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Midtemperature Solar Systems Test Facility Predictions for Thermal Performance Based on Test Data of Low- to Medium-Temperature Line-Focusing Solar Collectors

Whiteline Model W-11A Collector

Thomas D. Harrison

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MIDTEMPERATURE SOLAR SYSTEMS TEST FACILITY PREDICTIONS FOR THERMAL PERFORMANCE BASED ON TEST DATA OF LOW- TO MEDIUM-TEMPERATURE LINE-FOCUSING SOLAR COLLECTORS

WHITELINE MODEL W-11A COLLECTOR

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ABSTRACT

Thermal performance predictions based on test data are presented for the Whiteline Model W-11A solar collector for three output temperatures at eight cities in the United States.

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MIDTEMPERATURE SOLAR SYSTEMS TEST FACILITY PREDICTIONS FOR THERMAL PERFORMANCE BASED ON TEST DATA OF LOW- TO MEDIUM-TEMPERATURE LINE-FOCUSING SOLAR COLLECTORS

WHITELINE MODEL W-11A COLLECTOR

Introduction

Sandia National Laboratories, Albuquerque (SNLA) is currently conducting a program to measure the characteristics of commercially available solar collectors that have the potential for use in low-temperature applications such as domestic water heating and to predict their performance at different locations in the United States. 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, which presents the thermal performance predictions for the Whiteline Model W-11A 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.

Description of the Collector

A photograph of a five-module array of Whiteline Model W-11A collectors is shown in Figure 1.

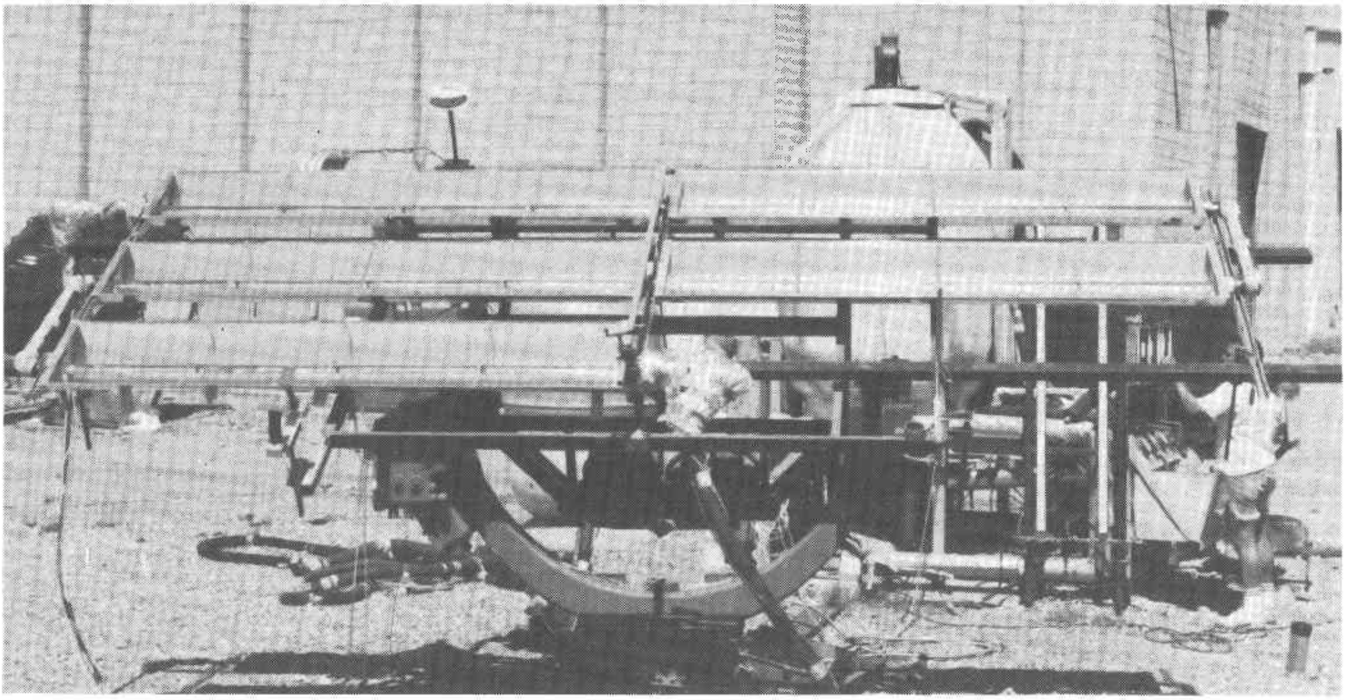


Figure 1. A Five-Module Array of Whiteline Model W-11A Solar Collectors

The Whiteline Model W-11A consists of a parabolic trough concentrator with a tubular receiver that is fixed in position at the focal line of the concentrator. A single sheet of clear plastic covers the trough and protects the reflective surface and the receiver tube. The system is normally installed in the single-axis tracking mode; however, the testing was done with the system mounted on a two-axis tracker. The test assembly consisted of five modules connected in series. The module characteristics are listed in Table 1. The tests were performed by DSET Laboratories, Phoenix, Arizona.

Table 1

Characteristics of the Whiteline Model W-11A Module

Concentrator	Linear-focusing parabolic trough
Reflective material	Aluminum, Coilzak®
Concentrator aperture dimensions	2.324 by 0.408 m (7.625 by 1.339 ft)
Aperture area	0.949 m^2 (10.2 ft^2)
Receiver	Metal tube with CuS/CuO coating
Support structure	Steel
Tracking system	Single-axis tracking
Drive mechanism	Electric
Transparent cover	Acrylic plastic
Heat transfer fluid	Water
Operating range	50° to 125°C (112° to 392°F)
Manufacturer	Whiteline, Inc. P.O. Box 3071 Asheville, NC 28802

Several modifications to the collector system were devised and tested by Whiteline, Inc., which judged that the improvements in performance were insufficient to justify a change.

