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

Sun-Heet Nontracking Solar Collector

Thomas D. Harrison

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

SUN-HEET NONTRACKING SOLAR COLLECTOR

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ABSTRACT

Thermal performance predictions based on test data are presented for the Sun-Heet nontracking solar collector for two 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

SUN-HEET NONTRACKING SOLAR COLLECTOR

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 Sun-Heet nontracking, 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 Sun-Heet solar collector is shown in Figure 1. The module has the following characteristics.

Reflector configuration	2 parabolic troughs housed in a single frame
Reflective surface	Anodized aluminum
Aperture dimensions	2.87 m x 1.64 m (9.42 ft x 5.38 ft)
Aperture area	4.70 m^2 (50.66 ft^2)
Support structure	Rectangular fiberglass framework, 3.13 m x 1.85 m x 0.33 m (10.27 ft x 6.07 ft x 1.08 ft)
Tracking system	System is manually adjusted for tilt on a monthly schedule.
Heat transfer fluid	Therminol-66®
Operating range	100° to 150°C (212° to 302°F)
Manufacturer	Sun-Heet, Inc. 2624 S. Zuni Englewood, CO 80110

Results of the Test Program

This collector was tested at the DSET Laboratories, Phoenix, Arizona, in May, 1980. 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.

$$\eta_p = 50.0 - 40.0\ \Delta t/I\ .\ (\%)$$

Peak efficiency is plotted in Figure 2.

