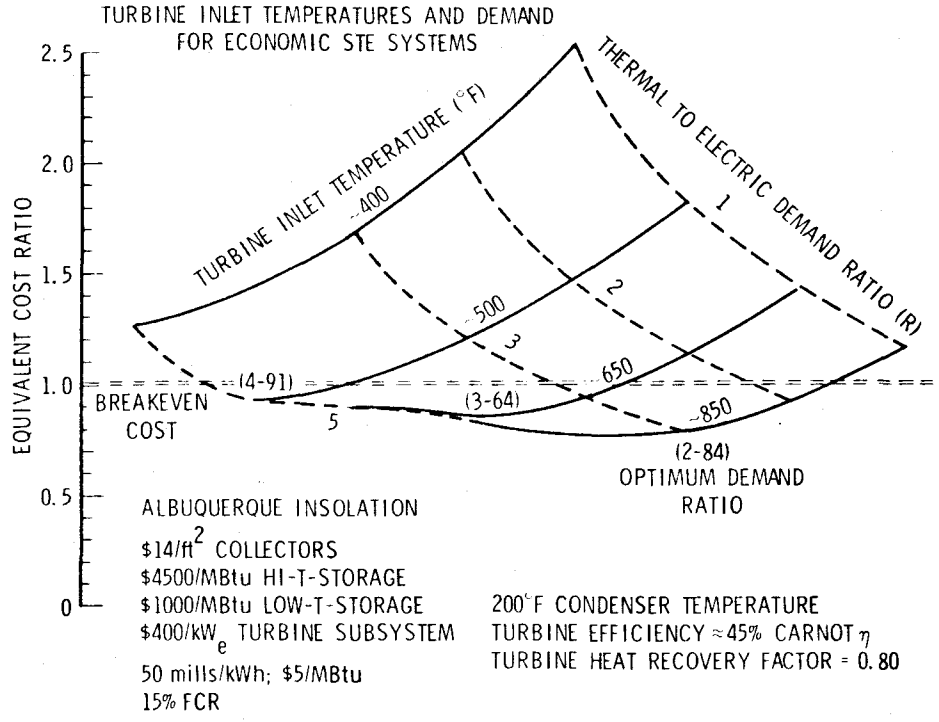


Figure 1. Solar Total Energy System Illustrative Results

ownership, reliability (i.e., quality of service), financing, costs of delivered energy, and the effects on the community of various societal/institutional impacts associated with plant construction and operation.

The study has only been underway a short time, and no definitive conclusions have been reached. Interviews have been conducted with personnel of a few small utilities, and more such interviews are planned. In addition, a series of performance and cost models are being formulated which will permit comparisons to be made of capital investment costs and costs of electrical service for the various scenarios of interest. Some preliminary results of exercising these performance/cost models are expected to be available by early March, 1977 for at least one scenario.

Aerospace is also supporting the ERDA Small Community Project through the technical evaluation of various unsolicited proposals as these are received. Several of these proposals have been submitted to ERDA, each requesting funding for a small community solar plant. Proposals of this type evaluated to date include those from Crosbyton, Texas; Bridgeport, Texas; the Arkansas Electric Company; and the Western Minnesota Municipal Power Agency.

Solar Irrigation System Project

The purpose of the Solar Irrigation System Project is to analyze the performance, economics, and general feasibility of solar irrigation systems; and to foster their development and commercialization. Aerospace Corporation is supporting the project through preparation of RFP's, the evaluation of solicited and unsolicited proposals, and through the performance of technical and economic trade-off studies of various solar system configurations and applications. Specific issues being addressed include the amount of energy storage and/or water storage which is optimum for various applications, the capital costs of systems and subsystems; the range of demand profiles associated with irrigation of various crops in the different regions of the U.S.; and the relative economics of solar irrigation.

The technical portions of an RFP were prepared for ERDA in late calendar 1976. This RFP requested conceptual design studies for a 150 KW solar irrigation system to be sited in the Southwestern U.S. Aerospace also participated in the technical evaluation of approximately 20 responses to the RFP.

Work is also underway in support of the analytical studies enumerated above. Specific activities to date have included the collection of demand data and steps toward the development of system simulation models from which the performance and operating economics of various solar irrigation configurations can be determined.

2.0 TECHNICAL PROJECT MANAGEMENT - Sandia Laboratories

2.1 Program Summary

Title:	Organization:
Technical Management ERDA/DSE Solar Total Energy Activities	Sandia Laboratories P. O. Box 5800 Albuquerque, N. Mex. 87115
Amount: $1,180,000	Principal Investigator: R. Stromberg

Effective Date:	Duration or Ending Date:	Contract No.
1 October 1976	1 October 1977	

Objectives and Tasks

Project management of ERDA/DSE's solar total energy activities at Sandia Laboratories is to support ERDA/DSE in planning for a Solar Total Energy effort and for technical monitoring of DSE-sponsored contracts. The cost budget category EA-03-01 is applicable to this activity.

The above authorization is to provide Sandia Laboratories funding to:

1) Maintain a long-range Solar Total Energy Program Plan in cooperation with the Solar Thermal and Project Branches of ERDA/DSE;

2) Prepare Annual Operating Plans based on the long range plan; and

3) To technically monitor existing ERDA/HQ issued contracts pertaining to Solar Total Energy.

2.2 Program Status

During this reporting period two new contracts have been placed, by Sandia Laboratories, as a part of the systems engineering activities. A description of these contracts is:

A. Program Title: Site Selection Algorithm

Contract Amount: $30,000

Contractor: Woodward-Clyde Consultants

Objective: Provide a decision methodology whereby, using as input an assessment of the attributes of proposed sites for Solar Total Energy Systems, the value of each site may be rank ordered relative to its ability to meet given criteria. The methodology is to be capable of testing the sensitivity of the rank order by varying the priority or weighting of the various criteria.

Completion Date: On or about 1 March 1977

B. Program Title: STE Impact on Utilities Study

Contract Amount: $35,570 (cost no fee)

Contractor: Electric Power Institute
Texas A&M Research Foundation

Objective: The objective of the study is to evaluate the impact of STE systems on electric utility design practice, including provisions for adequate service, reliability, and overall economics, presuming that STE systems

are operated under the control of electric utilities. The intent is to identify the benefits which would accrue to electric utilities through parallel operation with STE systems.

Completion Date: On or about May 1, 1977

Sandia Laboratories is also providing the technical project management for component and subsystem development in ERDA/DSE's Solar Total Energy activities. The objectives of this program element are:

a. To encourage the development of reliable, cost effective components and the necessary capabilities for fabrication by multiple suppliers;

b. To stimulate performance improvement and cost reduction through testing and evaluation of collectors, materials and components;

c. To support the solar total energy program goals by providing proven collector and subsystem designs for use in Large Scale Experiments and Demonstrations.

Contracts have been approved with Itek Corporation and General Electric Co. for fabrication and evaluation of candidate receivers for the Sheldahl SLATS collector being installed at the Collector Module Test Facility. Prototype hardware will be tested at that facility.

Contracts have been approved with FMC Corporation, Engineering System Division, and Del Manufacturing Co., to fabricate prototype collectors. The FMC unit is a ten foot wide Fresnel belt collector to be

oriented on an E-W alignment. The Del unit is a parabolic trough with a silvered, sagged glass reflector. Prototypes of both designs will be tested at the ERDA Collector Module Test Facility at Sandia Laboratories.

Responses to an RFP for immediate procurement of existing collector designs are due by February 7, 1977. This short term effort will assess the capabilities of the collectors available for testing in approximately four months.

A Request for Proposal is in preparation for development projects on new and innovative collector concepts. Advertisements have been placed in the Wall Street Journal and Commerce Business Daily seeking statements of interest from industry and universities.

An internal Sandia effort in the materials area continues to pursue structures for collector reflectors, reflector materials and coatings.

3.0 TECHNICAL PROJECT MANAGEMENT - Jet Propulsion Laboratories

3.1 Program Summary

Title:	Organization:
Management Support of Solar Thermal Research and Development Program	Jet Propulsion Laboratories 4800 Oak Grove Drive Pasadena, Calif. 91103
Amount:	Principal Investigator:
$909,000	Dr. V. Truscello

Effective Date:	Duration or Ending Date:	Contract No.
11/5/76	4/30/77	E(49-26)-1060

Objectives and Tasks

The objective of the project is to provide NASA support to ERDA in the management of a Solar Thermal Electric Research and Development Program. NASA has designated JPL as the coordinating center.

The project is divided into three tasks as follows: 1) Management overview and coordination in support of the R&D program; 2) Research and Development program planning and studies; and 3) Research and Development contract monitoring and direction.

3.2 Program Status

This program has just begun.

5.0 INDUSTRIAL APPLICATION STUDY - McDonnell Douglas

5.1 Program Summary

Title:	Organization:
Industrial Applications of Solar Energy	McDonnell Douglas Corporation 5301 Bolsa Avenue
Amount: $419,812	Principal Investigator: J. E. Rogan (714) 876-2755

Effective Date:	Duration or Ending Date:	Contract No.
15 September 1975	19.5 mo.*	EY-76-C-03-1132

Objectives and Tasks

Contract Objective:

Characterize applicability of solar total energy to industrial sector of U.S., prepare solar total energy systems conceptual design, estimate market penetration, and recommend project plans for preliminary design for demonstration plants.

Technical Approach:

Survey industrial energy users characterized by Standard Industrial Codes. Identify and characterize large energy user groups. Identify factors affecting market penetration such as availability of solar components, institutional constraints, and competing energy sources. Perform conceptual design and estimate costs for solar total energy systems, and estimate market penetration.

*Includes no-cost extension from July 15, 1976 to November 1, 1976.

5.2 Program Status

The contractor has surveyed both the Southwest and the entire United States and found that the following six groups of industries are the most energy intensive and account for about 80% of the total industrial usage in the United States and 88% in the Southwest: (See Figures 2 and 3).

1. Chemicals and Allied Products
2. Primary Metals
3. Petroleum and Coal Products
4. Paper and Allied Products
5. Stone, Clay and Glass
6. Food and Kindred Products

Within these categories about 1000 industries have been contacted in an effort to determine their specific energy requirements and demand schedules. About 11% of these contacts replied and only some of these provided usable load data.

Based upon each specific industry characterization supplied by these requests, a solar total energy system is synthesized. Table I illustrates the industries analyzed and Figure 4 shows a schematic of a typical synthesis, a concrete block plant located in south-central Texas. In an effort to rank the candidates on a consistent basis for further conceptual design or performing analysis, the contractor is utilizing figures of merit such as shown in Table II.

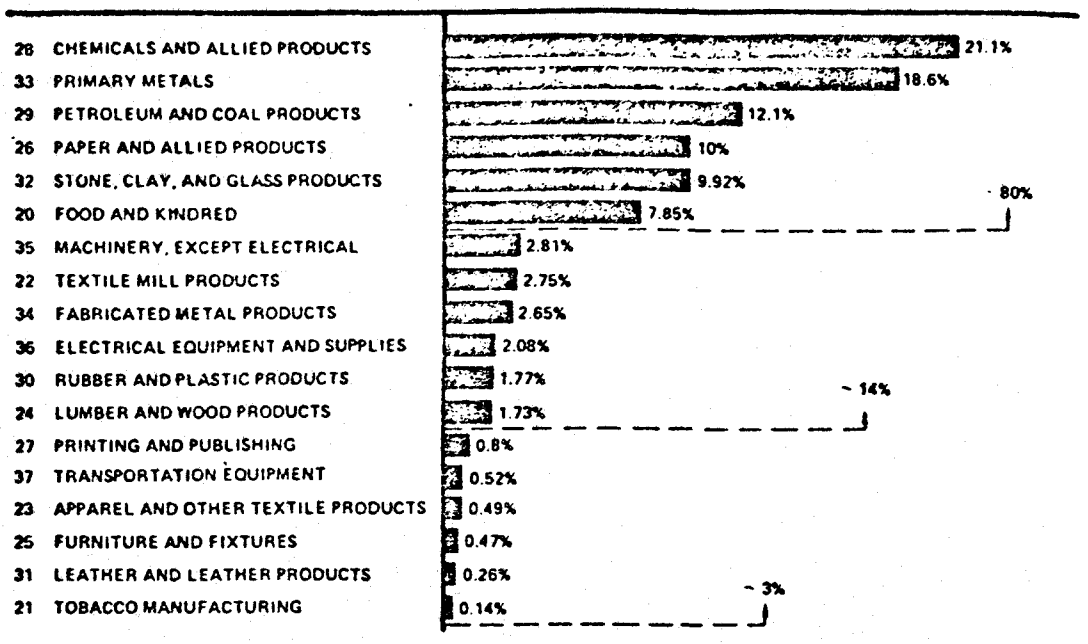


Figure 2. Nationwide Industrial Energy Consumption

	NATIONWIDE	SOUTHWEST
TOTAL	80%	88%
NATURAL GAS	85%	92%
FUEL OIL	77%	65%
ELECTRICITY	65%	69%

Figure 3. Total Energy Systems Industrial Applications of Solar Energy

Table I. Solar Total Energy Systems - Industrial Applications

INDUSTRIES ANALYZED

SIC CODE	DESCRIPTION	MAX COLLECTOR TEMPERATURE °F	SYSTEM PROCESS TEMPERATURE °F
2011	(2) MEAT PACKING	750	353; 180
2026	(2) FLUID MILK PROCESSING	750	240; 235
2033	PEACH AND PEAR CANNING	500	345
2033	(2) TOMATO PROCESSING	382; 750	327; 328
2063	(2) SUGAR BEET PROCESSING	600	332; 360
2092	TUNA PROCESSING	750	353
2611, 2621	PULP AND PAPER MILL	900	554
2819	NA_2SO_4 PRODUCTION	750 (600)[1]	570 D[2]
2834	PHARMACEUTICAL FACILITY	750	240
2851	PAINT MANUFACTURING	750	NO PROCESS HEAT
2874	(2) POTASH PROCESSING	750; 750 (600)	404, 697D; 240, 571D
2911	(2) PETROLEUM REFINING	750; TBD	365; TBD
2951	ASPHALT PAVING MATERIAL	750	658D
3271	(3) CONCRETE BLOCK MANUFACTURING	600; 650; 750	240
3272	PRESTRESSED CONCRETE PRODUCTS	600	240
3479	ELECTROPLATING/ANODIZING	600	250