Results of the Test Program

From the test data, by regression analysis, the efficiency of the collector was defined as a function of $\Delta t/I$, where Δt is the temperature difference between the coolant fluid average temperature and the ambient temperature in degrees Centigrade, and I is the irradiance of the sun in watts per square meter (W/m^2). The results, expressed in percent (%), were

Test 1: $\eta = 67.0 - 382.1\ (\Delta t/I)$

These results are plotted in Figure 2 for the range of $\Delta t/I$ within which the tests were conducted.

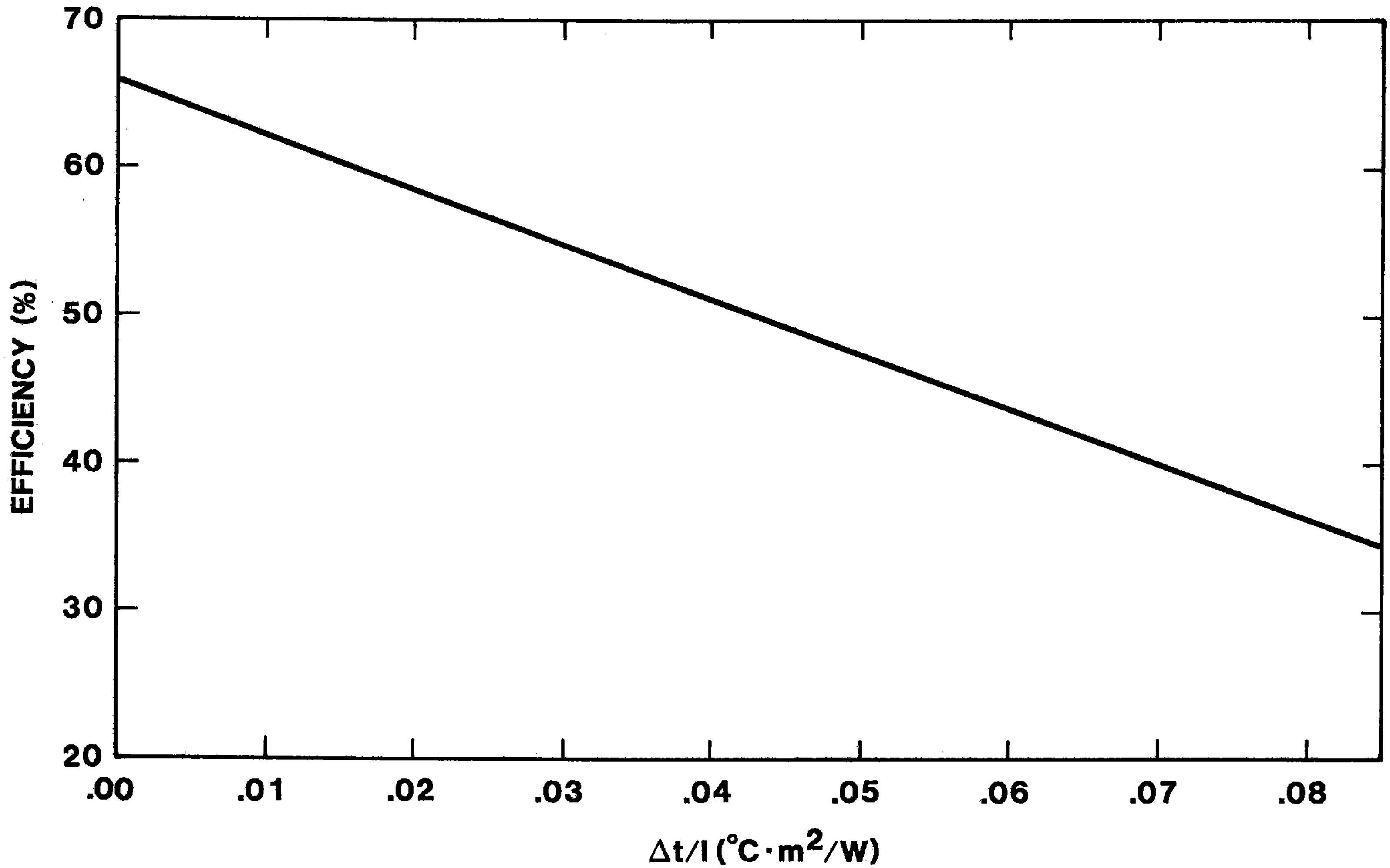


Figure 2. Efficiency versus Δt/I for the Whiteline Model W-11A Collector

Prediction of Thermal Performance

A computer program calculates the predicted thermal performance of the collector. The efficiency equation describes the collector performance, while solar and weather data are provided by TMY data tapes. The computer program calculates the collector thermal output per unit aperture area for each month of the Typical Meteorological Year (TMY). This calculation was made for eight locations: Phoenix, AZ; Santa Maria, CA; Ft. Worth, TX; Brownsville, TX; Albuquerque, NM; Dodge City, KS; Lake Charles, LA; and Miami, Fl. Three different collector output temperatures were considered. Figures 3 through 10 display the results of the computer prediction. These figures show the monthly thermal output ($kWh/m^2 \cdot mo$) for each location and output temperature. In Table 2, the monthly outputs have been summed to give the annual outputs. 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. A tilt angle of 18 degrees was assumed for the north-south (N-S) prediction calculations because most pitched on which this collector would be mounted have a tilt of 18 degrees. The prediction calculations for the N-S orientation were repeated using a tilt angle equal to the latitude at the location of the prediction (e.g., 33.433 degrees for Phoenix, AZ). The predictions did not differ significantly from those obtained using an 18-degree tilt and are, therefore, not included in this report.

Performance as a Domestic Hot Water Heater

A major use of the Whiteline Model W-11A is for heating water for domestic hot water systems at an output temperature of 60°C (140°F). The monthly performance of the system operating at this output temperature is summarized in Table 3. For the convenience of the reader, conversions to English units are included.

