SANDIA REPORT SAND82–2249 • Unlimited Release • UC–62a
Printed March 1983

Solar Total Energy Project Summary Description

Robert W. Hunke, James A. Leonard

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A02
Microfiche copy: A01

SAND82-2249
Unlimited Release
Printed March 1983

Distribution
Category UC-62a

Solar Total Energy Project Summary Description

Robert W. Hunke
James A. Leonard
Solar Systems Applications Division 9727
Sandia National Laboratories
Albuquerque, NM 87185

Abstract

The Solar Total Energy Project at Shenandoah, GA, is described.

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Solar Total Energy Project Summary Description

Introduction

This document describes the Solar Total Energy Project (STEP) at Shenandoah, GA. A summary description of the energy system, its location, and the project site are presented. The system is further described including design criteria and requirements, performance criteria, and operating requirements. The major subsystems of the STEP—the Solar Collection Subsystem (SCS), the Power Conversion Subsystem (PCS), the Thermal Utilization Subsystem (TUS), the Control and Instrumentation Subsystem (CAIS), and the Electrical Subsystem (ES)—are described, including their major components. Specific features of the control and instrumentation provisions for the system and subsystem operational modes are also described and the costs of construction presented.

Summary Description

Scope

A Solar Total Energy System (STES) is one which uses collected solar energy to supply high-grade (electrical/mechanical) and low-grade (thermal) energy needs. The basic function of the STES at Shenandoah is to supply the electric power, process steam, and cooling for the two 2300 (25 000-ft^2) Bleyle of America Plant and cogenerate electricity for the Georgia Power Co. grid. Figure 1 is an aerial photograph of the Shenandoah STEP.

The STES design is composed of three hydraulic loops or subsystems: the Solar Collection Subsystem (SCS), the Power Conversion Subsystem (PCS), and the Thermal Utilization Subsystem (TUS) that collect, transfer and condition the energy, and a central control subsystem that monitors and controls the system operation. The SCS uses hydraulic circuits that transport the energy from the collector field either to the high-temperature buffer storage or directly to the steam generator of the PCS. In the PCS, electrical power is produced by a Rankine cycle steam turbine alternator. Steam for process use is extracted between turbine stages. The TUS uses rejected energy from the PCS for producing chilled water for air conditioning.

Project Objectives

- Develop within industry the engineering and development experience on large scale solar total energy systems for subsequent demonstration projects
- Assess the interaction of solar energy technology with the application environment
- Narrow the prediction uncertainty of the cost and performance of solar total energy systems
- Expand solar engineering capability and experience with large-scale hardware systems
- Disseminate information on solar total energy

Loads

The loads include the Bleyle Plant electric loads, process steam used for pressing fabric, cooling for the Bleyle Plant, and electricity supplied to the Georgia Power Co. grid. The design loads used to size the STES are summarized in Table 1. In normal operation, the STES operates with a 50- to 75-kW base load from the utility, and electric load follows the Bleyle Plant load between 150 to 250 kW. Except for lunch and shift breaks, the Bleyle Plant electric load profile is relatively constant (Figure 2).

