ergy

SOLAR

ALO-3994-84/1
(DE85001486)

SOLAR TOTAL ENERGY PROJECT SHENANDOAH, GEORGIA SITE

Annual Technical Progress Report for the Period July 1, 1983—June 30, 1984

Work Performed Under Contract No. FC04-77ET20216

Georgia Power Company
Atlanta, Georgia

Technical Information Center
Office of Scientific and Technical Information
United States Department of Energy

ALO-3994-84/1
(DE85001486)
Distribution Category UC-62a

SOLAR TOTAL ENERGY PROJECT
Shenandoah, Georgia Site

Annual Technical Progress Report for the Period
July 1, 1983 through June 30, 1984

E.J. Ney
Manager, Solar Operations

for

Georgia Power Company
P.O. Box 4545
Atlanta, Georgia 30302

Prepared For The United States Department of Energy
Division of Solar Energy
Under Cooperative Agreement No. DE-AB04-77ET20216
(Formerly EG-77-A-04-3994)

CONTENTS

FOREWORD

Although summary and abstract information for the period July 1, 1977 through June 1983 is included, the detailed data in this Report reflect progress and status of the Shenandoah Solar Total Energy Project (STEP) only for the period July 1, 1983 through June 1984.

The following publications, available from the National Technical Information Service (see back of Title Page), contain detailed progress and status reports for the first five years of the Project. They also contain additional information on the socio-economics of the Shenandoah area; weather and insolation statistics; and technical details concerning the factory application, energy-usage monitoring instrumentation; interface drawings; and Solar Easements. This information was crucial to the Site Selection and Design Phases that preceded construction activity in 1981.

- Solar Total Energy—Large-Scale Experiment, Annual Report, July 1, 1977 through June 1978 (ALO-3994-77/3)
- Solar Total Energy—Large-Scale Experiment, Annual Report, July 1, 1978 through June 1979 (ALO-3994-77/4)
- Solar Total Energy—Large-Scale Experiment, Annual Report, July 1, 1979 through June 1980 (ALO-3994-77/5)
- Solar Total Energy—Large-Scale Experiment, Annual Reports, July 1, 1980 through June 1982 (ALO-3994-83/1)
- Solar Total Energy—Large-Scale Experiment, Annual Report, July 1, 1982 through June 1983 (ALO-3994-83/2)

General information on the Shenandoah STEP also can be obtained by writing to:

Manager, Solar Operations
Georgia Power Company
7 Solar Circle
Shenandoah, Georgia 30265

Section 1
CHRONOLOGICAL SUMMARY OF PROGRESS

Following is a chronological summary of key events that occurred throughout the first seven years of the Cooperative Agreement. A detailed progress report for the subject reporting period appears in Section 3 of this Report.

1977

May	Cooperative Agreement award announced.
June	Formal meetings—Site Team; Sandia; and Conceptual Design Teams (G.E., Stearns Roger, Acurex).
July	Energy-saving features incorporated into Bleyle plant design.
August	GPC participates in design review as Utility Advisor.
	Concrete flooring for Bleyle Plant poured, insulated roof completed.
	Government-furnished meteorology station installed, operation initiated.
	First set of design interface drawings submitted to Sandia.
September	GPC Team attends design reviews at Albuquerque.
	Interconnection piping task added to Cooperative Agreement.
October	First coordination meeting held with G.E. Design Team.
	Energy measurement program defined; measurement points selected.
	Formal change procedures (Master Index Sheet) instituted for interface drawings.
November	Interconnection Piping System inspected.
December	Knitwear Plant completed, keys presented to Bleyle.
	Plant side of interconnection piping system activated.

1978

January	Bleyle plant begins operation.
February	Mobile Instrument and Visitor Center installed at site.
March	Plans submitted to Sandia for adding eight instruments to Meteorology Station.
	Electrical data collection lines installed.
April	Site surveys completed.
	Solar easement document drafted.
	Initial kilowatt hour data recorded.
May	Rough grading bid package submitted.
	Instrumentation wiring completed, tested.
June	Meeting held to discuss planned expansion of Bleyle Plant.
	Legal document drafted to transfer 5.7-acre tract to GPC.
	Site tour and presentation made to Nevada Power Company and State of Nevada personnel.
	Testimony presented to House Sub-Committee on Government Relations.
	First Energy Data Report submitted, reflecting kWh consumption in Bleyle plant.
July	Groundbreaking ceremony for collector field and open-house held at site.
	Tours and presentations conducted for several groups including Georgia Professional Engineering Society and Governor's honor students.
August	Contract validation and approval of site grading and TTO programs received from DOE.
	Monthly energy data and first computer data tape submitted.
September	Final review conducted for land transfer and solar easement documents.
	Technical Interchange Meeting held.
October	DOE approval received for grading work—bids received for evaluation.
	Site Team meets with WBS-TV (Channel 2) to discuss Met Station; two-minute presentation broadcast on news programs on two consecutive days.
	Bleyle Plant wins Southeastern Electric Exchange competition in Industrial Building Category.
November	New data logger installed by EG&G and GIT personnel; channel capacity expanded from 8 to 16.
	Site clearing work begins: sediment fence installed, drainage trench begun, topsoil stockpiled.
December	Presentations made to Texas Utilities Service Company and other groups.
	Construction of energy dissipator completed.

1979

January	Presentations made to DOE representatives.
	Land Transfer and Solar Easement documents officially recorded in Coweta County Court House.
February	''Energy Challenge'' show presented to IEEE, Power Generation Division of Atlanta. Presentation made at meeting of Southern Company Services System Research Advisory Committee.
	Earth moving activities completed at STES site.
March	Series of meetings conducted with GPC and H&H engineers to evaluate Bleyle Plant HVAC system and Energy Measurement and Reporting Programs.
April	Presentations made to several Swedish engineers, Gulf States Utility Company, and representatives from Federal and State governments.
	Grassing of steep slope areas completed at site.
May	Site Team participates in 1979 International Solar Energy Society (ISES) convention; more than 600 attendees from 60 nations tour STES site.
	Grassing of entire site completed.
June	Presentations made to several groups including heating/air conditioning trainees at Atlanta Federal Penitentiary.
	Scope of Project is reduced and total number of collectors drops from 192 to 120.
July	Meteorology Station in full operation with 16 weather parameters being recorded.
August	DOE-requested soil and pier tests completed.
	STEP personnel participate in Energy Technology Conference at Georgia Tech.
	General Accounting Office conducts Management Audit of STEP site.
September	Final Power Supply Interface System Specifications completed.
October	Final correct operating mode for Bleyle economizer systems determined.
	Efforts started to make all data channels operational.
November	STEP Technical Paper presented at the American Nuclear Society Meeting.

1980

February	Figures for connected load and demand power are agreed upon.
	Mr. R. Hunke of Sandia Laboratories establishes office at STEP Site.
	Bleyle Plant Instrumentation Measuring Program terminated.
March	Location for Power Supply Interface System selected, north of the STEP Mechanical Equipment area.
April	Scope of Project is further reduced: collector field is reduced from 120 (originally 192) to 114, thermal storage system is reduced to a one-hour buffer system, and heating of the Bleyle Plant is removed from the requirements to be met with solar energy.
May	Design of Interconnecting System deferred due to program rescoping.
	Cooperative Agreement Access Road to Site provided.
June	Bleyle purchases building and 2.3 acres of adjacent land for expansion.
	STEP Construction Office and Visitor Center established.
	Weather Station moved to southeast corner of site.
July	Discussions between Sandia and Georgia Power Company resolve schedule changes for installation of equipment in power supply interface.
August	Proposals received for fabrication and installation of collectors.
	System Integration contract placed with Lockwood-Greene, Inc.
	Contract for Construction Inspection Services awarded to Heery and Heery, Inc.
September	Interface meeting held to discuss technical details of solar energy system.
	Plans and specifications for Mechanical Equipment Area received for review.
	Bids opened for Collector Field construction.
October	Modifications made to Cooperative Agreement to provide additional office space and to provide utility services to the trailers.
	Suppliers chosen for major equipment in substation.
November	Bids opened for Mechanical Equipment Area; recommendations made for suppliers.
December	Surveying and other pre-construction activities initiated at the Site.
	Contracts awarded for Collector Field Work and for purchase of collectors.

1981

January	First underground caissons put into place to support collectors.
February	Contract awarded to construct Mechanical Equipment Area.
March	All caissons are completed, and installation of underground piping begins.
	First cost proposal submitted for STEP operations.
April	Work begins to place lower base support frames on caissons; installation of underground piping completed.
May	All support frames installed on caissons; rock and asphalt roads completed.
	Walls of Mechanical Equipment Area erected, and steel roof deck put into place.
June	Collector field is nearly complete, bids taken for high temperature insulation work.
July	Permanent gas lines and phone cables installed, and personnel trailer moved to new location.
	Access roads paved while work on Mechanical Equipment Building nears completion.
August	Work begins for installation of equipment inside the Mechanical Equipment Building.
	Mr. J. Zimmerman of Sandia Laboratories arrives on Site to supervise operation activities.
	Electrical interface substation completed.
September	Cost proposal for STEP operations submitted.
	High Temperature Fluid piping is completed.
	Steam generator arrives at Site.
October	Five-day HTF conditioning tests conducted.
	Large storage tank is jacketed and insulated.
November	Cooling tower, condenser water pump, and chilled water pump installed. Other piping completed.
	Last of 114 collectors is installed, and stripping of protective coating begins.
December	Procedure prepared for conducting steam tests.
	Absorption chiller received, and piping, wiring and equipment installation proceeds.
	DOE and Georgia Power sign Agreement in Principle regarding STEP operations.

1982

January	Steam System Integrity Tests culminate with first generation of electricity to 100 kW level.
February	Insulation of steam generator completed.
	Initial steam is flowed to the Bleyle Plant to condition the insulation.
	Adjustment of collectors to meet acceptance criteria continues, but most are accepted.
March	Two-day inspection of STES conducted by Readiness Review Committee—no problems found.
	Mechanical Equipment Area contractor completes work.
April	Operational status review conducted by DOE, Sandia, and Georgia Power. Provisional acceptance is granted.
May	More than 500 people attend Site dedication ceremonies—generator synchronized to 200 kW and electricity from solar energy is produced for 44 minutes. All collectors are brought into focus for the first time.
June	Absorption chiller is started, leading to cogeneration with 250 kW (electric) and 50 tons of air conditioning (thermal).
	Final 'punch list' work completed by all primary contractors.
	Contract amendment for STEP operations is completed by Georgia Power.
July	Amended Cooperative Agreement is received from DOE. Two-shift STEP operations are initiated.
August	STES provides 600 ton-hours of air conditioning and 5600 pounds of process steam to Bleyle Plant.
September	Control and Instrumentation Subsystem (CAIS) auto-tracks simulated solar conditions and then stowes the collectors.
October	Operations are limited by various anomalies, especially cavitation problems in the Heat Transfer Fluid (HTF) pumps.
November	Water contamination is determined to be the cause of the HTF pump problem, and efforts begin to find the source.
December	Source of HTF water contamination is found in the steam generator, and leaks at the tube-tubesheet interface are welded.

1983

January	Turbine generator operation is resumed, producing 6,700 kWh of electricity, and 27,750 pounds of process steam.
February	At mid-month, 113 collectors operate continuously under CAIS control; 400 kWe generation level is reached.
March	CAIS continues to operate with various levels of success while anomalies are identified and corrected.
April	Two-shift work schedule resumes for the spring and summer, while work continues on updating as-built drawings and writing a system description.
May	Plans for the new Solar Center building are finalized.
June	Significant preparations are made regarding objectives and procedures for the Test Operations Phase.
July	System operates entirely on solar energy on several occasions.
	Repairs are initiated on collector field flow control system and on collector film.
August	Meeting is held with DOE and Sandia to recommend primary and secondary tests for the STEP.
	Bucket truck accidently strikes and damages one collector.
September	Eleven collector field air valve controllers incur water damage and are replaced, and fiber optic problems continue.
	Auburn University representatives visit the site to discuss research projects.
October	Corrosion problems caused by wetted thermal insulation in the collector field piping become significant. A retrofit plan is developed.
	Formal testing of the thermal storage tank is conducted.
November	Extensive work is done with computer hardware and software for control and data acquisition, while work continues on the fiber optic systems.
	Photovoltaic sign at the Shenandoah Solar Center (GPC) is dedicated.
December	Annual Site Operational Review is conducted by DOE. Top priority is given to 29 tests proposed by STEP personnel, and Georgia Power submits a proposal to extend the current Cooperative Agreement.

1984

January	Workers begin removing insulation and replacing corroded tubing in the collector field.
	Preparations begin for formal testing, as ETEC and Sandia representatives visit the STEP site for a Test Operations Phase (TOP) planning meeting.
February	Insulation is completed on the new piping in the collector field.
	Final Test Operations Phase (TOP) Plan is submitted.
March	Ed Addison, president of Southern Company, visits the Shenandoah site and expresses continuing support.
	Meeting is held to analyze procedures for carrying out TOP specifications.
April	First TOP tests are performed, and the reports are used at a planning meeting that includes Sandia, SERI, Cal State Poly, and Georgia Power.
May	Five additional TOP tests are performed, while an eclipse produces unique solar data for one day.
June	For the first time, recorded monthly direct insolation exceeds Solar Model Year (SMY) data at the STEP site.
	Two California Polytechnic University students begin six-month training programs leading to college credit and solar operator licenses.

Section 2
PROJECT OVERVIEW

The Solar Total Energy Project (STEP) at Shenandoah, Georgia, is a cooperative effort between the United States Department of Energy (DOE) and the Georgia Power Company to further the search for new sources of energy.

A part of the National Solar Thermal Energy Program, initially funded by DOE, the Shenandoah Project, shown in Figure 2-1, is the world's largest industrial application of the solar total energy concept. The objective of the Project is to evaluate a solar total energy system that provides electrical power, process steam, and air conditioning for a knitwear factory (operated by Bleyle of America, Inc.). During normal operation, solar energy generates a large part of the electricity and displaces part of the fossil fuels normally used to run the factory and produce the clothing.

Construction of the system was completed early in 1982, when operations were initiated. Solution of unexpected electrical and mechanical problems produced significant information for subsequent system designs. This Section presents an overview of the Project and a brief System Description. A discussion of various anomalies, together with subsequent high quality solar and thermodynamic system performance results, is included in Section 3.

History

In 1977, DOE declared Georgia Power Company the winner among 16 competitors from 14 states for the location and application of the Solar Total Energy Project. The Georgia Power site most nearly met all project requirements regarding weather, accessibility, energy requirements, and other important considerations.

Design work for the solar energy system was completed between 1978 and 1980. Georgia Power provided cost-sharing support and coordination throughout the design and construction stages, and assumed responsibility for operation of STEP in July 1982. It is anticipated that ownership will be transferred to the Georgia Power Company near the end of DOE operational funding. The complete STEP schedule is shown in Figure 2-2.