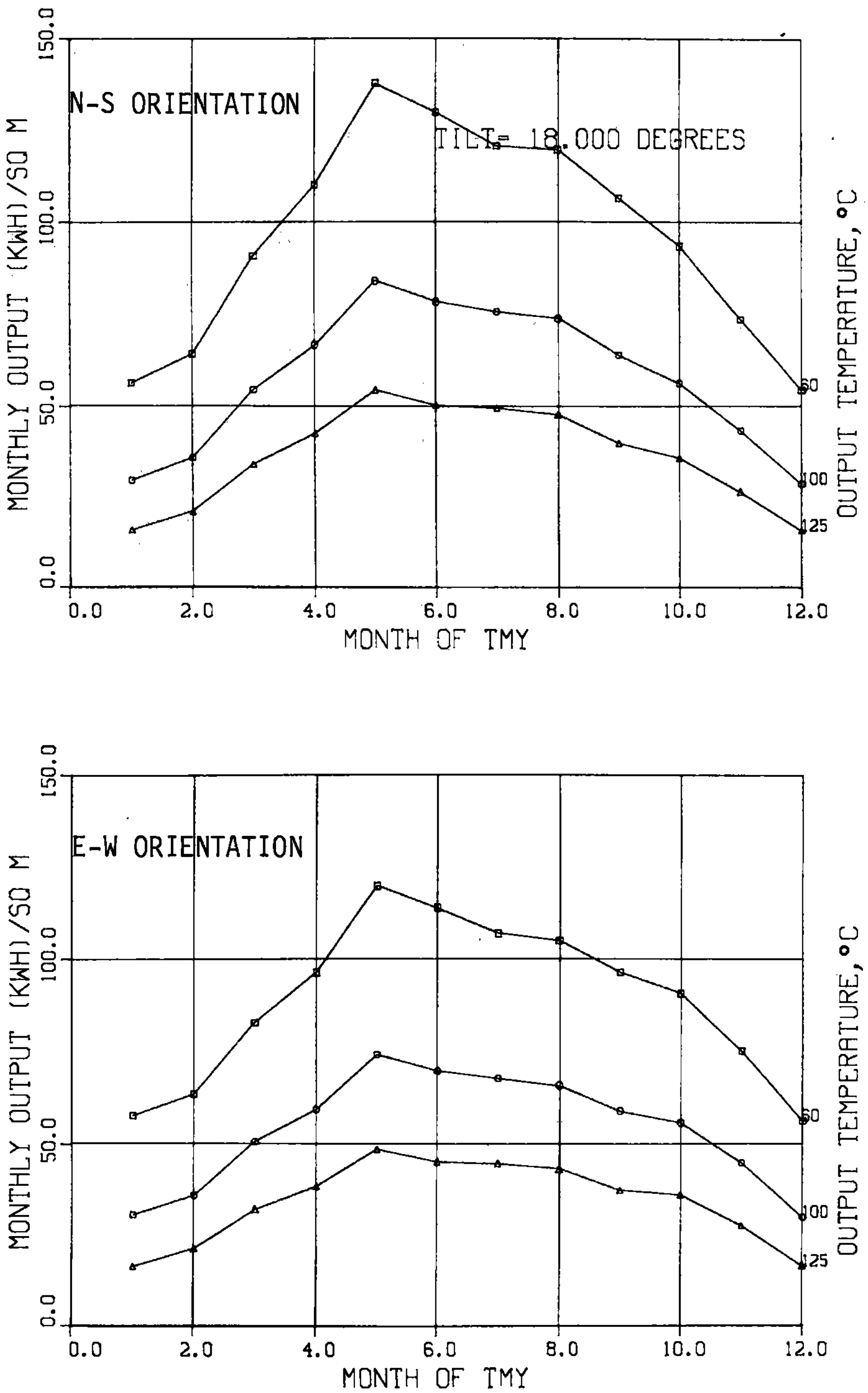
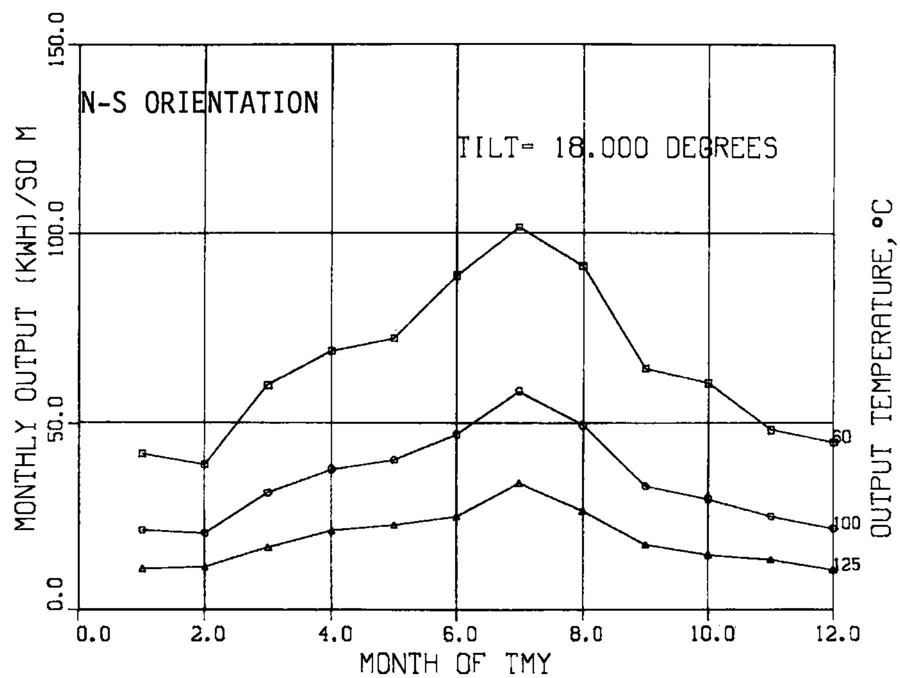


