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

Polisolar Model POL Solar Collector With Glass Reflector Surface

Thomas D. Harrison

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

POLISOLAR MODEL POL SOLAR COLLECTOR WITH GLASS REFLECTOR SURFACE

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ABSTRACT

Thermal performance predictions based on test data are presented for the Polisolar Model POL solar collector, with glass reflector surface, for three output temperatures at five cities in the United States.

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POLISOLAR MODEL POL SOLAR COLLECTOR
WITH GLASS 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 Polisolar Model POL 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 Polisolar Model POL collector is shown in Figure 1. The module has the following characteristics.

Reflector configuration	Four parabolic troughs
Reflective surface	Glass, type unknown
Aperture dimensions	0.775 m x 3.185 m (2.54 ft x 10.45 ft)
Aperture area	9.868 m^2 (106 ft^2)
Support structure	Glass
Tracking system	Shadow band
Drive mechanism	Electric
Heat transfer fluid	Therminol 66®
Operating range	50° to 200°C (112° to 392°F)
Manufacturer	Polisolar/AG Bern, Switzerland

This collector was purchased in 1978 for evaluation. It remained disassembled in storage until the summer of 1980 when it was shipped to DSET and assembled in accordance with instructions prepared by SNLA on the basis of manufacturer's instructions. Some degradation due to aging and some degradation of performance due to assembly errors are possible. If any such degradations exist, they are believed to be small.

Results of the Test Program

This collector was tested at 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