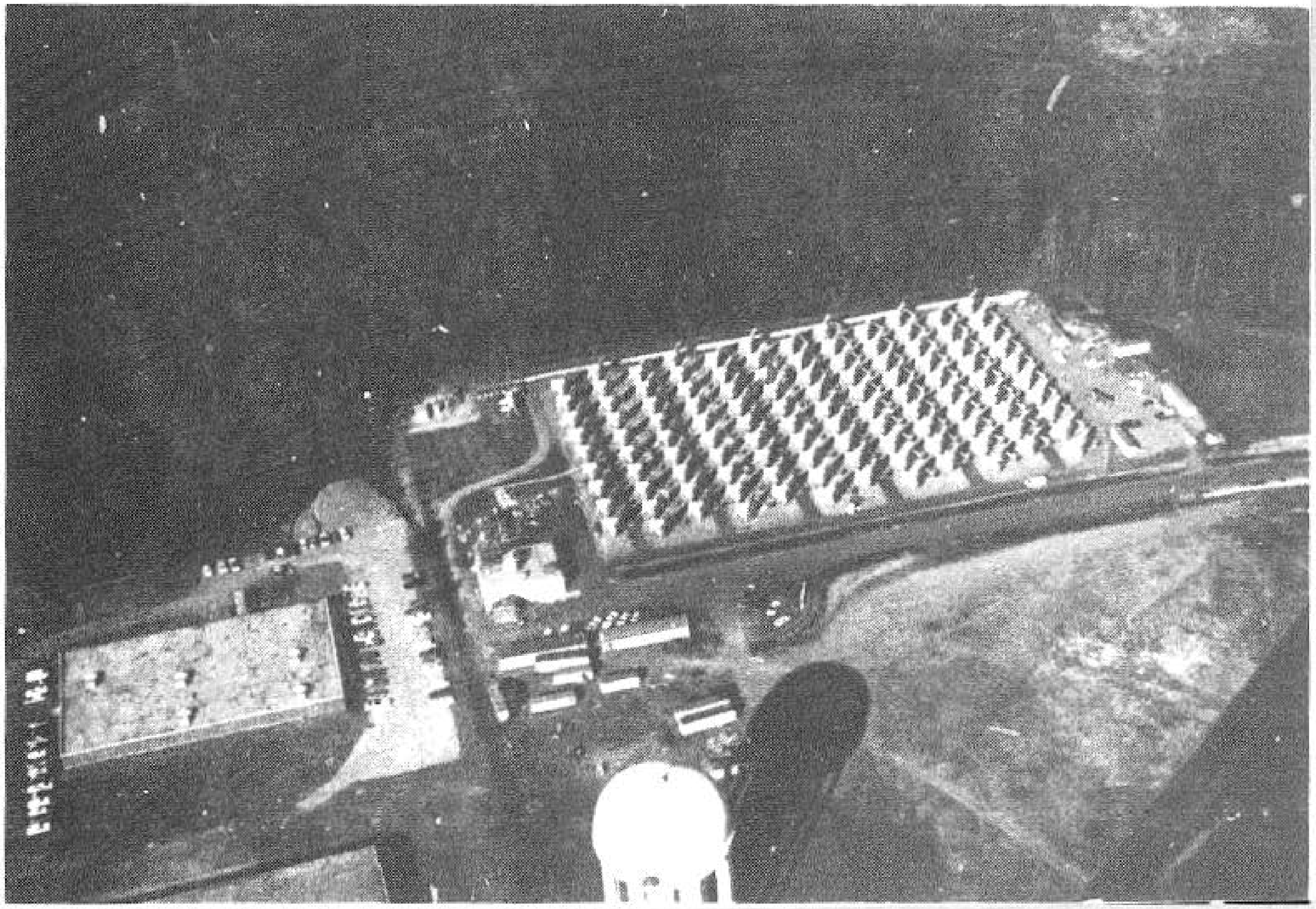

Figure 1. Solar Total Energy Project, Shenandoah, GA

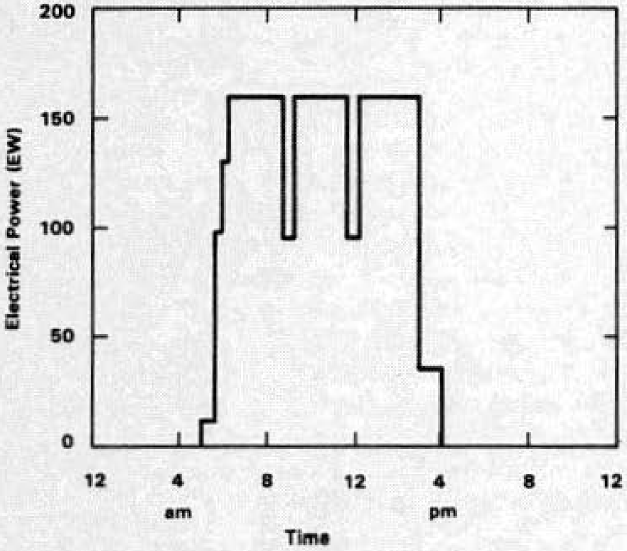

Figure 2. Bleyle Plant Electric Loads

Table 1. STES Design Loads

Served Load	Bleyle Plant Peak Load Requirement	STES Capacity
Electrical	161 kW	400 kW
Cooling	1.43×10^6 kJ/h (113 tons)	3.25×10^6 kJ/h (257 tons)
Heating	342×10^3 kJ/h (324 kBtu/h)	None
Process Steam	627 kg/h (1380 lb/h)	627 kg/h (1380 lb/h)

Process steam at saturated conditions is required during all working hours, with the design profile shown in Figure 3.

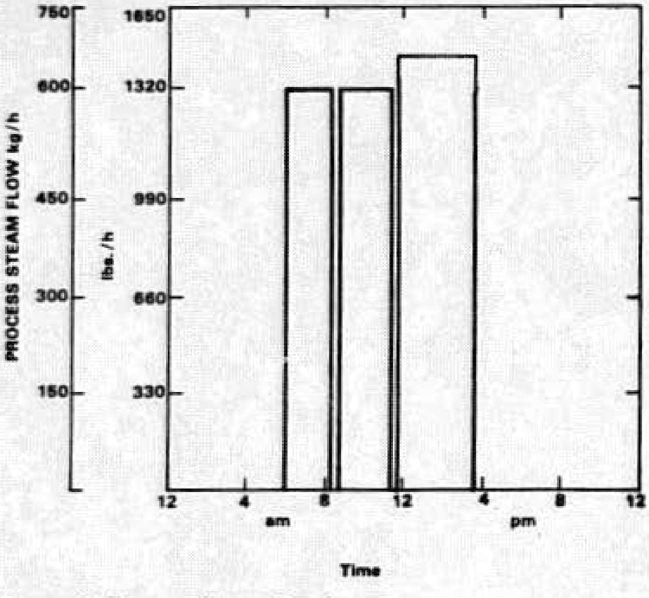

Figure 3. Process Steam Loads

The design cooling loads, which are based on ASHRAE design conditions, are summarized for the Bleyle Plant in Table 1. The cooling loads consist primarily of internal heat generated by the process steam and building lighting and are relatively constant during plant operating hours. The plant heating, ventilating, and air conditioning (HVAC) system incorporates an economizer cycle which supplies a portion of the cooling load from December to February. The cooling loads are served by a chilled water system supplied by an absorption chiller.

The maximum factory heating load, 342×10^3 J/s (324×10^3 Btu/h), occurs when the outdoor ambient temperature is minimum, while the plant is not in operation, and plant ventilation is maximum.

Overall System Description

The system is a fully cascaded total energy system shown schematically in Figure 4, with parabolic dish solar collectors, a steam Rankine cycle power conversion system with process steam extraction and an absorption chiller. The design includes an integrated control system.