Figure 3. Thermal Output for the Whiteline Collector for Phoenix TMY Solar Data



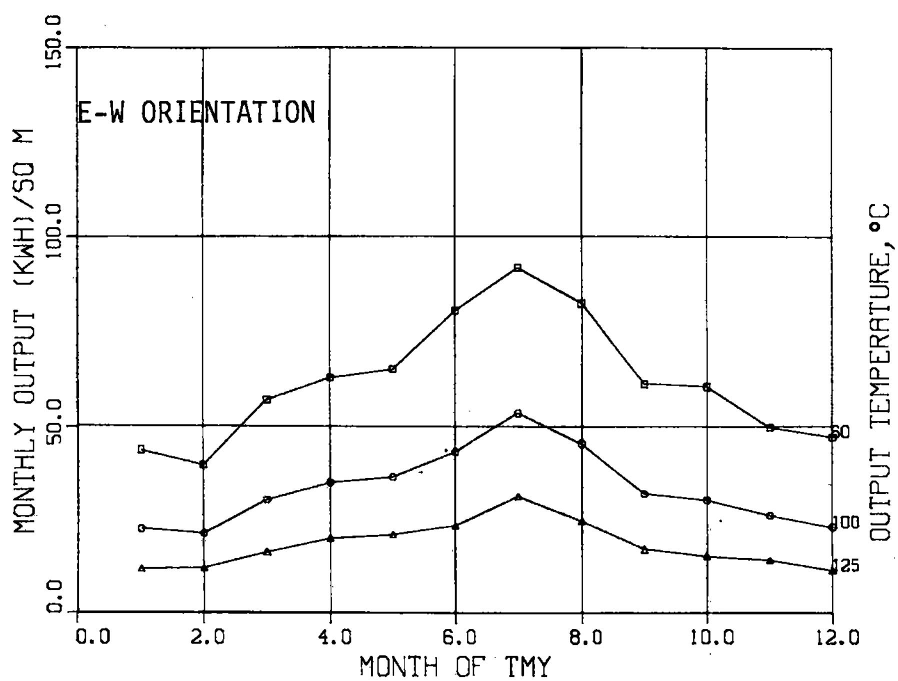


Figure 4. Thermal Output for the Whiteline Collector for Santa Maria TMY Solar Data

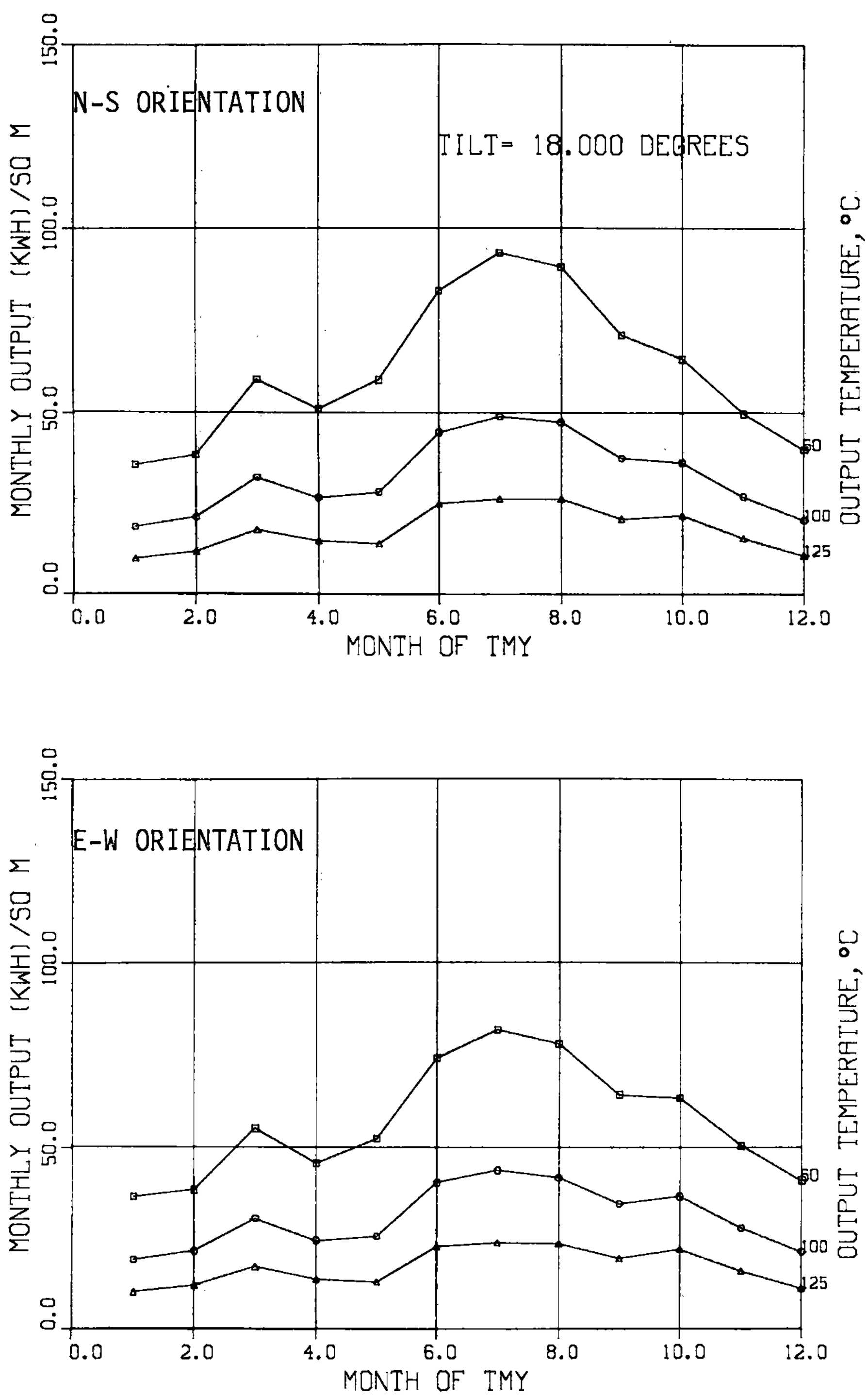


Figure 5. Thermal Output for the Whiteline Collector for Ft. Worth TMY Solar Data