1 VALUE IN( ) USED IN TRADE STUDY

2 D ~ DRIER TEMPERATURE ALL OTHERS STEAM

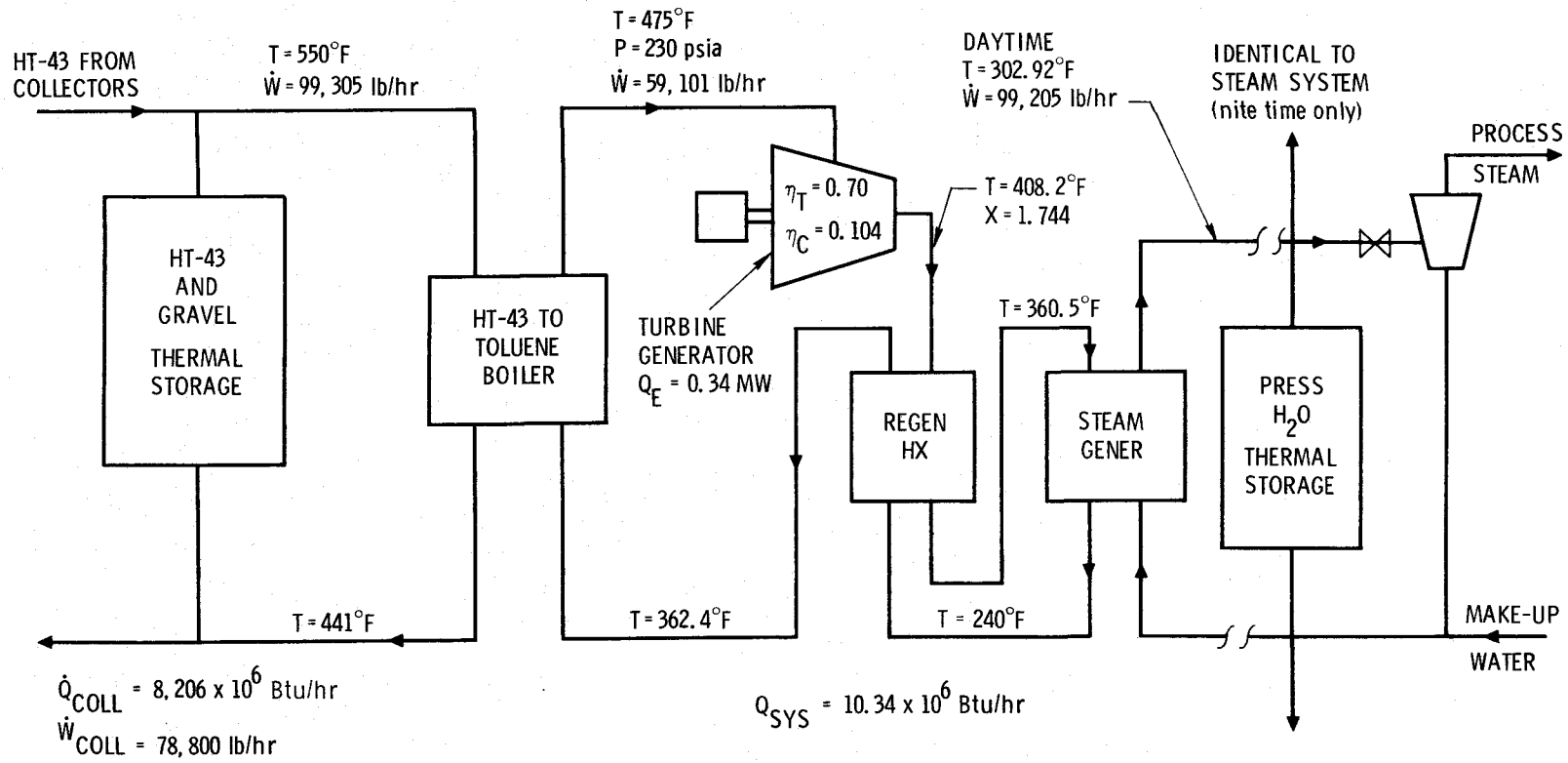


Figure 4. Concrete Block – South Central Texas – Toluene

Table II. Figures of Merit -- Concrete Block - So. Central Texas (REOO)

FIGURE-OF-MERIT	SOLAR ENERGY				LAND		ENERGY	FUEL	ELECTRICITY
	COLLECTED / INCIDENT		UTILIZED / COLLECTED	COLLECTED / AVAILABLE	REQUIRED / AVAILABLE		PROVIDED / REQUIRED	DISPLACED EQU. MCF	DISPLACED KWH
COLLECTOR TYPE*	DC	CR	BOTH	BOTH	DC	CR	BOTH	BOTH	BOTH
CASCADED STEAM	.436	.65	1.00	1.00	.198	.105	.551	10,695	487,084
TOLUENE	.463	.65	1.00	1.00	.186	.105	.551	10,695	487,084

*DC - Distributed Concentrating

CR - Central Receiver

6.0 COMMERCIAL APPLICATION STUDY - Atomics International

6.1 Program Summary

Title:	Organization: (Rockwell International)
Application of Solar Integrated Systems to Large Shopping Centers	Atomics International 8900 DeSoto Avenue Canoga Park, CA 91304
Amount:	Principal Investigator:
$249,950	S. J. Nalbandian (213)314-1000 X1336

Effective Date:	Duration or Ending Date:	Contract No.
10 May 1976	12 mos.	E(04-3)-1210

Objectives and Tasks

Contract Objectives:

Define solar total energy applicability to commercial sector of U.S., prepare solar total energy conceptual designs, estimate market penetion, and recommend project plans for preliminary designs for demonstration plants.

Technical Approach:

Survey energy user groups, such as shopping centers, within the U.S. commercial sector. Identify significant energy users. Identify factors affecting market penetration such as availability of solar components, institutional constraints, and competing energy sources. Perform conceptual design and estimate costs of solar total energy systems.

6.2 Program Status

The study logic flow is shown in Figure 5 and includes a progression from study inputs (types of applications, climatology...) to requirements, definition, concept definition, concept evaluation, and project utilization with costing and marketing feeding the latter. Examination of this study shows the extreme detail and complexity of the program.

The main flow of the requirements study involves the following elements (1) site selection criteria based upon typical climatic regions and demographics, (2) building selection criteria and (3) energy demands.

Based upon the fact that about 70% of the floor area of buildings normally considered to be commercial (Table III) are offices, banks, retail stores and shopping centers, the contractor has selected these buildings for preliminary modeling.

Table III. Building Models

- OFFICE/BANK BUILDINGS PLUS RETAIL STORES/SHOPPING CENTERS CONSTITUTE ABOUT 70% OF THE FLOOR AREA (IN PLACE AND PROJECTED) OF ALL BUILDINGS NORMALLY CONSIDERED TO BE COMMERCIAL
- PRELIMINARY MODEL SELECTION

TYPE	FLOOR AREA 1000 sq ft	FLOORS	PEAK ELECTRICITY w/sq ft	DEMAND kWe
1. OFFICE BUILDING, LOW RISE (OBL)	50	3	6	300
2. OFFICE BUILDING, HIGH RISE (OBH)	200	10	6	1200
3. RETAIL STORE, SMALL (RSS)	50	1	5	250
4. RETAIL STORE, LARGE (RSL)	200	3	5	1000
5. SHOPPING CENTER, SMALL (SCS)	200	1	7	1400
6. SHOPPING CENTER, LARGE (SCL)	800	2	9	7200

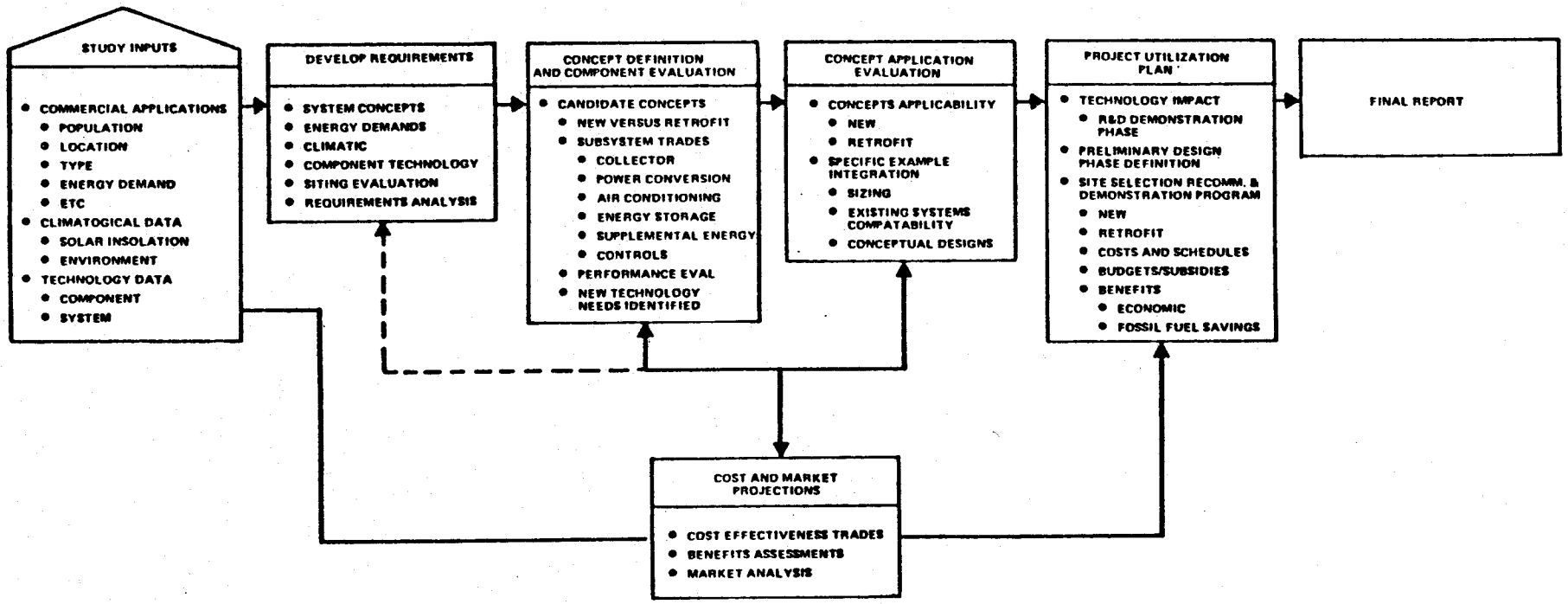


Figure 5. Study Logic Flow

7.0 MILITARY LARGE SCALE EXPERIMENT - American Technological University

7.1 Program Summary

Title:	Organization:
Solar Total Energy, Large Scale Experiment: Phase III Preliminary Design	American Technological University P.O. Box 1416 Killeen, Texas 76541
Amount:	Principal Investigator:
$2,326,854	Robert B. Crouch

Effective Date:	Duration or Ending Date:	Contract No.
23 November 1976	30 November 1977	EG-77-C-04-3878

Objectives and Tasks

This project is intended to provide for generation of electricity, space heating and cooling, and hot water for a troop housing complex at Fort Hood, Texas. The steady state and transient performance of a distributed collector STE system will be evaluated. Installation cost data for assessing STE systems operation in the Department of Defense environment will be obtained. This STE system is expected to include single-axis tracking focusing solar collectors, high-temperature pressurized water storage, conventional steam driven turbo-generator, low-temperature water storage for storing turbine exhaust heat for space-heating and domestic hot water, and control and equipment for interfacing with conventional military base electrical and thermal systems.

The current phase of the effort is to develop the preliminary design of the STE system, to execute a supportive engineering test program, and to provide other technical support and planning activities necessary for entering the detailed design and construction phase of the Military Large Scale Experiment.