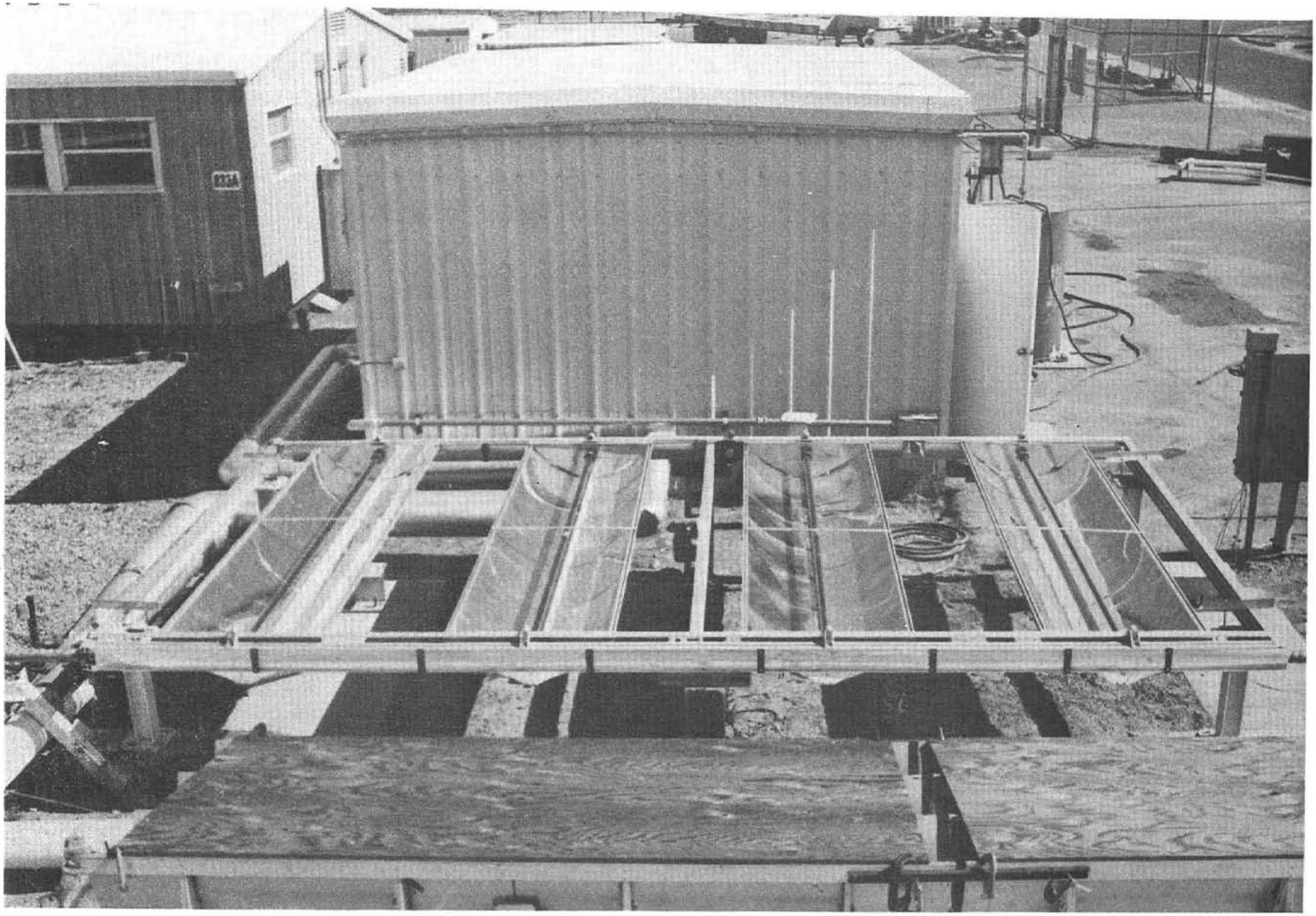


Figure 1. Polisolar Model POL Solar Collector

degrees Centigrade. I is the irradiance of the sun in watts per square meter.

$$\eta_p = 70.6 - 163.2\ \Delta t/I\ .\ (\%)$$

Peak efficiency is plotted in Figure 2.

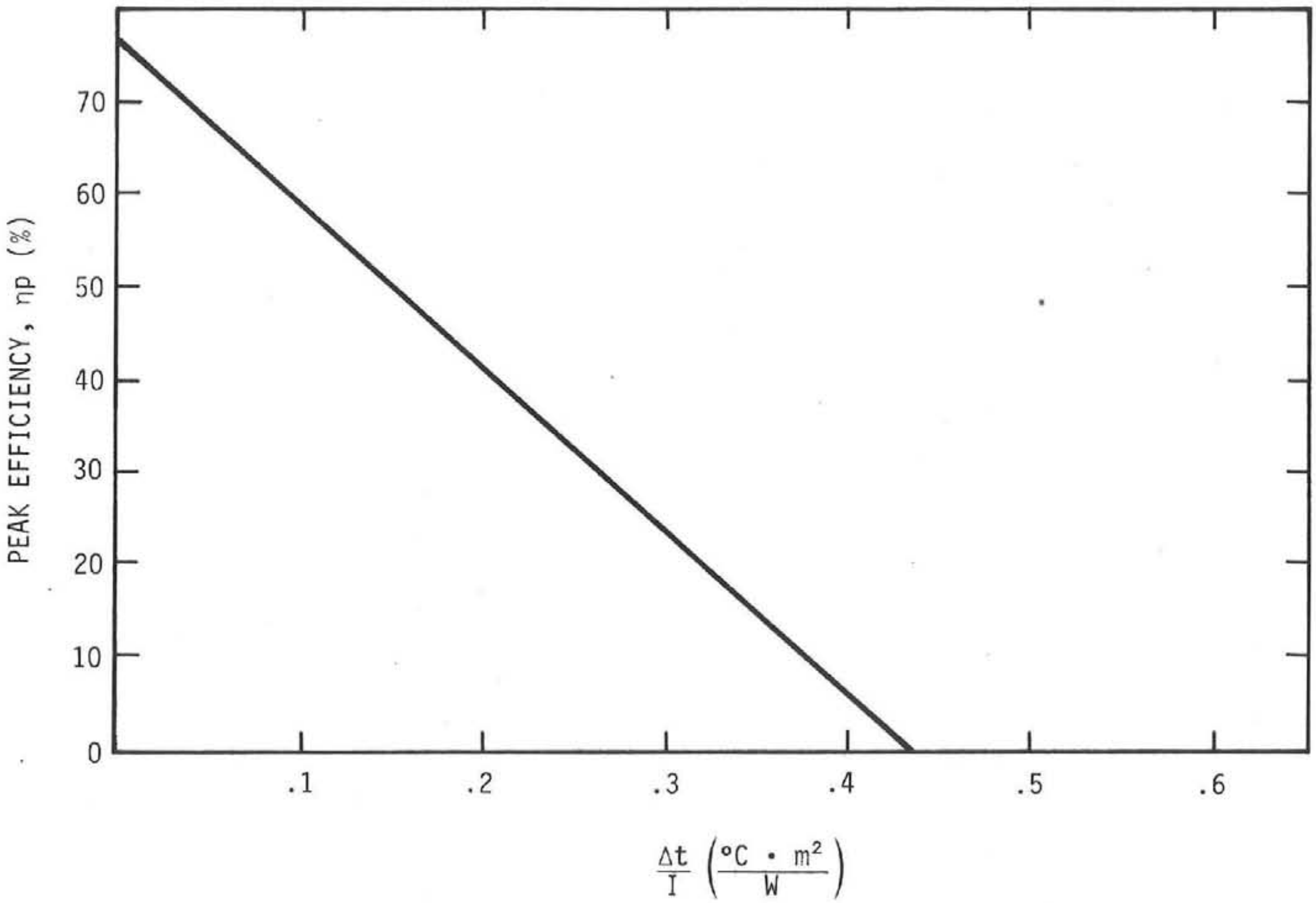


Figure 2. Peak Efficiency Plot for the Polisolar Model POL Solar Collector with Glass Reflector Surface

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

$$Q_L = 0.00 + 1.63\ \Delta t\ (\Delta t)^2\ .\ (W/m^2)$$

Heat loss is plotted in Figure 3.