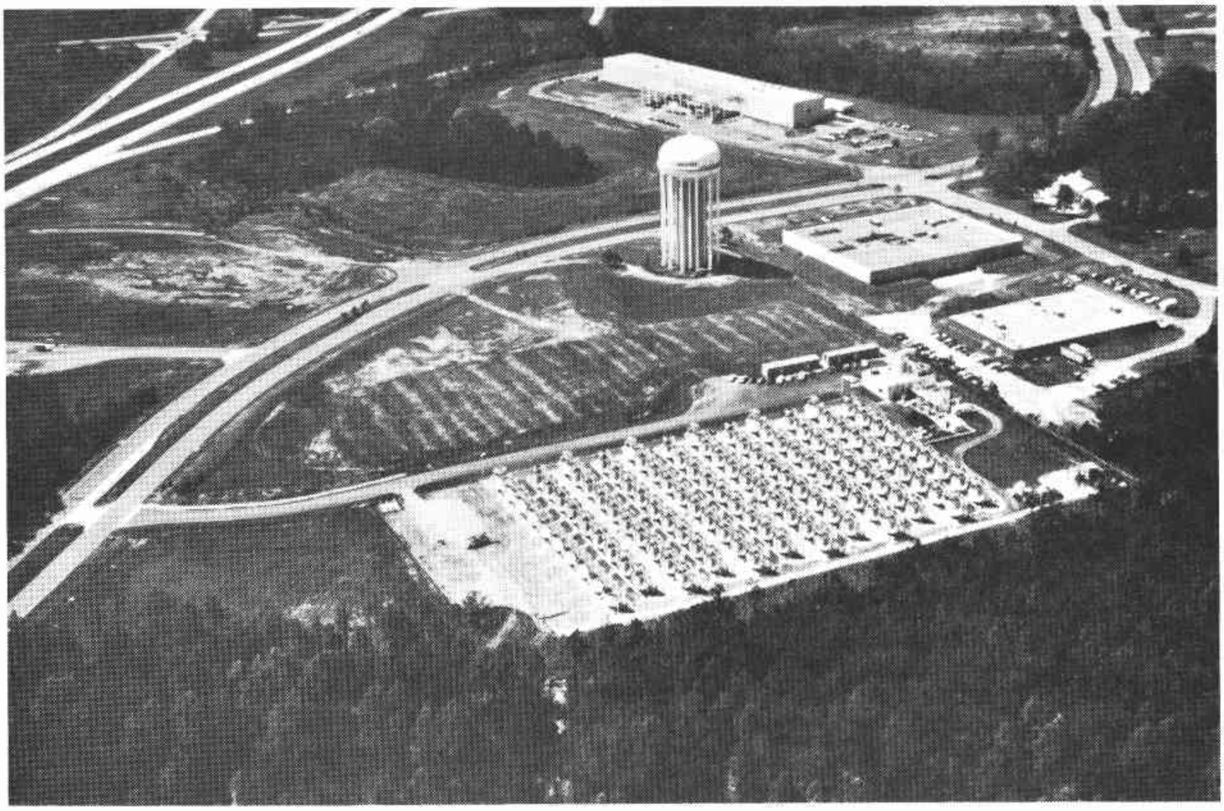


Figure 2-1. Aerial View of Completed STEP Site

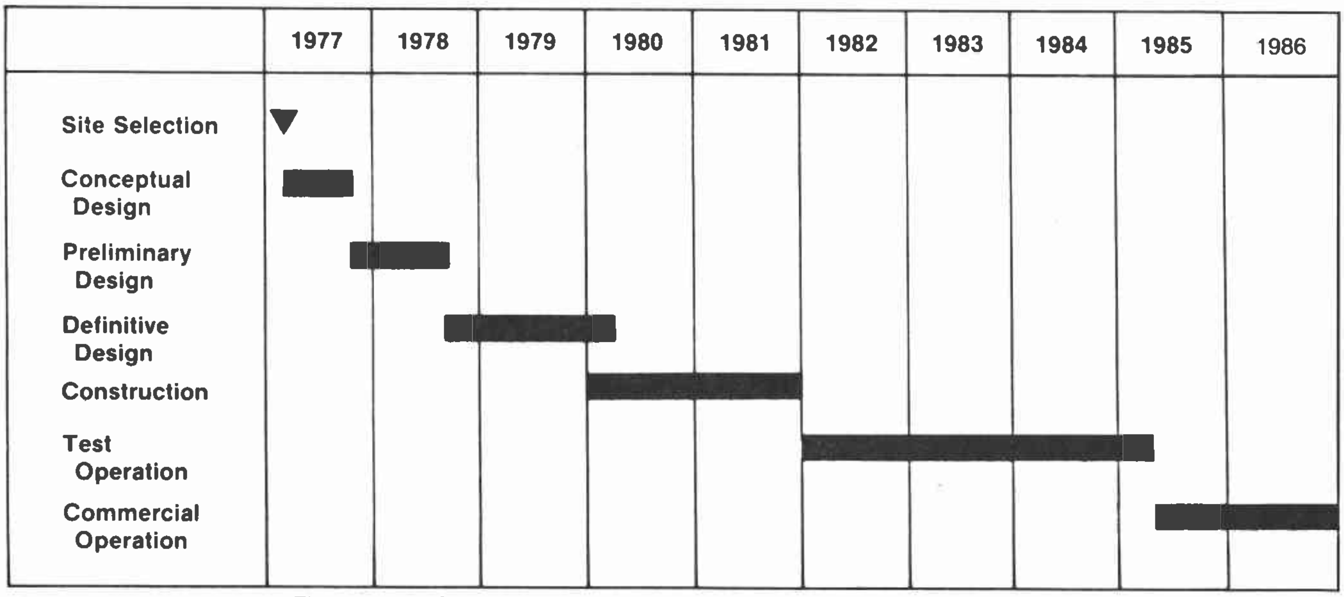


Figure 2-2. STEP Program Schedule Toward Commercial Operation

In the future, as full owner of the Project, Georgia Power will operate the facility as part of a Solar Center that will include further land acquisitions, additional offices, visitor space, exhibits, and test facilities for research and development of solar energy technology.

The eight-year period comprising site selection, design, construction, test operation, and dissemination of cost and performance data (shown in Figure 2-2) will culminate with a period of commercial operation that will complete the original ten-year cooperative agreement signed with Georgia Power in May 1977.

Total Energy Concept

The total energy concept—also called cogeneration—makes maximum use of waste heat from electrical power generation to meet other energy requirements. Combined with a solar energy system, the total energy concept offers these benefits:

1. It provides energy from a renewable source.
2. It makes maximum use of collected energy.
3. Its closed-loop system releases no pollution.
4. It is compatible with existing utility services.

Commercial Application

The 25,000-square-foot Bleyle Knitwear Factory has been operating since 1978 with conventional energy sources. The fully operational solar system is capable of generating 11 billion Btu annually, or 11 million Btu per hour peak thermal energy. This can be translated into 400 kW of electricity, 1380 pounds per hour of process steam at 350°F and 120 psig, and 257 tons of air conditioning, which can be supplied to the knitwear factory. Energy needs beyond the solar derived portion required by the Bleyle Plant are supplied by conventional sources.

The Bleyle Plant building was designed to incorporate DOE and Georgia Power recommendations for achieving energy efficiency:

1. Reduced height to minimize volume of building and wall area
2. Four-foot insulating earth berm as thermal buffer around the building
3. North-south orientation
4. Air conditioning economizer cycle
5. Super insulated walls and roof
6. High efficiency fluorescent lighting
7. Energy efficient equipment

Energy-conserving features alone, exclusive of the solar equipment, have reduced the factory's energy needs by 46%, thus saving more than $25,000 a year (at 1982 utility rates). Data gathered by Georgia Power instruments in the factory were used to determine the building's energy requirements, and this information was used to design the solar energy system.

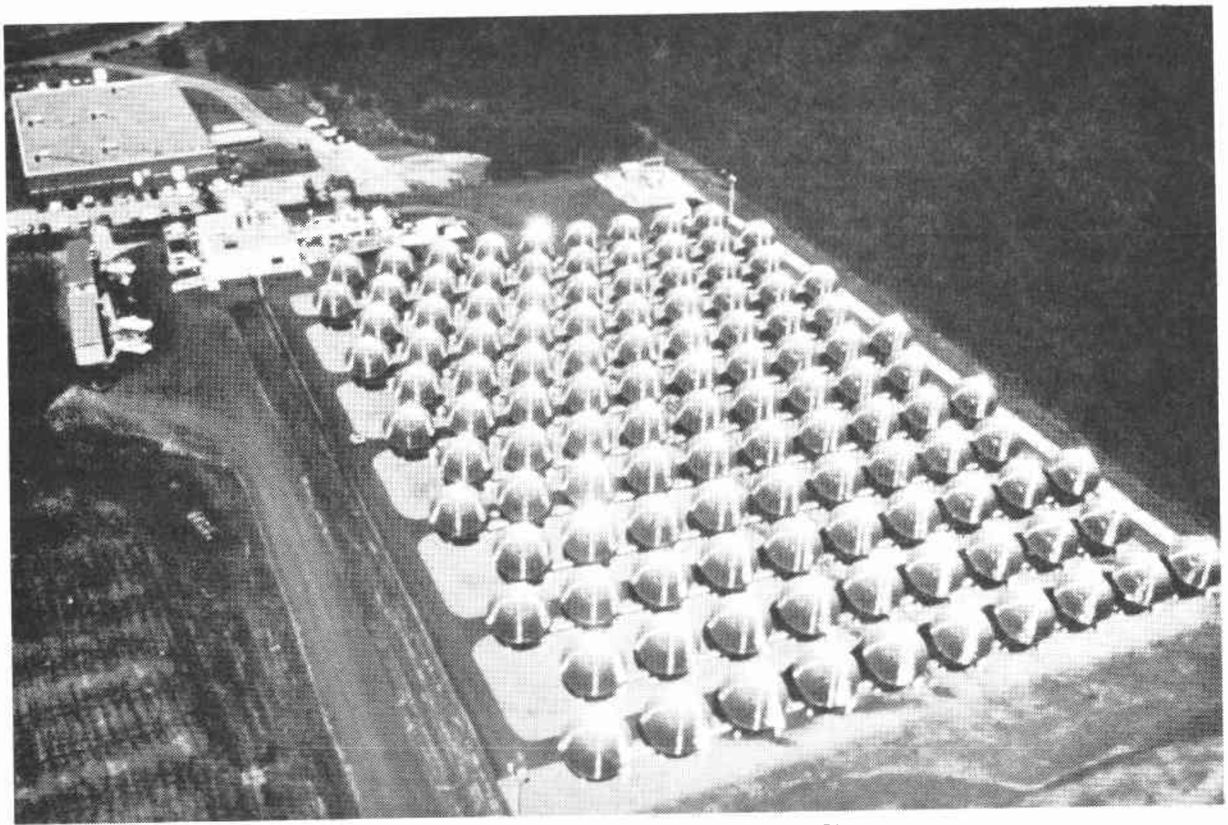


Figure 2-3. Layout of Completed STEP Site

Site Description

The aerial photograph in Figure 2-3 shows the physical layout of the project site. A field of 114 parabolic solar dish collectors—each 23 feet in diameter—tracks the sun and concentrates the rays to heat a circulating fluid. An easement obtained from adjacent landowners guarantees unobstructed sunlight for the collectors.

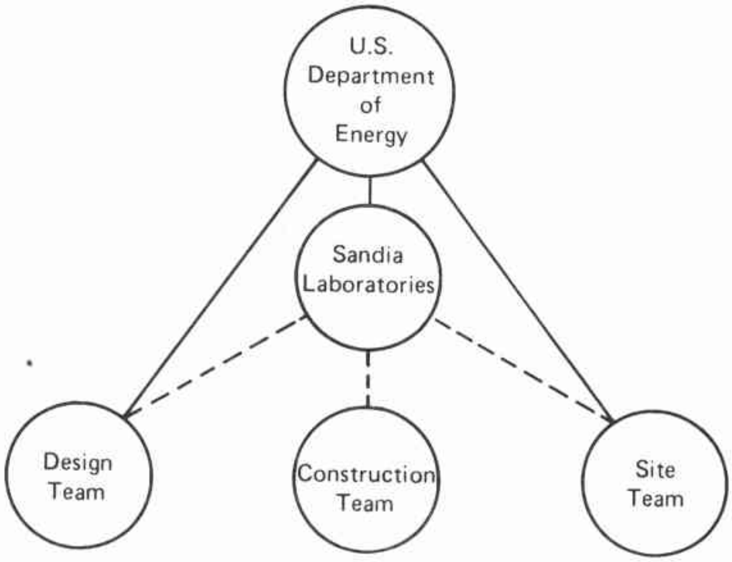
The Bleyle Knitwear Plant is shown in the upper left corner of the photo. Below the plant are the two trailers being used for offices and Visitor Center. The white building at the upper left corner of the collector field houses the operations and control equipment, and the area to the right of the building contains the steam generator, high temperature storage tank, and other mechanical equipment.

A meteorological station at the Site, operated by the Georgia Institute of Technology, constantly monitors the amount of solar energy available. The solar insolation and surface weather instruments make it one of the most sophisticated stations in America for gathering data about the sun. Information collected by the station was used in designing the solar total energy system and will continue to be used to support the national weather network.

A Georgia Power electrical substation (upper right) designed for the Shenandoah project is providing new technology and engineering experience for integrating the electrical output of the cogeneration solar system with the company's 15,000-plus megawatt system.

Participants

The organizations shown in Figure 2-4 participated in the development of the Shenandoah Solar Total Energy Project over the first six years of planning, designing, construction, initial operation, and testing. The diagram illustrates the relationships among the participants.



DESIGN TEAM	CONSTRUCTION TEAM	SITE TEAM
General Electric (Valley Forge)	Dow Corning Corp.	Georgia Power
Lockwood-Greene	L.B. Samford	Georgia Institute of Technology
Scientific Atlanta	B&W Mechanical Contractors	Heery & Heery, Architects and Engineers
Dow Corning Corp.	Joe North, Inc.	Shenandoah Development
Mechanical Technology	General Electric (Daytona Beach)	Owens-Corning Fiberglas Corp.
	Solar Kinetics	Westinghouse Electric Corp.
		Bleyle of America

Figure 2-4. Overall Organizational Relationship Among Participants in Solar Total Energy Project

Program Objectives

The overall U.S. Department of Energy (DOE) objectives for the National Solar Total Energy Project at Shenandoah, Georgia are to:

1. Produce engineering and development experience on large scale solar total energy systems as preparation for subsequent commercial size applications.
2. Assess the interaction of solar energy technology with the application environment.
3. Narrow the prediction uncertainty of the cost and performance of the Solar Total Energy System (STES).
4. Expand solar engineering capability and experience with large-scale hardware systems.
5. Disseminate information and results.

Site Objectives

The primary objective of the STEP Site/Application effort at Shenandoah is to provide a commercial facility to utilize solar-derived electrical and thermal energy, as well as a suitable area for erecting a solar energy system to provide the required energy to the facility. This includes data acquisition and analysis, as well as design interface.

The objectives of the Georgia Power Company within these parameters are to:

1. Evaluate the significance of an emerging alternate energy technology in an industrial application.
2. Promote the utilization of energy conservation and load management.
3. Consider the applicability of cogeneration facilities.
4. Analyze the economic potential of solar total energy in an industrial application.

The achievement of these objectives will allow Georgia Power Company to better provide reliable, economic and environmentally acceptable energy to the consumers of the State of Georgia and help lead the nation to a partial solution of the energy dilemma.

Project Description and System Design

The Solar Total Energy Project is in Shenandoah, Georgia, 25 miles southwest of Atlanta International Airport, at

Figure 2-5. Geographic Location of STES Site

Exit 9 of Interstate 85, as shown in Figure 2-5. The Site consists of 5.72 acres adjacent to and east of the Bleyle Knitwear Plant in the Shenandoah Industrial Park.

A solar total energy system uses collected solar energy to supply high-grade electrical and mechanical energy and low-grade thermal energy for selected applications. The Solar Total Energy Project (STEP) at Shenandoah supplies electric power to a utility grid, and process steam and air conditioning to a knitwear manufacturing facility. Excess power from the STEP is supplied to the Georgia Power Company electricity distribution network.

The STEP is a fully cascaded total energy system with parabolic dish solar collectors and steam Rankine cycle power conversion system capable of supplying 100-400 kWe output with process steam extraction. The design includes the Solar Collection Subsystem, the Power Conversion Subsystem, the Thermal Utilization Subsystem, and the Control and Instrumentation Subsystem, which are monitored to provide the data necessary to evaluate the STEP. Figure 2-6, a simplified schematic diagram of the STES, illustrates the concept of cogeneration with solar energy.

Operation: Operation of the system begins with circulation of a heat transfer fluid through the receiver tubes of the parabolic dish solar collectors. Solar radiation is focused in the receivers by the collector reflector and heats the silicone heat transfer fluid (HTF) to 750°F. The heat transfer fluid is then pumped to a heat exchanger. In the heat exchanger, the heat transfer fluid boils water and superheats the steam; the heat transfer fluid then returns to the collectors and the cycle is repeated. The superheated steam drives a turbine that in turn drives an alternator. Steam at 350°F is extracted from the turbine for knitwear pressing. The low-pressure steam exhausted from the turbine is used to produce chilled water for air conditioning, or is cooled as it passes through an air-cooled condenser.

Solar Collection Subsystem: The Solar Collection Subsystem (SCS) consists of an array of 114 parabolic dish collectors, each 23 feet in diameter, shown in Figure 2-7. The heat transfer fluid flowing through the collectors, whose receivers are connected in parallel, is heated from the inlet temperature at 500°F to 750°F. The receiver is a cavity type capable of receiving an incident concentrated solar flux equal to 235 suns. The concentrated solar flux impinges upon the receiver coil's absorptive surfaces enclosed within the insulated cylindrical shell.