7.2 Program Status

Some of the major accomplishments during the current reporting period (July, 1976 - January, 1977) are:

1. Completion of the conceptual design activities. The Phase II Final Report is in preparation.
2. Modification of the contract to provide $140,000 additional funding for the Solar Engineering Test Module (SETM) segment of the project. The 400 ft^2 module has been installed at the test site.
3. Completion of negotiations for the Phase III contract on November 23, 1976. The contract, for an estimated cost of $2,326,854, extending through November 30, 1977, has been signed.

8.0 SOLAR IRRIGATION PROJECT - Sandia Laboratories

8.1 Program Summary

Title:	Organization:
Solar Irrigation Program Technical Director	Sandia Laboratories P.O. Box 5800, Albuquerque, N.M. New Mexico State University Las Cruces, N.M.
Amount:	**Principal Investigator:**
$892,000 (Incremental Funding)	R. Alvis

Effective Date:	Duration or Ending Date:	Contract No.
16 March 1976	30 Months	E(29-1)-0789

Objectives and Tasks

The objective of this project is to evaluate the feasibility of utilizing solar energy to power agricultural irrigation systems, and to demonstrate a first generation system using state-of-the-art equipment.

The project will be approached in three phases. First, a system analysis phase will include the generation of site specific optimization techniques as well as a national demand model. Second, an experimental phase will involve the development of solar thermal irrigation systems and its installation on a working farm in Arizona and New Mexico. Third, a demonstration system will be designed and constructed.

Specifications for the ERDA/N.M. experiment will be complete in May, 1976, assembly will take place during the first three months of 1977 and the system will be operational in June 1977. The second experiment is in the design study phase by 3 companies. In 1978 construction will begin.

Workshops, seminars and technical publications in Agriculture periodicals will be used to communicate the data obtained during the program. The first workshop is planned for June 1977.

8.2 Program Status

One experiment is to be located in the Estancia Valley near Willard, New Mexico and is scheduled to be operational May 1, 1977. The second experiment is to be located in Southern Arizona and be in operation in FY79. The demonstration site has not been chosen, but is expected to be in operation in FY80.

Characteristics such as the shaft horsepower, pressure head, water lift and pump capacity are shown for the proposed system in Tables IV and V. The system will be designed to irrigate 60 acres for about a six month season. The concentrating/tracking collector area will be about 6720 sq ft facing north-south. A schematic of a solar powered irrigation system is shown in Figure 6. Sixteen bids have been received and evaluated for the development of the collectors. The Accurex Corporation was the winner and claims a capability of 9.7 Btu/sq ft/hr/$. The heat engine was purchased from Barber-Nichols after evaluating six separate bids.

Table IV. System Characteristics

POWER IRRIGATION SYSTEM		
SHAFT HORSEPOWER	~	26 HP
WATER LIFT	~	111 FT
PUMP PRESSURE HEAD	~	10 FT
PUMP CAPACITY	~	700 GPM
SEASON	~	100 DAYS
ACREAGE	~	60 ACRES
NONIRRIGATING HEAT SOURCE	~	10×10^6 BTU/DAY
NONIRRIGATING ELECTRICITY GENERATION	~	20 kW (200 kWh/DAY)

Table V . System Characteristics, Continued

ITEM	QUANTITY
Engine HP	26
Engine Efficiency	15.3%
Collector Area	6720 Sq. Ft.
Collector Orientation	N-S
Collector Type	Concentrating-Tracking
Average Collected Energy	
March - October	1663 BTU/FT^2 Day
Annual Average	1408 BTU/FT^2 Day
Engine Start Time	
June	6:33 A.M.
December	8:17 A.M.
Engine Running Time	
June	23+ Hr/Day
December	7 Hr 25 Min/Day
Thermal Reservoir Size	6500 Gal (Est.)
Pumping Rate	700 GPM

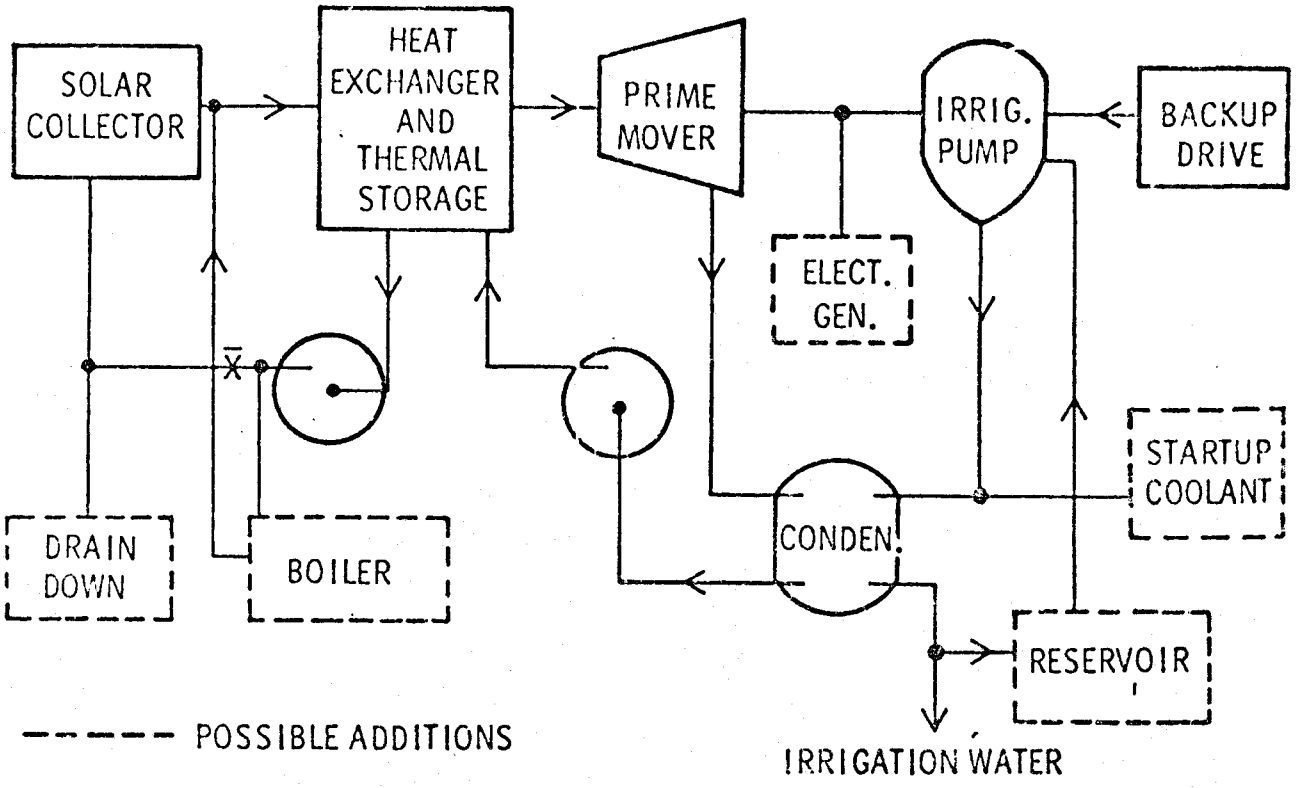


Figure 6. Solar Powered Irrigation System

9.0A NON-IMAGING COLLECTORS - University of Chicago

9.1A Program Summary

Title:	Organization:
Solar Energy Concentration	University of Chicago The Enrico Fermi Institute 5801 So. Ellis Ave., Chicago, Ill. 60637
Amount: $187,000	Principal Investigator: Dr. Roland Winston

Effective Date:	Duration or Ending Date:	Contract No.
	30 June 1977	E(11-1)-2446

Objectives and Tasks

This program is devoted to four principal tasks: (1) The New Mexico field test (demonstration), (2) Optical studies and tests, (3) Thermal properties testing of collector arrays, and, (4) Support to Argonne National Laboratory.

1000 Ft^2 of compound parabolic concentrators (CPC's) will be installed on a Navaho Indian School in the Spring of 1977 for the purpose of heating. A roof top test station for collector testing is being prepared at the University. Investigation of a non-tracking CPC for 600°C application has begun. A closed-loop fluid flow thermal test rig for collector evaluation is now in operation.

9.2A Program Status

The major thrust of Chicago's effort is being devoted to the Bread Springs, New Mexico Indian School heating project. This is a joint venture of the University, the Bureau of Indian Affairs, ITE - Gould, and Environmental Consulting Services. Chicago is supplying design, receivers, and instrumentation; ITE-Gould is providing fiberglass containers for the compound parabolic concentrators (CPC); the Bureau of Indian Affairs is providing architecture and engineering installation.

Collaboration with Argonne National Laboratory in the development of low cost CPC's constitutes about 20% of the Universities effort. Optical studies and tests include investigation of advanced CPC concepts, optical bench model tests with reflectometer and light box, testing of a 6.5 X CPC and preparation of a roof top collector test facility with meterological equipment. Thermal properties testing is centered around a closed loop flow system which is used to evaluate in-house (6.5 X CPC) and commercial collectors.

Installation of the 1000 Ft^2 of collectors at the Navaho Indian School is planned for Spring, 1977. The roof at the school has been repaired and upgraded. Receiver and reflectors are ready and awaiting fabrication of the fiberglass containers.

Preparation of the roof top test station for collector testing continues. In addition to collector arrays, positions will be provided for a pyranometer, radiometer, and other meteorological equipment.

A very preliminary study has been initiated on a non-tracking, high temperature (600°F), CPC system. This is in support of Argonne National Laboratory.

9.0B NON-IMAGING COLLECTORS (continued) - Argonne National Laboratory

9.1B Program Summary

Title: Investigations of Non-Imaging Solar Energy Collectors		Organization: Argonne National Laboratory Argonne, Illinois 60439
Amount: $700,000*		Principal Investigator: Dr. Roland Winston
Effective Date: 1 July 1975	Duration or Ending Date: 12 Months 30 June 1976	Contract No. 09 ENG 38

Objectives and Tasks

The goal of the program at Argonne is to demonstrate electrical power production with a non-tracking, compound parabolic concentrator (CPC) solar collection system. In support of this goal, two basic tasks are being accomplished:

(1) Development of low cost COC's

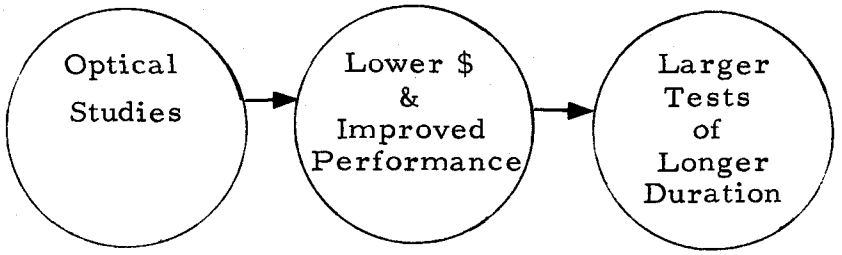
(2) Testing of CPC arrays.

Collector development has followed an evolutionary development cycle that is now focusing on CPC's with evacuated receivers that offer potential for electrical power generation. Approximately 100 Ft^2 of 3 X collectors are in fabrication for development testing.

*Funding shared by Solar Thermal Power and Heating and Cooling (ERDA).

9.2B Program Status

Development of low cost CPC's has followed the evolutionary cycle shown below. Initial work on the theorectical optical properties were verified experimentally with tests on 3 X and 10 X concentrators. However, heat losses were high as



Evolution Cycle of Compound
Parabolic Concentrator Development

well as costs. Various application studies indicated that development should be directed towards a low cost collector with a selective surface on the absorber enclosed in an evacuated glass jacket to lower heat losses.

The development of such a collector was initiated with the testing of a 3 X 6 Ft^2 collector with four evacuated tubes. A 3 X 30 Ft^2 lightweight aluminum collector containing 20 evacuated tubes is in fabrication and should be ready for test in March, 1977. Enough components have been ordered to produce approximately 100 Ft^2 of total 3 X collector area. At least 30 Ft^2 of this area will use thermoformed plastic mirrors for a direct side-by-side comparison with the aluminum collectors.

A program for the conceptual design of a 5 X CPC for electric power generation is in progress. The net result of the study will be a concept for a 2000 Ft^2 collector field suitable for installation on the total energy test bed at Sandia.

10.0 FACETED FIXED MIRROR COLLECTOR - Georgia Institute of Technology

10.1 Program Summary

Title:	Organization:	
Faceted Fixed Mirror Collector	Georgia Institute of Technology	
Amount:	Principal Investigator:	
$157,386	J. R. Williams (404)894-3293	
Effective Date:	Duration or Ending Date:	Contract No.
July 1975	31 Dec. 1976	A-40-1-4970

Objectives and Tasks:

This information was not provided by printing time.

