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THE SHENANDOAH CONCENTRATOR

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ABSTRACT

A 7-meter diameter, parabolic dish solar collector has been designed and developed for first application at Shenandoah, Georgia by the U.S. Department of Energy Solar Total Energy Project. Key features and requirements for the collector are outlined. Performance test results for collector testing at Sandia Laboratories in Albuquerque are summarized. The key features, requirements and performance of the solar collector subassemblies/subsystems are discussed: mount and drives, reflector, receiver and collector control unit. Problems experienced during collector testing in Albuquerque are identified and solutions described.

INTRODUCTION

Tradeoff studies performed during the Conceptual Design Phase (1) identifies the significant inherent performance advantages of point focusing solar collectors over line focusing solar collectors, for the Shenandoah, Georgia environment and Solar Total Energy System (STES) application. Roughly twice as much energy is collected per day per square foot of aperture with a point focusing collector. With point focusing, energy can be collected efficiently at higher operating temperatures, leading to higher STES electric power conversion efficiency via thermodynamic cycle.

After selection of the parabolic dish point focusing collector for the Shenandoah Project, optimization studies were performed during the Preliminary Design Phase (2) to determine the optimum collector size, and other key parameters. Studies considered the following:

- Solar collector costs, solar collector design and manufacturing processes and pipefield costs, as a function of size.
- Solar collector performance, as a function of size.
- Pipefield energy losses, as a function of solar collector size, and number of solar collectors required.

The optimum solar collector reflector was determined to have a diameter of 7 meters (23 feet).

Subsequently, preliminary and final solar collector development tests and designs have been completed. This paper gives key information and data on the final collector design, and on development testing results.

SOLAR COLLECTOR

The Shenandoah parabolic dish solar collector, shown in Figure 1, consists of four subassemblies/subsystems: (1) mount and drive, (2) reflector, (3) receiver, (4) collector control. Key features of the collector are:

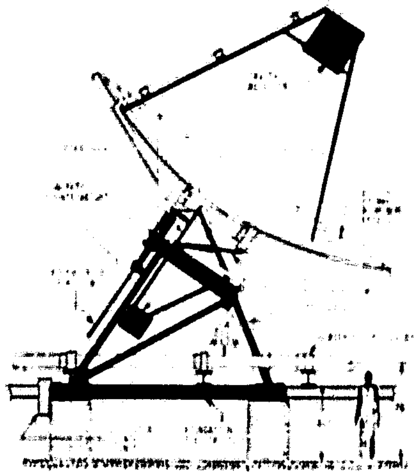

FIGURE 1. STES 7-METER PARABOLIC DISH SOLAR COLLECTOR

- Reflector diameter - 7 meters (23 feet)
- Receiver aperture diameter - 18 inches (46 cm)
- Geometric concentration ratio - 234
- f/D = 0.5 (focal length to diameter ratio)
- Cavity type receiver with coil-type heat exchanger
- Segmented reflector assembled from 21 die-stamped petals
- Polar and declination axes of rotation
- Motor and jackscrew drives
- Hybrid pointing control (computer and optical)
- Fabricated tripod mount structure with counter weighted, rotating yoke
- Drilled pier concrete foundations (3 per collector).

Key system requirements on the solar collector are:

- Energy output of 46000 Btuh (13482 watts) at 200 Btuh/ft^2 (630 W/m^2) direct insolation
- Fluid inlet temperature - 500°F (260°C)
- Fluid outlet temperature - 750°F (399°C)
- Heat transfer fluid - Syltherm™ 800
- Operate in winds to 30 mph (13.4 m/s)
- Survive winds of 90 mph (40.2 m/s)
- Maximum direct insolation - 325 Btuh/ft^2 (1025 W/m^2)
- Minimum direct insolation - 75 Btuh/ft^2 (237 W/m^2)
- Polar axis rotation - ± 90°
- Declination axis rotation - ± 23½°

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Solar collector specifications include the following:

- Collector overall efficiency - 56% min. @ 200 Btuh/ft^2
- Collector optical efficiency - 76% min., clean
- Receiver efficiency - 77% min. @ 200 Btuh/ft^2
- Parasitic power (average) - 62.5 watts.

Four prototype Shenandoah collectors were installed and tested at Sandia Laboratories in Albuquerque. Results are summarized in Figure 2. One collector had a FEK 244 (3M) metal acrylic reflective surface; one collector had a chemically brightened 5657-H241, one side bright aluminum reflective surface protected by an anodized coating; and two collectors had the same chemically brightened aluminum reflective surface, but were protected by a RTV 670 silicone coating. Results of testing are summarized, essentially in Figure 2. The collector with a FEK 244 reflective surface had the best performance and met design specifications. FEK 244 was selected as the reflective surface for the Shenandoah collectors.

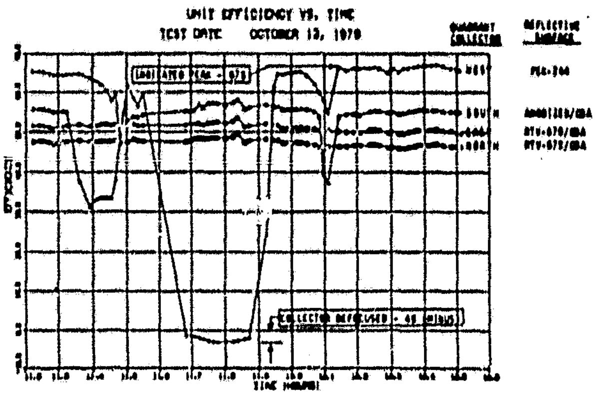

FIGURE 2. QUADRANT TEST SOLAR COLLECTORS

MOUNT AND DRIVES

The collector mount is a tripod structure fabricated from standard low-carbon/steel tube sections. The mount includes polar axis bearings and a bearing-mounted, concrete counter-weighted yoke structure. The yoke structure supports the hub via declination axis pivot points (2). The 3 legs of the mount tripod structure rest on a triangular base, which is fabricated from standard low carbon steel wide flange sections. The triangular base rests on and is bolted to the tops of the drilled pier concrete foundations (3).