Solar Collection Subsystem

The SCS consists of an array of 114, 7-m (23-ft) diameter parabolic dish collectors (Figure 5), which provide a 140°C (250°F) temperature rise to the heat transfer fluid (HTF) flowing through the collectors in a parallel-arranged, closed, hydraulic circuit. The collector output temperature is 400°C (750°F). The receiver is a cavity-type, with the incident concentrated solar flux impinging upon an absorptive surface enclosed within an insulated cylindrical shell. The parabolic dish reflector is made up of individual petals of die-stamped aluminum sheet laminated with second surface aluminized acrylic film. Each collector tracks in both the polar and declination axes. The parabolic dish collectors are arrayed on the Shenandoah collector field in a repeating diamond pattern (Figure 5). The field piping network consists of welded Schedule 40 pipes in the mainlines and high-temperature insulated steel tubing in the branch lines. The High-Temperature Storage (HTS) subsystem is filled with 26 500 L (7000 gal) of Syltherm 800 heat transfer fluid. One hour of storage, approximately 6.33×10^6 kJ (6 MBtu of 400°C) fluid, is provided as a buffer for transient conditions. Storage is in a thermocline mode. The large tank is shown in Figures 6 and 7. SCS also includes a natural gas-fired heater capable of supplying the PCS heat input requirements.

Power Conversion Subsystem

The PCS consists of a three-section, pool-type boiler with preheater, boiler, and superheater, a steam turbine-alternator set rated at 400 kWe (Figure 8), an air-cooled condenser and condensate storage tank, makeup demineralizer, deaerator, and boiler feed pump. In normal operation, steam at 380°C (720°F) and 4.8 MPa (700 psig) is generated in the boiler superheater and delivered to the turbine inlet. The turbine alternator set consists of a four-stage, high-speed (42,450-rpm) turbine coupled to a gearbox which reduces the speed to the 1800-rpm, 60-Hz alternator. The back of the two high-pressure turbine stages has an extraction port for process steam and steam for regenerative feed water heating. The two low-pressure turbine stages operate into an air-cooled condenser at 110°C (230°F) and also provide steam to the TUS.

Thermal Utilization Subsystem

The TUS major components include a 3.25×10^6 kJ/h (257-ton) absorption chiller derated to provide 1.43×10^6 kJ/h (113 tons) with inlet steam at 110°C and a cooling tower for heat rejection from the absorption chiller. The absorption chiller and cooling tower are standard off-the-shelf items. The absorption chiller has self-contained controls to sense load variations and supplies chilled water directly to the Bleyle Plant piping system.