10.2 Program Status

The continuing program at Georgia Tech in cooperation with Scientific Atlanta, Inc., for the development of an economical faceted fixed mirror collector (FFMC) solar concentrator has recently entered a new phase with the first tests of the improved concentrator employing an evacuated tubular receiver and a liquid heat collection fluid. Preliminary low temperature results indicate that a collection efficiency of 57%, exclusive of losses in the supply tubing, has been achieved. This is about twice the efficiency obtained from the obsolete air-heating collector previously constructed and evaluated.

The improved concentrator uses the existing mirror array and the closed-loop sun-tracking system employed earlier with the air-cooled receiver. As such it benefits from the basic advantages of the FFMC design as follows:

1. Economical rear-surfaced flat glass mirror elements are employed. No expensive optical elements of complex geometry are required.
2. The mirror elements are in a stationary array aligned on a circular cylinder. There is no need for moving the extensive mirror array in following the sun.
3. Only the terminal concentrator and tubular receiver assembly need move on a circular arc in sun tracking so a simple mechanism can position the receiver.
4. The concentrator provides a nearly uniform distribution of radiation at the focal line. Optical aberation and hot regions on the absorber plate are avoided.

The improved performance of the FFMC system has resulted from the installation

11.0 SEGMENTED LINE FOCUS COLLECTOR - Sheldahl

11.1 Program Summary

Title:	Organization:
A Segmented Line Focus Solar Collector--Verification of Performance and Cost Effectiveness	Sheldahl, Inc. Advanced Products Division Northfield, Minnesota 55057
Amount: $304,877	Principal Investigator: Ross A. Stickley

Effective Date:	Duration or Ending Date:	Contract No.
1 October 1976	31 March 1977	02-7671C

Objectives and Tasks

A collector module of approximately 400 square feet of reflector area is to be designed, fabricated and tested in Albuquerque, New Mexico. The module will be tested at temperatures up to 600°F with a receiver which is also to be designed and fabricated.

Performance of the unit will be modeled utilizing insolation data and will be compared with test results.

The cost of the unit on a production basis will be developed. These costs will be utilized in economic evaluation of various applications including total energy systems.

11.2 Program Status

The collector was originally planned to operate with Therminol 66 as the working fluid. The decision was subsequently made to use pressurized water in the Phase II collector field and heat exchange to Therminol 66; this required that absorber tube wall thickness be increased appreciably because of the high pressures associated with the 600F (nominal) water system. The result was a considerably heavier absorber and fluid loop and a significant increase in the thermal mass, and consequently the thermal inertia and capacity, of the fluid system.

Subsequent functional and economic analyses of the counter flow heat exchanger resulted in selection of a water-side temperature of 640F, which further complicated the problem, since considerable time (nearly 3 hours) and thermal energy (estimated at 9% of field output in summer and 15% in winter) were required to bring the receiver to operating temperature.

A decision was made to modify the receiver design to alleviate the thermal mass problem and at the same time reduce the cost and complexity of fabrication. As a baseline, an earlier planar concept was modified to a two-tube ("down and back") configuration, and a selective coating added to reduce re-radiation losses through the single-glazed aperture. Test and Analysis indicated that this approach, although not as optically efficient as the Vee-entrant concept, should provide comparable overall efficiency and should accomplish the original objectives of mass and cost reductions.

A prototype absorber was assembled and evaluated in an existing 20-foot-long collector installed at Northfield. The selective coating was applied to the receiver tubes by the Olympic Plating Company, Canton, Ohio, and shipped to Sheldahl for assembly. Tests conducted during late 1976 confirmed performance predictions and resulted in fabrication of a

similar receiver for use during evaluation of the 400 sq ft 600°F unit at Sandia. That unit has been shipped to Albuquerque and assembled on-site and is awaiting connection to the fluid test loop.

12.0 LINEAR FRESNEL COLLECTOR - McDonnell Douglas

12.1 Program Summary

Title:	Organization:	
Preliminary Design of Solar Collector Field Subsystem	McDonnell Douglas Corp. Huntington Beach, CA 92647	
Amount:	Principal Investigator:	
$287,357	Donald Steinmeyer	
Effective Date:	Duration or Ending Date:	Contract No.
26 February 1976	10 months 31 Dec. 1976	02-7671A

Objectives and Tasks

This award provides for the preliminary design of a solar collector field subsystem utilizing the linear fully tracking Fresnel lens collector concept. The subsystem is to be designed and installed at Sandia's Solar Total Energy Systems Test Facility.

In addition, the award provides for tests of "bench model" or "breadboard" hardware if required to indicate feasibility.

12.2 Program Status

Linear Fresnel Lens

McDonnell Douglas is developing the linear Fresnel Lens collector under a preliminary design contract (02-7671A). After carefully reviewing the results of their current contract, the decision was made not to continue the development of their concept at this time. This decision was based mainly on the high potential cost of the collector in mass production.

Hardware Status

1. The preliminary design work has been completed.
2. A pair of full scale collectors have been extensively tested on Sandia's Solar Collector Module Test Facility.
3. A thermal analysis of the collector has been completed to compare with the test results and locate problem areas.
4. Optical measurements of the Fresnel Lens have been made.

Problems

1. The transmittance of the Fresnel Lens is limited to about 84%.
2. The cost of enclosing the receiver in a sealed container attached to the edges of the Fresnel Lens is high.

13.0 FIXED MIRROR CONCENTRATOR - General Atomics

13.1 Program Summary

Title:	Organization:
Fixed Mirror Concentrator	General Atomics Co. (Gulf) San Diego, CA 92138
Amount:	Principal Investigator:
$292,762	John L. Russell, Jr.

Effective Date:	Duration or Ending Date:	Contract No.
31 March 1976	11 Months	E(04-3)-0167

Objectives and Tasks

The principal objectives of the program are:

1. The preliminary design of a solar collector for one quadrant of the Sandia demonstration facility

2. The demonstration of the feasibility of the proposed method of construction: glass mirrors cast in concrete.

13.2 Program Status

Fixed Mirror Slat Collector

The General Atomic Company is developing the Fixed Mirror slat Collector (FMSC) under a preliminary design contract (02-7671D). The results of their effort to date are sufficiently encouraging to warrant the placing of a final design and construction contract with them. At the present time, they are preparing a quotation for such a contract which would result in the installation of a 2800 sq. ft. collector subsystem at Sandia's Solar Total Energy System Test Facility by September 30, 1977.

Hardware Status

1. Final design configuration of the collector has been determined.
2. A first generation wooden form for casting the concrete trough has been used to develop their casting technique.
3. A precision aluminum form has been constructed and used to study problems in making accurate castings.
4. A prototype receiver has been constructed and is being tested above a mirrored trough.

Problems

1. Developing a suitable secondary reflector for their receiver.

14.0 PARABOLIC DISH COLLECTOR - Raytheon

14.1 Program Summary

Title: Preliminary Design of Solar Collector Field Subsystem		Organization: Raytheon Company
Amount: $340,465		Principal Investigator: Leo Paradis
Effective Date: 3/31/76	Duration or Ending Date: 11 Mo. 2/28/77	Contract No. 02-7671B

Objectives and Tasks

This award provides for the preliminary design of a solar collector field subsystem utilizing the fully tracking parabolic dish collector concept. The subsystem is to be designed to be installed at Sandia's Solar Total Energy System Test Facility.

In addition, the award provides for tests of "bench model" or "breadboard" hardware if required to indicate feasibility.

14.2 Program Status

Parabolic Dish Collector

At the present time Raytheon is preparing a quotation for a contract which would result in the installation of a single 22-ft diameter parabolic dish at Sandia's Solar Collector Module Test Facility by September 30, 1977.

Hardware Status

1. Preliminary design of collector is complete.
2. A simulation of the receiver has completed its testing on Sandia's Solar Collector Module Test Facility.
3. The concentrator will be made up of water white glass segments, which have been sagged to a spherical contour and silvered on the back.
4. A hail test of the mirror will be accomplished shortly.

Problems

1. Finding mirror manufacturers that can reliably supply the mirror segments.

15.0 EVALUATION OF A TWO-PHASE TURBINE FOR SOLAR ELECTRIC POWER GENERATION - Biphase Engines Inc.

15.1 Program Summary

Title:	Organization:
Evaluation of a Two Phase Turbine Solar Electric Power Generation	Biphase Engines, Inc. 2907 Ocean Park Blvd. Santa Monica, Ca. 90406
Amount:	Principal Investigator:
$296,003	Mr. R. Spies (213) 450-3892

Effective Date:	Duration or Ending Date:	Contract No.
1 June 1976	12 Mo.	E(04-3)-1255

Objectives and Tasks

The objective of this program is to design, fabricate, test, evaluate, and deliver a two-phase turbine system compatible with the operating parameters of the Sandia Solar Total Energy Test Facility.

Specific tasks are outlined as follows:

(1) System Performance Calculations and Design -- trade-off studies to determine design point operation and performance potential using Sandia Solar Total Energy Test Facility interfaces.

(2) System Fabrication and Shakedown Tests -- purchase components, assemble test hardware and run initial tests at Biphase using electrical heat source simulation.

(3) Performance Testing, Packaging, and Delivery -- install system into test trailer, run performance maps, and deliver to Sandia with installation and operation manuals.

(4) Performance and Cost Estimates -- to be conducted for three applications whose parameters are to be provided by ERDA.

15.2 Program Status

System performance calculations and design is almost complete. Fabrication has been initiated on the test turbine housing and purchase orders for components are being released. Test rig design is complete except for details on the separator rim and fluid scoop inlet. Test data on fluid scoop inlets is being obtained from the Biphase Geothermal program (ERDA contract E(04-3)-1228). A computer nozzle program to determine optimum shape and size is currently being exercised.

Detail design of the test loop is underway. A high pressure heater has been purchased, and a commercially available condenser has been identified. The regenerator has not been fabricated, and a mobile trailer has not yet been purchased.

Calculations of the electrical energy that can be delivered using the Sandia Solar Total Energy Test Facility input characteristics show a $\sim$41 KW_e output compared to 32 KW_e for the organic Rankine cycle (Figure 7). The two-phase turbine element requires no close tolerances or expensive materials of construction and should lead to reduced turbine costs.

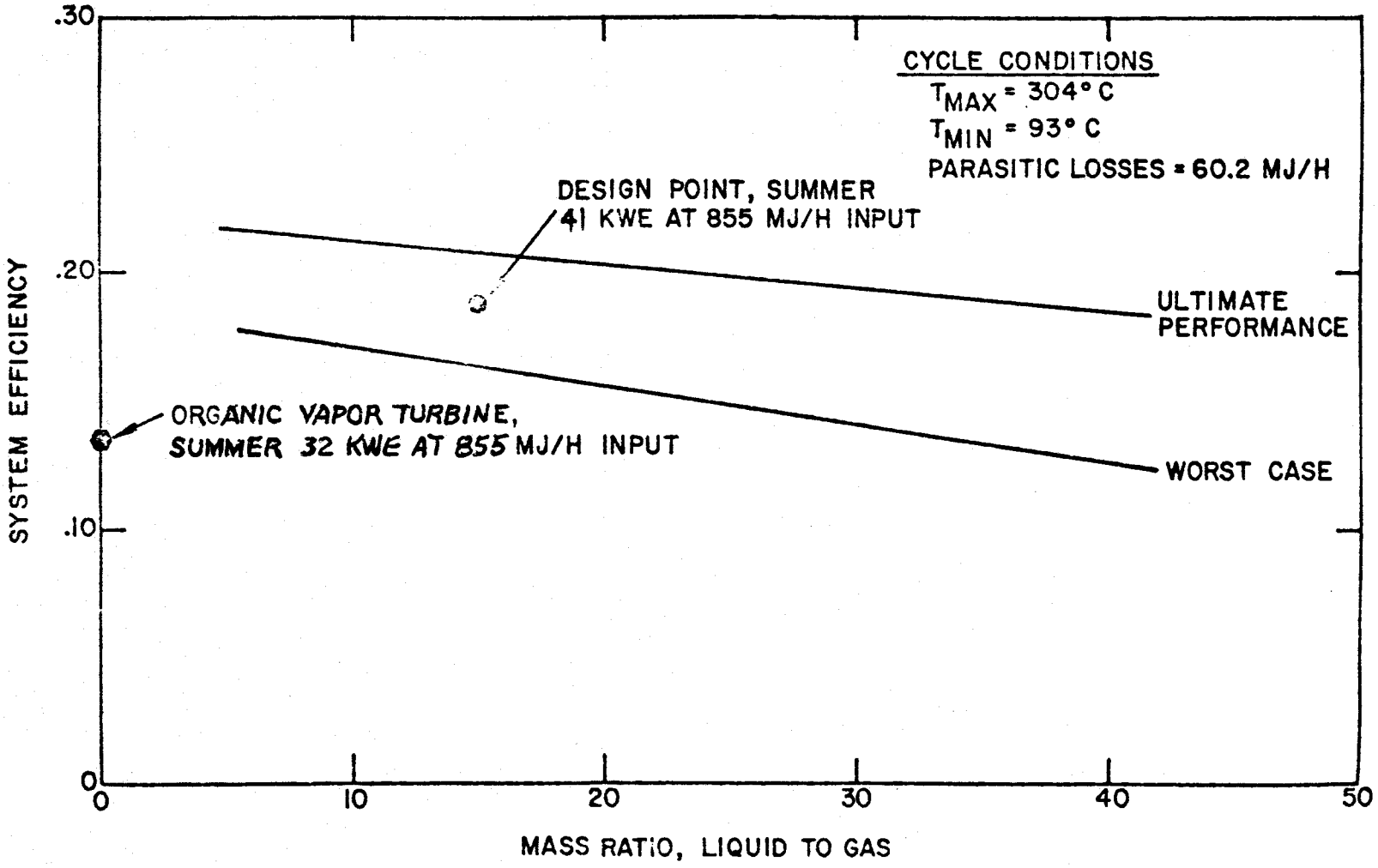


Figure 7. Comparison of Two-Phase Turbine and Organic Vapor Turbine System Efficiency for Solar-Electric Power Generation

16.0 LOW TO MEDIUM GRADE THERMAL CONVERSION PROCESS AND MACHINE - Solar King

16.1 Program Summary

Title: Research and Development Of The Solar King Low-Medium Grade Thermal Conversion Process and Machine		Organization: Solar King, Inc. 277 Gould Street Reno, Nevada 89502
Amount: $41,000		Principal Investigator: Brian Pardo, Solar King, Inc. W. M. Alexander, Baylor Univ.
Effective Date: 5/19/76	Duration or Ending Date: 6 Mo.	Contract No.