Each parabolic dish is made up of die-stamped aluminum petals and was assembled in the field. The aluminum petal is laminated with a second surface—aluminized acrylic reflective film—prior to forming. Each collector tracks individually in polar and declination axes to follow the sun from morning to evening, and from season to season. The para-

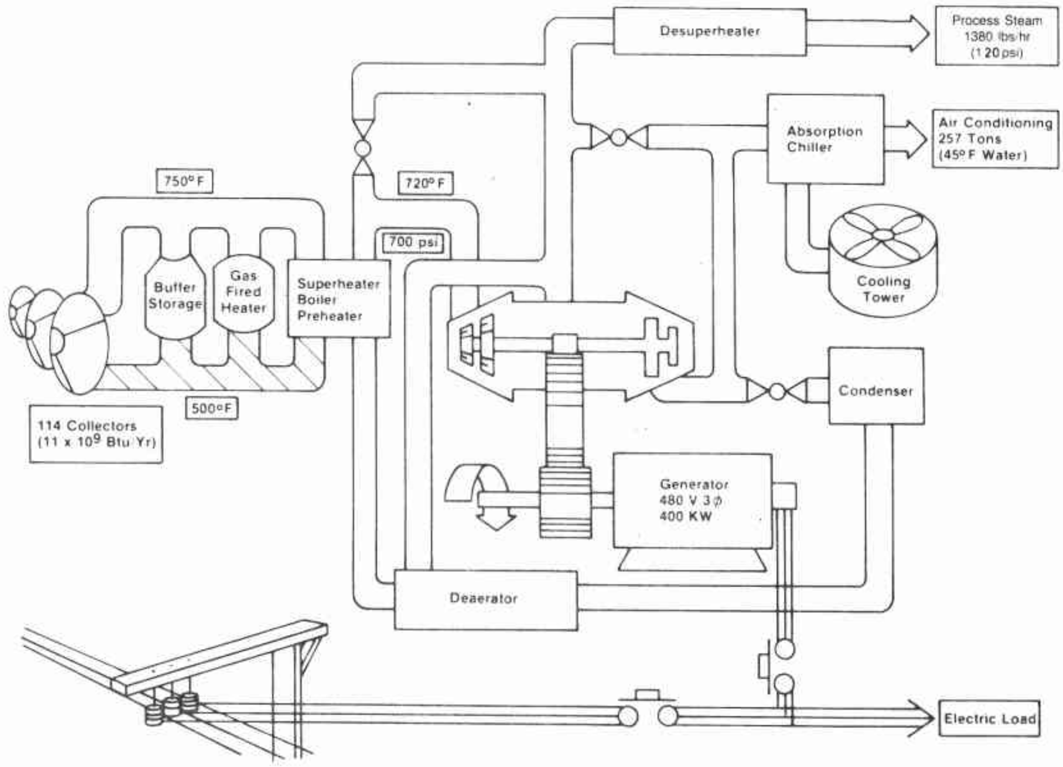


Figure 2-6. Illustration of STES Concept

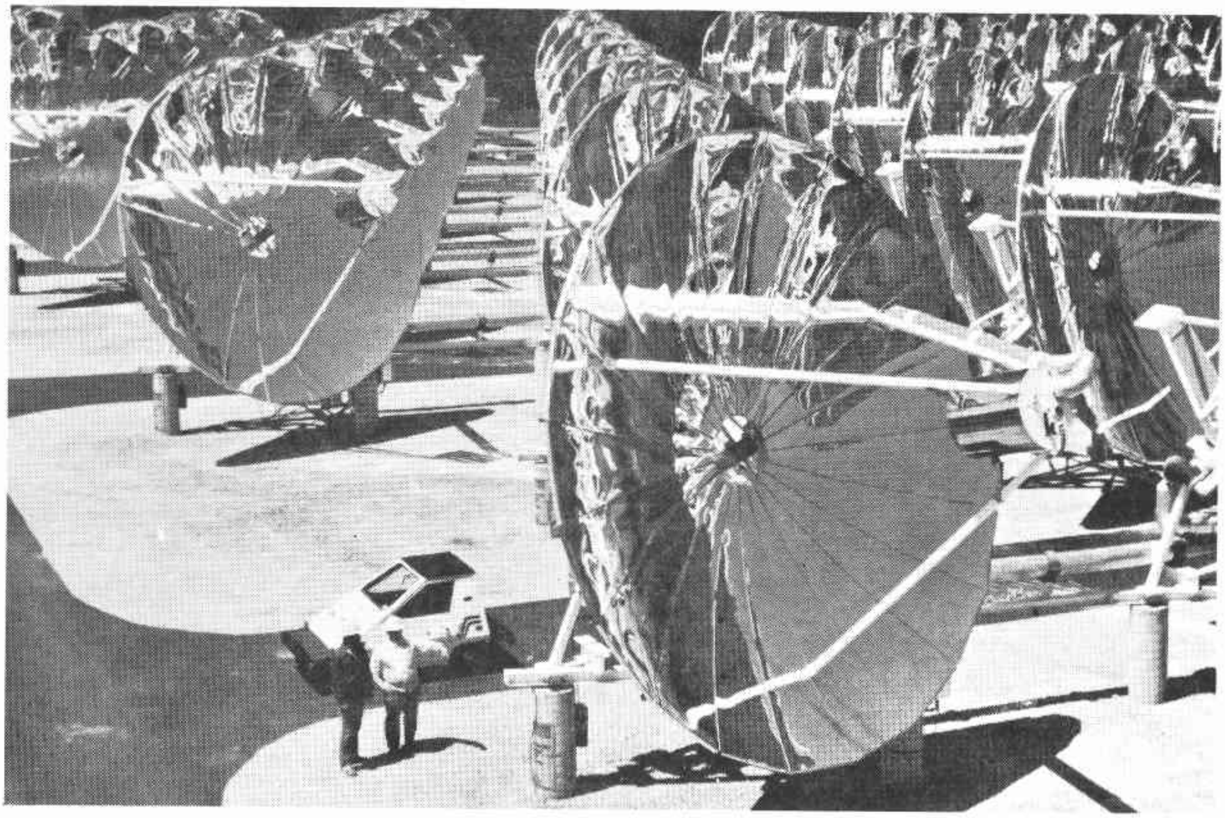
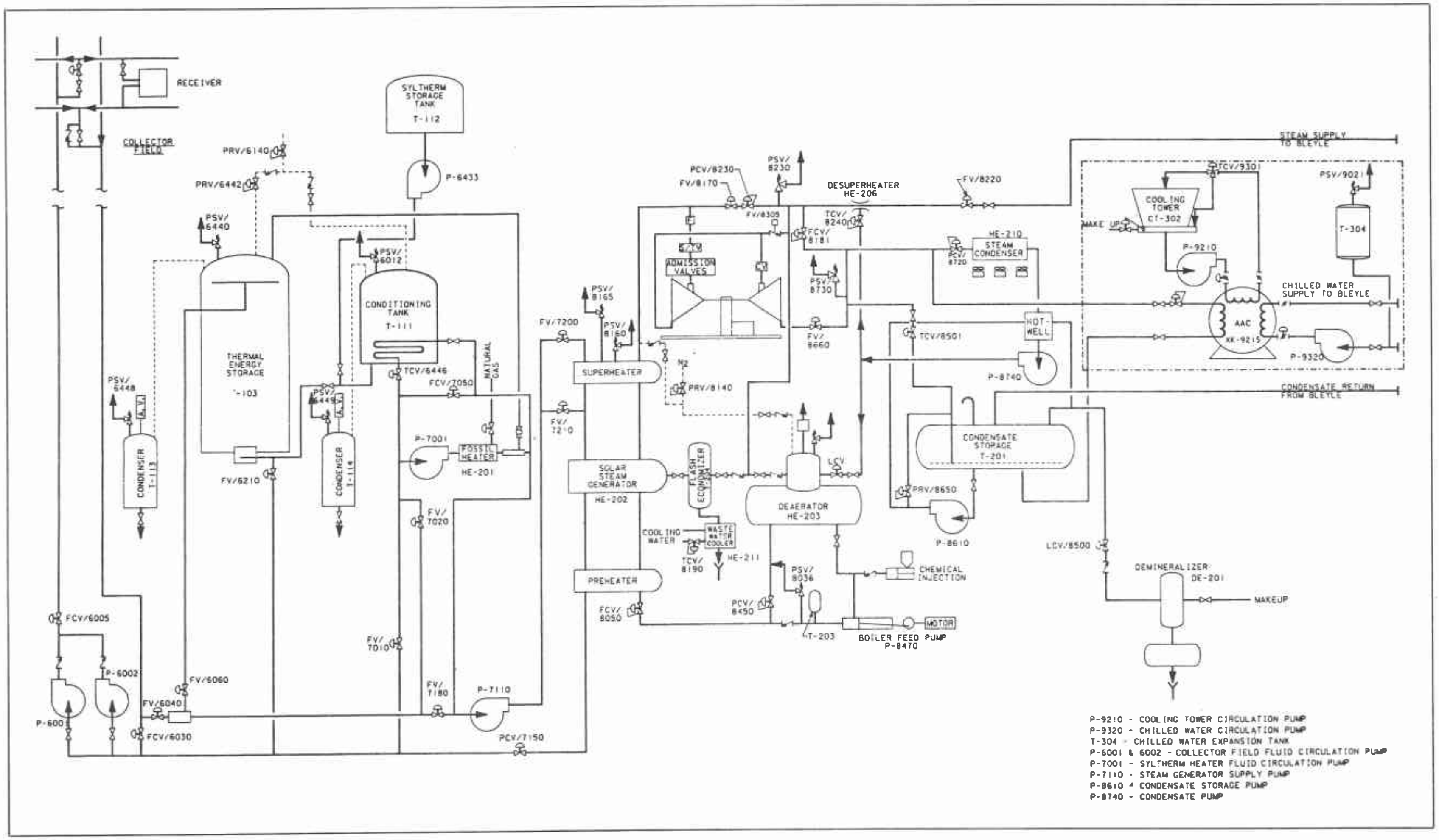


Figure 2-7. STEP Parabolic Solar Collectors

Simplified Schematic Diagram of STES



bolic dish collectors are arrayed on the Shenandoah collector field in a repeating diamond pattern.

The field piping network consists of welded pipes in the main manifolds, and steel tubing in the branches. All are covered with a high-temperature insulation. The SCS provides one hour of thermal storage at 750°F as a buffer against transient solar conditions. Energy is stored in the silicone heat transfer fluid in a thermocline tank. A natural gas fired heater capable of supplying the power conversion subsystem energy input requirements is used during startup and to supplement the solar energy system as necessary.

Power Conversion Subsystem: The Power Conversion Subsystem (PCS) consists of a three piece pool-type boiler with preheater, boiler and superheater, a steam turbine-alternator rated at 500 KVA, an air-cooled condenser and condensate storage tank, make-up demineralizer, deaerator, and necessary pumps. In normal operation, steam at 720°F and 700 psig is generated in the boiler-superheater and delivered to the turbine inlet.

The turbine alternator consists of a four-stage, high-speed (42,450 rpm) turbine, a gearbox that reduces the speed to 1800 rpm, and a 60 Hz alternator. The low pressure side of the high pressure turbine stages has an extraction port for process steam and steam for regenerative feed water heating. The low pressure turbine stages exhaust into an air cooled condenser at 230°F and provides steam to the Thermal Utilization Subsystem (TUS).

Thermal Utilization Subsystem: The Thermal Utilization Subsystem serves as the condensing medium for the steam and the heat source for the cooling of the Bleyle Plant. The exhaust heat from the steam turbine provides the heat input to the Thermal Utilization Subsystem. When the turbine is out of service, steam is provided directly to the Thermal Utilization Subsystem.

The steam from the turbine or the turbine by-pass is routed to the absorption air conditioner. The chilled water produced by the absorption air conditioner cools the cooling water supply to the Bleyle Plant. Any excess steam is circulated through the air-cooled condenser. The condensed water from the condenser and the absorption air conditioner is then placed in the hot well and the condensate storage tank.

Control and Instrumentation Subsystem: The STEP control system provides a full range of operations covering minimum operator control to extensive data collection for analysis of experimental operations. The control system partitions control functions between a minicomputer and its peripheral equipment and micro-processors distributed through the system. These micro-processors exercise some control functions locally. The Collector Control Units (CCU) located at each collector and the Control and Instrumentation Subsystem (CAIS) are connected by redundant serial links. This allows communication among the distributed control system components by a single pair of leads. Other sensors, including the weather instruments, interact with the central control computer through the Energy Utilization Processor (EUP).

The CAIS provides the following:

1. Control of all subsystems and components for normal and fail-safe operation.
2. All control logic for operational modes as selected by the operator.
3. Collection, monitoring of data and processing of information for:
   - Automatic decisions
   - System status information
   - Stored information for subsequent system analysis and evaluation
   - Automatic initiation of safety measures to prevent hazards to personnel, damage to equipment and property, and loss of data

In addition, operator control is provided for experimental modes to characterize system and component performance over ranges of operational parameters and to identify operating strategies for more effective electric and thermal energy displacement. The switch to the experimental modes allows the operator to initiate solar collection experiments, and to monitor and record data. Diagnostic routines may be initiated in the event of a malfunction.

The CCUs perform the following functions:

1. Receive system control information from the CAIS and provide signals to collector field control equipment, such as drive motors and valves.
2. Interpret local data to identify potential hazards and initiate control actions to preclude damage to the collector.
3. Maintain proper sun tracking automatically once sun acquisition by central computer has been established.
4. Relay data from local instruments to the CAIS for further processing or storage.

System Loads: The STEP loads include electric loads and process steam and cooling for the knitwear manufacturing facility. The design loads used to size the STEP are summarized in the following table. Except for lunch and shift breaks, the knitwear manufacturing facility electrical load profile is relatively constant over a one-shift operation.

Process steam at saturated conditions is required during all working hours.

	Peak Load Requirements For Knitwear Manufacturing Facility	STEP Capacity
Electrical	161 kW	400 kW
Cooling	1420 Mj (113 tons)	3260 Mj (257 tons)
Process Steam (177°C, 350°F)	626 Kg/hr (1380 lbs/hr)	626 Kg/hr (1380 lbs/hr)

The cooling loads consist primarily of internal heat generated by the process steam, machinery, people, and building lighting and are relatively constant during plant operating hours. The plant's heating, ventilating, and air conditioning (HVAC) system incorporates an economizer cycle that supplies a portion of the cooling load during the winter months. The cooling loads are met by a chilled water system supplied by an absorption chiller.

The total number of heating degree days for Atlanta is 3,095, and the total number of cooling degree days is 1,595 (using 65°F as a base). The heating season generally extends from October to April, with occasional heating required in May and September. The cooling season extends from May through September with occasional cooling required during March, April and October. This balanced situation allows research data gathered at Shenandoah to be generalized for much of the United States.

Collector Field: Portions of the collector field are surfaced with blacktop for vehicular access. The main collector supply and return lines are constructed of ASTM-A106 Schedule 40 welded pipe and run in an east-west direction. The branch lines to the individual collectors, constructed of ASTM A-192 seamless steel tubing (welded), run in a north-south direction.

The Mechanical Building is in the southwest corner of the Site. The building contains the control room, motor control center, absorption air conditioning unit, and turbine alternator. Located north of the building is the heat transfer fluid storage and conditioning equipment, including the large thermal energy storage tank, the fossil-fuel-fired heater for the fluid, the steam generator (unfired boiler), and the collector field circulating and boiler pumps. The hardware is on a concrete pad with provisions for containing spills, and the drain system contains a separator for reclaiming the fluid. Also contained in this area is the unfired boiler's ancillary equipment. All the equipment is insulated and sealed for outdoor application.

High Temperature Storage: The primary component of the High Temperature Storage (HTS) system is the thermal energy storage tank. This subsystem also incorporates a liquid nitrogen storage system to maintain a blanket of inert gas at a minimum pressure of 9 psig over the heat transfer fluid. Maximum pressure in the tank is controlled by an automatic venting system that directs the released vapors to a condensing tank to remove any volatiles generated by the normal (minimal) cracking of the heat transfer fluid at high temperatures.

The thermal storage tank is a vertical, cylindrical, ASME pressure-rated steel tank, 10 feet in diameter with a capacity of 11,800 gallons. Each of two domed heads has a capacity of 680 gallons (90.9 cu. ft.). The tank is insulated with glass fiber board (K – 0.42 Btu-in/hr-ft^2 – °F at 400°F avg. temp.) built up to a thickness of 18 inches and weatherproofed with a heavy gauge aluminum jacket. Fluid is introduced into or extracted from the tank through upper and lower distributors to minimize turbulence.

The tank serves two primary purposes. When fully charged to its maximum design operating temperature of 750°F, it can provide approximately one hour of system operation (depending on loads). It also functions as a buffer against momentary loss of energy output from the collector field, as occurs on partly cloudy days, to maintain constant output from the Power Conversion Subsystem. On sunny days, the tank is used to extend operating time as solar insolation diminishes in the late afternoon. A secondary function is that of an expansion tank to accommodate the thermal expansion of the silicone heat transfer fluid. For this reason, the tank is never completely filled; there is always a vapor space above the fluid.