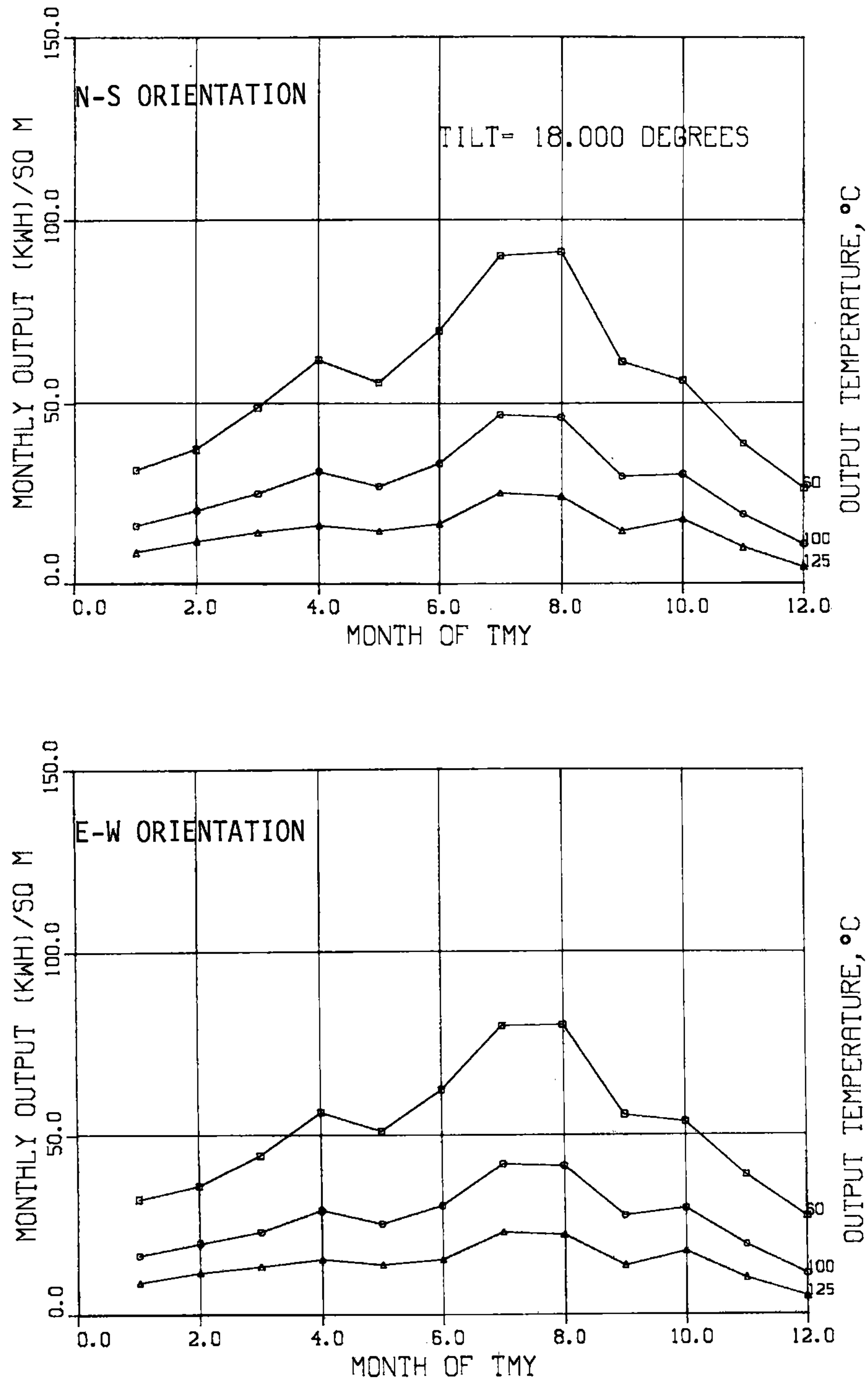


Figure 6. Thermal Output for the Whiteline Collector for Brownsville TMY Solar Data