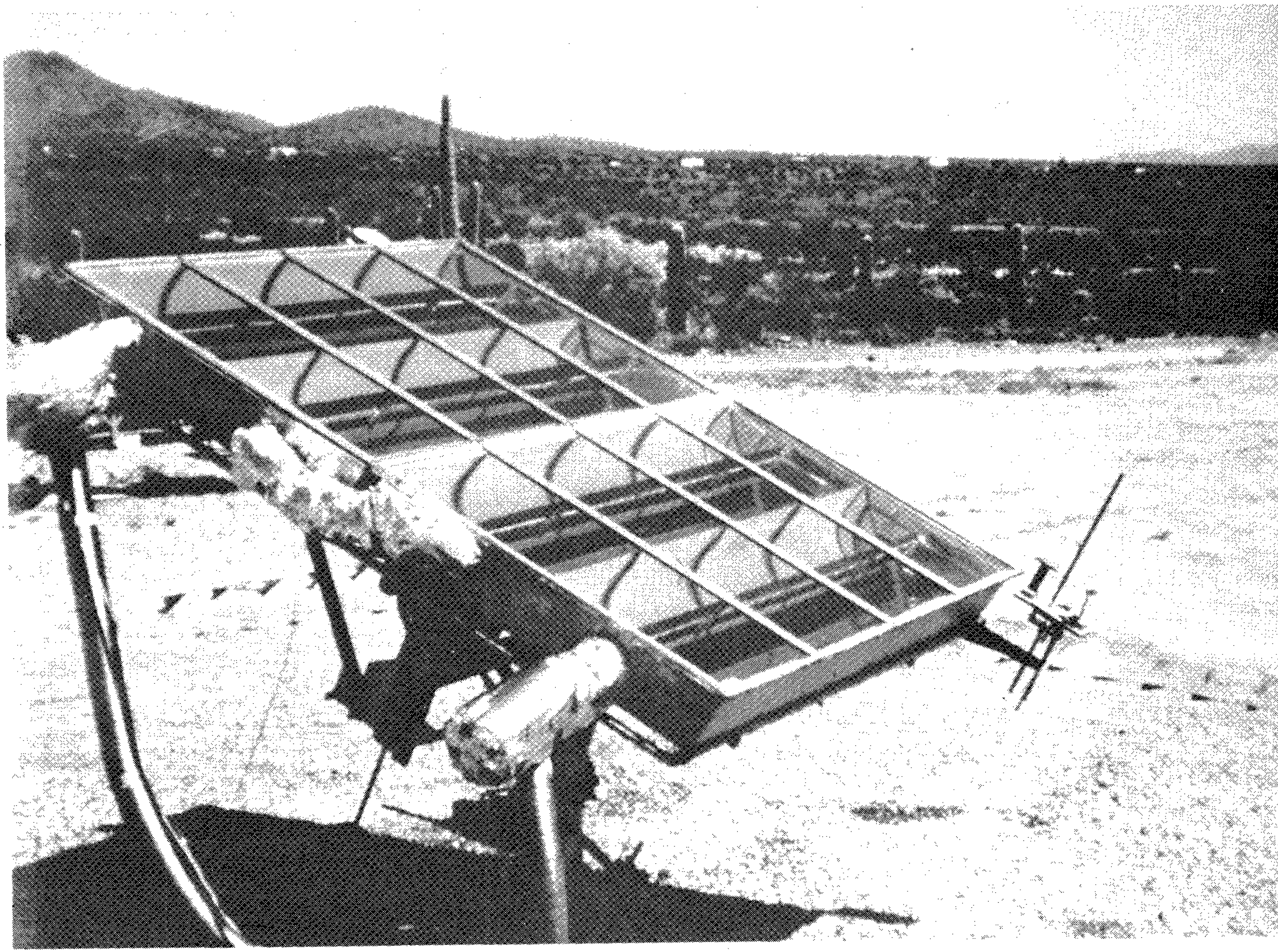

Figure 1. Sun-Heet Nontracking Solar Collector

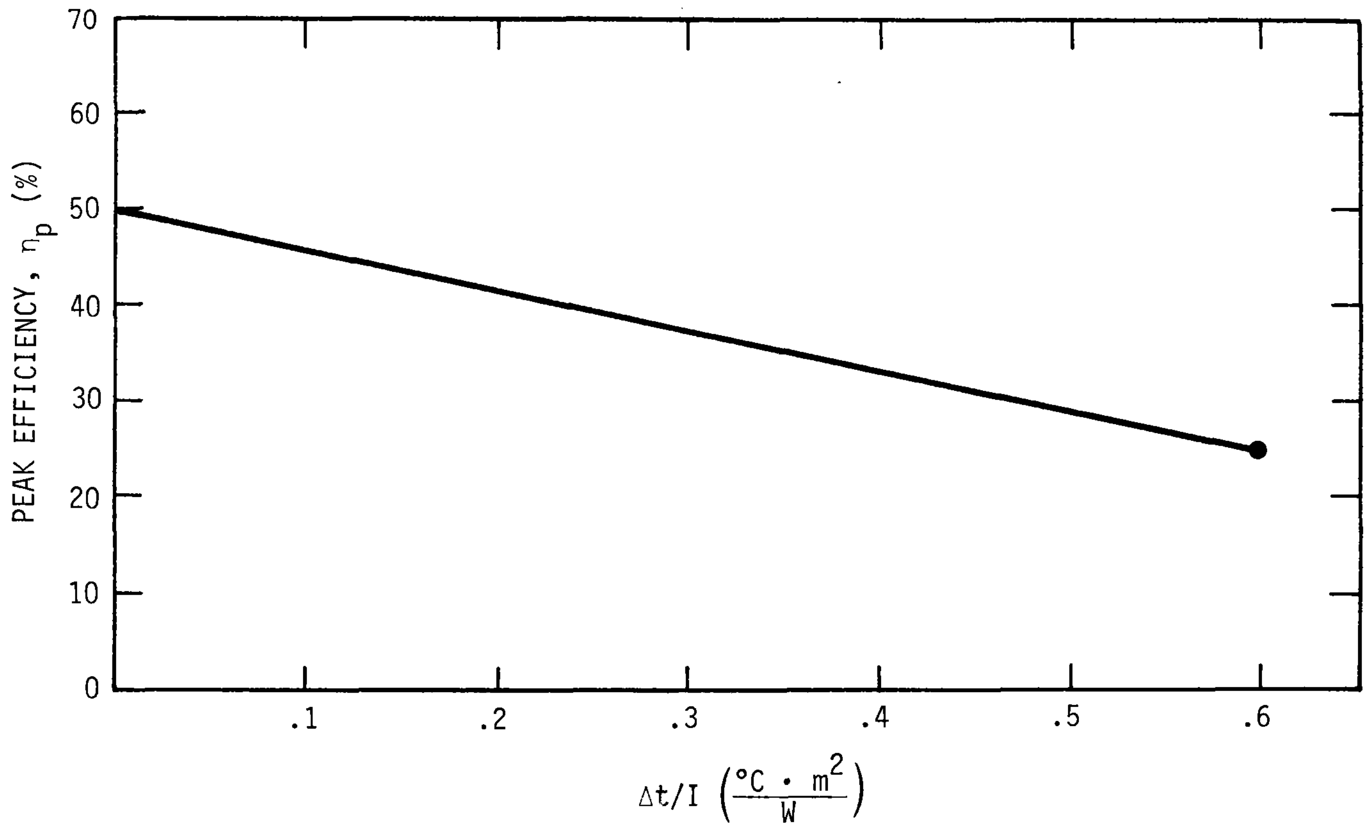

Figure 2. Peak Efficiency Plot for the Sun-Heet Nontracking Solar Collector

2. Since the Sun-Heet collector is nontracking, the method described in Reference 1 for quantifying the incident angle modifier, K, is inapplicable. Therefore, for the Sun-Heet collector, the following method is used.

The Sun-Heet collector is assumed to be facing due south and tilted at an angle s (i.e., the angle between the normal to the aperture plane and a vertical line is s). The N-S vertical plane through the normal to the aperture plane is termed the "N-S plane." The plane through the normal to the aperture plane and perpendicular to both the aperture plane and the N-S plane is termed the "E-W plane." The south profile angle (SPA) is defined as the angle between the normal to the aperture plane and the projection of the sun's ray onto the N-S plane. The east profile angle (EPA) is defined as the angle between the normal to the aperture plane and the projection of the sun's ray upon the E-W plane. SPA and EPA are calculated from

$$SPA = \arctan\left[\frac{\tan EL}{\cos AZ}\right] - s$$