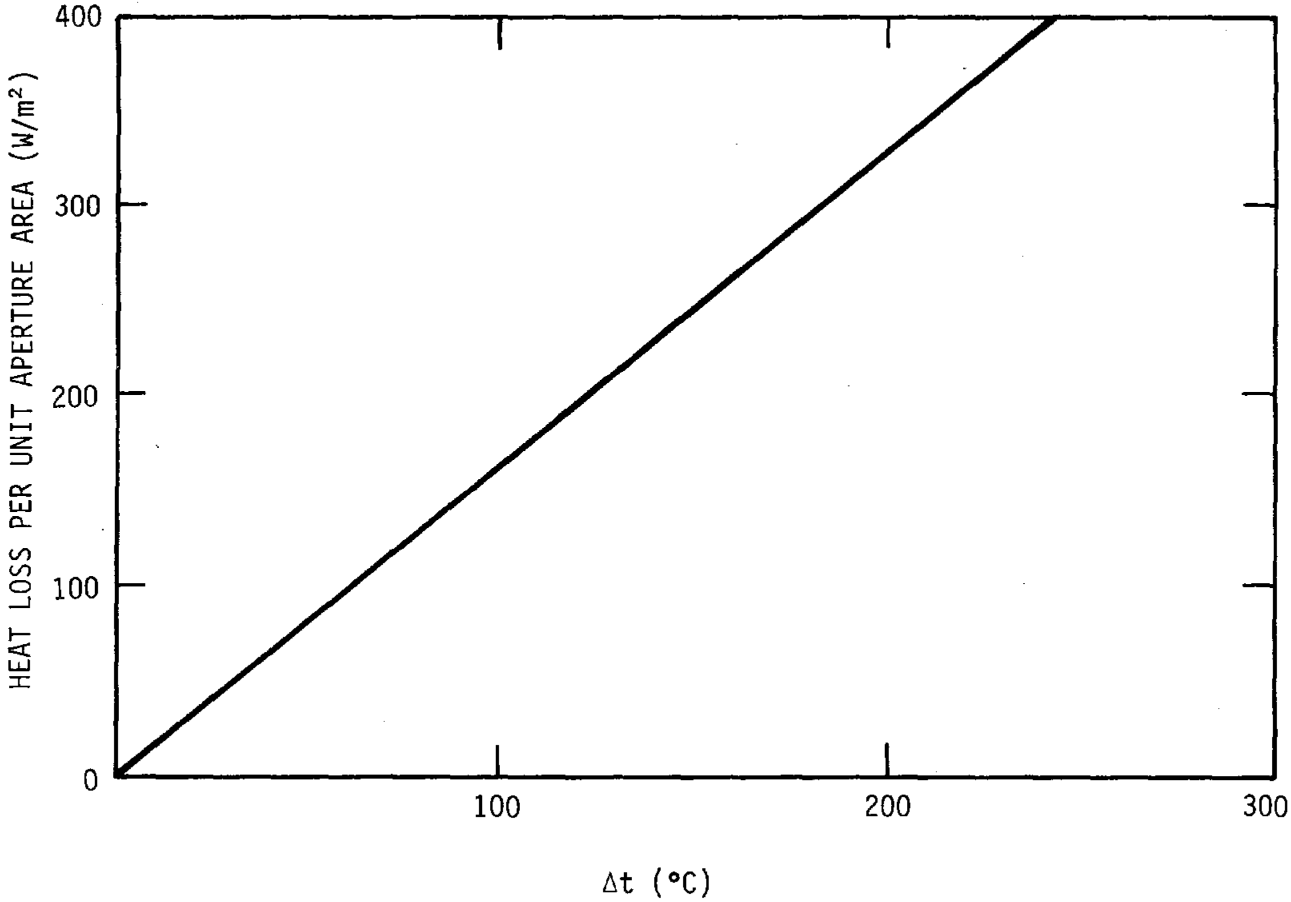


Figure 3. Heat Loss Plot for the Polisolar Model POL Solar Collector with Glass Reflector Surface

3. Optical losses -- 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 $K_O K_E$ as a function of θ are

θ (degrees)	$K_O K_E$	θ (degrees)	$K_O K_E$
0	1.00	40	0.89
10	0.98	50	0.81
20	0.97	60	0.64
30	0.94		

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 case, the collector axis was tilted toward the south at an angle equal to the local latitude. Figures 4 through 8 are graphical displays of the results of the computer prediction. These figures show the monthly thermal output ($kWh/m^2 \cdot mo$) 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 end or gap losses and no shadowing due to packing.