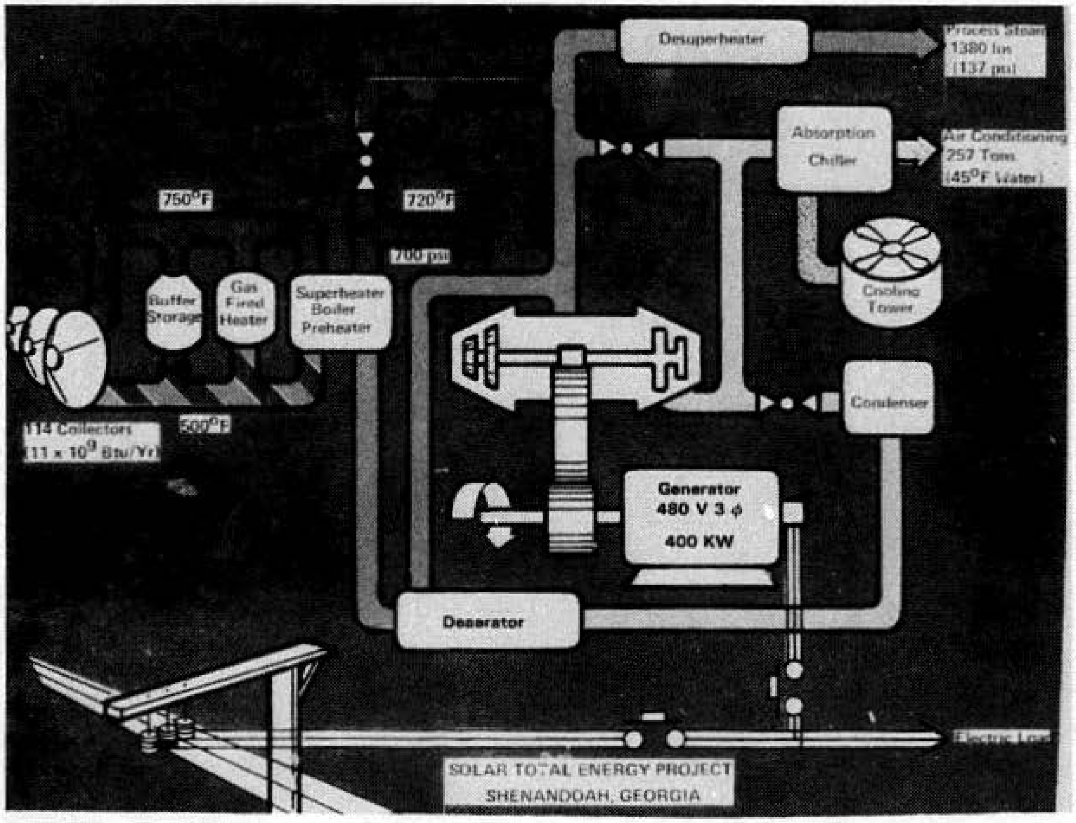

Figure 4. STEP Simplified Schematic

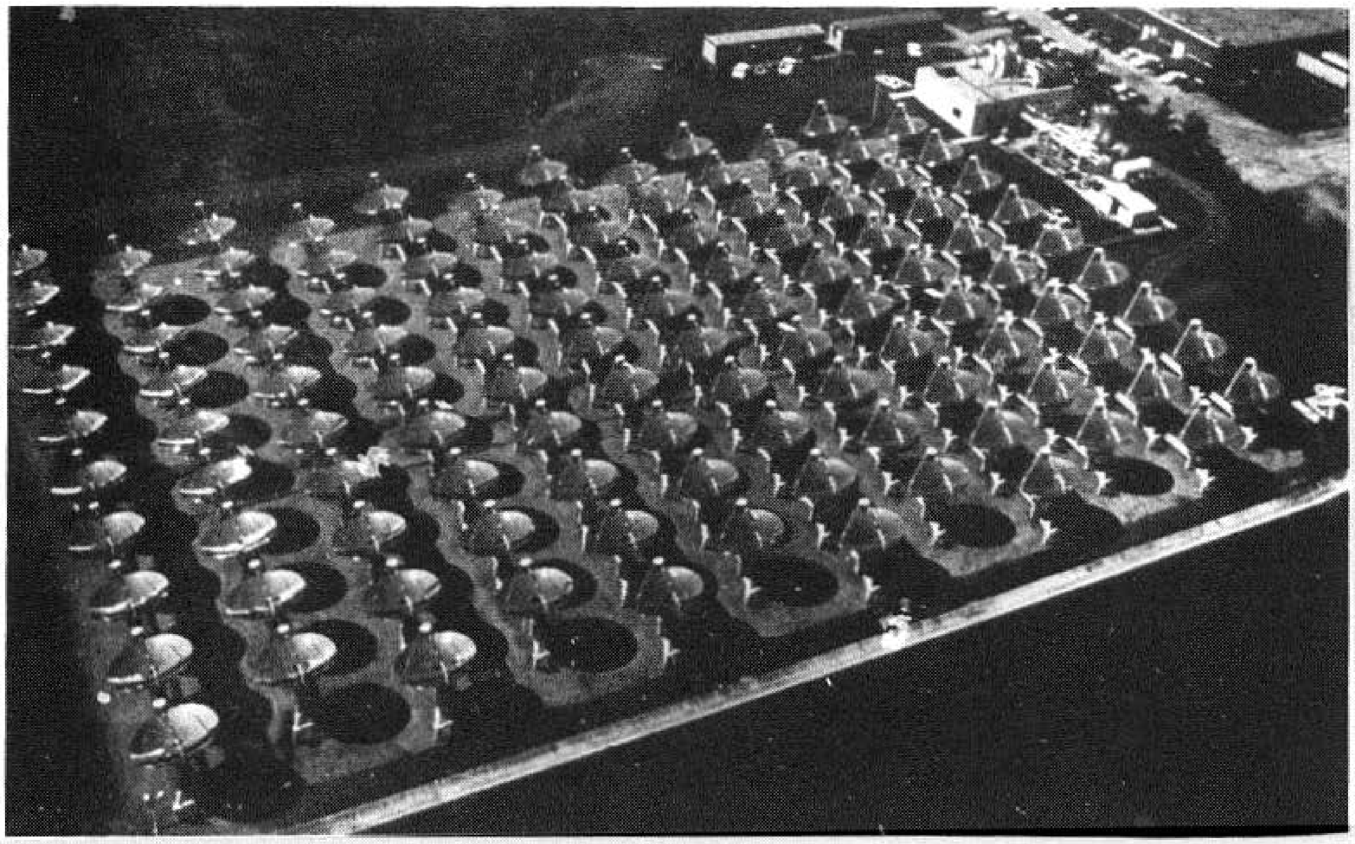

Figure 5. Solar Collector Field, Bleyle Plant Shown in Upper Right

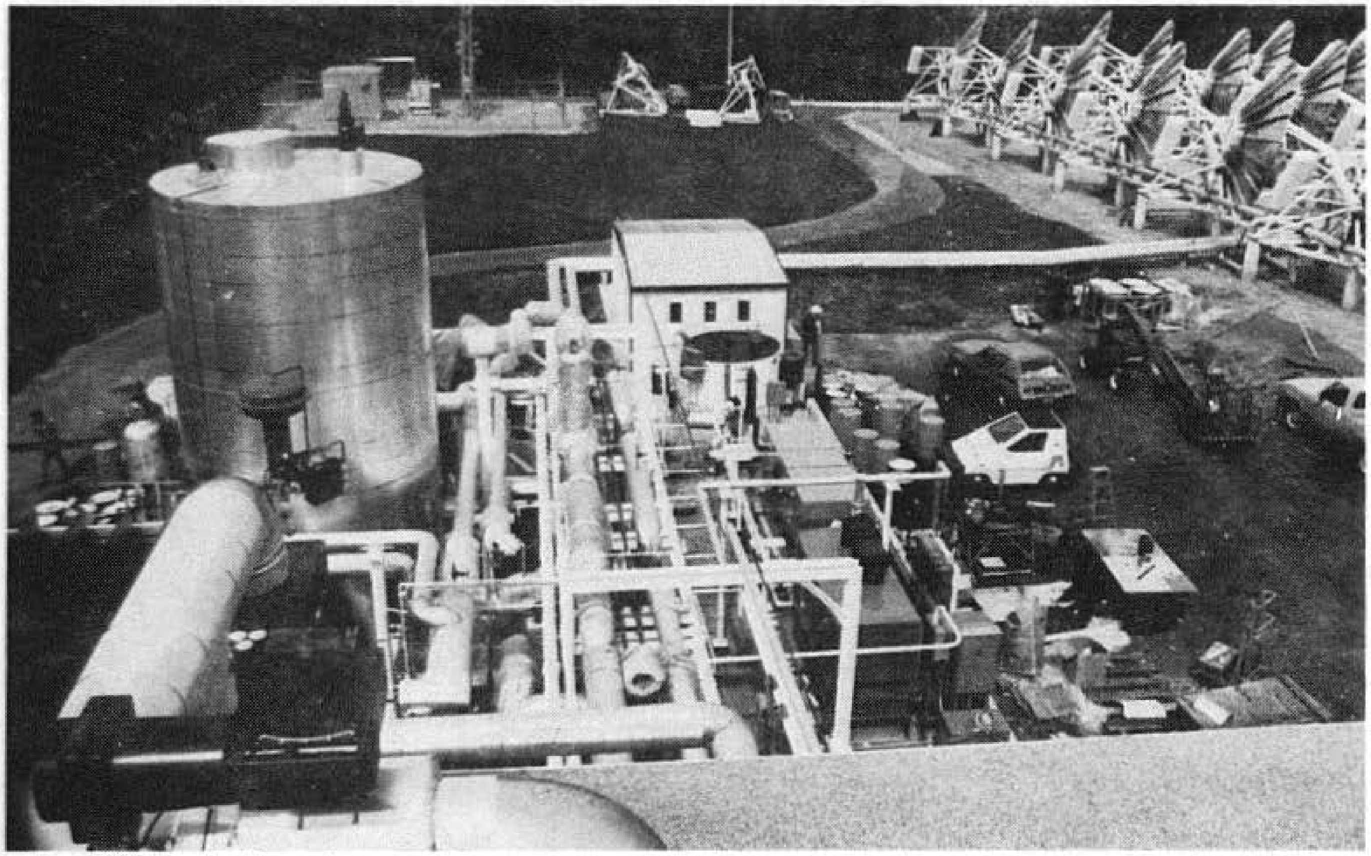

Figure 6. Mechanical Area, January 1982

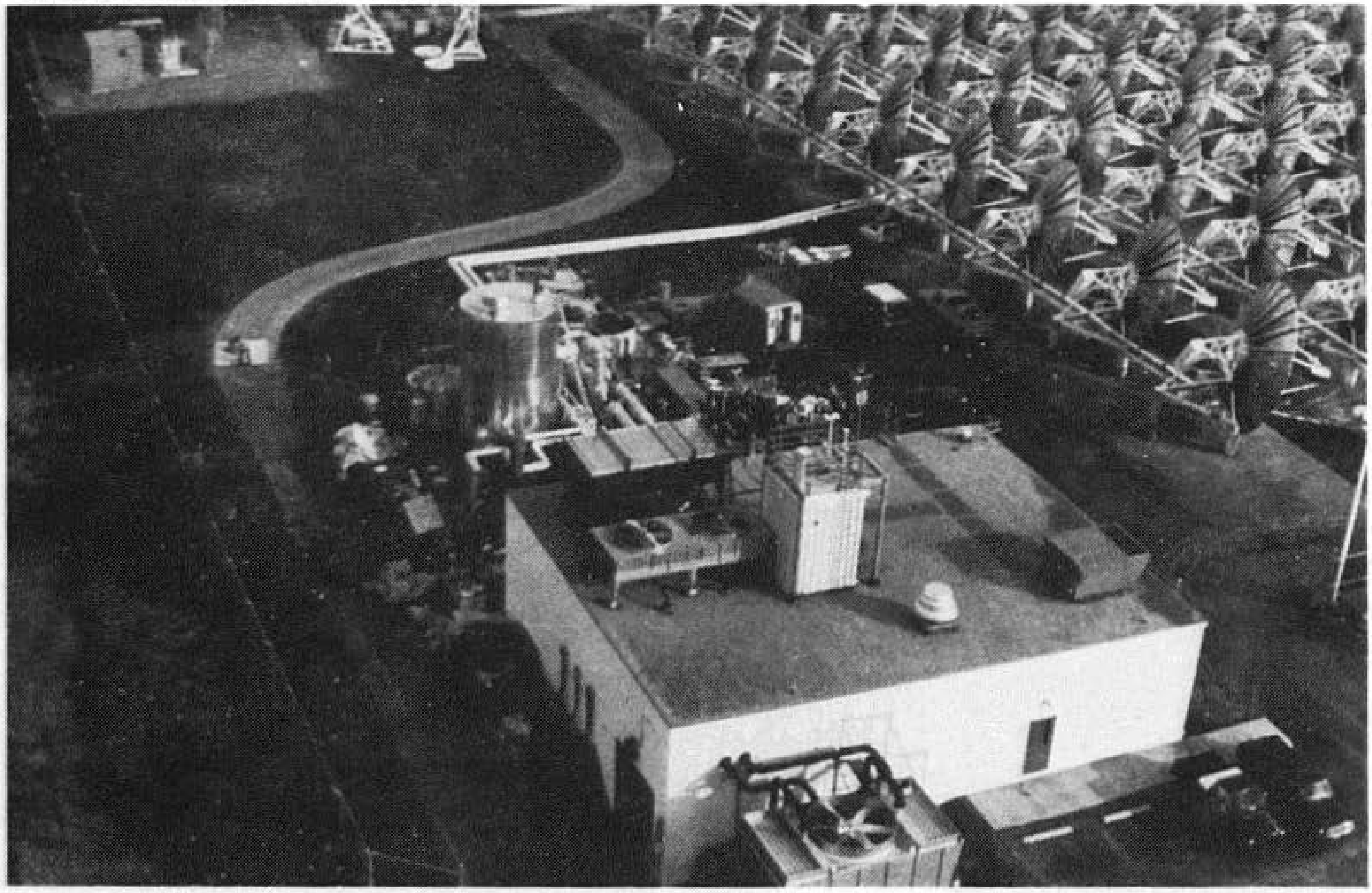

Figure 7. Building and Mechanical Area, January 1982

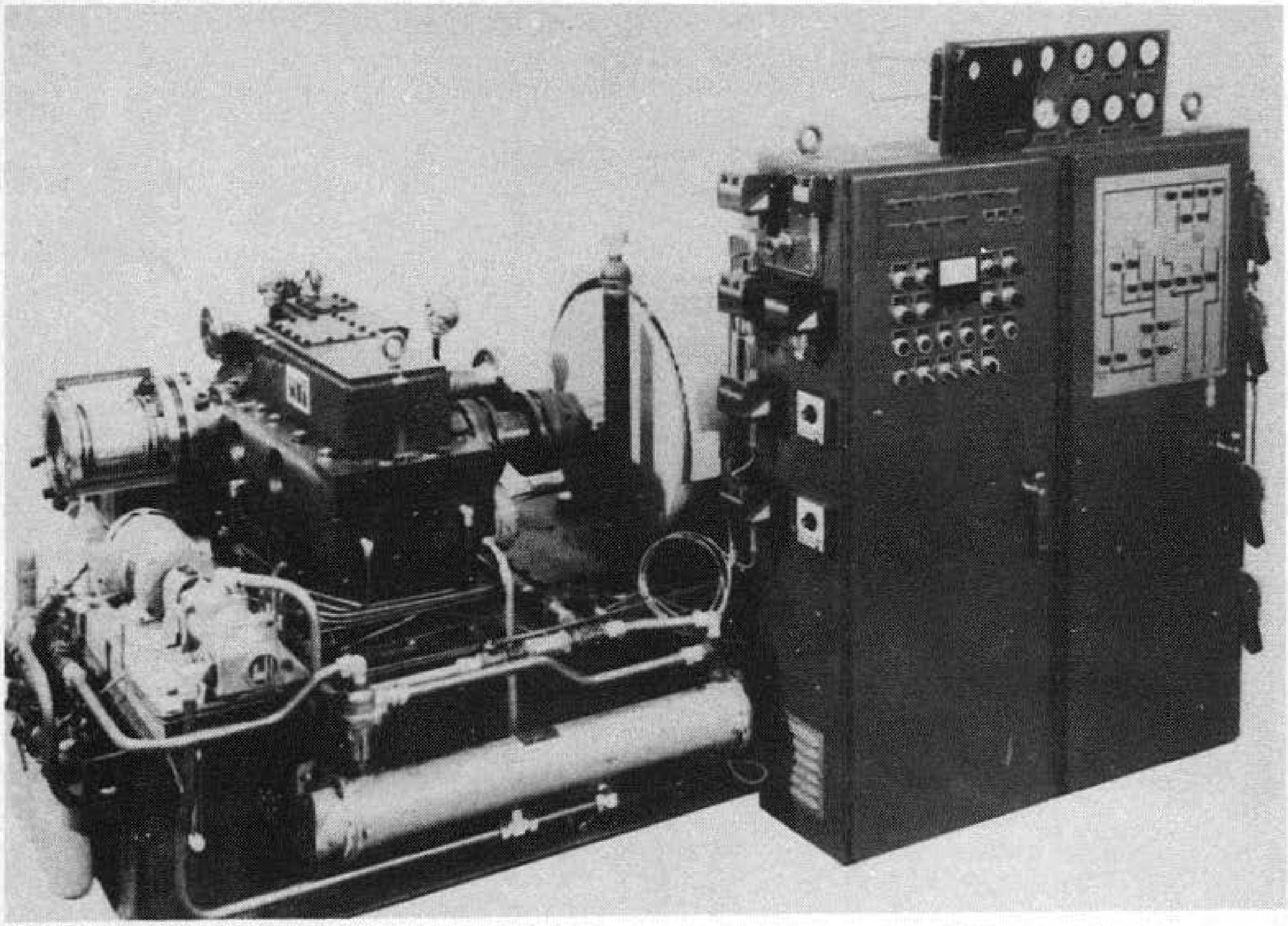

Figure 8. Rankine Cycle Steam Turbine Alternator

Control and Instrumentation Subsystem

Basic Operating Philosophy

CAIS (Figure 9) is designed to allow maximum operational flexibility. Six modes of operation are defined in the operating software:

- Normal
- Experimental
- Diagnostic
- Fail-Safe
- Degraded
- Maintenance

In the normal mode of operation, the control system initiates collector tracking, energy storage, electrical power generation, and air conditioning. The electrical requirements of the Bleyle Plant are monitored and sufficient power is generated to supplement the base load supplied by Georgia Power Co.

