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

Custom Engineering Trough With Glass
Reflector Surface and Sandia-Designed Receivers

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:

CUSTOM ENGINEERING TROUGH
WITH GLASS REFLECTOR SURFACE AND SANDIA-DESIGNED RECEIVERS

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ABSTRACT

Thermal performance predictions based on test data are presented for the Custom Engineering trough and Sandia-designed receivers, with glass reflector surface, for three output temperatures at five cities in the United States. Two experimental receivers were tested, one with an antireflective coating on the glass envelope around the receiver tube and one without the antireflective coating.

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

CUSTOM ENGINEERING TROUGH
WITH GLASS REFLECTOR SURFACE AND SANDIA-DESIGNED RECEIVERS

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 Custom Engineering trough using Sandia-designed experimental receivers. 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 Custom Engineering collector is shown in Figure 1. The module has the following characteristics.

Reflector configuration	Parabolic trough, 5 troughs per string
Reflective surface	Corning 0317 heat-formed glass, 1.5 mm (0.06 inch) thick
Aperture dimensions	2.74 m x 18.28 m (9 ft x 60 ft)
Aperture area	50 m ² (540 ft ²)
Support structure	Fiberglass honeycomb
Tracking system	Computer-pointed
Drive mechanism	Electric
Heat transfer fluid	Therminol-66®
Operating range	100° to 300°C (212° to 572°F)
Trough manufacturer	Custom Engineering 2805 S. Tejon St. Englewood, CO 80110

Two receivers were tested, one with an antireflective coating on the glass envelope around the receiver tube and one without the antireflective coating. The receivers were designed and fabricated by SNLA. The test results for both are reported below.

Results of the Test Program

This collector configuration was tested at the Systems Test Facility of the Midtemperature Solar Systems Test Facility at SNLA. 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.

Figure 1. Custom Engineering Solar Collector

Case 1 -- with antireflective coating on glass envelope

$$\eta_p = 73.4 - 24.9 \Delta t/I - 47.4 (\Delta t/I)^2 \cdot (\%)$$

Case 2 -- without antireflective coating on glass envelope

$$\eta_p = 73.4 - 23.4 \Delta t/I - 156 (\Delta t/I)^2 \cdot (\%)$$

Peak efficiency for both cases is plotted in Figure 2.

Figure 2. Peak Efficiency Plot for the Custom Engineering Solar Collector with Antireflective Coating and without Antireflective Coating

2. 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 optical incident angle modifiers were the same for the case with the antireflective coating as for the case without the antireflective coating.

The values of K_O as a function of θ are

θ (degrees)	K_O	θ (degrees)	K_O
0	1.00	40	0.90
10	0.98	50	0.82
20	0.96	60	0.79
30	0.93		

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. Figures 3 through 7 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 for the case with the antireflective coating. The graphs for the case without the antireflective coating are very similar and therefore are not included here. The monthly outputs have been summed to give the annual output for each parameter variation, and the results for Case 1 (with the

Figure 3. Thermal Output of the Custom Engineering Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Fresno TMY Solar Data

Figure 4. Thermal Output of the Custom Engineering Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Albuquerque TMY Solar Data

Figure 5. Thermal Output of the Custom Engineering Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Fort Worth TMY Solar Data

Figure 6. Thermal Output of the Custom Engineering Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Charleston TMY Solar Data

Figure 7. Thermal Output of the Custom Engineering Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Boston TMY Solar Data

antireflective coating) are shown in Table 1; the results for Case 2 (without the antireflective coating), in Table 2. 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.

Table 1

Predicted Annual Thermal Output ($\text{kWh/m}^2\cdot\text{yr}$) for Case 1
with Antireflective Coating on Glass Envelope

	Solar Energy Available	Output Temperature					
		100°C		200°C		300°C	
		Orientation		Orientation		Orientation	
		E-W	N-S	E-W	N-S	E-W	N-S
Fresno	2260	1124	1320	1021	1183	896	1022
Albuquerque	2583	1304	1465	1198	1330	1072	1174
Fort Worth	1764	893	992	799	868	690	732
Charleston	1358	702	732	610	621	503	500
Boston	1173	574	604	491	505	400	402

Table 2

Predicted Annual Thermal Output ($\text{kWh/m}^2\cdot\text{yr}$) for Case 2
without Antireflective Coating on Glass Envelope

	Solar Energy Available	Output Temperature					
		100°C		200°C		300°C	
		Orientation		Orientation		Orientation	
		E-W	N-S	E-W	N-S	E-W	N-S
Fresno	2260	1098	1283	914	1042	676	747
Albuquerque	2583	1276	1428	1091	1194	848	901
Fort Worth	1764	869	957	704	746	498	501
Charleston	1358	675	697	511	507	324	306
Boston	1173	545	568	401	402	242	233

Previously Published Predictions

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance of the Solar Kinetics T-700 Solar Collector with FEK 244 Reflector Surface, SAND80-1964/1 (Albuquerque: Sandia National Laboratories, November 1980).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance of the Suntec Solar Collector with Heat-Formed Glass Reflector Surface, SAND80-1964/2 (Albuquerque: Sandia National Laboratories, November 1980).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance of the Acurex Solar Collector with FEK-244 Reflector Surface, SAND80-1964/3 (Albuquerque: Sandia National Laboratories, January 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data; Sun-Heet Nontracking Solar Collector, SAND80-1964/4 (Albuquerque: Sandia National Laboratories, March 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data; AAI Solar Collector with Pressure-Formed Glass Reflector Surface, SAND80-1964/5 (Albuquerque: Sandia National Laboratories, March 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data; Acurex Solar Collector with Glass Reflector Surface, SAND80-1964/6 (Albuquerque: Sandia National Laboratories, March 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data; Solar Kinetics T-700 Solar Collector with Glass Reflector Surface, SAND80-1964/7 (Albuquerque: Sandia National Laboratories, March 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data; Alpha Solarco Model 104 Solar Collector with 0.125 Low-Iron Glass Reflector Surface, SAND80-1964/8 (Albuquerque: Sandia National Laboratories, April 1981).

Thomas D. Harrison, Midtemperature Solar Systems Test Facility Program for Predicting Thermal Performance Based on Test Data; Solar Kinetics T-600 Solar Collector with FEK 244 Reflector Surface, SAND80-1964/9 (Albuquerque: Sandia National Laboratories, April 1981).

Reference

¹T. D. Harrison, Midtemperature Solar Systems Test Facility Program for Predicting Thermal Performance of Line-Focusing, Concentrating Solar Collectors, SAND80-1964 (Albuquerque: Sandia National Laboratories, November 1980).

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