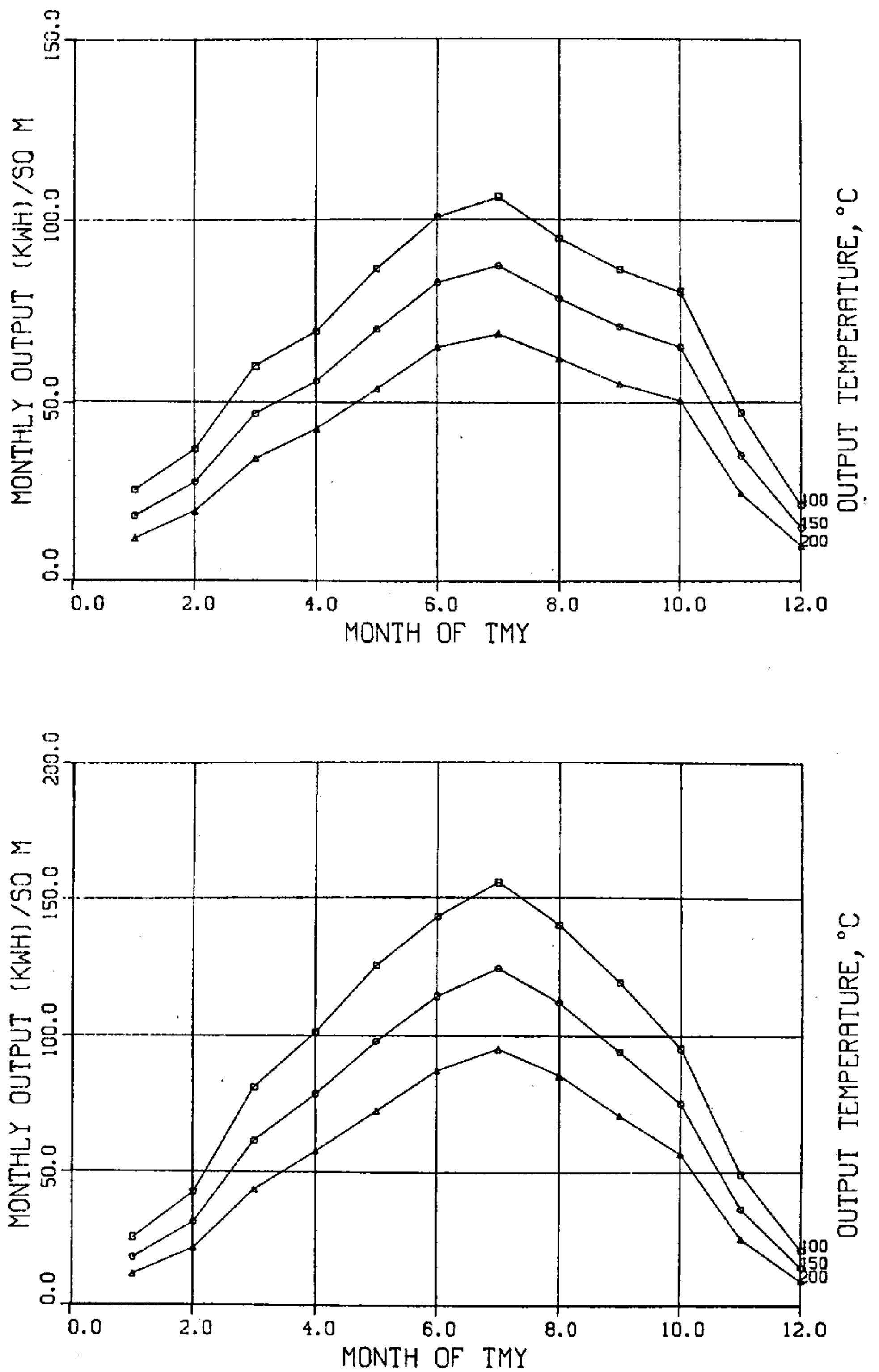
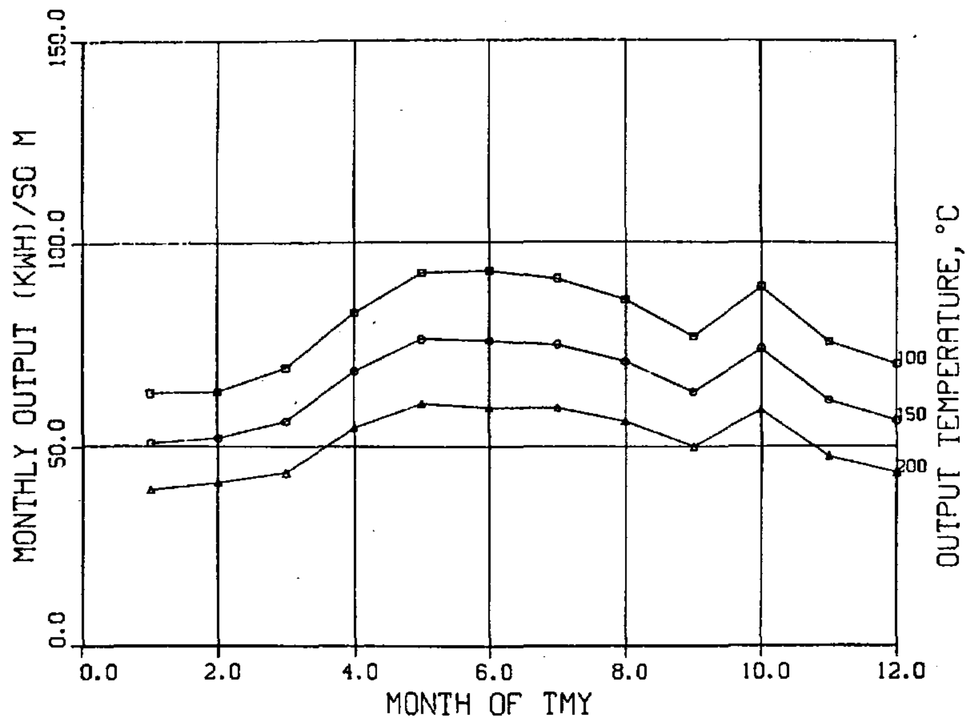