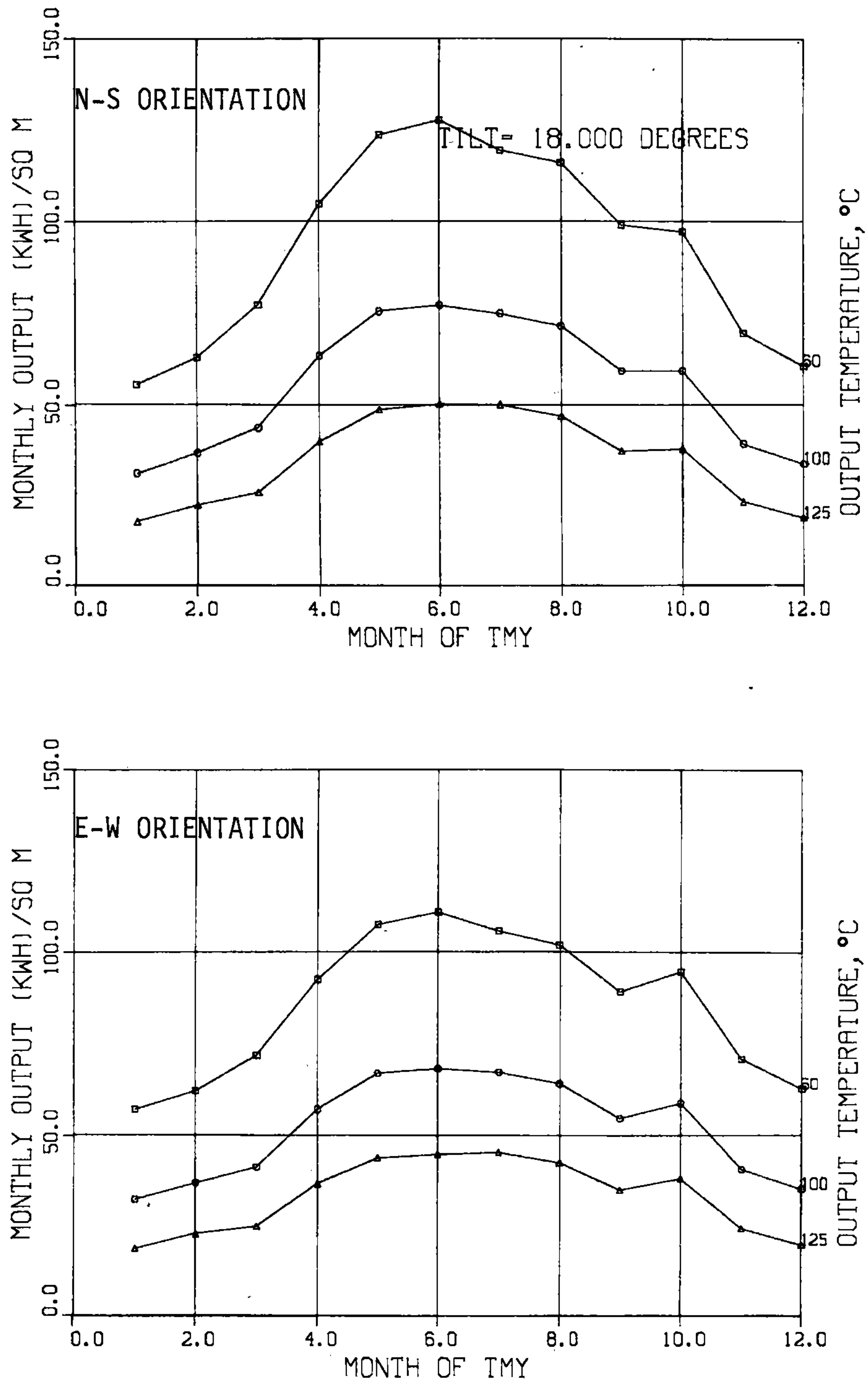
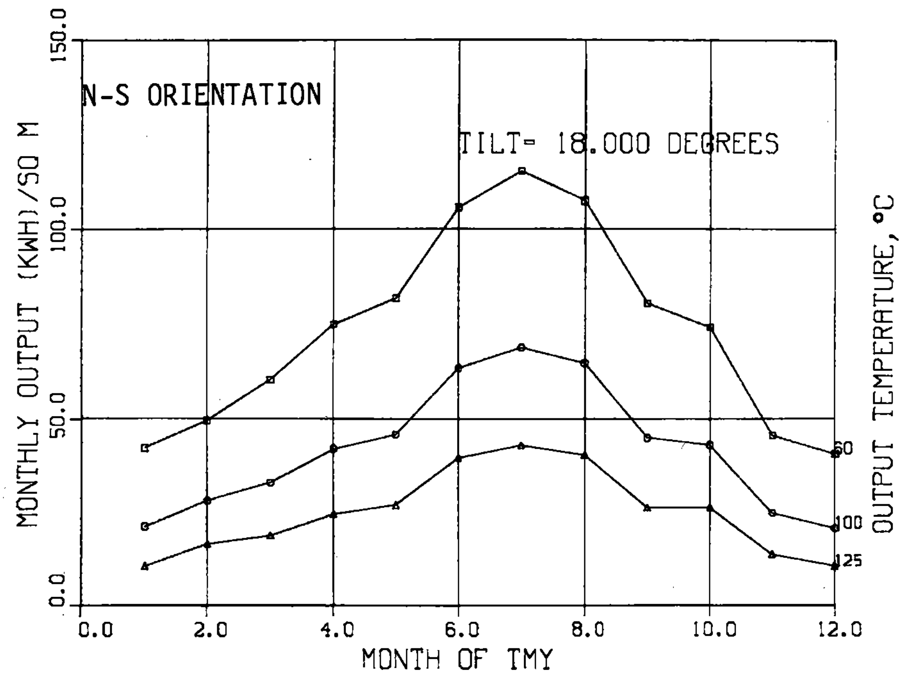


Figure 7. Thermal Output for the Whiteline Collector for Albuquerque TMY Solar Data



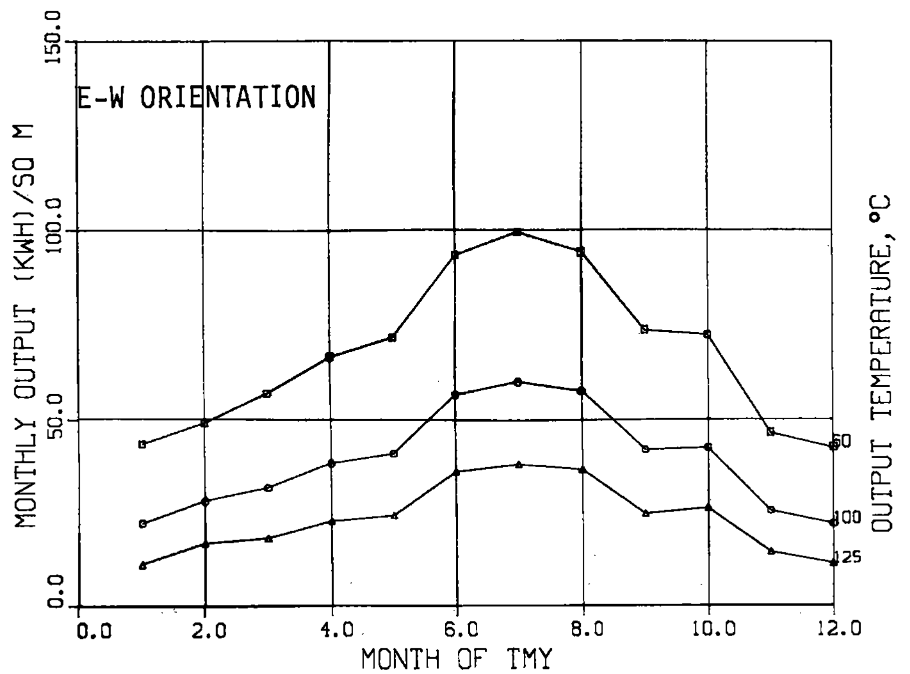


Figure 8. Thermal Output for the Whiteline Collector for Dodge City TMY Solar Data