Knitwear Manufacturing Application

The Bleyle Knitwear Manufacturing application for the STES at the Shenandoah Site offers a high degree of rapid and widespread commercialization, it requires energy beyond the sunlight hours, and it provides a usage for any desired degree of thermal storage incorporated into the STES. In addition to its use of electrical energy and cooling requirements, the plant requires approximately 1000 lb/hr of low temperature process steam for pressing clothes.

Meteorology Station

In the design of advanced-concept solar energy systems such as the Solar Total Energy System in Shenandoah, it is important that a comprehensive and accurate solar data base be available. This is important since many of the design decisions are based on estimates of system performance in specific modes of operation under representative "normal" and "extreme" conditions. In addition, concentrating solar

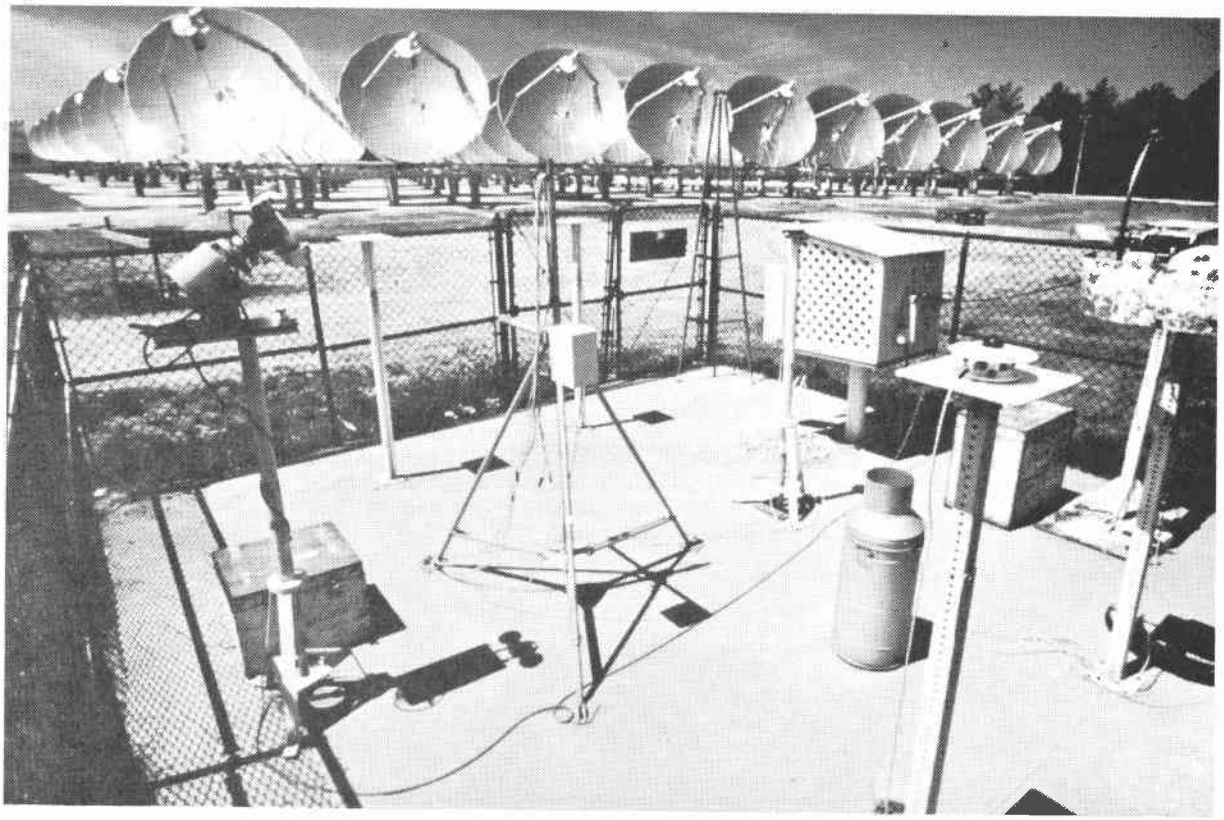


Figure 2-8. STEP Meteorology Station

collectors such as those in the Shenandoah Total Energy System can effectively collect only the direct component of solar radiation, which to date has been measured at only a few research sites across the United States.

The original weather station, installed at ground level, consisted of eight solar radiation and surface weather instruments, appropriate mounting or support structures, and a compact, portable, cassette tape data logger. Figure 2-8 shows the meteorology station as it exists today. The following table lists the original instruments and the variables they measure:

Instrument	Variable
1. Pyranometer (horizontal)	Global radiation
2. Pyrheliometer	Direct normal radiation
3. Pyrheliometer	Direct normal radiation
4. Resistance thermometer	Dry bulb temperature
5. Humidity cell	Relative humidity
6. Cup anemometer	Wind speed
7. Wind vane	Wind direction
8. Pressure transducer	Barometric pressure

Each variable is measured at one minute intervals, 24 hours per day, and the results are stored on small digital magnetic tape cassettes.

The station was originally installed on a fenced concrete pad located at ground level at the center of the southwest quadrant of the Total Energy System collector field (it has since been moved to the southeast corner).

The logger operates from a common power source but is capable of operation from batteries for up to 45 minutes. At a recording interval of one minute, the logger can record data from the eight instruments for a little more than ten days before a cassette is filled.

The following table describes new equipment added to the Meteorology Station as part of the Southeastern Regional Solar Meteorological Research and Training Project at Georgia Tech, and under subcontract to GPC.

Instrument	Variable
1. Pyranometer (unshaded)	Global radiation
2. Pyranometer (shaded)	Diffuse radiation
3. Pyranometer (tilted 34°)	Global radiation on latitude plane
4. Pyranometer (CSIRO)	Net radiation
5. Rain gauge	Rainfall
6. UV pyranometer	Ultra-violet radiation
7. Nephelometer	Turbidity

Section 3
DETAILED PROGRESS REPORT

This section contains a detailed, chronological record of activities at the Shenandoah Solar Total Energy Project over the subject reporting period (July 1, 1983 through June 30, 1984). This information is provided under the terms of Cooperative Agreement No. DE-AB04-77ET20216 in fulfillment of requirements for reporting and information dissemination.

Progress is reported in each of the primary task areas (where appropriate) under the terms of the Agreement:

- Acceptance Testing
- Test Operations
- System Performance Analysis
- Maintenance
- Personnel and Training Services
- Information Dissemination/Technology Transfer

Following is a summary of STEP energy production, energy usage in the Bleyle Knitwear Plant, and insolation data for the entire reporting period. This information is provided as a frame of reference for the summary of activities that makes up the remainder of Section 3.

STEP ENERGY PRODUCTION

Month	KW/hr Generated	Ton Hrs Produced	Process Steam (lb) Produced	Btu x 10^6 Nat. Gas For Fossil Fired Heater
July	20744	8111	76955	1202
August	610	727	11411	92
September	906	905	13773	144
October	5516	1828	27726	459
November	524	186	2697	80
December	377	0	6757	150
1983 Total	216435	40702	648234	11748
1984				
January	3142	0	12388	158
February	1378	0	11417	260
March	7501	604	26590	504
April	4279	185	15380	438
May	11615	849	17713	846
June	11399	482	3543	557

BLEYLE KNITWEAR PLANT

Month	kWh (Total)	kWh (HVAC)	Btu x 10^6 Nat. Gas for Process Heat
July 1983	65040	30977	82
August	54320	36198	107
September	51840	31783	179
October	43360	12842	157
November	39280	10730	190
December	34080	5621	180
January 1984	34960	5550	212
February	36480	10427	113
March	44320	15366	156
April	46000	19521	146
May	54216	25145	188
June	61448	34104	173

STEP YEAR-TO-DATE MONTHLY DIRECT INSOLATION

	Empirical	Solar Model Year
	Avg (Btu/ft^2/day)	Avg (Btu/ft^2/day)
July 1983	1046	1602
August	700	1543
September	544	1471
October	1314	1587
November	880	1511
December	324	1163
January 1984	461	926
February	648	1328
March	1147	1444
April	814	1602
May	1438	1675
June	1556	1547

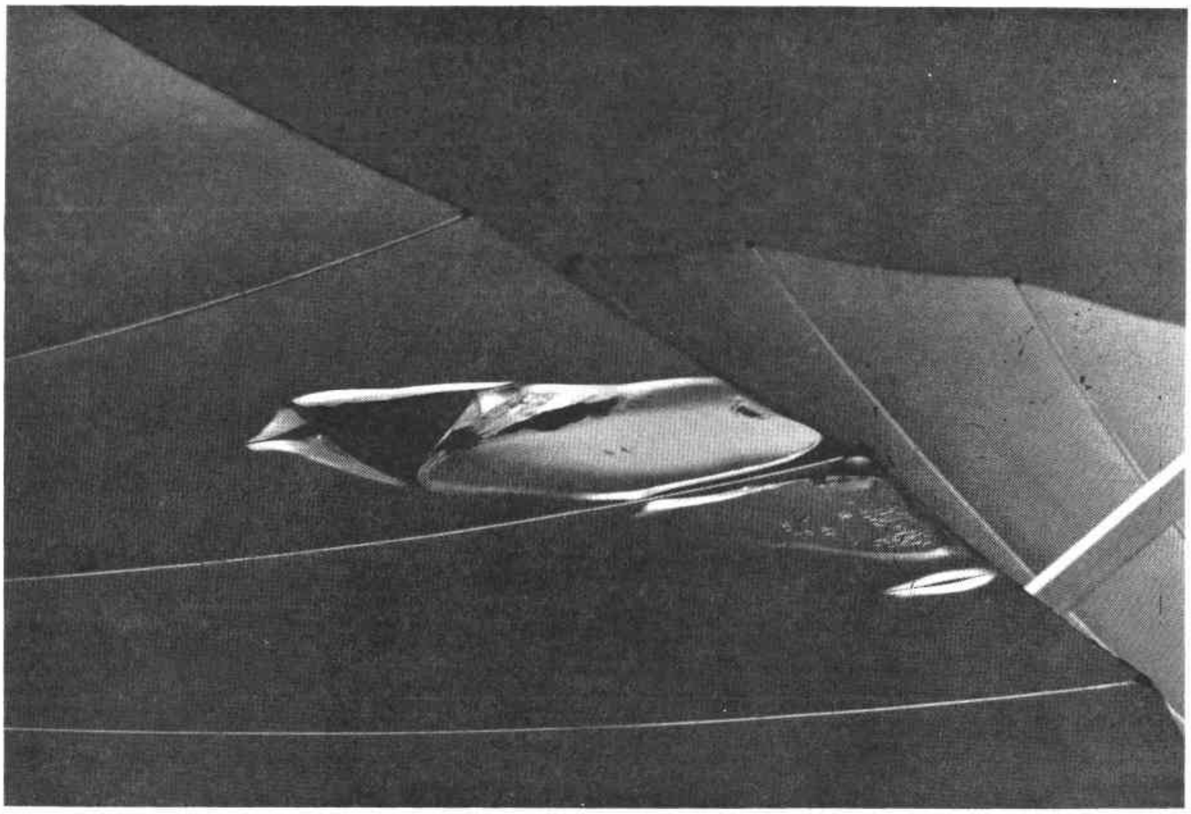


Figure 3-1. Collector Film Degradation

ACTIVITIES FOR JULY, 1983

On several occasions during the month, the STEP system was operated on solar energy only, including Mode A (co-generation) and Mode C (thermal energy only). On July 29, the STEP system was started on solar energy only.

Dr. J. Cummings of the Electric Power Research Institute (EPRI) visited the site with representatives of two other companies under contract to EPRI to assist in test planning at STEP. Recommendations made by Sandia and Georgia Power were reviewed and preliminary work was begun as test specifications and procedures were being developed.

A weekly operations meeting was initiated to keep the STEP staff updated and to plan activities for the subsequent week. Among the operations conducted during the month, Heat Transfer Fluid (HTF) was treated in the Conditioning Tank, then transferred to thermal storage. The transfer brought the Thermal Storage Tank to 95 percent of capacity.

An extensive effort was made to resolve flow control anomalies on the entire collector field. Problems had developed in control from 0 to 25 percent open, requiring adjustments on several of the 18 valves inspected.

The STEP system was down for three days in July when the heating element in the air dryer failed, and major solar collector film repair began. The damage, shown in Figure 3-1, resulted from tunneling film degradation.

A representative of 3M spent a day inspecting each collector. Other operations activities for July included the following:

- Updated As-Built drawings were provided by Lockwood Greene.
- Plant startup was delayed on July 5 for four hours until a ruptured safety plug on a bulk storage nitrogen tank was repaired.
- The phyroheliometer, which had moisture problems, was removed, dried, and reinstalled.
- A steam leak at the high pressure turbine inlet was repaired.
- The declination motor on collector #604 failed and was replaced.
- The HVAC chiller shut down for 14 minutes on July 11

because a plugged air line increased the condenser water temperature.

- Auburn University representatives participated in startup of the STEP system to achieve better insight into software work.
- A steam condenser override controller was repaired.
- A spare solar collector was shipped to Sandia-Albuquerque upon request by Sandia National Laboratories.
- The deaerator high pressure alarm was repaired.
- The HVAC cooling tower was cleaned.

Information Dissemination

The STEP site continued to attract interest among people from a wide range of technologies and backgrounds. The Georgia Electric Industry Committee, a trade group of various electric industry participants, was given a comprehensive STEP presentation and tour, and a status report was presented to the Newnan Optomist Club.

Paul Spaduzzi, of Georgia Power Retail Marketing Applications, spoke at the monthly Staff meeting about integrated Communications System development, and a representative of Varitek, Inc. visited the Site and discussed the use of its butterfly valves in the STEP. Other activities included the following:

- Georgia Power Tifton District management was provided a tour.
- *Solar Age* magazine was sent photographs of the Shenandoah cogeneration plant upon request.
- The August issue of *Car and Driver* magazine featured pictures of a sports car taken on the STEP site.
- The *Atlanta Constitution-Journal* took pictures at the Site for a feature article.
- A *National Geographic* photographer spent a day taking pictures of the solar collector field for an article on mirrored surfaces.
- A four-hour presentation on solar technology was given to 24 Georgia high school industrial art teachers at a workshop at Georgia Southern College.
- Approximately 50 walk-on visitors were provided material and tours, as appropriate.

ACTIVITIES FOR AUGUST, 1983

During August, the Fossil Fired Heater (FFH) was inoperative for an extended period, and very little energy was produced because of scheduled maintenance during the seven days when the Bleyle Plant was closed for vacation, and because of a large amount of needed maintenance in the collector field and balance of plant.

Heavy maintenance continued in the Collector Field Subsystem. After considerable delay, a supply of fiber optic cables arrived on August 16, and a concerted effort was made to eliminate problems on 22 solar collectors. By month's end, this work was completed. However, the 250 RTDs ordered were overdue, and 30 RTDs in the collector field were inoperative as of August 31. Both RTDs of collector #602 were inoperative, and four other collectors had long-fiber-optic problems that were being addressed.

Visual trap-type moisture indicators were being installed ahead of field valve air regulators because of a moisture problem, and five of nine valve controllers damaged by water were replaced. The extensive calibration and repair required for instrumentation was nearly completed by the end of the month.

The fossil fired heater was shut down on August 16 when insulation and a seal failed. A new burner was installed and the unit was checked by the Eclipse Company (under warranty). The failure put the unit out of service for 14 days until Eclipse personnel returned, evaluated the unit for damage, and replaced the failed insulation. No guarantee or assurance was given by Eclipse that the repair would last, but the Company recommended a one-hour, low-fire startup of the heater, and no low-fire on shutdown. It also recommended that the STEP staff circulate heat transfer fluid for one hour through the heater after turning it off.

Significant time was spent preparing computer programs. A program was being developed to take information from the 11/44 and transfer it to the Tektronics floppy disk drives for data reduction and plotting. Data required for the planned tests were to be identified in a Test Specification and were to be operative for the test. Other activities included the following:

- During a meeting between DOE and Sandia, DOE recommended a series of primary and secondary tests at the STEP.
- The Site bucket truck struck collector #902, causing severe damage. Three petals and a new receiver were installed, and recommendations were made to minimize chances of recurrence.
- A.T.S. supported instrumentation calibration and repair as needed to perform various STEP tests.
- The orifice plate on the main steam line was removed to replace gaskets on each side.
- The Thermal Storage Tank pressure safety valve was checked for blockage, but it was clean.
- The pyroheliometer failed and was repaired.
- A low oil switch was installed on the new air compressor.
- A stuck air dryer shuttle valve was cleaned, and all motors and pumps were lubricated.
- The colorgraphic printer was repaired and returned.
- The pyroheliometer wires, broken again, were repaired and retrofitted to correct operational problems.
- Sandia locally priced a fossil-fired heater oil catch tank.