Figure 4. Thermal Output of the Polisolar Model POL Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Fresno TMY Solar Data



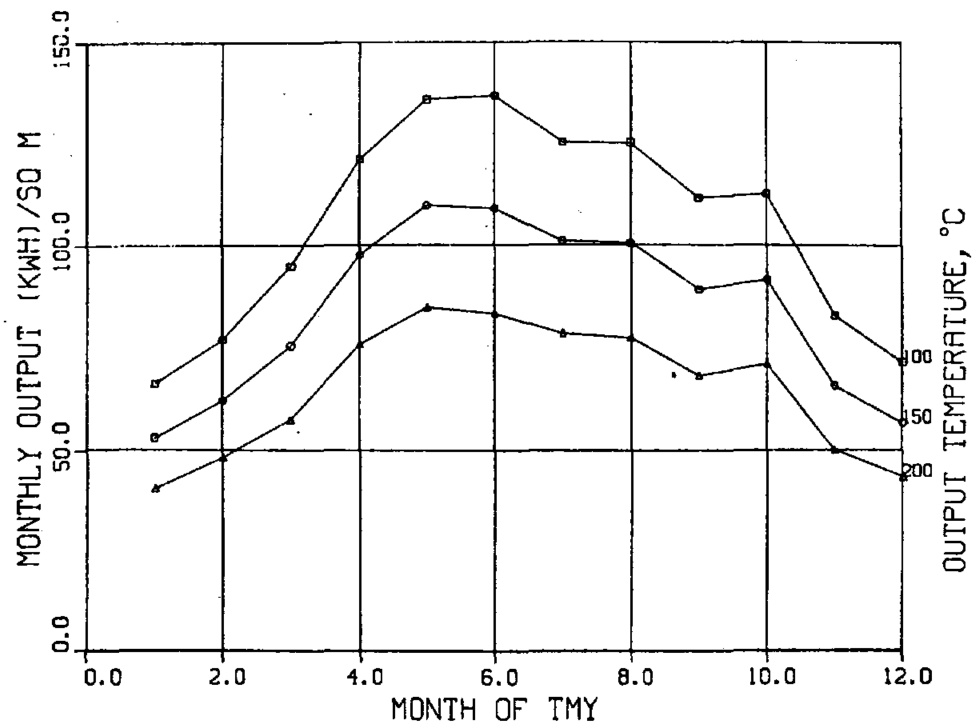


Figure 5. Thermal Output of the Polisolar Model POL Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Albuquerque TMY Solar Data

