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

Toltec Two-Axis Tracking Solar Collector with
3M Acrylic Polyester Film Reflector Surface

Thomas D. Harrison

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

TOLTEC TWO-AXIS TRACKING SOLAR COLLECTOR
WITH 3M ACRYLIC POLYESTER FILM REFLECTOR SURFACE

Thomas D. Harrison
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ABSTRACT

Thermal performance predictions based on test data are presented for the Toltec solar collector, with acrylic film 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

TOLTEC TWO-AXIS TRACKING SOLAR COLLECTOR
WITH 3M ACRYLIC POLYESTER FILM REFLECTOR SURFACE

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 Toltec two-axis tracking 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 Toltec two-axis collector is shown in Figure

1. The module has the following characteristics.

Reflector configuration	Four parabolic troughs
Reflective surface	3M acrylic polyester film
Aperture dimensions	1.02 m x 2.95 m (3.35 ft x 9.68 ft)
Aperture area (four troughs)	12.04 m ² (129.6 ft ²)
Support structure	Fiberglass on a steel frame
Tracking system	Shadow band, two-axis tracking
Drive mechanism	Electric
Heat transfer fluid	Therminol 66®
Operating range	50° to 200°C (112° to 392°F)
Manufacturer	Toltec, Inc. 40th and East Main, RR/1 Clear Lake, IA 50428

Results of the Test Program

This collector was tested at Sandia National Laboratories, Albuquerque, New Mexico. From the test data, two 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.

$$\eta_p = 72.2 - 83.6 \Delta t/I - 62.51 (\Delta t/I)^2 \cdot (\%)$$

Peak efficiency is plotted in Figure 2.

Figure 1. Toitec Two-Axis Tracking Solar Collector

Figure 2. Peak Efficiency Plot for the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface

2. Optical losses -- The value of the optical incident angle modifier for two-axis tracking collectors is judged to be 1 at all times because the incident angle is always zero degrees.

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 six locations: Fresno, California; Albuquerque, New Mexico; Fort Worth, Texas; Charleston, South Carolina; Boston, Massachusetts; and Phoenix, Arizona. Three different collector output temperatures were considered. Figures 3 through 8 are graphical displays of the results of the computer prediction. These figures show the monthly thermal output ($\text{kWh/m}^2 \cdot \text{mo}$) for each location and output temperature. 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 end or gap losses and no shadowing due to packing.

Figure 3. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Fresno TMY Solar Data.

Figure 4. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Albuquerque TMY Solar Data.

Figure 5. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Fort Worth TMY Solar Data

Figure 6. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Charleston TMY Solar Data

Figure 7. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Boston TMY Solar Data

Figure 8. Thermal Output of the Toltec Two-Axis Tracking Solar Collector with Acrylic Polyester Film Reflector Surface and Phoenix TMY Solar Data

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

	Solar Energy Available	Output Temperature		
		100°C	150°C	200°C
Fresno	2260	1366	1193	1018
Albuquerque	2583	1579	1403	1224
Fort Worth	1764	1041	894	750
Charleston	1358	766	638	514
Boston	1173	635	520	412
Phoenix	2477	1536	1358	1176

CAUTION: The above predictions are somewhat optimistic for more than one trough. Thermal losses from the manifolds which interconnect the four troughs were included in the calculation of the efficiency equation, and there were no end losses because the incident angle is zero degrees. However, as stated on page 10 of Reference 1, losses due to shadowing were not included. For low sun angles, there is some shadowing of troughs behind the one nearest the sun. The amount of shadowing is a function of latitude, season of the year, and trough spacing.

This is the final report in this series.

Previously Published Predictions

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6011	Patents

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