Information Dissemination

The Georgia Power Electrical Engineering Committee, which met at the STEP site for its quarterly meeting, was given a tour, and a presentation was provided to the Valdosta Kiwanis Club. Georgia Power Executive Vice-President H.G. Baker and Vice-President John Roberts also visited Shenandoah for an update.

Avondate Mills representatives visited the Site to discuss possible uses of solar energy at its Alabama textile mill and to tour the STEP cogeneration facilities. Other activities for the month included the following:

- An article on STEP construction was featured in the August 1983 issue of *Highway and Heavy Construction*.
- Georgia Power Statesboro district and local managers were provided a briefing and tour.
- DOE and Sandia personnel came to Shenandoah for an update and discussions of STEP activities.
- Approximately 40 walk-on visitors were provided materials and tours, as appropriate.

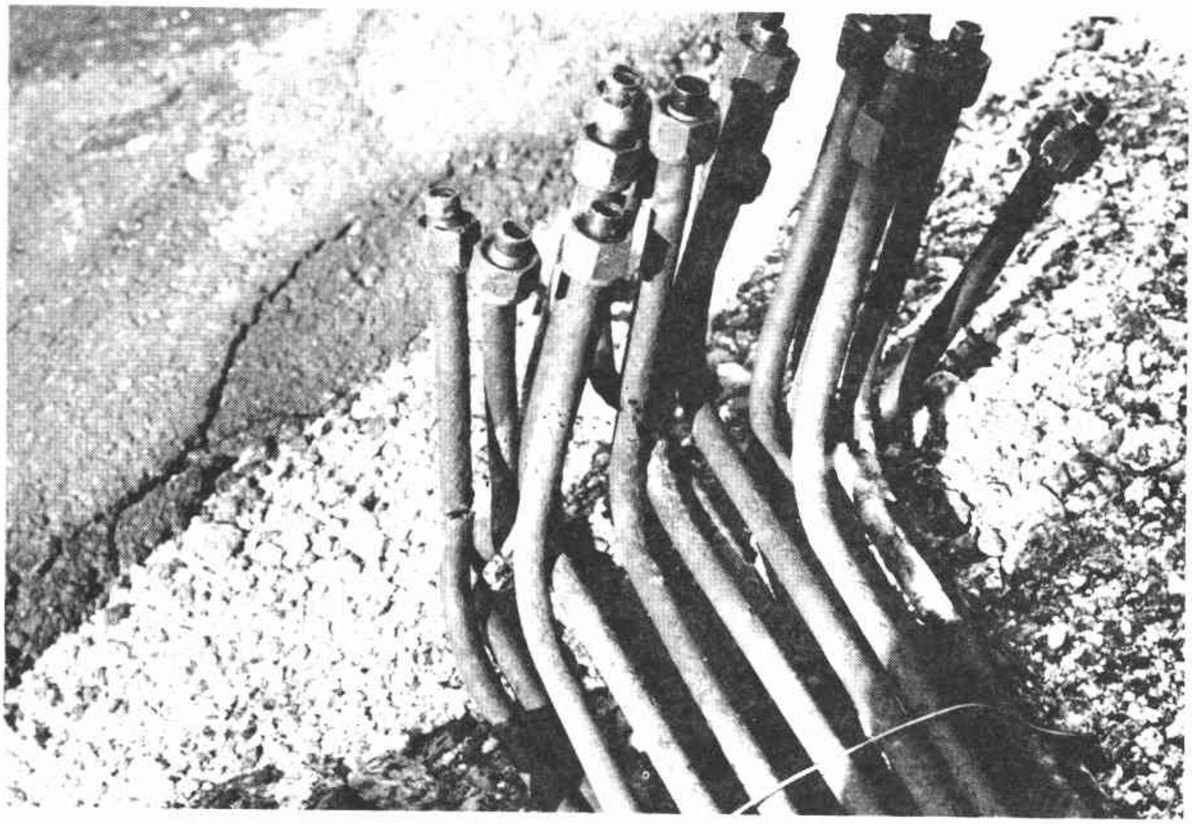


Figure 3-2. Corroded Piping Removed from Solar Collectors

ACTIVITIES FOR SEPTEMBER, 1983

Significant problems occurred in the collector field control valve air system. The controllers on five of the nine valves (damaged by water) had to be replaced, and the remaining water was removed by adding water traps and by thoroughly blowing out the system. At month's end, 11 controllers had been replaced or repaired.

Also during September, a serious corrosion problem developed within collector field piping, as shown in Figure 3-2. It was initially noticed when an oil spot was observed under one of the collectors. Subsequent inspections revealed water leaks into the insulation of the eight-foot sections of pipe behind the collector dishes.

The STEP staff worked closely with Sandia to analyze this corrosion problem. Samples of piping, caulking, rigid insulation, and fiberglass insulation were sent to Sandia for analysis, and the problem was documented with photographs of uncorroded and severely corroded piping. Each collector had at least two feet of seriously corroded piping above the first (lower) flex joint.

During routine operation of the STEP, it was determined that the normal position of the boiler feed pump pressure control bypass valve should be changed from closed to opened to avoid cycling the mechanical safety relief valve. Each time the boiler feed pump was started, the relief valve was forced open to accommodate flow from the positive displacement boiler feed pump for several seconds until the bypass valve had sufficient time to respond. The frequent cycling of the relief valve had caused two previous failures of the valve bellows.

To avoid additional valve failure, a modification was recommended to cause the bypass valve to open when the boiler feed pump is off, and to add a check valve in the boiler feed pump discharge line to prevent backflow from the steam generator to the deaerator. The modification was sent to Sandia for consideration.

At the end of September, several anomalies remained to be resolved in the solar collector field: 10 RTD problems and 26 collectors with fiber optic problems (21 short receiver optics, and four 54-foot long optic cables). Use of fiber optic gel was discontinued, since it caused discoloration and a loss of light through the optic coupling. A procedure was ordered for cleaning and repairing the fiber optics.

A great deal of effort was spent eliminating the problem of water within the collector field air system. Installation of water traps in the system was nearly complete, and there was no recurrence of water since the system was flushed out.

The Control and Instrumentation Subsystem (CAIS) had one failure: the Energy Utilization Processor (EUP) would randomly report erroneous data to the DEC 11/44 computer, which made control of the system impossible.

General Electric provided manpower to fix the EUP; however, shortly after the GE representative arrived, the EUP started functioning properly. Since there were no subsequent failures, the original problem remained unresolved.

Initial efficiency measurements taken in September for the fossil fired heater yielded an average efficiency (at high fire and 700-750°F fluid temperature) of 66 percent (based on carbon dioxide readings). September 22 was a good day because the solar insolation exceeded 1000 watts per square meter and the system was operated in the solar cogeneration mode. It was also a bad day because the Energy Utilization Processor failed, shutting down the system for seven days. Following is a summary of other operations for September:

- A Digital Equipment Corporation (DEC) representative was on site to repair the DEC 11/44, which was down because of a blown hardware chip.
- Repair of Collector #902, damaged by the bucket truck, was completed.
- A pipe at the air compressor failed and was repaired, which delayed startup for four hours; a new steam generator pressure gauge was installed; a hand valve was added to shut off air flow to the collector field; and Pyrotronics Company modified and activated the halon fire control system in the STEP control room.
- After considerable delay, 80 RTDs were received and a concentrated effort by the STEP staff was immediately undertaken to install them.
- Again after considerable delay, 150 short- and 150 long-fiber optic cables were received.
- Kaye Instruments repaired the Ramp Scanner (a faulty capacitor in one of the power supplies was the problem).
- A procedure for tests to be performed on the thermal storage tank was drafted and sent to Sandia and Georgia Power for review.
- The turbine-generator protective relay opened all the 480V bus breakers at the STEP site due to panel wiring problems, causing a 17-minute electrical outage at the Bleyle Plant and the STEP site.

Information Dissemination

Representatives of the Clemson University Mechanical Engineering Department were on site to discuss planned activities at the Shenandoah Solar Center, and the Georgia Power Safety Department presented a substation safety seminar for the STEP staff. Included was a discussion and tour of the STEP substation to ensure safe operation of electrical facilities.

A total of 60 GPC customer service representatives from the Macon Division visited the Site for discussions and tours. Other visiting organizations included the following:

- Sandia and DFVLR from Almeria, Spain.
- Monsanto, to discuss use of the heat transfer fluid in the STEP system.
- Global Energy, to discuss third-party financing of solar systems.
- Auburn University, to discuss potential research projects at Shenandoah (mutual interests and capabilities were reviewed).
- Bleyle's corporate headquarters in West Germany.

In other activities, plans were made for the October visit of Dr. Howard Coleman from the U.S. Department of Energy; information was sent upon request to a Columbus, Georgia high school senior who was preparing for a debate on the merits of solar energy; information was provided upon request to a Melbourne, Florida commercial page director who was planning a solar system for her facility; and comprehensive STEP information was mailed to a University of Colorado physics professor for classroom use.

During September, approximately 50 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR OCTOBER, 1983

The corrosion problem in the collector field, affecting 1500 feet of piping, was addressed by Sandia and GPC. A thorough analysis was made of the piping and insulation that needed attention. Sandia visited the Site to inspect the collector field and make recommendations for resolution of the issue.

A plan was tentatively set for Sandia and Georgia Power to work together in retrofitting collector piping. New stainless steel piping would replace corroded sections, then new insulation and jacketing would be installed. In support of these activities, infrared photographs were taken of some of the affected piping for analysis.

Fiber optic cables continued to fail at an unacceptable rate, and new fiberglass sleeving was installed around these cables to slow the rate. At the end of the month, 35 collectors still were inoperative because of optic problems.

Formal testing of the thermal storage tank was performed during October. The test involved monitoring cooldown rate (thermal losses) overnight, and operating the turbine-generator in the cogeneration mode with steam being produced by stored energy in the tank. The amount of time that the system could be operated using energy from the tank was measured at electric generation levels of 250 and 300 kWe: the time at 250 kWe was 45 minutes, and the time at 300 kWe was 40 minutes.

Several problems were isolated in the Control and Instrumentation Subsystem. It was determined that to make the computer function properly, new system level software was required. The Digital Equipment Corporation (DEC) was contracted to aid in the installation of the new software kit. It was projected that the new kit would be installed by the end of the second week in November.

The Test Operations Phase (TOP) Plan was completed during October, and Auburn University continued to work closely with the STEP staff on a reliability study. An Electrical Engineering Department professor, a graduate student, and an undergraduate student were on site during the month (the Auburn graduate student had developed a computer program so that data from the STEP out-of-service reports could be entered into the computer to automatically update component reliability data). One of the follow-on efforts would be to calculate the probability that the system would operate in any of the operational modes, given that solar insolation was adequate.

October 6 was a good solar day. The STEP system was operated in the hybrid (solar plus fossil boost) cogeneration mode. The collectors came into focus position at 8:38 a.m., and the hybrid condition was achieved at 10:22 a.m. Following is a summary of additional activities during the month:

- The Fossil Fired Heater temperature controller was found defective and was replaced.
- On October 3, startup was delayed for two hours because of computer problems. Later, the Control and Instrumentation Subsystem crashed twice, curtailing operations.
- The data logger from Georgia Tech was reinstalled in the weather station.
- The valve control program was installed, and it controlled the first four rows.
- The GPC Safety Department inspected the facilities, and no significant problems were found.
- A flow test was run with all the turbine flow meters in series; all were operating properly.
- The level of oil in the high temperature fluid tank was discovered to be too low; 600 gallons of Syltherm were conditioned and added.
- Conditioning of the heat transfer fluid to a temperature of 750°F was completed.
- Collector rows 8 through 12 were autotracked.
- Reflectometer readings were taken on the eight test collectors, yielding efficiencies of 79 to 81 percent; wiring was installed from the Motor Control Center to the boiler feedwater pumps for installation of an air bleed valve; and fiber optics on seven collectors were damaged when communication was lost to branch 11 in the collector field.

Information Dissemination

Among the most notable visitors to the STEP site was DOE representative Dr. Howard Coleman, who was given a comprehensive briefing and tour and watched a plant startup.

Thirty-four visitors toured the Shenandoah facilities as part of the United States Agency for International Development's alternate energy training program. Most of the participants were from third world developing countries.

Union Electria (Enrique Medina) and a Madrid university professor (Antonio Gomet) visited Shenandoah for information that might be applicable in Spain. In an unrelated event, a technical paper, 'Development of the Solar Total Energy Project at Shenandoah, Georgia, 'was presented at Solar '83 International Solar Energy Symposium in Palma de Mallorca, Spain. Other activities during October included the following:

- A presentation was given to the ASHRAE Southwest Georgia Chapter in Albany.
- Dr. Bill Harrison, Southern Company Services senior vice-president, visited Shenandoah to review solar R&D activities.
- Three Georgia Power corporate office building operational personnel toured the STEP facilities.
- A presentation was provided to the Auburn University student chapter of IEEE.
- A representative of Southern Electric International visited the Site for a discussion and tour.
- Scientific Atlanta reviewed the solar activities with special interest in collector design.

During October, approximately 29 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR NOVEMBER, 1983

Following a thorough analysis of the pipe corrosion in the collector field, a solution was initiated. It was determined that the seven-foot sections of insulated nested tubing between the small and large flex hoses had to be replaced. Sandia National Laboratory issued purchase orders for the stainless steel pipe and for insulation and weather proofing, and Georgia Power was to remove the old insulation and piping, install new piping, and pressure test the piping before it was insulated and water proofed.

During November, extensive work was performed on the Digital Equipment Corporation (DEC) PDP 11/44 computer. Georgia Power, DEC, and private consultants were involved in the effort to make the data acquisition system operational, but problems with hardware and software hampered trouble-shooting efforts. By the end of the month, all the hardware anomalies had been corrected and the software anomalies identified.

Several steps were taken during trouble-shooting. First, the current revision of the DEC operating system (RSX-11M V4.1) was installed to correct some of the software problems. During this installation, hardware problems with the central processing unit of the computer were discovered, requiring replacement of the processor. Software anomalies in the application code were detected and corrected.

Although the data acquisition system was not fully operational by the end of November, major progress had been made and the system was partially operational. The remaining problem was analyzed by DEC, and it was determined to be in the operational software. (Similar problems have been documented by DEC at three other sites employing the same software and computer equipment.)

Efforts continued to eliminate the fiber optic problems. At month's end, the total number of inoperative collectors had been reduced from 35 (in October) to eight. All eight had long-fiber-optic problems; no short-optic problems remained.

The boiler feed pump blew a gasket while the plant was operating, and the STEP staff had to defocus the field until the boiler feed pump was repaired. The positions of all declination defocus direction switches on the collectors were changed to allow the collectors to defocus to the north as a function of sun angle. Other activities included the following:

- A representative of DEC began work to resolve several Control and Instrumentation Subsystem (CAIS) issues, including the installation of the new RSX version.
- The final of three HTS tests was run using the turbine with a load of 200 kW and 250 kW.
- STEP lost communication to the field and the staff had to jumper collector #1103 to box the collectors.
- A Test Operations Phase (TOP) plan was sent to DOE and Sandia to satisfy a contract milestone.
- The auxiliary cooling system was flushed with chemicals to clean away dirt and rust in the piping system, and anti-freeze was added.
- Two CCUs were repaired on collectors #1003 and #1005, and two processor boards were replaced on the DEC PDP 11/44.
- Good results were found using the new high speed disc sander to repair the long-fiber optics.
- Reflectometer readings taken on the test collector sampling yielded efficiencies of 79 to 81 percent, the same range as for October.

Information Dissemination

The dedication for PV-2, Georgia Power's photovoltaic sign, was a noteworthy event as shown in Figure 3-3. The solar powered lighting system was reviewed by Georgia State Legislator Neal Shephard, Georgia Society of Professional Engineers President Gene Ratliffe, SEIA/G President Bill Schwendler, and Solarex President John Corsi.

Forty visitors from the Auburn University School of Business toured the Shenandoah facilities and were given a presentation, and tours and presentations also were given to nine representatives of the Corp of Engineers.

Twenty girl scouts from Riverdale were provided a presentation and tour of the Shenandoah facilities to obtain their Energy Saver badges, and Solar Energy Industries Association of Georgia (SEIA/G) held its monthly meeting at the Site. Other activities included the following:

- Forty-five fourth graders from Galloway elementary school in Atlanta were given a presentation and tour.
- During November 4 through 8, the STEP exhibit shown in Figure 3-4 was featured at the Lenox Square shopping mall in Atlanta as part of the German-American Week activities.
- Solar project displays (featuring STEP) and manpower were provided for the 6th World Energy Engineering Congress (WEEC) where a paper was presented, and for the International Pig Trade Show. Both were in Atlanta.

During the month, approximately 30 walk-on visitors were provided materials and tours, as appropriate.