A switch to alternate modes allows the operator to initiate solar collection experiments, monitoring, and recording experimental data as needed. The operator may initiate diagnostic routines in the event of a malfunction. The critical components of the system are fail-safed to prevent damage during power or primary control failures or over temperature conditions. The system is operational in alternative modes when certain components, such as a collector branch, are not available due to routine maintenance or component failures.

Control of the solar collectors is by serial data control loops from the central computer. Coarse solar tracking is provided by a computer-stored sun position algorithm. Fine tracking is provided by an optical quadrant detection feedback control loop on each receiver. The temperature of the fluid at each receiver is monitored and the branch fluid flow rate is adjusted to achieve the desired fluid temperature. Automatic defocus (north or south and ahead or behind sun position) activates if the fluid in any collector receiver exceeds a safe temperature. Automatic stowing (maximum south and east position) actuates if necessary to protect the collectors under adverse climatic conditions, such as high winds.

The HTS subsystem is monitored with temperature sensors to determine charge and discharge readiness of storage. The HTF will be routed according to the HTS status. If storage is fully charged and no additional energy can be handled, collector stowage will automatically occur to prevent fluid over-temperature. A microprocessor control unit controls the HTS and interfaces the HTS with the central console.

The PCS consists of the steam generator (boiler) and the steam turbine alternator. This subsystem is also under control of the microprocessor. Automatic startup/shutdown sequences as well as built-in protection functions are an inherent part of this equipment. The electrical requirements of the knitwear factory are monitored and alternator output is moderated according to factory needs or the excess electrical power is provided to the utility grid.