$$EPA = \arctan\left[\frac{\tan EL}{\sin AZ \cdot \cos s}\right]$$

where

EL = elevation angle of the sun and

AZ = azimuth angle of the sun

SPA is positive when it falls below the E-W plane.

The incident angle modifier, K, for the Sun-Heet collector is defined as

$$K = K_S \; K_E$$

where

K_s is a function of SPA and

K_E is a function of EPA

The values of K_s are tabulated in Table 1.

The values of K_E are tabulated in Table 2.

Table 1

K_s As a Function of SPA

SPA (degrees)	K_s
30	0.602
20	0.618
10	0.906
0	0.989
-10	0.993
-20	0.964
-30	0.689

Table 2

K_E As a Function of EPA

EPA (degrees)	K_E
0	0.989
15	1.023
30	1.031
45	0.967
60	0.923

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. Two different collector output temperatures were considered. Figures 3 through 7 are graphical displays of the results of the computer prediction. These figures show the monthly thermal output (kWh/m^2·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 3. The computer predictions are normalized to 1 square meter of aperture area.

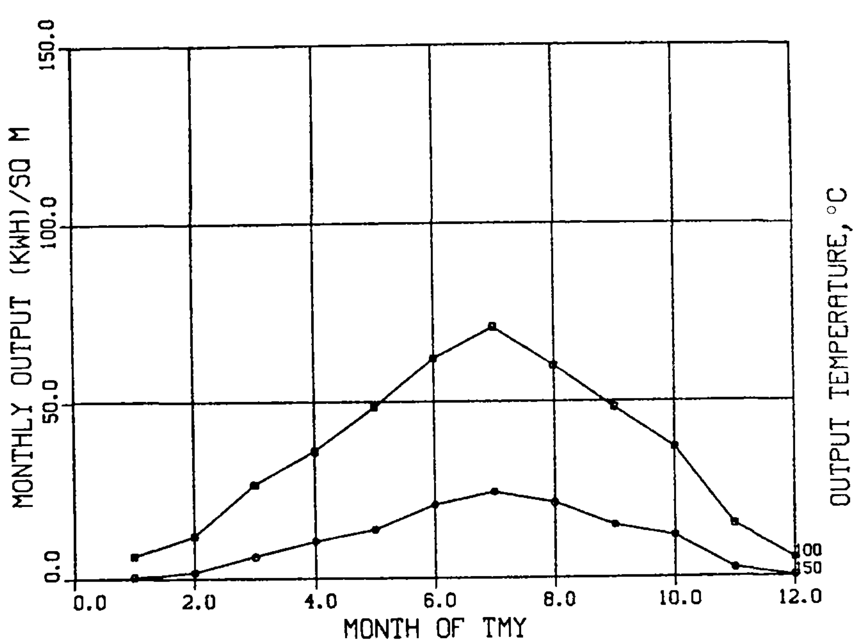

Figure 3. Thermal Output of the Sun-Heet Nontracking Solar Collector with E-W Orientation and Fresno TMY Solar Data