Two, 1/10 hp, ac motor-driven jackscrews in series provide $\pm 90^\circ$ rotation around the polar axis, and one such jackscrew provides $\pm 23\frac{1}{2}^\circ$ rotation around the declination axis. Fluid supply and return lines to and from the receiver each include 2 flexible lines. The polar flex lines (1 supply and 1 return) are in a common boot enclosure, and the declination flex lines are in a common boot enclosure.

REFLECTOR

The segmented reflector assembly consists of 21, die-stamped aluminum petals, 21 supporting aluminum sheet metal ribs, and a fabricated steel hub weldment. Each petal is 10.6 feet long, 41.2 inches wide at the outside radius, and 2.4 inches wide at the inside radius. The FEK reflective film is applied to the flat sheet blanks prior to forming petals to contour. Slope error of the petal surface is 0.5 degree rms. Total reflectance of the FEK is 86%, and effective reflectance is 82%.

The petals, support ribs and hub are bolted together to form the reflector assembly. Aluminum struts (3) fabricated from standard low carbon steel tube sections are then bolted to the reflector assembly to support the receiver.

RECEIVER

The cavity-type receiver has a cone/cylinder configuration, coil-type heat exchanger inside. The coil has [illegible] turns, and is wound from 1/2 inch O.D. x 0.035 inch wall, Type 409 stainless steel tubing. The coil is coated with Pyromark-Black. The cannister is Type 430 stainless steel, 0.0178 inch thick, rolled and spot welded into a 36-inch high x $32\frac{1}{2}$-inch diameter cylinder. Keowood B (4 pcf) is the insulation used between the coil and the cannister. The aperture plate, on the bottom of the cannister cylinder, consists of 4, 90-degree segments of 0.120 inch thick, type 430 stainless steel. These segments are covered with Astroquartz #570 and are assembled to form an annular aperture plate with an 18 inch aperture. The aperture plate design, including addition of Astroquartz, was developed to solve over-temperature and warping problems experienced with the first aperture plates (of different designs) tested. Tips of fiber optics cables (4) protrude through the aperture plate, at quadrant points near the inner radius of the aperture plate. The mounting design of the fiber optics tips were also changed to increase temperature capability and solve early problems encountered in test. Figure 3 shows an isometric cataway of the Quadrant Test Receiver.

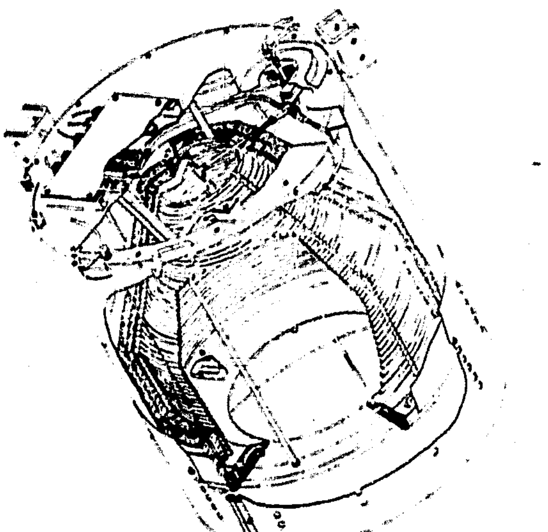

FIGURE 3. QUADRANT TEST RECEIVER ISOMETRIC CUTAWAY

COLLECTOR CONTROL

A collector control unit (CCU) is mounted on each collector. It interfaces with the control room/central control system, which generates by digital computer, pointing commands for coarse ($< 0.6^{\circ}$) pointing of each collector. The CCU contains the following major functions:

- 4 sun energy tracking sensors (at fiber optics terminals)
- Sun tracking electronics
- 2 RTD signal conditioners
- 2 potentiometer position signals
- Control electronics and relays for 3 Collector movement motors
- Serial data link communications station and associated control functions.

The major CCU operating modes are:

- Manual
- Computer track
- Auto-track
- Defocus
  - Emergency/overtemperature ($760^{\circ}F$)
  - Commanded

In the auto-track mode, differential signals from opposing pairs of fiber optics/transducers are used to cause appropriate contact closures/openings for each collector drive motor, for fine tracking control ($< 0.25^{\circ}$).

ACKNOWLEDGEMENTS

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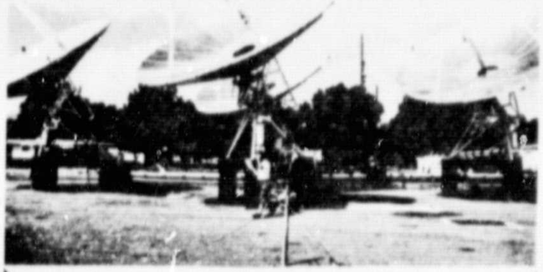

FIG. 4. QUADRANT TEST SOLAR COLLECTORS

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2. "Solar Total Energy - Large Scale Experiment at Shenandoah, Georgia, Phase III Preliminary Design Final Report", General Electric Company Space Division Document No. 78SDS4243, King of Prussia, Pennsylvania, September 1978