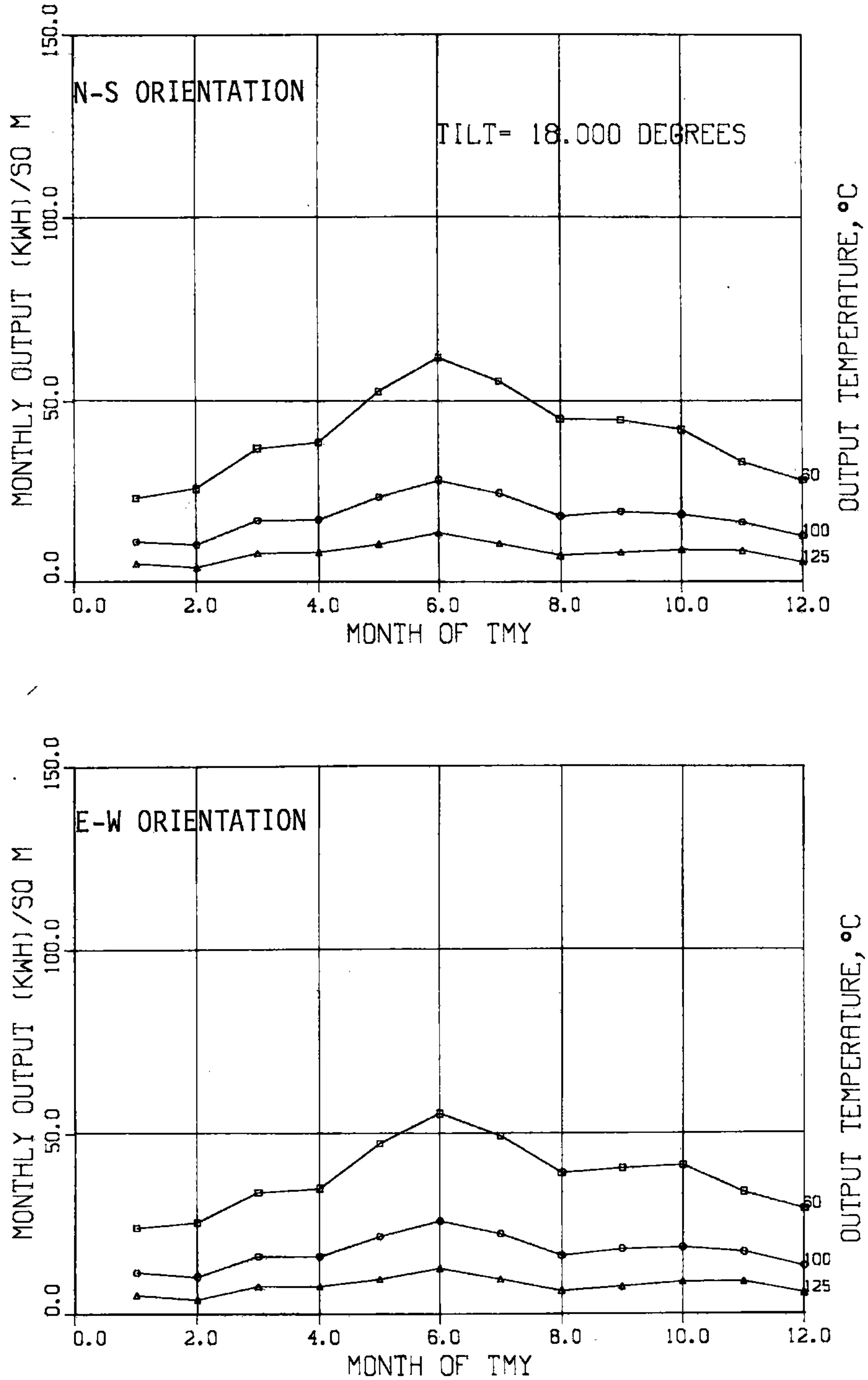


Figure 9. Thermal Output for the Whiteline Collector for Lake Charles TMY Solar Data