Objectives and Tasks

The objective of this program is to demonstrate the feasibility of the Solar King, Inc. engine concept by assembling and testing a 5HP and a 25HP hydraulic pump utilizing high pressure resulting from the thermal expansion of a working fluid. In addition, the theoretical capability of the concept will be evaluated to establish actual and potential performance parameters. This work is aimed at Agricultural applications.

Two tasks will be performed to demonstrate the feasibility of the Solar King, Inc. engine concept:

Task 1: Dismantle 5HP engine located at Reno, Nevada. Reassemble at Baylor University in Test Loop. Perform Theoretical analysis and compare with test results.

Task 2: Procure parts for a 25HP engine and test loop. Assemble. Perform analysis incorporating results of Task 1. Compare analysis to test results. Identify potential improvement in performance and recommend research plan to implement the recommendations.

The Contractor proposed a $5,000,000 overall program. His addendum to this proposal is for a $150,007 feasibility study on the 5HP and 25HP thermal engine. DSE is funding $41,000 (Task 1) of this 150,000 program by this action and may fund the remaining $109,007 as a second increment subject to successful completion of the first task and availability of funds. Any future procurement will be subject to the data generated from this feasibility study and its adaptability to the Solar Program.

16.2 Program Update

This initial conceptual engine was built and operated in Reno, Nevada. This engine was dismantled and moved to the grounds of the IES building. Studies of the precise functional operations of this conceptual engine have been completed.

The hydraulic motor in the conceptual engine was dismantled and repairs made to weakened or damaged parts. Some aluminum sections have been replaced with steel units.

The theoretical thermodynamic properties of conceptual engine system have been studied. The results of this work are used in analyzing the performance of the central heat exchanger in the engine.

An experimental laboratory test loop was established to obtain heat transfer performance data from the original heat exchangers. The appropriate data has been obtained for the steel core heat exchangers.

An analysis of the data from the experiments has been conducted, and a low-medium grade thermal engine constructed from the components of the conceptual engine. This engine uses an off-the-shelf hydraulic motor. The low-medium grade design goal is for a five horsepower engine operating in the low-medium grade temperature ranges. At this time, the engine has been operating at temperatures up to 180^{o}F. The data obtained shows horsepower vs. temperature relationship.

Studies have been initiated concerning the heat transfer performance characteristics of heat exchangers using copper alloy cores. Experimental data is being used to design and operate a thermal engine similar to the engine above.

17.0 SELECTIVE OPTICAL COATINGS - University of Arizona

17.1 Program Summary

Title:	Organization:
Chemical Vapor Deposition of Refractory Metal Reflectors For Spectrally Selective Solar Absorbers	University of Arizona Optical Sciences Center Tucson, Arizona 85721
Amount:	Principal Investigator:
$80,000	B. O. Seraphin H. S. Gurey (602) 884-2382

Effective Date:	Duration or Ending Date:	Contract No.
4/1/76	12 Mo.	E(29-2)-3673

Objectives and Tasks

The objective is to determine the conditions under which CVD refractory metals can be successfully used on alloy steels for solar coatings.

Specific Tasks are:

(1) Optimize emittance of tungsten and molybdenum films.

(2) Evaluate elevated temperature lifetimes of diffusion-barrier layers between these films and steel substrates.

(3) Evaluate potential diffusion-barrier layers between the solar absorber and the tungsten and molybdenum films.

(4) Lifetime testing of composite stack.

17.2 Program Status

Objective (1) Optimize infra-red reflectance of tungsten and molybdenum films.
Molybdenum and tungsten films have been prepared for which the emittance is only 0.9% and 1.9%, respectively, above the emittance of the bulk metal.

Objective (2) Evaluate the elevated temperature lifetimes of diffusion-barrier layers between films of molybdenum or tungsten and steel.
No results reported.

Objective (3) Evaluate potential diffusion barrier layers between silicon solar absorber and tungsten or molybdenum.
No results reported.

Objective (4) Lifetime testing of composite stack.
No results.

Tungsten and molybdenum emittance measured at 0.9% and 1.9%, respectively, above base metal. Lack of promising results has resulted in program redirection and shift away from refractory films.

18.0 SOLAR THERMAL CONVERSION AND AMORPHOUS SILICON - Argonne Laboratory

18.1 Program Summary

Title:	Organization:
Cost Effective Amorphous Silicon Coatings.	Argonne National Laboratory Energy and Environmental Systems 9700 South Cass St. Argonne, Ill. 60439
Amount:	Principal Investigator:
$50,000	R. W. Griffith 8-388-4111

Effective Date:	Duration or Ending Date:	Contract No.
19 May 1976	9 Months	09-ENG 38

Objectives and Tasks

The objective of this program is to shift absorptance vs wavelength curve of normal crystalline silicon to longer wavelengths by using amorphous silicon.

Specific tasks are:

(1) Perform theoretical analysis which will help predict physical and chemical modifications and additions to silicon which will produce the desired optical properties shifts.

(2) Modify amorphous silicon so as to produce thermally stable optical properties.

(3) Determine adaptability of process to lower cost silicon.

(4) Evaluate total system effect of use of silicon coating.

18.2 Program Status

Objective (1) Production of high absorptance-low emittance amorphous silicon.

Amorphous silicon produced with 0.6 absorptance and low emittance.

Objective (2) Produce thermally stable amorphous silicon coatings.

Amorphous silicon with boren additive produced which had no change in optical properties after anneal at 575 C.

Objective (3) Investigation of lower grade silicon feedstock.

Data not reported.

Objective (4) Evaluation of total collector system performance resulting from use of amorphous silicon coating.

Results not reported.

19.0 MIRROR MATERIALS & SELECTIVE COATINGS - Sandia Laboratories

19.1 Program Summary

Title:	Organization:
Mirror Materials & Selective Coatings	Sandia Laboratories P.O. Box 5800 Albuquerque, New Mexico 87115
Amount:	Principal Investigator:
$180,000	

Effective Date:	Duration or Ending Date:	Contract No.

Objectives and Tasks

This materials development effort is conducted as a continuing effort to provide new and improved reflector materials and coatings for application in solar energy programs. Primary funding comes from the component and subsystems development element of the solar total energy program. These materials R&D efforts are divided into solar selective coatings, mirror materials and reflector structures.

19.2 Program Status

Coatings

The solar absorption, α_s, and emittance, ε, properties of electrodeposited black chrome as a function of plating current density (C.D.), time and substrate were studied. These properties are shown in Figure 8 as a function of the C.D.-time product for plating parameters of 150, 200, and 350 A/ft^2. Note that the optical properties are only a function of the C.D.-time product, which measures the total charge transfer during the plating. Absorption reaches a maximum between 350 and 600 (A-min)/ft^2 and shows a small decrease (~2%) for C.D.-time value around 1500 (A-min)/ft^2. On the other hand, the emittance is an approximately linear function of the C.D.-time product over the range of parameters studied.

Mirror Materials

A bi-directional reflectometer has been constructed which determines the specular reflectance of mirror materials as a function of collection angular aperture. Although it is easy to rank a mirror on the basis of its solar average hemispherical reflectance value, it is not immediately obvious whether a mirror whose specular reflectance rapidly reaches a constant value as a function of the angular aperture is better than a mirror that starts low but increases more gradually to a higher value. Therefore, a data analysis procedure was developed to characterize the properties of the mirror material. Data for a variety of mirror materials are shown in Table VI.

The effect of dirt accumulation on the specular reflectance profiles and the subsequent effectiveness of several mirror cleaning procedures for aluminized FEP teflon are shown in Figure 9. Weathered materials were obtained from Sandia's Solar Total Energy Test Facility and were subjected to one of the following four cleaning procedures: (1) high pressure water; (2) Jet-X with detergent; (3) a mist spray of a commercial cleaner (C-120)

from McGean Chemical Co; and (4) hot soapy water with a cloth wipe. All cleaning was followed with a deionized water rinse. Note that the reflectance loss in the as-received condition averaged 25% as compared to unexposed material. After cleaning, the reflectance loss averaged only ~4% for cleaning procedures #1-3. For procedure #4, the loss was ~10%. Optical micrographs of the exposed teflon surface show a large number of scratches which are not present in the other mirror samples. Because this is the only mirror that was wiped during the cleaning process, it appears that the scratches and thus the reflectance loss are a result of the wiping. The optical pictures of the other mirrors show residual dirt particles, ranging in size from 1-5 microns on the teflon surface, that probably lead to the average residual reflectance loss of ~4% in the other samples.

Reflector Structures

The reflector structure shapes and supports the mirror surface, thus it influences concentrator accuracy and resistance to hail impacts and environmental damage. A laser ray trace system has been used to evaluate the focal quality of mirrors as received from the suppliers and after environmental exposure. The laser system traverses the trough in a series of transverse scans. The data from these traces can then be used to compute the standard deviation of the reflected rays about the actual focus. The actual focal length and standard deviation can then be used to calculate the optimum position and diameter of the receiver tube.

An environmental test chamber has been used for accelerated aging of parabolic trough test sections. The chamber is on an 8 hour cycle with 2 hours at each extreme (-29°C and 54°C) and 2 hours in transition. Humidity is controlled between 82% and 45% with frost forming on units during each cold excursion. Test sections are periodically reinspected after subjection to this exposure.

Hail damage tests have been conducted on several types of reflector structure/reflector combinations. The hail test facility can provide simulated hail balls at terminal velocity in sizes from 0.5 to 1.5 inch. Damage assessment techniques have also been developed.