Energy to the TUS is provided by means of steam from the PCS. The control system provides flow and temperature control to maintain the TUS pressure and temperature. The absorption air conditioning unit responds to the requirements of the Bleyle Plant. The microprocessor control unit provides control and monitor functions for this system.

Control System Design

The Control and Instrumentation Subsystem is comprised of a central control console, the central minicomputer and a microprocessor control unit. The operator can monitor and control basic system functions from the control panel. All other detailed monitored and controlled functions are via the computer keyboard and cathode ray tube (CRT) interface. Monitored data are recorded from experiments, alarms, and normal operation on magnetic tape and in hard copy form on the computer line printer. Signal conditioning circuitry is provided as needed in the processors. The minicomputer is programmable to allow a high degree of system control and monitoring flexibility.

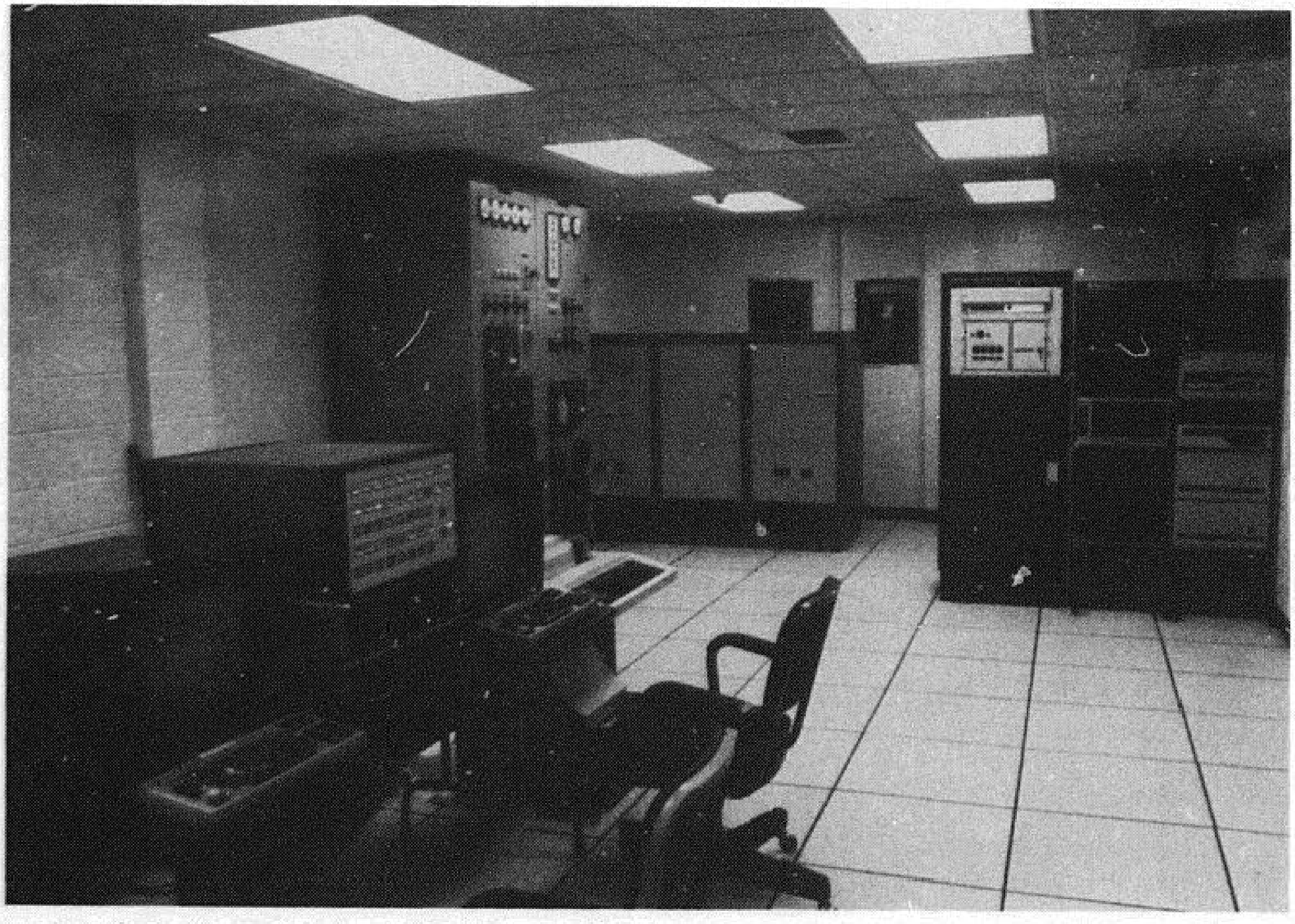

Figure 9. Control Room, Data Acquisition Center, and Switchgear

Location and Site Description

The Solar Total Energy Project (Figure 1) is located in Shenandoah near Newnan, GA about 40 km (25 mi) southwest of Atlanta on Interstate 85 and Georgia Highway 34.

The site (Figure 10) consists of approximately 23,000 m^2 (5.72 acres). The Bleyle knitwear plant is located along the west property line of the development. Access is via Amlajack Boulevard.

Positioned directly south of the site on a parcel of land with a peak elevation of 300 m MSL (970 ft) is a 3800 m^3 (1 000 000 gal) water tower. The height of the water tower is approximately 50 m (166 ft). The Shenandoah water tower is clearly visible from I-85.

STEP Total Construction Costs

Expenditures to construct the STEP are presented in seven main categories:

- Collector Field Construction
- Building and Mechanical Area Construction
- Insulation
- Control and Instrumentation System
- Collectors
- Long Lead Procurement
- Construction Inspection

All contracts were fixed-price, competitively bid except the Control and Instrumentation System, which was a fixed-price, sole-source procurement. Figure 11 shows the percentage of costs encompassed in each of the seven categories identified above and costed in Table 2.

