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Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data

Alpha Solarco Model 104 Solar Collector With 0.125-Inch
Schott Low-Iron Glass Reflector Surface

Thomas D. Harrison

Prepared by Sandia National Laboratories, Albuquerque, New Mexico 87185
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MIDTEMPERATURE SOLAR SYSTEMS TEST FACILITY
PREDICTIONS FOR THERMAL PERFORMANCE BASED ON TEST DATA

ALPHA SOLARCO MODEL 104 SOLAR COLLECTOR
WITH 0.125-INCH SCHOTT LOW-IRON GLASS REFLECTOR SURFACE

Thomas D. Harrison
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ABSTRACT

Thermal performance predictions based on test data are presented for the Alpha Solarco Model 104 solar collector, with 0.125-inch Schott low-iron glass reflector surface, for three output temperatures at five cities in the United States.

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MIDTEMPERATURE SOLAR SYSTEMS TEST FACILITY
PREDICTIONS FOR THERMAL PERFORMANCE BASED ON TEST DATA

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Introduction

Sandia National Laboratories, Albuquerque (SNLA), is currently conducting a program to predict the performance and measure the characteristics of commercially available solar collectors that have the potential for use in industrial process heat and enhanced oil recovery applications. A detailed account of the methods used to make the predictions is given in Reference 1. For the convenience of the reader, some of this information is repeated in this document. This document presents the thermal performance predictions for the Alpha Solarco Model 104 solar line-focusing collector. The program is limited to thermal performance only and does not include consideration of other factors, such as

1. Losses at the ends, at gaps, and from shadowing due to packing,
2. Collector warm-up penalties,
3. Degradation of performance,
4. Cost of the collector,
5. Losses in the energy transport system and system warm-up penalties,
6. Reliability,
7. Cost of installation,
8. Cost of operation and maintenance, and
9. Wind effects.

The program is authorized by the Department of Energy, Division of Solar Thermal Energy Systems, and is partially funded through the Solar Energy Research Institute.

Description of the Collector

A photograph of the Alpha Solarco Model 104 collector is shown in Figure 1. The module has the following characteristics.

Reflector configuration	6 parabolic troughs, 90° rim angle
Reflective surface	0.125-inch Schott low-iron glass second surface
Aperture dimensions	0.63 m x 2.83 m (2.06 ft x 9.2 ft)
Aperture area	8.9 m ² (95.84 ft ²)
Support structure	ABS plastic
Tracking system	Alpha Solarco
Drive mechanism	Electric
Heat transfer fluid	Therminol-66®
Operating range	100° to 200°C (212° to 392°F)
Manufacturer	Alpha Solarco 1014 Vine St. Cincinnati, OH 45202

Results of the Test Program

This collector was tested at the DSET Laboratories, Phoenix, Arizona. From the test data, three parameters were defined.

1. Peak efficiency (η_p) -- the efficiency of the collector when the sun's rays are at normal incidence to the aperture plane (equivalent to solar noon) expressed as a function of $\Delta t/I$. Δt is the temperature difference between the heat transfer fluid outlet temperature and the ambient temperature in degrees Centigrade. I is the irradiance of the sun in watts per square meter.

$$\eta_p = 74.9 - 247.6 \Delta t/I^2 \quad . \quad (\%)$$

Peak efficiency is plotted in Figure 2.

Figure 1. Alpha Solarco Model 104 Solar Collector
with 0.125-Inch Schott Low-Iron Glass
Reflector Surface

Figure 2. Peak Efficiency Plot for the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface

2. Receiver thermal loss (Q_L) -- the heat lost per unit aperture area expressed as a function of Δt .

$$Q_L = 0.00 + 0.551 \Delta t + 5.56 \times 10^{-3} (\Delta t)^2 \text{ . (W/m}^2\text{)}$$

Heat loss is plotted in Figure 3.

Figure 3. Heat Loss Plot for the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface

3. Optical loss coefficient (K_O) -- K_O , in conjunction with the end-loss coefficient, K_E , and the "cosine effect," determine the incident angle modifier, K . Specifically, $K = K_O K_E \cos\theta$. See Reference 1.

The values of K_o as a function of θ are

θ (degrees)	K_o	θ (degrees)	K_o
0	1.00	45	0.76
15	1.00	60	0.37
30	0.86		

In these data, no correction has been made for "end effects."

Prediction of Thermal Performance

A computer program calculates the predicted thermal performance of the collector. The performance parameters defined above are the input data describing the collector while solar and weather data are provided by TMY data tapes. With this input, the computer program calculates the thermal output of the collector for each month of the TMY in units of kilowatt hours per square meter (kWh/m^2) of collector aperture area. This calculation was made for five locations: Fresno, California; Albuquerque, New Mexico; Fort Worth, Texas; Charleston, South Carolina; and Boston, Massachusetts. Three different collector output temperatures and both E-W and N-S orientations were considered. For the N-S orientation, the collector axis is tilted toward the south at an angle equal to the latitude of the location. Figures 4 through 8 are graphical displays of the results of the computer prediction. These figures show the monthly thermal output ($\text{kWh}/\text{m}^2 \cdot \text{mo}$) for each location, output temperature, and orientation. The monthly outputs have been summed to give the annual output for each parameter variation, and the results are shown in Table 1. The computer predictions assume 1 square meter of collector aperture in the middle of a row of infinite length with no gap losses and no shadowing due to packing.

Figure 4. Thermal Output of the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface with E-W and N-S Orientation and Fresno TMY Solar Data

Figure 5. Thermal Output of the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface with E-W and N-S Orientation and Albuquerque TMY Solar Data

Figure 6. Thermal Output of the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface with E-W and N-S Orientation and Fort Worth TMY Solar Data

Figure 7. Thermal Output of the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface with E-W and N-S Orientation and Charleston TMY Solar Data

Figure 8. Thermal Output of the Alpha Solarco Model 104 Solar Collector with 0.125-Inch Schott Low-Iron Glass Reflector Surface with E-W and N-S Orientation and Boston TMY Solar Data

Table 1
Predicted Annual Thermal Output (kWh/m².yr)

	Solar Energy Available	Output Temperature					
		100°C		150°C		200°C	
		Orientation		Orientation		Orientation	
		E-W	N-S	E-W	N-S	E-W	N-S
Fresno	2260	706	1010	490	668	289	374
Albuquerque	2583	831	1155	598	800	376	481
Fort Worth	1764	556	732	368	460	198	234
Charleston	1358	408	502	242	286	109	123
Boston	1173	300	395	170	213	69	83

NOTE: For the N-S orientation, the collector axis is tilted toward the south at an angle equal to the latitude of the location (e.g., tilted at 36.77° for Fresno, 35.05° for Albuquerque, etc.).

Previously Published Predictions

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