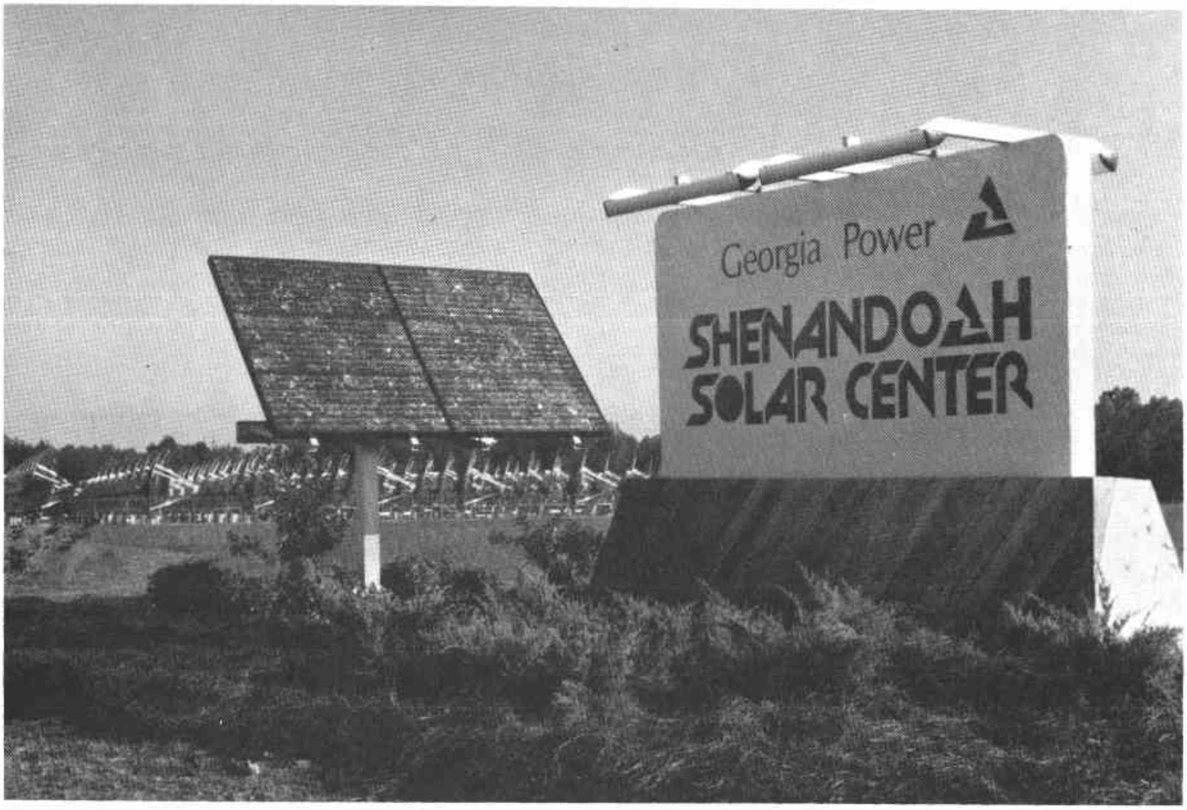


Figure 3-3. Dedication of PV-2, Georgia Power's Photovoltaic Sign

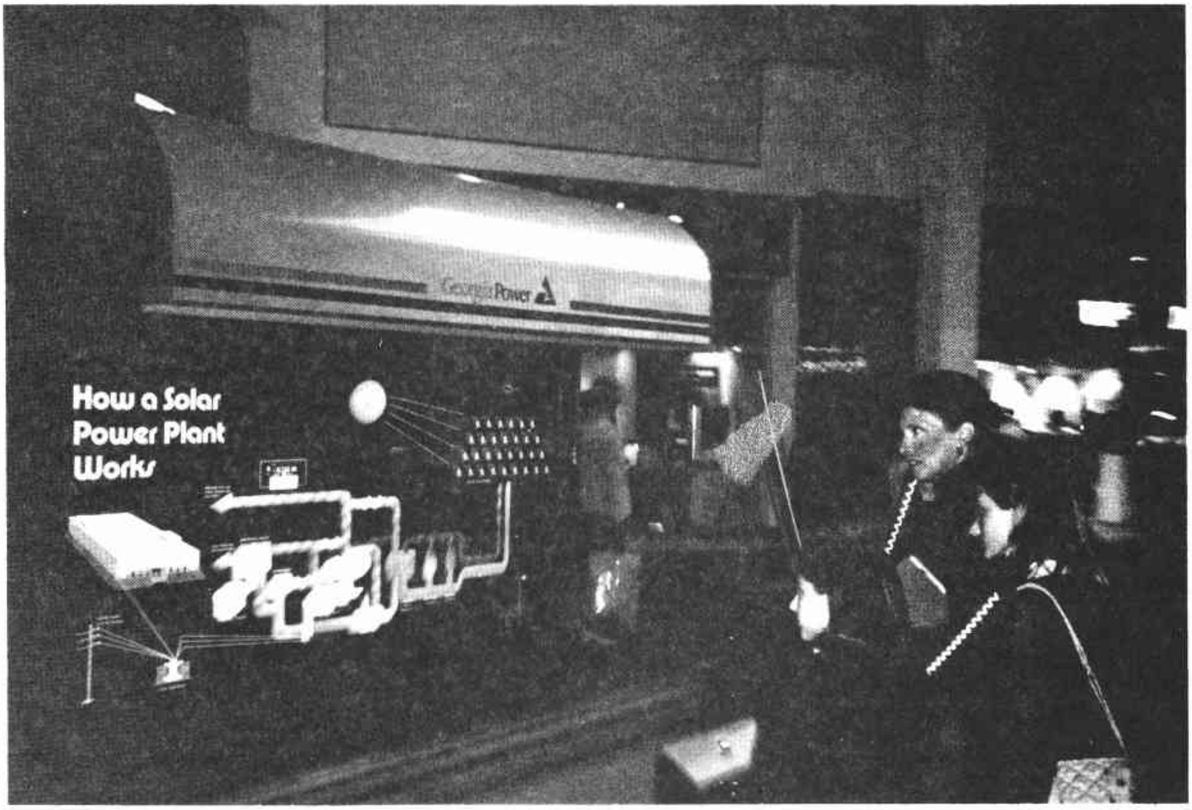


Figure 3-4. Part of STEP Exhibit at Lenox Square Shopping Mall

ACTIVITIES FOR DECEMBER, 1983

The highlight of the month was the STEP Annual Site Operational Review by the Department of Energy. During this meeting, a detailed report was presented on what had transpired since the last Operational Review Meeting and on current status. It was determined that the top priority for the coming months should be to perform, at a minimum, the 29 tests developed by the STEP staff and Sandia as part of the Test Operations Phase (TOP) Plan.

At the Review Meeting, it was determined that Georgia Power should provide a proposal to DOE to be used in extending the Cooperative Agreement; the Form 60 proposal was later submitted. Also discussed was one of the greatest anomalies encountered since the startup of STEP: the operation of the Control and Instrumentation Subsystem. Many developments had been made in CAIS during the preceding year, and the December status was as follows:

- Implementation of an upgraded software version, the RSX-11M VERSION 4.1, was complete.
- The collector timer defocus activation control had been installed.
- An improved data archiving program had been implemented in the Data Acquisition Subsystem.
- The software license was transferred from Sandia to Georgia Power.
- Collector field temperature control software had been revised.
- The magnetic tape data collection and archiving anomalies had been temporarily solved.

Although STEP personnel were ready to aggressively conduct formal tests, two areas remained to be addressed and resolved. The first was the remaining computer anomalies, and the second was the scheduled retrofit of corroded piping in the collector field. As of the end of December, it had been planned that the piping would be replaced during a two-week period in January.

During December, approximately 50 gallons of Heat Transfer Fluid were spilled on the patio area because of improper shutdown of the balance of plant. At the time of shutdown, the collector field pump was left on and the Steam Generator Pump and the Fossil Fired Heater Pump were inadvertently turned off instead. While these two pumps were being turned off, the outlet valve of the Steam Generator was closed, which did not leave an open path for the flow of the Heat Transfer Fluid, causing a relief valve to open and allowing the Heat Transfer Fluid to spill. As soon as the spill was noticed, all pumps were turned off. Changes were then initiated to preclude recurrence of this error.

The STEP experienced another problem due to the extremely low temperatures. The feedwater line to the steam generator froze because of low temperatures, and the existing heat tracing system failed since it could not withstand the 400°F operating temperature of the boiler feedwater line (the heat tracing system was melted). A supplier of high temperature heat tracing systems was contacted.

During December, a major effort was made to repair damaged collector film. A survey of the affected collectors showed that 736 square feet of film had to be replaced. Of the total, 350 square feet were replaced during December, leaving an additional 386 square feet to be repaired later.

Digital Equipment Corporation (DEC) continued to work on the PDP 11/44. DEC field service personnel ran complete diagnostics to locate and resolve the source of intermittent system crashes. They also performed a detailed analysis of the system crash outputs, which revealed that the DEC firmware that controls the magnetic tape was causing a problem. All appropriate documentation detailing this malfunction was forwarded to Digital's Central Engineering group in Maynard, Massachusetts. Meanwhile, a suitable work-around was implemented until the software could be corrected.

An in-depth analysis of the STEP Supervisory Control Program (TICTOC) revealed a program coding error that was causing both local and system wide data to be corrupted. The error was corrected, but problems still existed. New software was developed to help eliminate problems with the graphic system interfacing with the minicomputer (PDP 11/44).

In other operations, data were collected from the weather station for total direct normal insolation in Btu per square feet. These data were 35 percent less than the solar model year developed by Georgia Tech—part of the worldwide phenomenon of reduced insolation.

An annual inspection and calibration was made to the two STEP respirators by the Georgia Power Central Respirator Repair at Forest Park, and a Syltherm leak was detected on collector #909 in the section of pipe between the flex hoses. Heat transfer flow was terminated to the collector. Other activities in December included the following:

- The four 55 ft optic cables were repaired on collectors #809 and #409.
- The Bleyle Plant switched to space heating with its hot water boiler for the winter, which meant that the STEP would not be providing air conditioning until the plant again required it.
- A sample of Syltherm 800 Heat Transfer Fluid was sent to Dow Corning for analysis.

- Four college students began work at the site during their holiday break with an emphasis on repairing collector film.
- The chemical feed pumps were wired so that they would not turn on until the system was operational.
- The Bleyle Plant lost steam due to a boiler failure; STEP steam was provided so that plant operation could continue.
- The gasket on the steam generator site glass ruptured due to freezing the previous night, which resulted in an immediate shutdown of STEP plant operation.

Information Dissemination

In December, the Department of Energy (DOE) Annual STEP Review was held for representatives of DOE (Washington), DOE (Albuquerque), and Sandia (Albuquerque). The STEP Annual Technical Progress Report (July 1, 1982 through June 30, 1983) was distributed for discussion. Other activities during December included the following:

- Solarvolt International visited to discuss matters of mutual interest.
- Twenty people from the Southwest Georgia Chapter of ASHRAE were provided a presentation and tour.
- Industrial Risk Insurers visited.
- Pictures were taken at STEP for use in a Southern Company annual report.
- Carlo Baldelli of Agroenergia in Rome, Italy, was provided a tour, as were 30 people from the Auburn University School of Business.
- A STEP exhibit was provided for display at DOE headquarters in Washington. It was part of a set of solar displays used in the lobby of the Forrestal Building.
- Georgia Power Economic Services presented a solar energy economic review to a STEP staff meeting; Bleyle of America (Ingo Bleyle) and five associates toured STEP facilities; and information was provided to Coats & Clark in Toccoa, Georgia upon request.

During the report period, approximately 25 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR JANUARY, 1984

January was an extremely low solar insolation month, 50 percent lower than the solar model. But because of the low insolation levels, STEP personnel were able to accomplish several objectives inside the plant. The first was in regard to the Collector Field System where temporary workers removed insulation from the tubing, removed the corroded piping, and installed new stainless steel tubing, as shown in Figure 3-5. Care was taken to ensure proper installation and that the flex hoses were not torqued too tightly.

The new Collector Field tubing was pressure treated for two days—the first day at a pressure of 10 psi and a fluid temperature of 250°F, and the second day at 10 psi and 500°F. Three leaks at the swage lock fittings of collectors #109 and #405 were corrected immediately.

Joe North contractors were ready to begin insulating on January 23, but because of the weather they were unable to start until January 30. By the end of the month, they had reinsulated 78 collectors, but only 12 had aluminum jacketing.

The second area of accomplishment was in regard to the Instrumentation System. The biggest problem was with the two turbine flow meters in collector branch number six, where the temperature of the Syltherm 800 fluid was destroying the magnetic pick-ups of the meters. After several attempts to repair the flow meters, they were returned to the supplier for repair or replacement. A thorough analysis of all instrumentation was then conducted to prepare for formal testing. A new flow meter is shown in Figure 3-6.

The Digital Equipment Corporation (DEC) continued to trouble-shoot the intermittent system crashes. Personnel installed a disturbance analyzer on the Uninterruptable Power Supply (UPS) in the hope of isolating the problem of computer crashes to the UPS, and finished a standard computer program for communication between the PDP 11-44 and PDP 11-03. DEC also assisted in training STEP personnel in the development of software for its computers.

On one of the few good solar days, STEP generated 921 kWh and 3707 pounds of process steam, but during shutdown the steam bypass valve to the turbine was leaking. It was removed and the valve seat was resurfaced, which delayed operations for four days. During this period, the steam generator sight glass also was repaired, but in the process of thawing the frozen sight glass a gasket ruptured. For safety reasons, all parts of the sight glass were replaced;

Figure 3-5. Replacement of Corroded New Stainless Steel Tubing

Figure 3-6. Newly Installed Flow Meter on Syltherm 800 piping

four glasses, four pieces of mica, and four asbestos gaskets.

Late in the month, preparation began for the Testing Operations Phase in the following areas:

- Collector Field System: ensuring that all insulation was properly installed to limit heat loss in the field.
- Instrumentation System: ensuring that all instrumentation was calibrated and working properly.
- Balance of Plant: ensuring that the Fossil Fired Heater, Turbine Generator, Steam Generator were working properly.
- Computer Control: continuing with efforts to isolate the intermittent computer crashes.

Early in the month, the turbine generator had blown a gasket at the first stage of the extraction steam line, but it was replaced and the problem resolved. On the same day, a pin hole leak was repaired in a weld in the boiler feed water line between a flow control valve and the steam generator. Other operations during January included the following:

- New RSX Version 4.1 control software was proven operational over two days of full plant operation.
- The Balance of Plant was set up to start the nitrogen blowdown of Syltherm in the Collector Field.
- An independent contractor, Steve Woods, installed a drain valve in the boiler feed water line and made an RTD weld in the low pressure condensate line from the steam condensor fans.

Information Dissemination

Solar information was provided to Phillips Chemical Company in Pasadena, Texas, upon request; representatives of Jacksonville Electric Authority were given a presentation and tour; and Georgia Tech and Scientific Analysis personnel met at the site to discuss future activity at the Shenandoah Solar Center.

In other activities, Sandia was given information relative to STEP ramp scanners, Sunmaster visited to discuss potential solar activities, and 35 walk-on visitors were provided materials and tours, as appropriate.

During ASHRAE's convention in Atlanta, 78 people from around the world were provided presentations and tours of STEP facilities.

ACTIVITIES FOR FEBRUARY, 1984

During February, several maintenance and housekeeping items were resolved. The insulation of the replaced HTF piping was completed, and several wiring and instrumentation anomalies were eliminated. For instance, STEP had been experiencing problems with the emergency generator synchronizing with the uninterruptable power supply. The phase direction of the emergency generator was found to be in the direction of 1-2-3, while Georgia Power uses 3-2-1. The STEP system was changed for compatibility.

Since documentation was developing as quickly as the STEP itself, and since information dissemination has always been an important part of the Cooperative Agreement, a technical library was established at the Site to control specifications, drawings, operating and maintenance manuals, brochures, technical papers, operating procedures, and other important materials. A word processor was set up to catalog the contents of the library.

Following a comprehensive safety check and other critiques, several changes were made in STEP housekeeping. A new design for the control room was chosen and progress was made on its implementation. Color code guidelines from ANSI were followed as painting was done throughout the plant.

At the end of the report period, the final Test Operations Phase (TOP) Plan was provided by the Energy Technology Engineering Center (ETEC) for the Electric Power Research Institute (EPRI). ETEC had worked closely with Sandia and GPC in the development of the document. The TOP Plan was used by DOE and GPC in determining the contents of a Cooperative Agreement extension (see Appendix).

The heat tracing system for the boiler feed water line was received early in February to resolve the problem of freezing and delayed startup. On Feburary 8, STEP provided 1209 pounds of process steam to the Bleyle Plant while running a check on instrumentation.