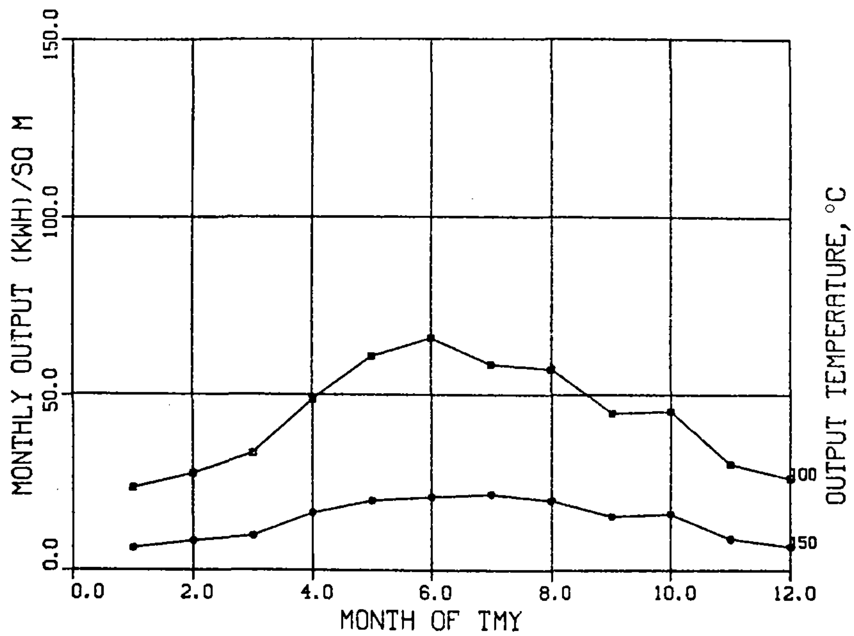

Figure 4. Thermal Output of the Sun-Heet Nontracking Solar Collector with E-W Orientation and Albuquerque TMY Solar Data

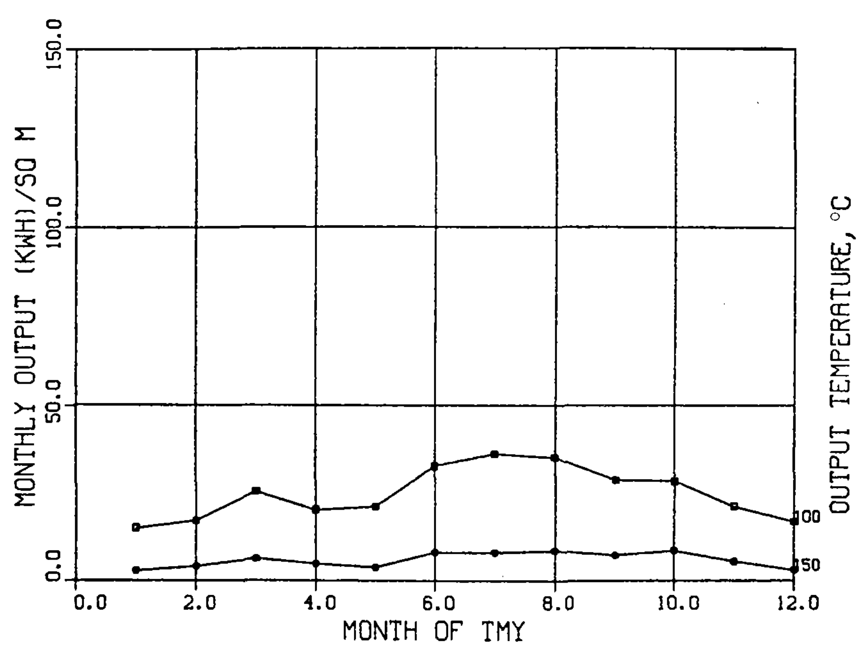

Figure 5. Thermal Output of the Sun-Heet Nontracking Solar Collector with E-W Orientation and Fort Worth TMY Solar Data