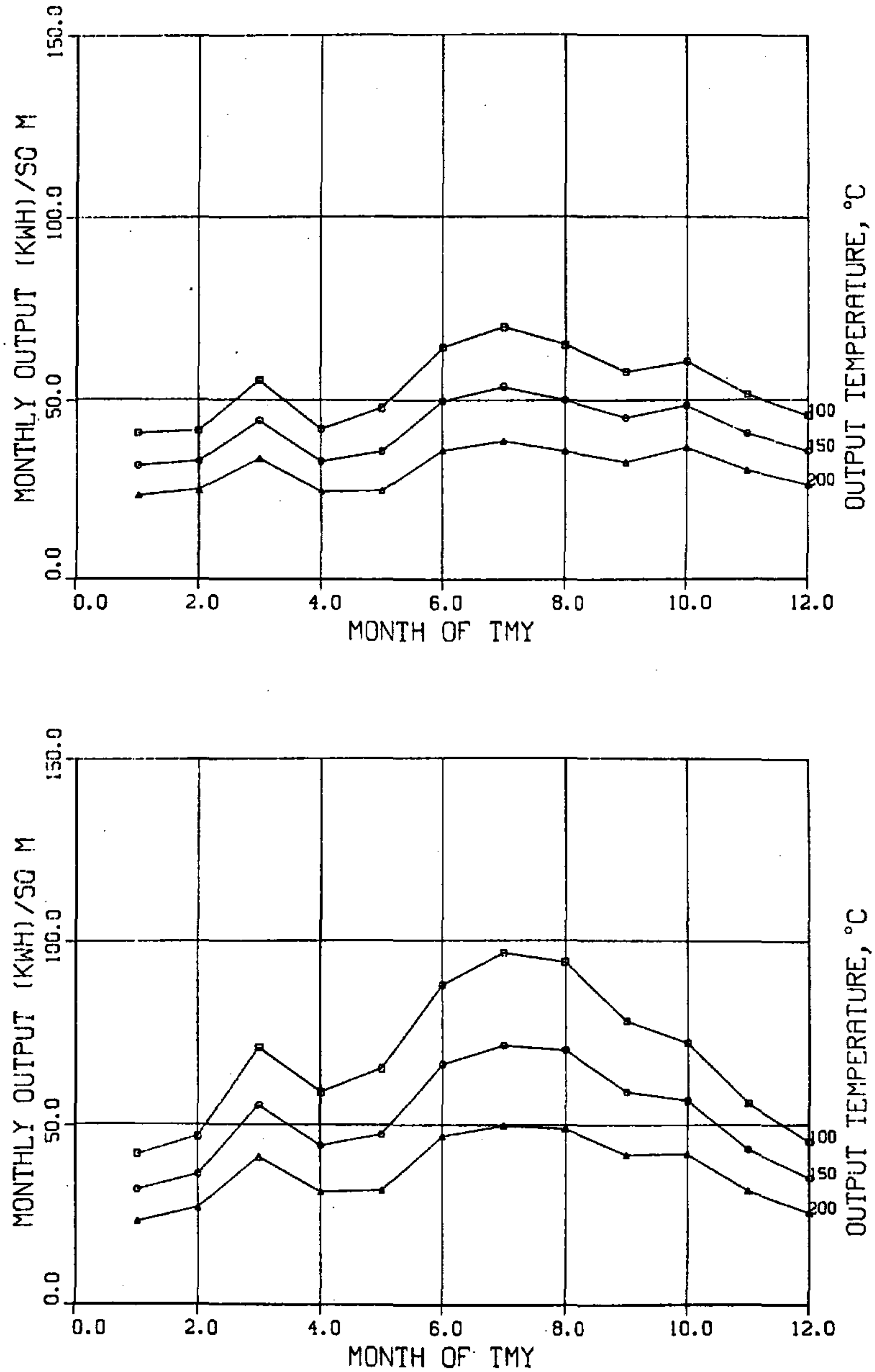


Figure 6. Thermal Output of the Polisolar Model POL Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Fort Worth TMY Solar Data