The STEP plant was brought into operation slowly on two occasions to test the turbine synchronizer switch. When steady state condition was achieved, the turbine was brought on line; the generator synchronized with the GPC grid with no problems. The synchronizer scope was turned off without further difficulties. Other operations included the following:

- A storage trailer was ordered for storing parts and other materials.
- DEC software support personnel were on site to work on a program for archiving on tape.
- Lock washers were installed on the extraction steam line of the turbine generator as recommended by MTI. This action was taken to reduce the failure rates of the associated gasket.
- Eight square feet of collector surface film were replaced. A strip of film was placed on the seam of the film to stop the worming caused by water.
- More than 350 gallons of heat transfer fluid, stored in 55-gallon drums while the collector field was drained during retrofit, were pumped back into the conditioning tank.
- The emergency generator phase direction was checked using an amprobe phase sequencer and a five-horsepower, three-phase, induction motor. The phase direction was found to be backwards and was immediately corrected.
- To test the emergency auxiliary power transducer, personnel closed the 'H' breaker and opened the 'K' breaker. The test went smoothly and everything operated properly.

STEP was operated for six hours on February 28, generating 414 kWh and 4567 pounds of process steam. The STEP staff continued to monitor all instrumentation to ensure proper operation during the test periods.

Information Dissemination

Representatives of Edison Electric Institute, Potomic Electric Power Company, and Texas Power and Light were provided a presentation and tour of the STEP facilities. In addition, McDonnell Douglas visited to discuss development of its parabolic dish/Stirling engine, shown in Figure 3-7, and Exhibit Group Atlanta presented a preliminary design for potential exhibit space for the new Shenandoah Solar Center building. Seven Japanese visitors from the New Energy Development Organization in Tokyo also visited the STEP site for a solar briefing.

An update on STEP activities was provided for 400 people at the Annual Marketing Meeting of Georgia Power Company, and the Applied Research and Testing Council (ART) of Georgia Power held its monthly meeting at the STEP site, including a presentation and tour. Other activities included the following:

- Twenty seventh- and eighth-grade students from Smyrna Christian Academy toured STEP and were given a solar briefing.
- A STEP presentation was provided to the Royal Swedish Academy of Engineering Sciences and Swedtrade, Incorporated.

February, 1984

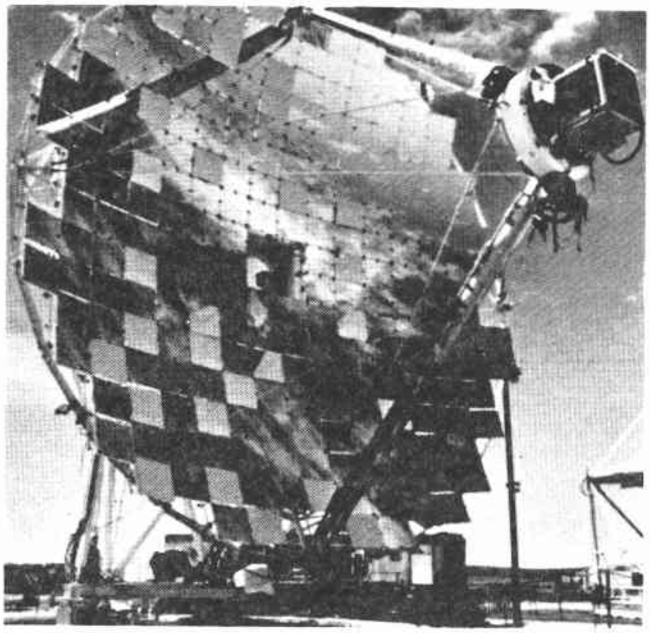


Figure 3-7. McDonnell Douglas Parabolic Dish/Stirling Engine

- A public broadcasting system station (WHA-TV) was at the site for an interview and filming of the STEP facilities.
- A solar presentation was given to the Alabama Society of Professional Engineers in a meeting at Auburn, Alabama.
- A Saudi Arabian visitor was provided a solar update at Shenandoah.
- A presentation was given at the Warm Springs-Manchester Rotary Club.

During February, approximately 40 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR MARCH, 1984

Significant events during March included several hours of operation of the plant in preparation for Test Operations Phase (TOP) activities; progress in preparing for the implementation of the test plan; a visit by Ed Addison, president of Georgia Power's parent company, Southern Company; correction of several anomalies related to the Electric Supply Subsystem; and publication of an Overview and Course Guide for the Solar Energy Training Program.

During this month, the STEP plant produced 6225 kWh of electricity, 604 ton-hours of air conditioning, and 26,590 pounds of process steam. On several occasions the collector field produced 70 to 80 percent of the total energy required, operating in a solar fossil fired heater cogeneration mode.

Planning increased for the implementation of the TOP Plan, and EPRI sent Dick Cummings (Cummings Engineering) to assist in these prepartions. A tentative sequence involved the following steps: following any specified test, a first level analysis would be made. This analysis, along with a disc of the collected test data, would be sent to Sandia. The easier test would be run first, with fossil fired heater input and constant output. The first test was to involve fossil fired heater input with 200 kWe only as the output, as described in the Test Plan as TOP-BF-12-2.

One of the highlights of the month was the visit of Ed Addison, president of Southern Company, shown in Figure 3-8. He was given a comprehensive briefing on the history of Shenandoah; current status of STEP activities and other solar activities within Georgia Power Company; and a broad range of plans for the future. He was enthusiastic about activities at the Shenandoah Solar Center and indicated that he would support them in the future.

During attempts to coordinate all systems as required by the TOP Plan, a large number of problems surfaced to inhibit operations, as well as symptoms of two unknown problems. The first symptom was that one phase current of the generator incorrectly lagged its corresponding voltage by approximately 10 degrees. The second symptom was that the power monitoring equipment indicated that the total power used at the Bleyle Plant and STEP exceeded by 40 percent the power delivered by the STEP generator and Georgia Power.

Many of the problems and anomalies found during March were addressed and corrected, or suitable temporary solutions were being used so that test operations would not be delayed further. Efforts continued to identify the cause of the symptoms to avoid potential problems with the measurements.

A meeting was held to analyze the procedures for carrying

Figure 3-8. Ed Addison, President of Southern Company, Receives Briefing on STEP Operations

out the test specifications in the plan produced by ETEC for EPRI and to verify that these plans would fulfill the Statement of Work as presented by the Department of Energy. Dick Cummings, representing EPRI, and Bob Thompson, a private consultant, participated in the meeting.

In other activities, the collector field defocus direction for declination was switched from north to south on all collectors, and during the week of March 5 STEP operated using the fossil fired heater with solar boost (the collector field was in focus for a total of seven hours). Other operations including the following:

- The STEP staff disconnected the plant substation to trace current transformer (CT) and potential transformer (PT) wiring in 'J' and 'K' breaker panels.
- During the week of March 12, STEP operated using the Fossil Fired Heater with the plant operating in a hybrid condition for five hours and 35 minutes.
- Eight glass rods and ten short-fiber-optic cables were replaced in the collector field.
- Auburn representatives were on site to work on several CAIS problems including CCU timer activation.
- Considerable time was spent correcting power instrumentation meter anomalies.
- The Georgia Power Electrical Engineering Department spent several hours assisting the STEP staff with meter anomalies, and several hours were spent in wire tracing within electrical panels. Excess wire was removed and other changes were made to correct the circuitry.

Information Dissemination

The Solar Energy Training Program Overview and Course Guide was published this month. The six-month formal training program was developed to provide a comprehensive solar course using STEP as the main component. Nine courses would require approximately 243 hours of classroom and field trip time, with the remaining time scheduled for STEP operations. The course was targeted for several groups, but it was hoped that Auburn and Georgia Tech would use the course for college credit. The course was to be offered to Southern system member companies, as well as to EPRI and its utility members, the international community, DOE, and industry.

Ed Addison, present of Southern Company (Georgia Power's parent company), was given a comprehensive briefing and tour of the Shenandoah facilities. He was supportive of the solar activities of Georgia Power. The *Newnan Times-Herald* interviewed Addison on site and published a story concerning the latest developments with STEP and other solar facilities.

A nuclear committee with representatives from Georgia Power and Southern Company Services held its monthly meeting at the Shenandoah site. During the meeting, a presentation and tour was provided. ATS and four representatives of R.J. Reynolds toured STEP for the purpose of inspecting the instrumentation subsystem.

Technical Industries Incorporated visited the site and requested a future tour for members of his organization, while 25 students from Drake University in Des Moines, Iowa visited the Shenandoah Solar Center for a presentation and tour.

A solar presentation was given to 42 members of the American Society of Safety Engineers, and 30 seventh- and eighth-grade students from Newnan Christian School also visited.

On March 22 and 23, a five-person TV crew from Toronto did extensive filming on site as part of a one-hour documentary on solar energy to be broadcast in October, 1984.

Dr. Dallas Russell of Auburn presented a status report on the STEP Reliability Study to the 16th IEEE Southeastern Symposium on System Theory at Mississippi State University. This Study should be completed by the end of the year.

A Solar-Tron representative was on site to discuss potential photovoltaic applications, PNG Conservation Company visited to discuss potential uses of solar energy, and two representatives of the Newnan Chamber of Commerce visited the STEP site to discuss possible use of facilities in a promotion of tourism in the area. Other activities included the following:

- The February, 1984 edition of *Textile Industries* magazine featured an article on STEP entitled "Solar Collector Field Halves Thermal Energy Losses."
- The 1983 Annual Report for The Southern Company included a dramatic picture of the STEP collectors.
- A solar exhibit was provided for the Moultrie Industrial Expo in Moultrie, Georgia.

During March, approximately 50 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR APRIL, 1984

April contained three significant operational dates: the 5th, 13th, and 26th. The first TOP test (TOP-BF-2A), performed on April 5, satisfied item No. 15 of the work statement of Amendment 12 of the U.S. DOE/GPC Cooperative Agreement No. DE-SE04-77Et10216. System modifications were required following analysis of test results. The test report was used for discussion and comments at a planning meeting between Sandia National Laboratories, Solar Energy Research Institute, California State Polytechnic University and Georgia Power Company on April 26.

April 5: TOP-BF-12-3a Test Specification called for constant 200 kWe power output only, with the fossil fired heater used as input. The Heat Transfer Fluid was to be maintained at 685°F. It took one hour and 36 minutes to establish the initial plant operating configuration and to bring it to a steady state condition. A constant power level of 200 kWe was produced for 60 minutes. Operations were normal and no major problems were encountered. There were, however, anomalies associated with the tests. The extraction steam pressure indicator was inoperative, and it was determined that the measurement of the Heat Transfer Fluid flow was erroneously low by a factor of 2. Following an analysis of test results, it was necessary to replace the HTF meter with a Vortex flow device.

On April 13, the Vortex flow device accurately measured flow. It was consistent with the thermodynamic heat in mass balances performed within this system. Future test data would be taken with the Vortex flow device, which increases reliability for future steam generator characteristics.

On April 26, a meeting was held by the STEP staff with Sandia National Laboratories, Solar Energy Research Institute (SERI), and the California State Polytechnic University (Cal Poly). A point by point review was made of the method and form of the TOP test reports. In addition to the requirements being met by Georgia Power, Sandia was carrying out its responsibilities with assistance from Cal Poly and SERI. In addition, the first level analysis also would be provided to EPRI or its designees. It was anticipated that further analysis would be made to satisfy the general requirements of the electric utility industry.

In other operations, Sauresein (a protective coating) was put on seven RTDs within the collector field. These were then insulated, and lead wires were repaired on four additional RTDs. The RTDs on several collectors were calibrated, and a sample of high temperature fluid was sent to Dow Corning for analysis. Because of moisture contamination, the oil was changed in the turbine.

An attempt to perform TOP test BF-12-2 was aborted because of pressure fluctuation of the turbine oil. The auxiliary cooling water pump was short cycling in an attempt to cool the turbine oil. The air differential on the turbine high pressure air valve was adjusted to eliminate this anomaly.

The turbine lube-oil filters were changed to prevent the turbine from tripping because of the lube-oil pump, and the fittings on the turbine low pressure warmup line and the fittings on the steam line from the filters to the steam trap were tightened. The line from the High Temperature Storage Tank to the pressure transducer was unclogged.

In trouble-shooting the collector control units on collector #705, it was found that the zero and span potentiometers on the outlet RTD were out of calibration, which was then corrected. A test was run to compare data from the new Vortex meter to the data collected on the HTF during the April 5 test.

An inspection of the HTF leak found on collector #1107 revealed that the hand valve packing needed tightening. Twelve collectors had insulation added to protect fiber optics and RTDs, and 28 were autotracked to verify their operation following fiber optic and RTD repairs.

Information Dissemination

Several members of the Southern Company Services Organization—including Alan Franklin, Executive Vice President, and Bill Dunlap, Vice-President—visited the STEP site to discuss research and development activities within the Southern Company system. Representatives of Alabama Power Company also visited to discuss photovoltaic activities at Alabama Power and Georgia Power.

Two representatives from the Bleyle organization from Germany were provided a presentation and tour of the STEP facilities, personnel from Georgia Power's Safety Department visited, and ten students from Southwest High School in Macon, Georgia were provided a presentation and tour.

Three representatives from Yokagawa came to discuss the HTF flow meter problem at PCV 7150. They suggested a Vortex flow meter that would resolve this operational problem. In addition, 25 mechanical and electrical engineering students from Tuskegee Institute were given a presentation and tour.

Two Brazilian electric utility engineers visited Shenandoah to learn more about solar energy and to find out what potential it might have in their own country, and 30 students from the Columbus (Georgia) Vocational Technical School visited the Solar Center for a presentation and tour.

April, 1984

During a STEP staff meeting, a presentation was given by Dr. Dallas Russell on the development and status of the Reliability Study that he and his associates at Auburn are doing on the STEP solar cogeneration system. Among other visitors were Southern Railway engineers who discussed potential uses of solar energy within their company, and people attending a Georgia Power Architects and Engineers Energy Design Conference in Atlanta.

Georgia Power's display on the Shenandoah Solar Center was judged best exhibit by the Georgia Society of Professional Engineers' Northwest Chapter during an exhibition at the Georgia Square Mall in Athens, Georgia.

During April, approximately 55 walk-on visitors were provided materials and tours, as appropriate.

ACTIVITIES FOR MAY, 1984

The most significant development during May was the performance of five Test Operations Phase (TOP) tests. Three of the test reports had been completed by the end of the month.

The TOP tests satisfied several Work Statement Items of Amendment No. A012 of the U.S. DOE/PGC Cooperative Agreement No. DE-FC04-77Et10216. Following is the status of the test performed during May.

Test I.D.	DOE Item	Date	Test Report
TOP-BF-12-2a	15	4/5/84	Completed 4/19/84
TOP-AF-11-3a	13	5/1/84	Completed 5/4/84
TOP-BF-12-3a	16	5/14/84	Completed 5/17/84
TOP-AF-11-4a	14	5/17/84	Incomplete
TOP-BF-13-2a	17	5/21/84	Completed 5/31/84
TOP-BF-14-2a	19	5/22/84	Incomplete

Steam generator efficiency calculations yielded unacceptable results, since these valves were perturbed by either flow or temperature variations or measurements. Variation in the heat transfer fluid's density and specific heat as a function of temperature was being studied, but a final resolution for the steam generator anomally had not yet been achieved.

Problems associated with power measurements were identified and corrected. In a continuing review of station service loads, the cooling tower pump and the air compressor electrical profiles were recorded. A constant coincident demand of approximately 18 kWe was produced by the absorption chiller's cooling tower pump. The STEP air compressor cycled frequently as anticipated; it was operating at approximately 22-23 kWe for 35-40 percent of the time.

May 30 was a unique solar day. The results of the solar eclipse at 12:30 p.m. are illustrated in Figure 3-9, where direct normal insolation is plotted against time.

At the conclusion of the month, a review was made regarding the barrels of heat transfer fluid to determine the amount of cyclics that had been produced over the past year's operation. From the period beginning on April 11, 1983 and concluding on May 21, 1984, 28 barrels of HTF cyclic had been produced.