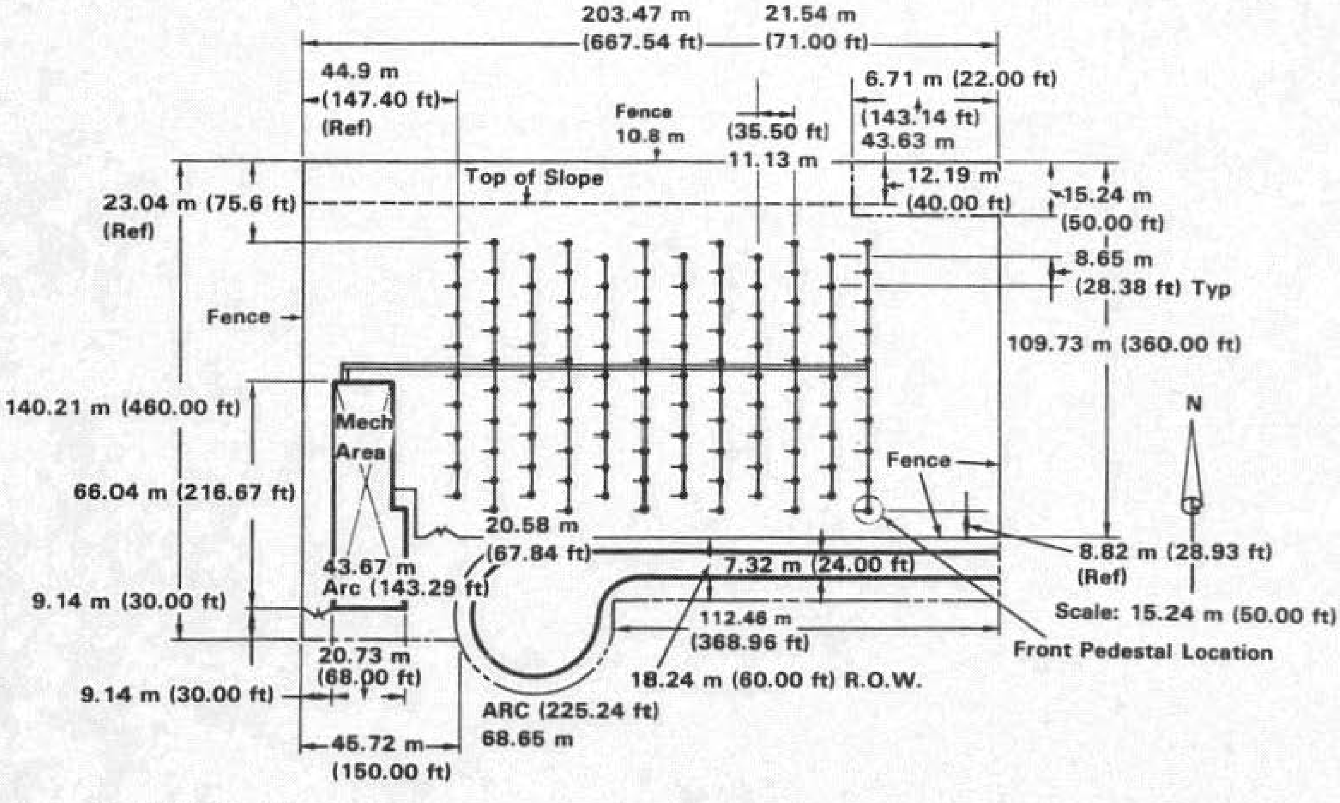

Figure 10. STEP Site Plan

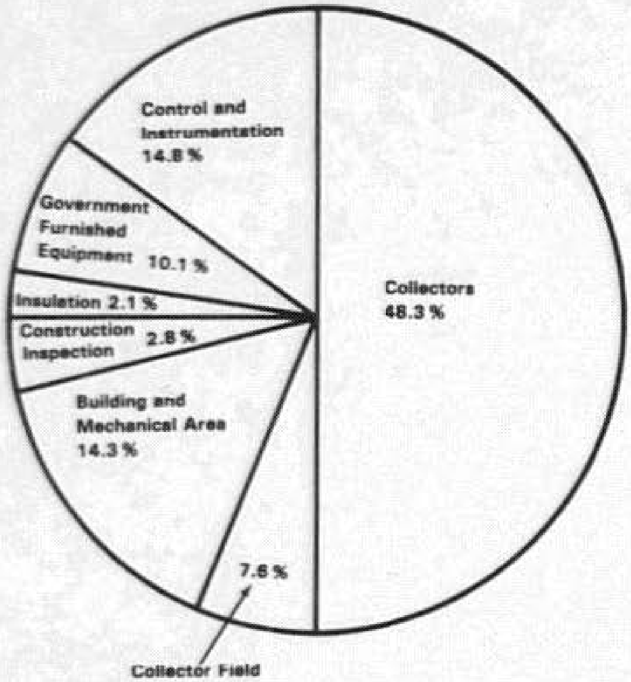

Figure 11. Construction Cost ($12 030) Distribution for the Solar Total Energy Project

Table 2. Construction Costs

Item	Cost ($ Thousands)	% of Costs
Collectors	$ 5 807	48.3
Collector Field	916*	7.6
Building and Mechanical Equipment Area	1 721	14.3
Control and Instrumentation	1 779	14.8
Government-Furnished Equipment	1 213**	10.1
Insulation	252	2.1
Construction Inspection	342	2.8
	$12 030	100.0

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*Includes $100 000 for initial site grading

**Includes $500 000 for MTI turbine-alternator

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