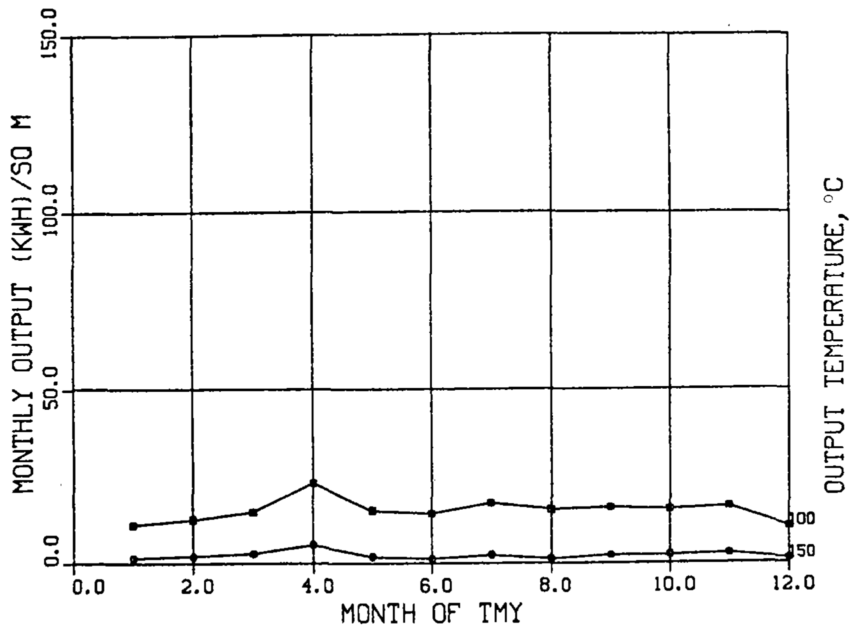

Figure 6. Thermal Output of the Sun-Heet Nontracking Solar Collector with E-W Orientation and Charleston TMY Solar Data

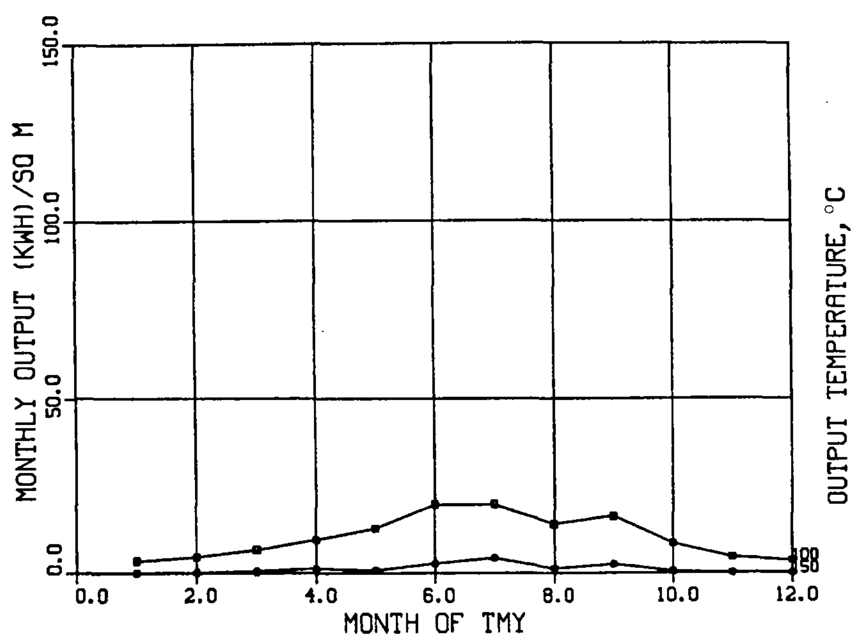

Figure 7. Thermal Output of the Sun-Heet Nontracking Solar Collector with E-W Orientation and Boston TMY Solar Data

Table 3

Predicted Annual Thermal Output (kWh/m^2•yr)

	Solar Energy Available	Output Temperature 100°C	150°C
Fresno	2260	431	131
Albuquerque	2583	525	174
Fort Worth	1764	303	73
Charleston	1358	186	28
Boston	1173	126	14

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).

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[1]T. 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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