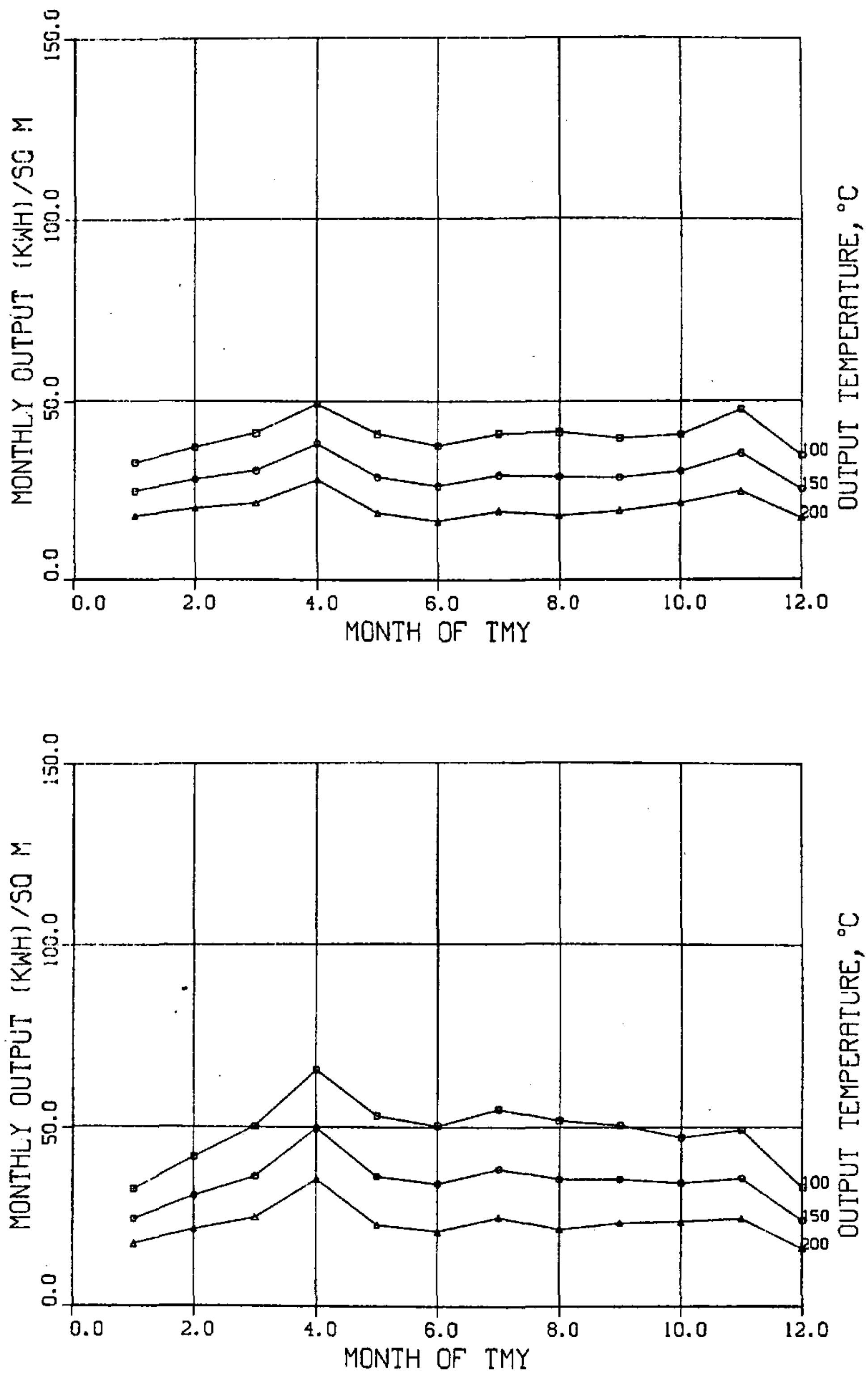
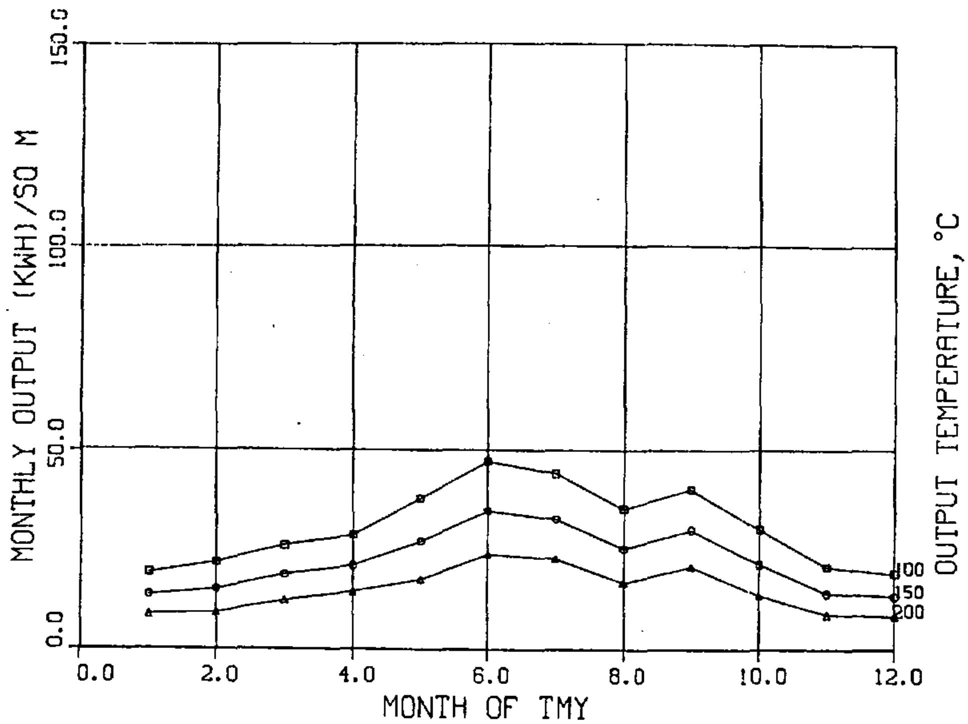