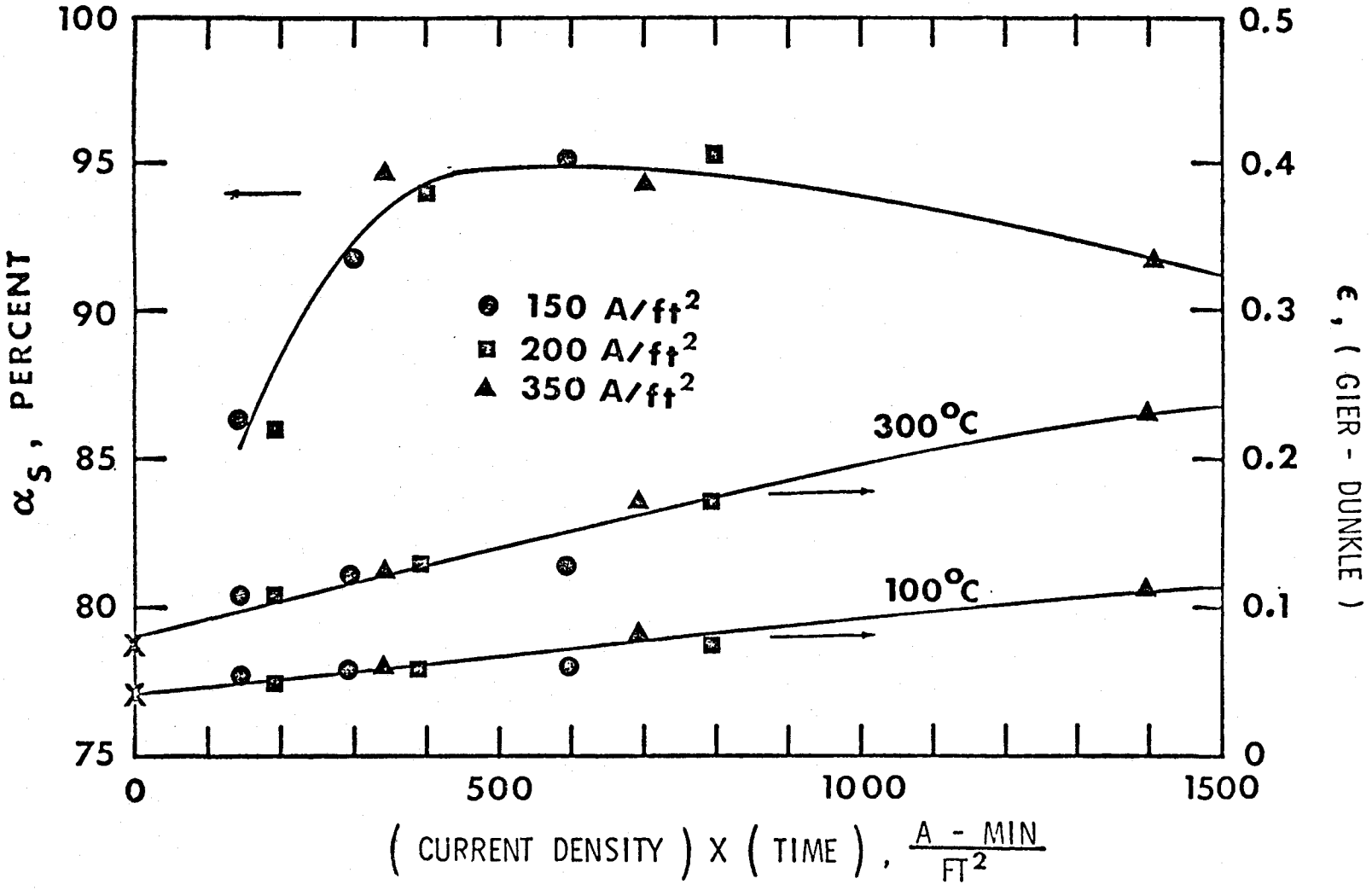


Figure 8. Black Chrome on Zodiac Nickel

Table VI . Properties of Various Mirror Materials

Material	Measurement Wavelength (nm)	R_1	σ_1 (mrad)	R_2	σ_2 (mrad)	$R_s(2\pi)$
I. Second Surface Glass						
a) Laminated Glass - Carolina Mirror Co.	500.	0.92	0.15	--	--	0.83
b) Laminated Glass - Gardner Mirror Co.						
Perpendicular to streaks	600.	0.92	0.4[a]	--	--	0.90
	500.	0.92	0.4[a]	--	--	
Parallel to streaks	800.	0.88	< 0.05	--	--	
	500.	0.92	< 0.05	--	--	
c) Corning Microsheet (Vacuum Chuck)	550.	0.77	1.1	0.18	6.2	0.95
II. Metallized Plastic Films						
a) 3M Scotchcal 5400	500.	0.86	1.9	--	--	0.85
	600.	0.86	2.0	--	--	
	700.	0.82	2.1	--	--	
	900.	0.84	1.9	--	--	
b) 3M FEK-163	500.	0.86	0.90	--	--	0.85
	600.	0.86	0.78	--	--	
	700.	0.82	0.86	--	--	
	900.	0.84	0.86	--	--	
c) Sheldahl Aluminized Teflon	400.	0.73	1.4	.15	12.1	0.87
	500.	0.80	1.3	.07	30.9	
	700.	0.80	1.6	.04	39.8	
	900.	0.81	1.4	.03	31.4	
III. Polished, Bulk Aluminum						
a) Alcoa Alzak						
Perpendicular to rolling marks	670.	0.66	0.39	0.21	9.7	0.85
	505.	0.56	0.42	0.33	10.1	
	407.5	0.45	0.53	0.42	9.8	
Parallel to rolling marks	670.	0.70	0.24	0.17	7.7	
	505.	0.62	0.29	0.27	7.1	
	407.5	0.58	0.46	0.29	9.0	
b) Kingston Ind. Kinglux						
Perpendicular to rolling marks	498.	0.65	0.37	0.23	16.1	0.85
Parallel to rolling marks	498.	0.67	0.43	0.21	18.5	
c) Metal Fabrications Bright Aluminum	550.	0.44	1.4	0.43	10.3	0.84

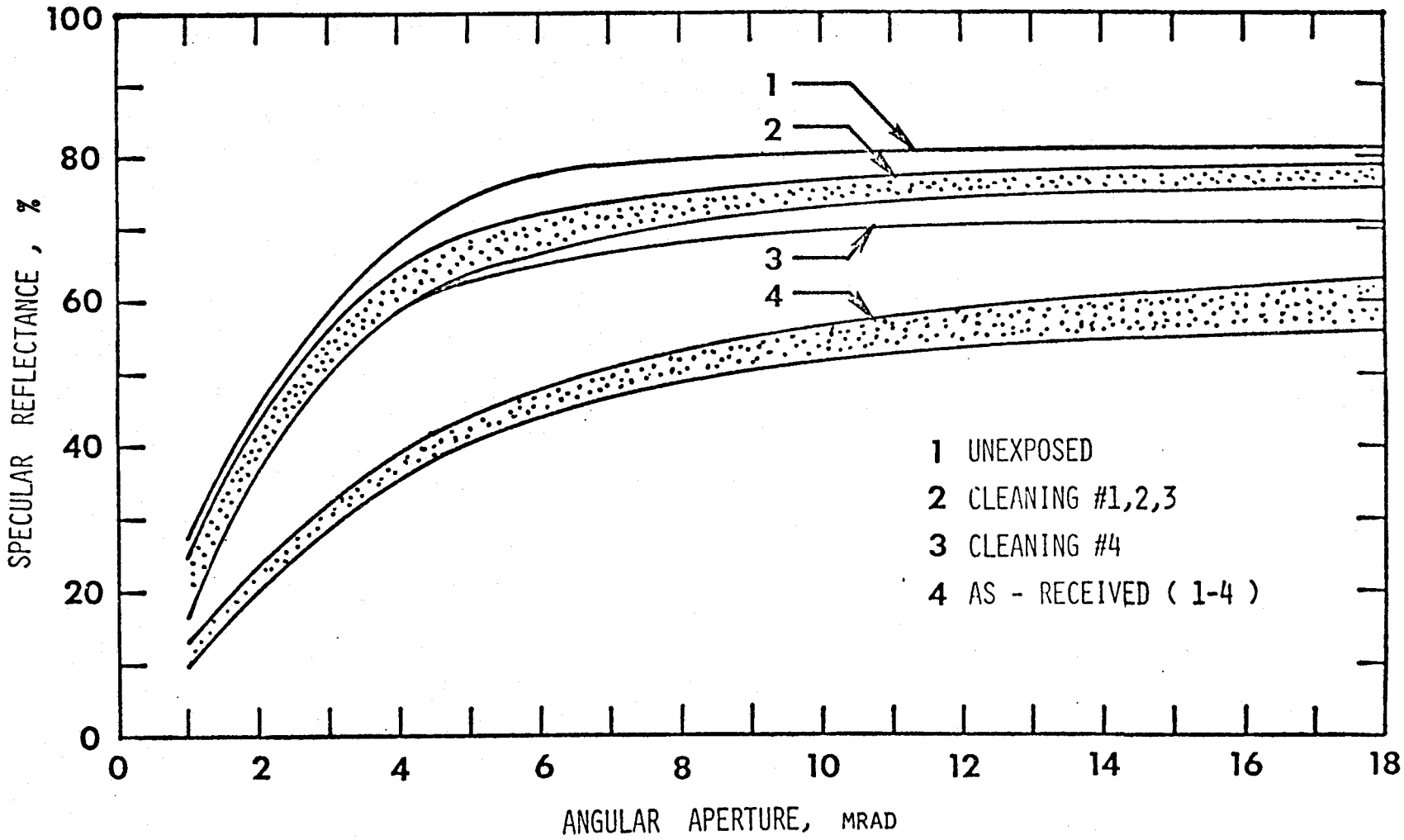


Figure 9. Aluminized FEP Teflon

20.0 IMPROVED ABSORBER COATINGS - Engelhard Industries

20.1 Program Summary

Title:	Organization:
Improved Absorber Coatings for Thermal Utilization of Solar Energy	Engelhard Industries Menlo Park, NJ 08817
Amount: $254,000	Principal Investigator: Herbert Myers 201-321-5200

Effective Date:	Duration or Ending Date:	Contract No.
1 July 1976	24 Months	AER-75-17470

Objectives and Tasks

Investigate the possibility of using thermal decomposition of organo-metallic compounds to produce solar selective coatings.

Specific tasks are:

(1) Produce and measure optical characteristics of gold film with additives of Si, Bi, Cr, and Ba compounds.

(2) Substitute silver in the gold films to produce a lower cost film with no impairment of absorptance or emittance.

(3) Prepare and measure the optical properties of conducting oxides in order to produce spectrally selective coatings.

(4) Establish high temperature emittance measurement capability.

20.2 Program Status

Objective (1) Improved absorptance of "doped" gold. ---

Films made by the addition of either 4.4% of Bi_2O_3 or 4.4% of Bi_2O_3/0.5% BaO have increased values of α to approx 0.8 while maintaining values of ε at approximately 0.08.

Objective (2) Substitution of silver or copper for gold. ---

Film made by 1 to 1 substitution of silver for gold in the film developed in objective (1) produced a film with the poor absorptance of approx 0.5.

Objective (3) Investigate optical properties of compound oxide conductors. ---

Conductive thin films of PbO-RuO_2 have been prepared and measured and while they have values of α of over 90% they also have high ε.

Objective (4) Establish high temperature emittance measurement capability. ---

Apparatus has not been completed and made completely operational.

21.0 MEASUREMENT OF CIRCUMSOLAR RADIATION – Lawrence Berkeley Laboratories

21.1 Program Summary

Title:	Organization:
Measurement of Circumsolar Radiation	Lawrence Berkeley Laboratory Berkeley, California 94720
Amount:	Principal Investigator:
$420,000	Michael Wahlig

Effective Date:	Duration or Ending Date:	Contract No.
15 September 1975	12 Mo. 30 June 1976	05 ENG 48

Objectives and Tasks

The objective of this project is to develop suitable instrumentation and carry out a measurement program to:

1. Provide data on solar and circumsolar radiation as a function of angle and wavelength to determine if these types of measurements are necessary in order to calculate performance of focusing systems.

2. Determine the adequacy of the 5 deg field of view pyrheliometers now utilized to measure direct normal incident insolation.

A portable prototype instrument has been developed, tested, and used to make measurements at Berkeley. Three additional "fixed-site" instruments have been constructed and deployed at field site. Computer programs for the storage, retrieval, and analysis of the data have been developed.

The basic circumsolar radiation instrument is a "scanning telescope" mounted on a precision solar tracker. The instrument scans through a 6 deg arc with the sun at the center and measures the brightness of the solar and circumsolar radiation as a function of angle.

21.2 Program Status

Deployment of the second and third of the three fixed-site instruments occurred in July 1976 at China Lake, California and Ft. Hood, Texas. The first instrument was sited at Sandia-Albuquerque in May 1976. All three instruments are now operating automatically fifteen hours each day. The portable instrument is being modified for automatic operation, including night retrace for automatic morning acquisition of the sun.

Automatic weather stations have been installed on the portable instrument and on the one at Ft. Hood, Texas. A digital interface system has been acquired to access the weather measuring instruments that will be installed by Sandia at the 5 MW test facility. The fourth weather station will be installed when the telescope now at China Lake is moved to the site of the 10 MW pilot plant.

The transfer of data received weekly from each site to permanent storage files has been started. Initiation of work on a reduced data base to enable more convenient processing of the circumsolar and solar information has begun. When established, this base can be used for a variety of statistical studies, such as the determination of the fraction of time that pyrheliometers are adequate to predict the performance of various collector systems.

Requests have been fulfilled for specific and sample data from the following: Frank Biggs of Sandia-Albuquerque, for sun shape on clear days to use as input to the HELIOS program; McDonnell-Douglas, for interpreting the data from Fresnel collectors tested at Sandia; Mike Riches of ERDA; A. Hoffman of ATU; Professor van de Hulst of the Huygens Laboratory in Leiden, Netherlands; A. L. Fymat of Cal-Tech; and China Lake Naval Weapons Center. Active interest in collaboration has been expressed by Vern Derr of NOAA and A. Deepak of NASA Langley Research Center.

22.0 SOLAR THERMAL RESEARCH PROJECTS – University of Minnesota

22.1 Program Summary

Title:	Organization:
Research Applied to Solar Thermal Power Systems-Concluding Phase	University of Minnesota Department of Mechanical Engineering Minneapolis, Minnesota 55455
Amount:	Principal Investigator:
$251,000	R. C. Jordan

Effective Date:	Duration or Ending Date:	Contract No.
July 1, 1976	30 Sept 1977	E(11-1)-2595

Objectives and Tasks

The initial work on this contract dates back to NSF grants (1973). Effort is divided into two tasks or work groups (1) the University of Minnesota and (2) Honeywell.

The University of Minnesota will perform experiments on phase change storage; in particular, the determination of heat transfer coefficients during the melting of the storage medium and the measurement of the size/shape of the melt region and its temperature distribution.