In other activities, problems continued with operation of the turbine generator arc valves. Arrangements were made with

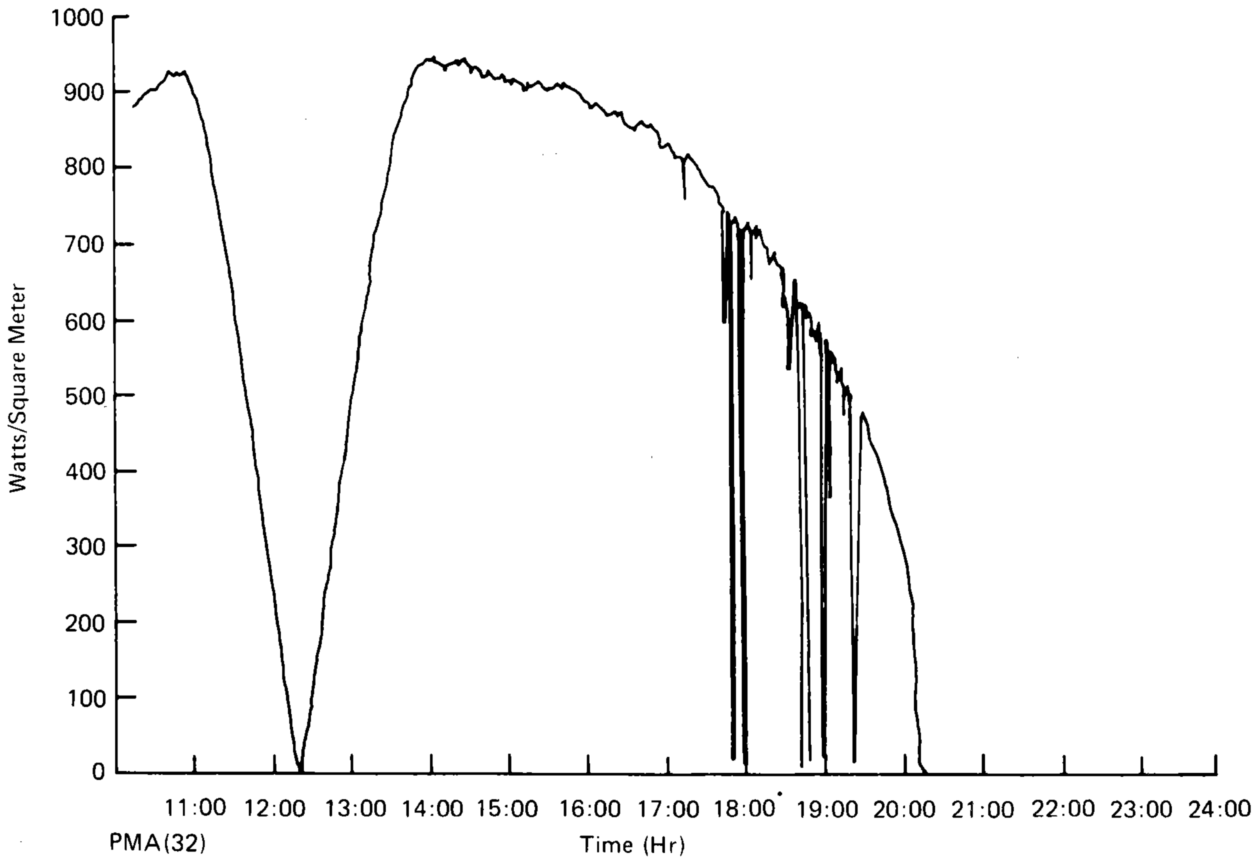


Figure 3-9. Direct Normal Insolation on Solar Eclipse Day

MTI to send a representative to address this problem. During his visit, these actions were taken:

- The exhaust pressure controller was calibrated.
- The relays that control the arc valves were adjusted.
- System debris was cleared from air lines.
- The Woodward controller was adjusted.

A Georgia Power Test Engineering representative was at the site to test the electric meter anomalies. Two malfunctioning current transformers were replaced in the STEP substation cubicle, which resolved some of the operational questions. The following actions also were taken during May:

- The warmup turbine valve was removed for servicing to eliminate steam leak.
- JT8914 was tested and calibrated; data system noise was traced to the Lambda power supply in the energy utilization processor (EUP).
- The declination jackscrews and both polar jackscrews on collectors No. 706, 209, 601, 605 were greased.
- Digital Equipment Corporation (DEC) replaced an interface board (DZ-11) in the DEC 11-44 computer.
- The CRT terminal in the control room was out of service for three days for maintenance.
- Steam leaks were repaired at turbine 5/16.

A survey was made of the collector field ECP surfaces, and 606.5 square feet of film required replacement. 84.75 square feet had been removed and cleaned by the end of the month, but had not been replaced.

A test was run varying the kilowatt output while maintaining a constant fluid temperature to further study steam generator and turbine generator efficiency anomalies. Then, another test was run on the system holding the electrical output constant while varying the fluid temperature. The results were still being evaluated at the end of the month.

In other activities, hand valves were adjusted in the collector field to a 50 percent level. When the declination motor on collector No. 405 failed due to moisture, a spare motor was installed. Packing also was replaced in the boiler feedwater pump to stop a water leak, and several collector motors were greased to ensure their continued operation.

A special heat transfer fluid flow test was run to compare values. A series flow through the field and steam generator flow meters was accomplished at 500°F.

Information Dissemination

Representatives of the Georgia Office of Energy Resources Jardine Air Cargo Ltd. visited the Shenandoah Solar Center, as did 46 grade school students from Stonewall Elementary (Fulton County).

A comprehensive solar presentation was given to SECTAM XII, The South Eastern Conference on Theoretical and Applied Mechanics, at Pine Mountain, Georgia. STEP information was provided to Eichleay Engineers, Inc. in Pittsburgh, upon request.

A STEP technical paper was presented to the national meeting of American Society of Civil Engineers' in Atlanta; a group of 25 Auburn University graduate students was given a presentation and tour; and a STEP presentation was given to 40 members of a retired persons association as part of a lecture series entitled "Information Please."

During May, approximately 25 walk-on visitors were provided materials and tours as appropriate.

ACTIVITIES FOR JUNE, 1984

Several significant developments occurred during June, including five TOP tests were performed. Efforts to continue the tests were curtailed, however, because of the large number of solar collectors that were inoperative. On June 26, additional personnel were assigned to the collector field to resolve the problems, which involved 48 collectors with bad RTDs (25 output and 23 midpoints) and 24 potentiometer anomalies. These included five polar pots and 19 declination pots. In addition, 400 square feet of reflective film remained to be replaced, and several collector motors required repair.

Test BH-21-2a was performed with a hybrid input of the solar collector field with fossil fired heater boost; an electrical output level of 341 kW was achieved. Tests HB-20-2a and AH-22-2a were performed in a hybrid mode. Electrical outputs of 330 and 200 kWe were produced. The first test was electric output only; the second test was electric output with air conditioning and process steam being provided. In Test BH-19-3a, 108 collectors were available. Electric generation reached levels to approximately 350 kWe. A total of 3215 kilowatt hours was generated in 10.1 hours.

On June 25, two California Polytechnic University students begain a six-month training program. Their efforts were to be concentrated in four areas:

- Learn to operate the solar cogeneration plant and become licensed STEP operators.
- Participate in a series of two dozen lectures on various subjects relating to solar energy.
- Write a term paper on some facet of the STEP plant or other related solar activity.
- Visit and study several other solar systems at nearby locations.

Following completion of this training course, Cal Poly was to give the students undergraduate college credit, and they were to receive an operating license from the president of Georgia Power.

In other activities, it was significant that in June the recorded direct insolation exceeded the Solar Model Year (SMY) data. The recorded value averaged 1556 watts per square meter compared to the Solar Model Year average value of 1547. This was the first time since January that empirical data were greater than SMY data.

On June 8, the lithium bromide solution within the absorption chiller crystallized and clogged up the pipes. The unit was out of service for five days until a Trane serviceman repaired the unit. The crystallization was caused by the cooling tower water temperature being at a level below 83°F. Other operations including the following:

- All data files from 3/12/84 through 6/18/84 were transferred from disk to tape.
- The Georgia Power Company Safety Department was at this site performing noise tests.
- The Solar Solstice test (BS-01-1a) was performed on June 25.

Information Dissemination

A comprehensive STEP presentation was provided to the International Energy Agency workshop on the design and performance of large scale thermal collector arrays. Some 75 people attending this international solar meeting heard the presentation. Site visits included the following:

- An industrialist from Australia
- A representative of Sandia National Laboratories
- Fifteen members of a Consumer Advisory Council
- Twelve marketing personnel from the Tucker District of Georgia Power
- Two members of the Georgia Power Purchasing Department.

During this report period, 35 visitors were provided materials and tours, as appropriate.

Section 4
PLANNED ACTIVITIES FOR NEXT CONTRACT YEAR

Test Operations Phase

As the current series of 29 tests is completed for the U.S. Department of Energy, additional tests will be conducted for the Electric Power Research Institute (EPRI). These will involve long range, high technology test and education functions, and the results will be disseminated to EPRI's member utilities. The objective will be to produce maximum energy from the STEP at minimum cost.

New Technologies

The two most significant projects scheduled to begin are the 40 kWe photovoltaic experiment, and the 33-month 25 kWe solar/Stirling engine test (pages 3-17 and 3-18) developed by McDonnell Douglas. Other efforts will include applications for small remote photovoltaic systems, flat-plate solar domestic water heating, and perhaps a solar pond experiment.

Solar Energy Training

During the next contract year (July 1, 1984 through June 30, 1985), the two students from California Polytechnic University will complete their six-month program leading to three college credits and certification as solar cogeneration system operators. Meanwhile, Dr. Kim Byung-Chul, of Cho Sun University (Gwang-Ju, Republic of Korea), will be at the STEP site for a year of work and study toward the same objective. His participation is part of an arrangement with Georgia Tech.

Technology Transfer

Work will begin on a new Solar Center to be constructed at the STEP site. The facility will be able to accommodate bus tours and large groups, and will promote the message that Georgia Power is on the leading edge of solar and other new energy technologies. Visitors to date have included civic groups, school students, universities, industries, and government and international agencies.

In addition to display areas, the new Solar Center will contain classroom space for Solar Energy Training (SET) Program participants, offices for STEP personnel and consultants, a full technical library documenting the STEP and related solar projects, and a large conference room.

MANAGEMENT AND OPERATING SERVICES TO BE PERFORMED BY PARTICIPANT

The Participant will perform the 29 Priority 1 tests of the Test Operation Phase Plan (TOP), which are listed in Table 1 of this Attachment 1. If all of the Priority 1 tests are not completed prior to September 30, 1984, the Participant will complete the tests expeditiously within a time schedule agreed to by the Participant and the Contracting Officer, without additional cost to the Government. The Participant shall submit to the Contracting Officer a report for each Priority 1 test within seven (7) working days after completion of each such test. Each report shall include the following:

For the Fossil, Solar, and Hybrid Tests

- Copy of the Daily Log which notes any changes in operation and time of occurrence.
- STES outputs (rate and cumulative)
  Turbine-Generator electrical
  Process Steam
  Chilled Water
- Energy Input to Steam Generator (rate and cumulative)
- Energy Output of Steam Generator (rate and cumulative)
- Efficiency Output of Turbine-Generator and Steam Generator
- Station Service (STES electrical usage)
- Temperature into Steam Generator
- Temperature of the High Pressure Steam

Solar and Hybrid Tests

- Direct Normal Insolation (rate, cumulative per hour and all day cumulative)
- Energy out of the Solar Collector Field (SCF) Branch 6 and collectors 603/610 (rate and cumulative)
- Efficiency of the SCF, Branch 6 and collectors 603/610
- Temperature in/out of the SCF, Branch 6 and collectors 603/610
- HTF flow in/out of the SCF, Branch 6 and collectors 603/610

NOTE: The Branch 6 and collectors 603/610 data are desirable on all solar/hybrid tests but necessary on only four of the tests.

TABLE 1 TO ATTACHMENT 1
Test Operation Phase Plan (TOP) Priority 1 Tests

TOP Notation	Input*	Description	HTF Temp.	Output
BS-01-3 1.	FS/SO	Sun following—equinox	685–735°F	Electricity (Elec.) (variable)
BS-01-1 2.	FS/SO	Sun following—summer solstice	685–735°F	Elec. (variable)
BS-01-2 3.**	FS/SO	Sun following—winter solstice	685–735°F	Elec. (variable)
BS-01-4 4.	FS/SO	Sun following—cloudy	685–735°F	Elec. (variable)
BS-01-5 5.	FS/SO	Sun following—hazy	685–735°F	Elec. (variable)
AS-04-1 6.	FS/SO	Constant Power	685–735°F	Elec. (200 kW) & Process Steam
AS-04-3 7.	FS/SO	Constant Power	685–750°F	Elec. (300 kW) & Process Steam
BS-05-3 8.	FS/SO	Constant Power	685–750°F	Elec. (300 kW)
AS-09-1 9.***	FS/SO	Load Following—Stand Alone	685–750°F	Elec. (variable) & Process Steam
AS-08-1 10.	FS/SO	Load Following—Grid Connected	685–750°F	Elec. (variable) & Process Steam
AS-10-3 11.	FS/SO	Peak Shaving Load 50 kW	685–750°F	Elec. (variable) & Process Steam
AS-06-1 12.	SO	Constant Power	685–750°F	Elec. (200 kW) & Process Steam
AF-11-3 13.	FO	Constant Power	720°F	Elec. (200 kW) & Process Steam
AF-11-4 14.	FO	Constant Power	720°F	Elec. (300 kW) & Process Steam
BF-12-2 15.	FO	Constant Power	685°F	Elec. (200 kW)
BF-12-3 16.	FO	Constant Power	685°F	Elec. (300 kW)
BF-13-2 17.	FO	Constant Power	720°F	Elec. (200 kW)
BF-13-3 18.	FO	Constant Power	720°F	Elec. (300 kW)
BF-14-2 19.	FO	Constant Power	750°F	Elec. (200 kW)
BF-14-3 20.	FO	Constant Power	750°F	Elec. (300 kW)
AF-17-2 21.***	FO	Load Following—Stand Alone	750°F	Elec. (variable) & Process Steam
AF-17-1 22.	FO	Load Following—Grid Connected	750°F	Elec. (variable) & Process Steam
AF-18-1 23.	FO	Peak Shaving—(Load 50 kW)	750°F	Elec. (variable) & Process Steam
AH-22-2 24.	Hybrid	Constant Power	720°F	Elec. (400 kW) & Process Steam
BH-20-2 25.	Hybrid	Constant Power	685°F	Elec. (400 kW)
BH-21-2 26.	Hybrid	Constant Power	720°F	Elec. (400 kW)
BH-19-3 27.	Hybrid	Constant Power	750°F	Elec. (400 kW)
AH-25-1 28.***	Hybrid	Load Following—Stand Alone	750°F	Elec. (variable) & Process Steam
AH-25-2 29.	Hybrid	Peak Shaving (Load + 50 kW)	750°F	Elec. (variable) & Process Steam

All of the tests may be performed with or without providing cooling as an output.

It is very desirable to have the solar (FS/SO and SO) tests run with the solar collector field under temperature control, but they may be run under manual flow control in a hybrid mode if necessary.

***Definitions:**
FS/SO—Fossil Start/Solar Only
FO—Fossil Only
Hybrid—Solar with fossil providing additional energy.

**To be performed within two weeks of winter solstice.

***Since the Stand Alone subsystem has not been validated, these tests will be performed within the limits of the existing control equipment.

SOLAR TOTAL ENERGY PROJECT
TEST STATUS REPORT

Date: July 6, 1984

Test Spec No.	DOE Data Item No.	Description	Test Date	HTF Temp. Spec/Oper	Elec Power Spec/Oper	Report Sent
TOP-BF-12-2a	15	Constant Power	4/05/84	685/705	200/238	4/27/84
TOP-AF-11-3a	13	Constant Power	5/01/84	720/720	200/236	5/04/84
TOP-BF-12-3a	16	Constant Power	5/14/84	685/685	300/225	5/17/84
TOP-AF-11-4a	14	Constant Power	5/17/84	720/712	300/209	6/14/84
TOP-BF-13-2a	17	Constant Power	5/21/84	720/733	200/205	5/31/84
TOP-BF-14-2a	19	Constant Power	5/22/84	750/750	200/201	6/08/84
TOP-BH-21-2a	26	Constant Power	6/07/84	720/740	400/341	7/05/84
TOP-BH-20-2a	25	Constant Power	6/08/84	685/685	400/330	
TOP-AH-22-2a	24	Constant Power	6/08/84	720/720	400/200	
TOP-BH-19-3a	27	Constant Power	6/15/84	750/TBD	400/TBD	
TOP-BS-01-1a	2	Sun Following	6/25/84	Var/TBD*	Var/TBD	

*This test may be repeated

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-544-063/10398

ALO-3994-84/1

SOLAR TOTAL ENERGY PROJECT SHENANDOAH, GEORGIA SITE

DOE

United States Department of Energy
Office of Scientific and Technical Information
Post Office Box 62
Oak Ridge, Tennessee 37831

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF ENERGY
DOE-350

U.S.MAIL

10723 FS- 1
US DEPARTMENT OF ENERGY
ATTN S D ELLIOTT, DIR
SOLAR ONE PROJECT OFFICE
PO BOX 366
DAGGETT, CA 92327