Figure 7. Thermal Output of the Polisolar Model POL Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Charleston TMY Solar Data



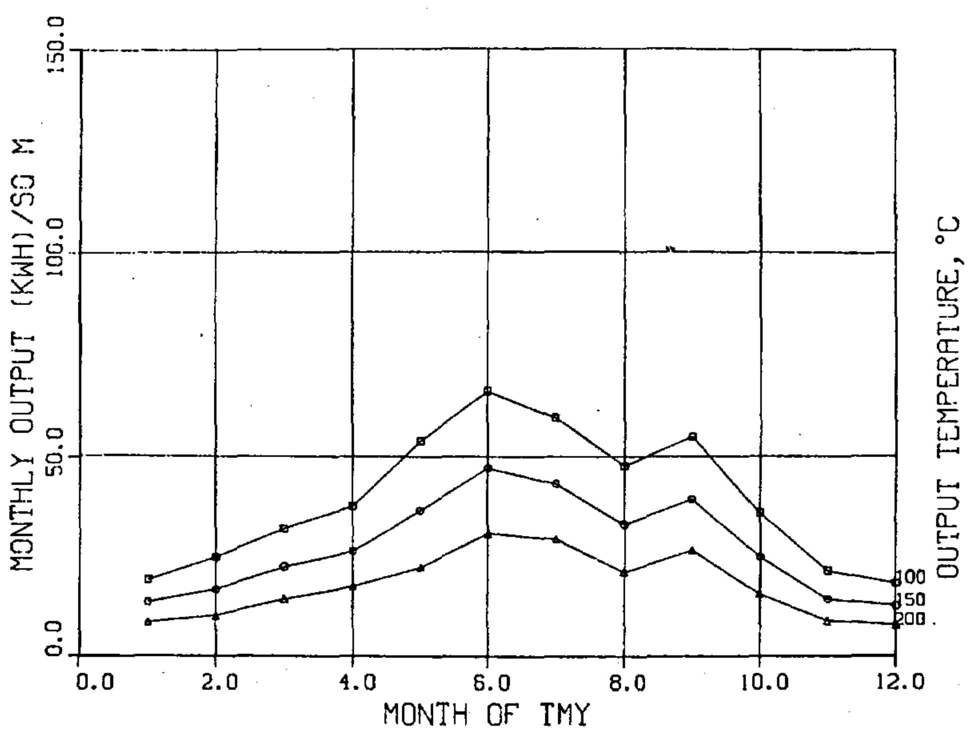


Figure 8. Thermal Output of the Polisolar Model POL Solar Collector with Glass Reflector Surface with E-W and N-S Orientation and Boston TMY Solar Data

Table 1

Predicted Annual Thermal Output ($kWh/m^2 \cdot yr$)

		Output Temperature					
		100°C		150°C		300°C	
		Orientation		Orientation		Orientation	
	Solar Energy Available	E-W	N-S	E-W	N-S	E-W	N-S
Fresno	2260	816	1100	654	859	500	638
Albuquerque	2583	954	1260	781	1012	616	780
Fort Worth	1764	644	816	504	620	372	444
Charleston	1358	487	583	358	419	245	280
Boston	1173	373	473	270	333	179	215

Previously Published Predictions

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3151	W. L. Garner (3)
	(Unlimited Release)
	For DOE/TIC
	(Unlimited Release)
6011	Patents