Honeywell's work is divided into three parts: (1) Resumption of testing with their scale model parabolic trough, (2) resumption of lifetime testing of reflector materials, and (3) conceptual design of an optimized collector, i.e., what it would take to upgrade the scale model concept to a device that would furnish 300°C steam.

22.2 Program Status

The University of Minnesota has built two molten salt ($NaNO_3$/NaOH, 475°F) test units. One unit, the visualization apparatus, is for shape/dimension melt zone testing; the other is for heat transfer coefficient measurements. The two molten test units are intended to be complementary and have nearly the same dimensions.

Successful prototype tests have been run on each unit and the first formal test completed on the shape/dimension unit. The test program for both units will consist of various heating element configurations and several heat rates for each configuration.

Honeywell, under subcontract to the University, is attempting to develop a low cost selective coating (like black chrome) for the stainless steel (316) heat pipe used in the scale model parabolic trough. Small laboratory samples are being evaluated prior to application to the heat pipe.

In addition, reflector material lifetime samples with a 2-year exposure history have been taken off the shelf for continued exposure. Several new reflector coatings will be added to the test set.

The scale model parabolic trough, in which the heat pipe will be tested, was intended to be a research tool. A conceptual design study will identify those areas which would require upgrading to make the model a producer of steam at 300°C.

23.0 SOLAR TOTAL ENERGY/SINGLE COLLECTOR TEST FACILITY - Sandia Laboratories

23.1 Program Summary

Title:	Organization:
STE/Single Collector Test Facility	Sandia Laboratory P.O. Box 5800 Albuquerque, New Mexico 87115
Amount: $3,844,000 FY '76 $3,735,000 FY '77	Principal Investigator: R. H. Braash

Effective Date:	Duration or Ending Date:	Contract No.
1/1/75	12 Mo.	E(291)-0789

Objectives and Tasks

The objectives of Sandia's Solar Total Energy System Test Facility Program are (1) to establish the feasibility of the solar total energy concept, (2) to provide a versatile system which can be used as an engineering evaluation center or test bed for component and subsystem development, (3) to design a system of sufficient size to require realistic integration of all subsystems, and (4) to conduct a demonstration capable of attracting widespread public interest.

23.2 Program Status

The system depicted in block diagram form in Figure 10, operates as follows: A heat transfer fluid, Therminol 66* (T-66), is pumped through receiver tubes located at the focus of a series of parabolic trough reflectors (Figure 11) where it is heated to an outlet temperature of 310°C (590°F). The heated T-66 is stored in a sensible heat high temperature storage tank from which it is pumped through a heat exchanger in which toluene is boiled and superheated. The superheated toluene is the working fluid for the 32 kWe turbine/generator. The turbine/generator reject heat from the condenser becomes the thermal energy source for the heating and cooling components of the system. The supplementary fossil fuel heat supplies for the system are also shown schematically in Figure 10

A solar collector module test facility (Figure 12) is also being operated. This facility is currently being expanded to incorporate three separately controlled fluid loops capable of testing three different collectors simultaneously. The three test stations will use Therminol-66 to 315°C (600°F), high pressure water to 330°C (630°F) and 18.3 MPa (2650 psi), or low pressure water 110°C (230°F) and 0.51 MPa (75 psi).

A recent overall view of the collector field, Turbine and Control Building, and Solar Projects Building is shown in Figure 13. Plans for the near future include providing electricity, heating, and cooling to the Solar Projects Building as a solar total energy demonstration and as a supplement to the schedule of engineering tests being conducted at the facility. Another 1977 milestone will be the expansion of the collector field to include quadrants by General Atomic, Raytheon and Sheldahl. These fields will incorporate a variety of collector concepts. An artist's concept depicting the completed facility is shown in Figure 14.

*Registered trademark of Monsanto Industrial Chemicals Company.

Some recent program highlights are as follows:

July	Solar Total Energy Test System Facility (STETSF) Dedicated
August	Test Schedule for STETSF Prepared
August	Test of McDonnell Douglas Fresnel Lens Collector Complete
September	Definition of Requirements, Control Techniques, and Operational Modes of Expanded STETSF Complete
October	GA, Raytheon, and Sheldahl Selected to Supply Collector Field Subsystems for Expanded STETSF
December	Construction Started for Heating and Cooling Subsystems for Solar Energy Projects Building
December	Construction Started for Expanded Solar Collector Module Test Facility
January	Contract Placed for High Temperature Storage Tanks for Expanded STETSF

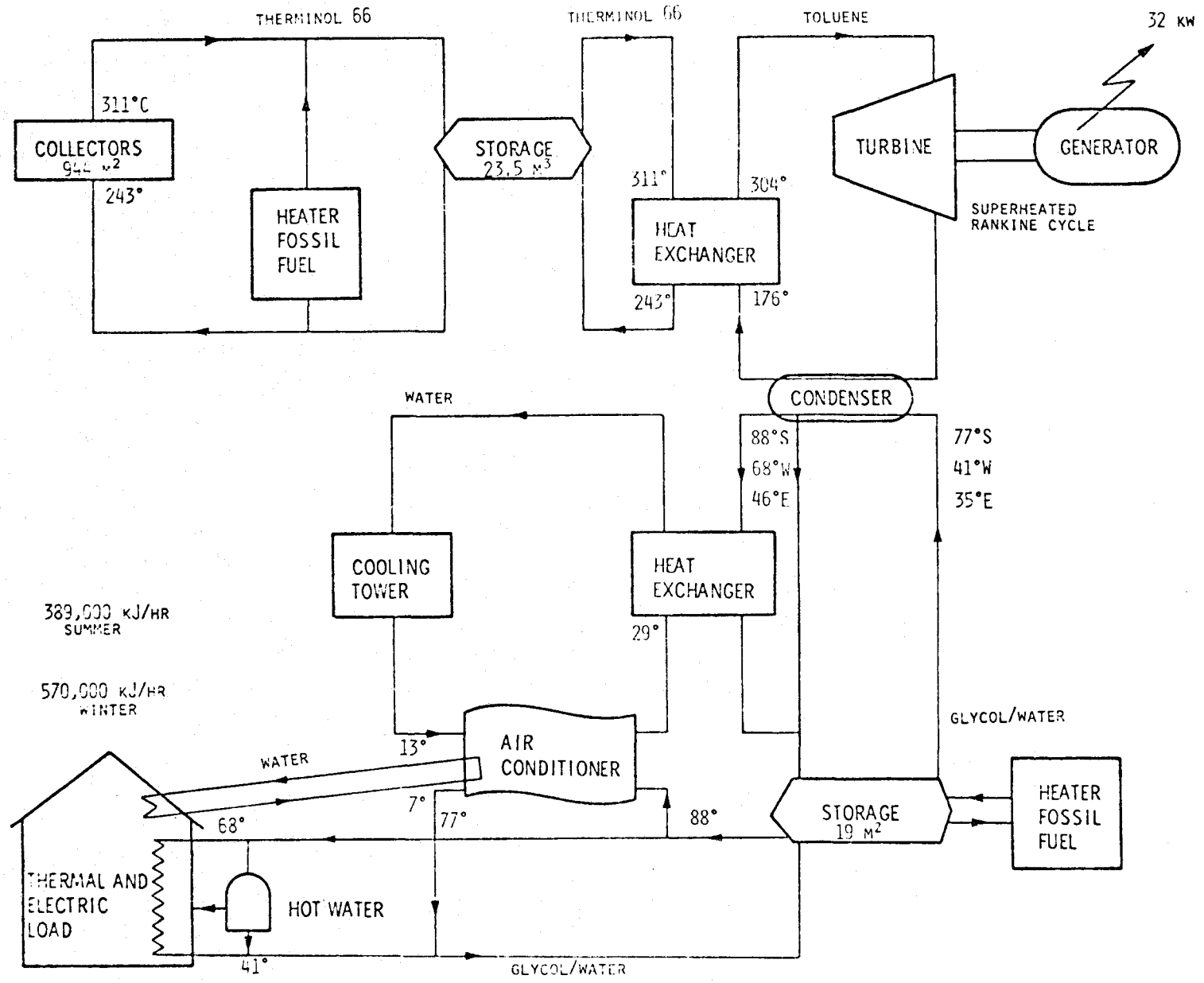


Figure 10. Cascaded Solar Total Energy System

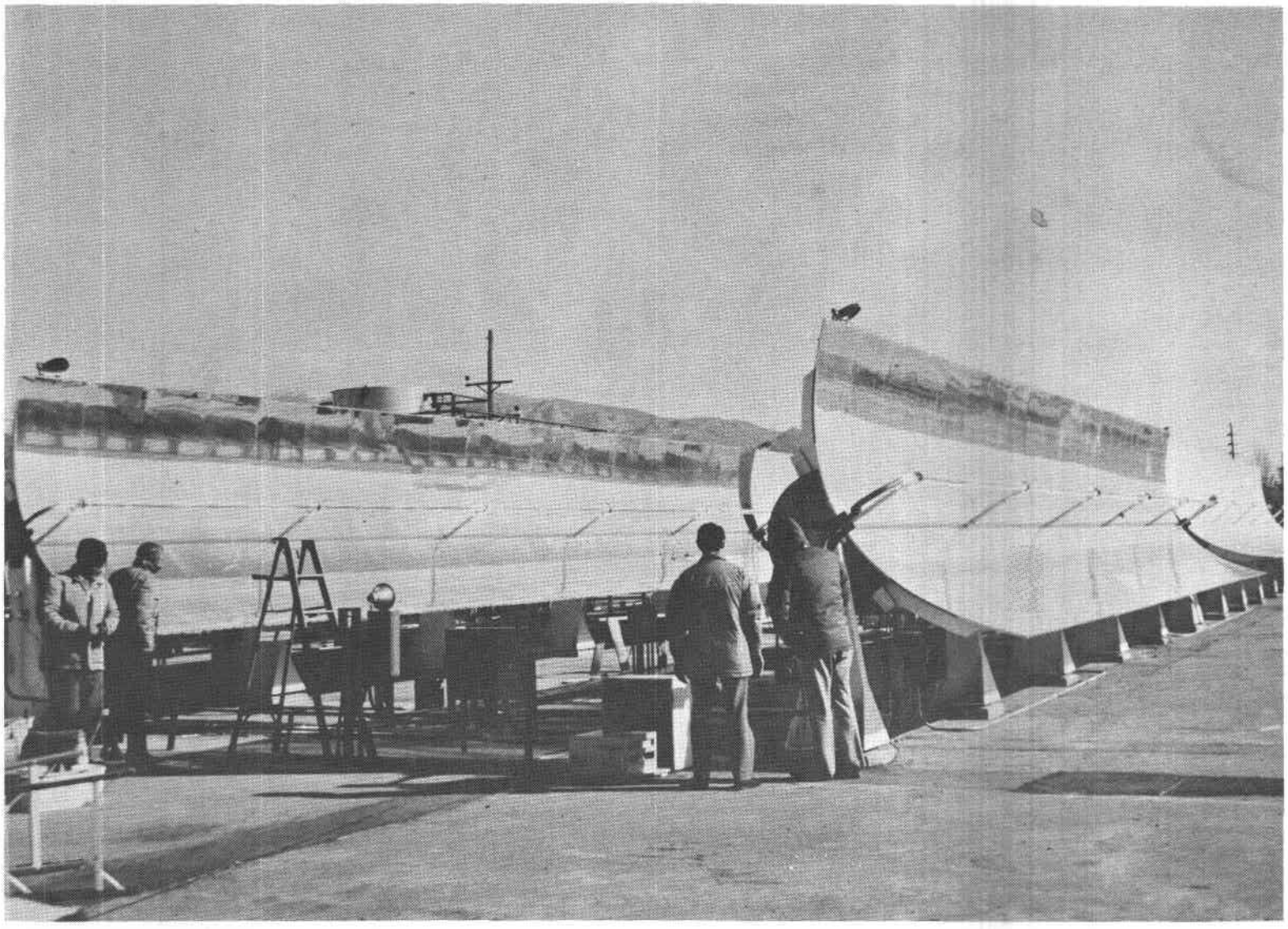


Figure 11. Parabolic Trough Reflectors

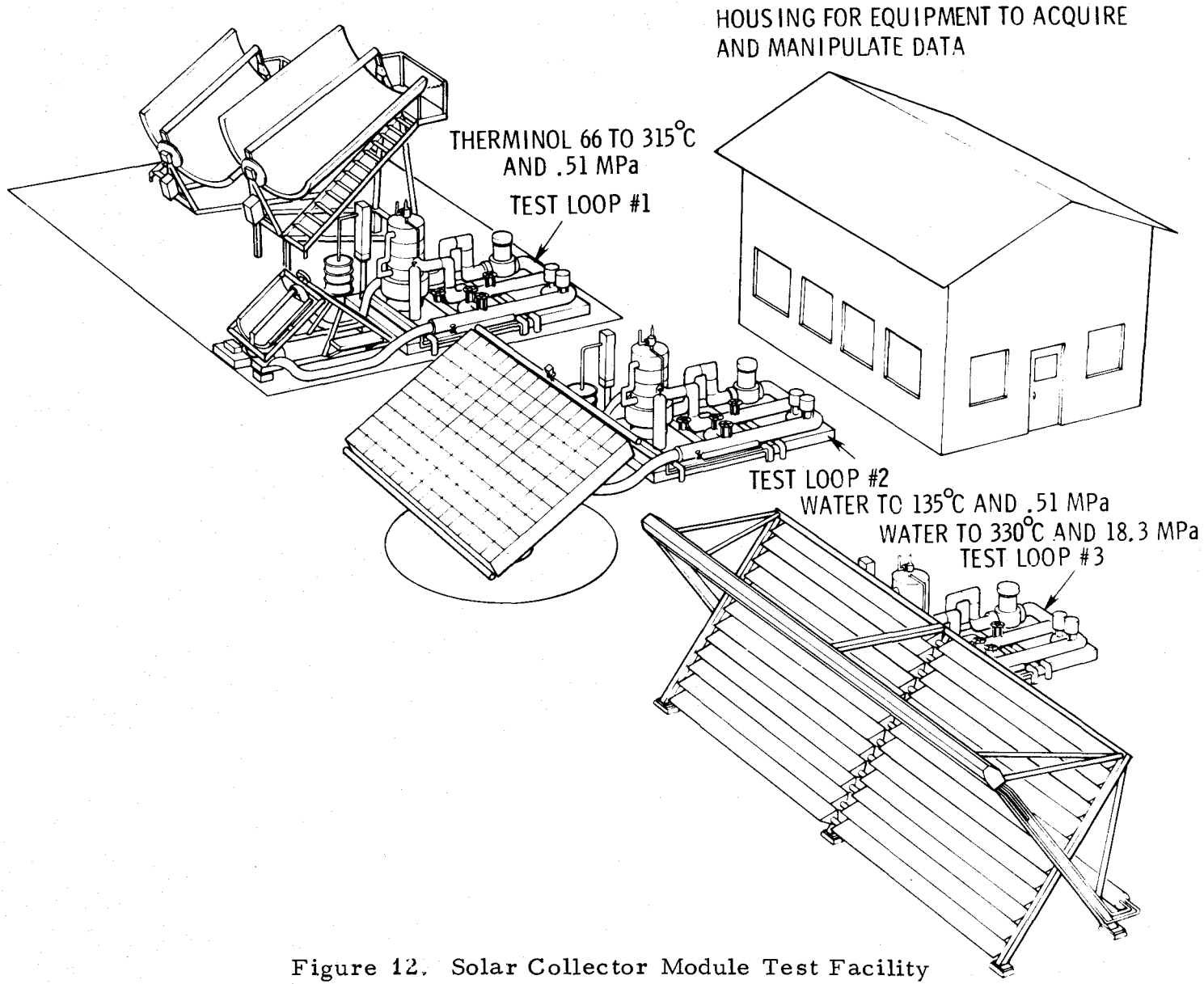


Figure 12. Solar Collector Module Test Facility

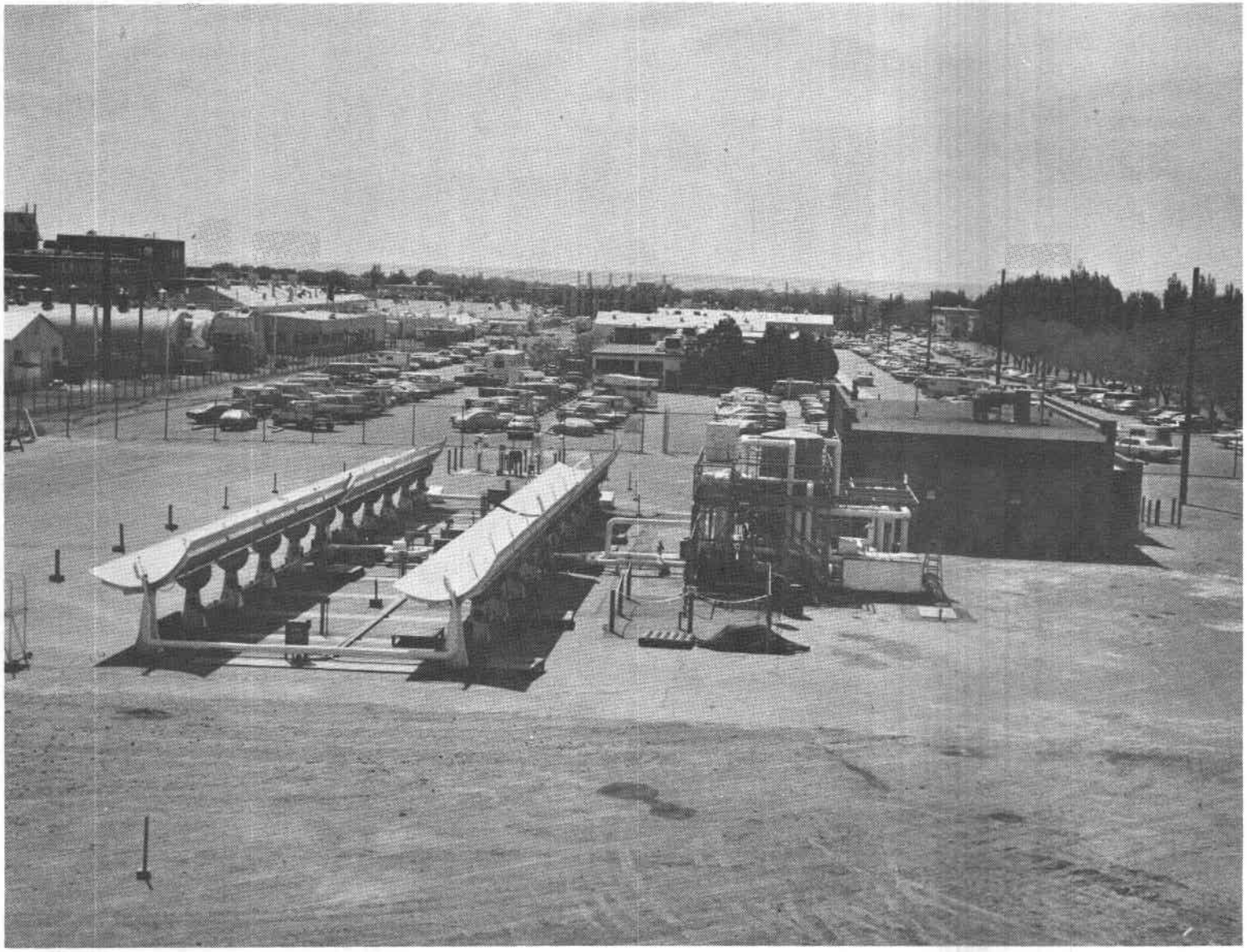


Figure 13. Collector Field, Turbine and Control Building, and Solar Projects Building

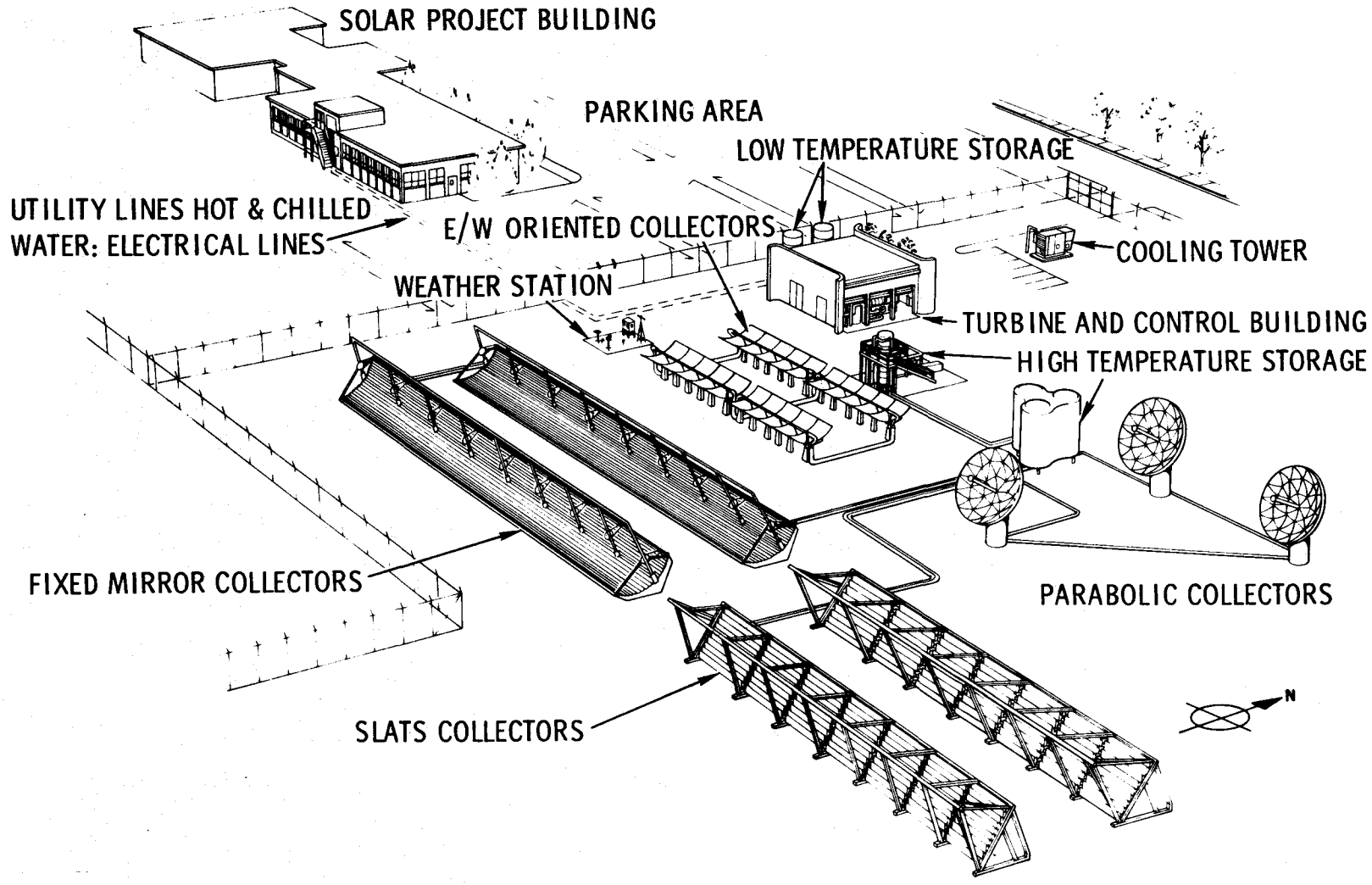


Figure 14. Solar Total Energy System Test Facility

24.0 400KW_{th} SOLAR THERMAL TEST FACILITY

24.1 Program Summary

Title:	Organization:
Development & Evaluation of a 400 KW_{th} Solar Steam Generating Plant and Test Facility in the U.S.	Georgia Institute of Technology Engineering Experimental Station Atlanta, Georgia 30332
Amount: $475,000	Principal Investigator: Nick E. Poulos

Effective Date:	Duration or Ending Date:	Contract No.
1 January 1976	19 Months	E(40-1)-5018

Objectives and Tasks

The goals of this program are four-fold:

(1) The transfer of existing technology, developed in Italy during the past 15 years, to the Solar Thermal conversion effort in the United States.

(2) To develop operating experience in the solar generation of steam by central receiver.

(3) Provide a test facility to aid in the design, development, and evaluation of advanced central receiver components.

(4) Provide a high temperature solar thermal source for materials research and development.

Facility preparation is underway after a 2 month delay due to bad weather. The facility is still expected on-line by July 31, 1977. Some difficulty has been experienced receiving primary components from the Italian supplier. Authorization paperwork for upgrading the facility and making it more versatile is in the approval cycle.

24.2 Program Status

The design of the 400 KW_{th} Solar Thermal Test Facility (STTF) represents an improved version of a smaller facility developed by Professor Francia of Italy. The primary motivation is to transfer this existing technology to the solar thermal conversion effort in the United States.

The original contract calls for a tower and receiver located centrally in a heliostat field. A recent proposal, currently in the approval cycle, also provides for a heavy duty (10-ton) south tower at the edge of the field, a total flux calorimeter, and general facility upgrading.

Check-out and evaluation of the STTF is scheduled to begin about May 1977 with the facility on-line, i.e., available for solar thermal tests by July 31, 1977.

Site preparation at the Georgia Tech campus is well under way after a 2 month delay due to bad weather. All excavation and footings are complete and installation of the heliostat support structure under-way.

Ansaldo of Italy is responsible for the major portion of the equipment, i.e., heliostat drive, bending (focus) devices, receiver, etc. To date, these critical components have not been received. The latest communication with Ansaldo resulted in a promise of partial delivery by the end of February 1977.

A proposal submitted to ERDA outlined the advantages of upgrading the facility. The most prominent suggestion was the addition of a south tower which would permit testing of heavier (10-ton) receiver components and also provide personnel access to the focal zone. These recommendations are currently in the approval cycle.