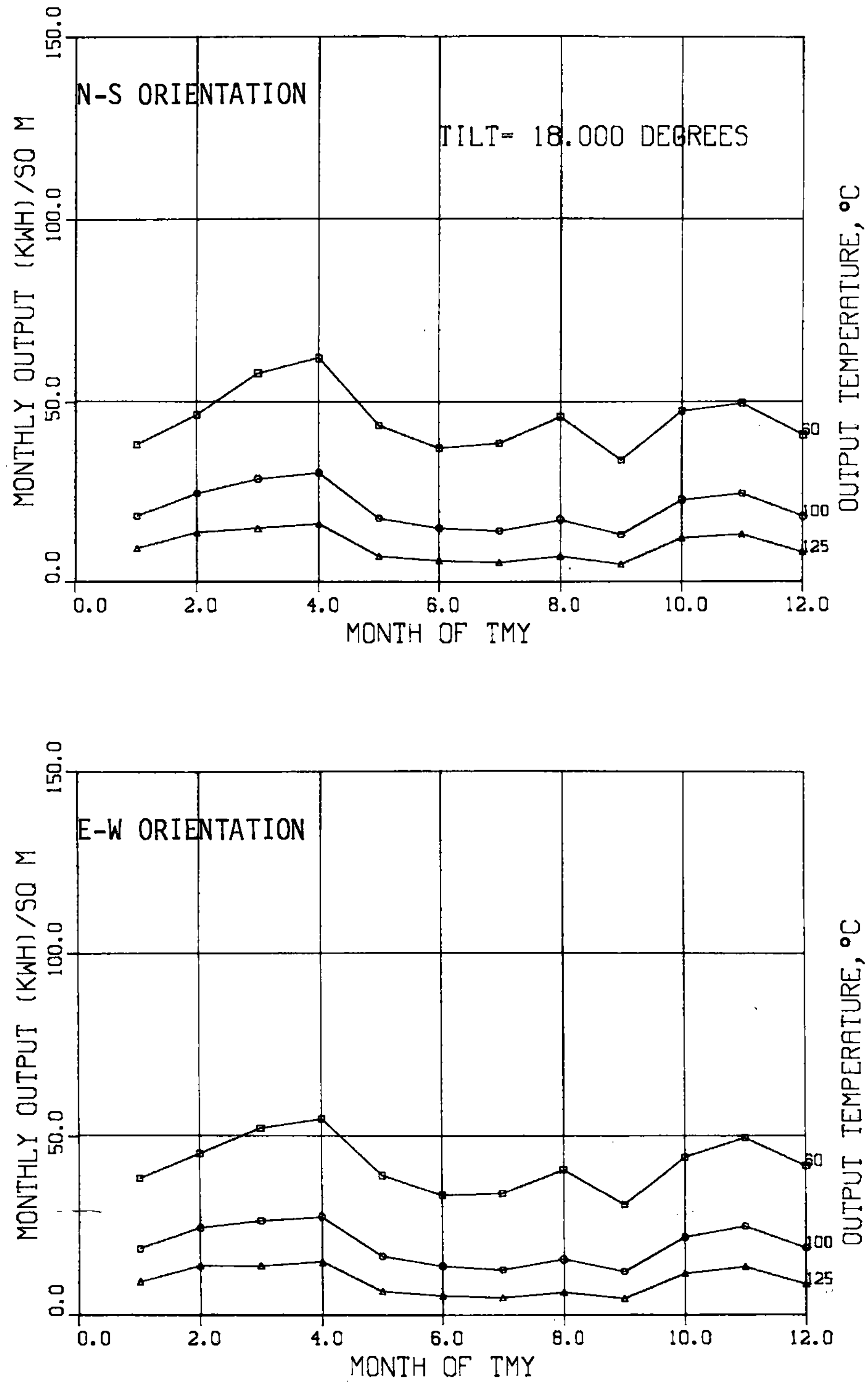


Figure 10. Thermal Output for the Whiteline Collector for Miami TMY Solar Data

Table 2

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

Location	Solar Energy Available	Output Temperature (°C) 60 Orientation E-W	60 N-S	100 Orientation E-W	100 N-S	125 Orientation E-W	125 N-S
Phoenix	2477	1064	1157	644	691	410	435
Santa Maria	1958	743	783	403	419	221	228
Ft. Worth	1733	682	735	370	392	207	217
Brownsville	1584	619	671	319	339	173	182
Albuquerque	2583	1027	1112	667	625	399	422
Dodge City	2080	811	879	470	503	384	300
Lake Charles	1275	456	490	209	220	95	99
Miami	1401	506	544	235	248	115	119

Table 3

Predicted Monthly Thermal Output for an Output Temperature of 60°C (140°F)
(Thermal output is given in kWh/m^2 with conversion to kBtu/ft^2, shown in parentheses.)

	Phoenix, AZ	Santa Maria, CA	Ft. Worth, TX	Brownsville, TX	Albuquerque, NM	Dodge City, KS	Lake Charles, LA	Miami, FL
JAN								
Available energy	153 (48)	119 (38)	102 (32)	91 (29)	159 (51)	134 (43)	71 (22)	106 (34)
Collected energy E-W	58 (18)	44 (14)	37 (12)	32 (10)	57 (18)	44 (14)	24 (8)	38 (12)
Collected energy N-S	56 (18)	42 (13)	36 (11)	32 (10)	56 (18)	42 (13)	23 (7)	38 (12)
FEB								
Available energy	161 (51)	111 (35)	104 (33)	98 (31)	170 (54)	136 (43)	82 (26)	120 (38)
Collected energy E-W	63 (20)	40 (13)	39 (12)	36 (11)	62 (20)	49 (16)	26 (8)	45 (14)
Collected energy N-S	64 (20)	39 (12)	39 (12)	38 (12)	63 (20)	50 (16)	26 (8)	47 (15)
MAR								
Available energy	208 (66)	159 (50)	151 (48)	123 (39)	200 (63)	162 (51)	101 (32)	139 (44)
Collected energy E-W	83 (26)	57 (18)	55 (17)	45 (14)	72 (23)	57 (18)	34 (11)	52 (17)
Collected energy N-S	91 (29)	60 (19)	59 (19)	49 (16)	77 (24)	60 (19)	37 (12)	58 (18)
APR								
Available energy	232 (74)	170 (54)	123 (39)	143 (45)	239 (76)	180 (57)	107 (34)	148 (47)
Collected energy E-W	96 (31)	63 (20)	46 (15)	56 (18)	93 (29)	67 (21)	35 (11)	55 (17)
Collected energy N-S	110 (35)	69 (22)	51 (16)	62 (20)	105 (33)	75 (24)	39 (12)	62 (20)
MAY								
Available energy	274 (87)	172 (55)	143 (45)	132 (42)	261 (83)	184 (58)	129 (41)	113 (36)
Collected energy E-W	120 (38)	65 (21)	52 (17)	51 (16)	107 (34)	72 (23)	47 (15)	39 (12)
Collected energy N-S	138 (44)	72 (23)	59 (19)	56 (18)	123 (39)	82 (26)	53 (17)	44 (14)
JUN								
Available energy	250 (79)	212 (67)	177 (56)	158 (50)	265 (84)	215 (68)	143 (45)	95 (30)
Collected energy E-W	114 (36)	81 (26)	74 (24)	62 (20)	111 (35)	93 (30)	55 (18)	34 (11)
Collected energy N-S	130 (41)	89 (28)	83 (26)	70 (22)	127 (40)	106 (33)	62 (20)	38 (12)
JUL								
Available energy	226 (72)	225 (71)	195 (62)	193 (61)	237 (75)	234 (74)	129 (41)	106 (34)
Collected energy E-W	107 (34)	92 (29)	82 (26)	80 (25)	106 (33)	99 (32)	49 (16)	34 (11)
Collected energy N-S	120 (38)	102 (32)	93 (30)	90 (29)	119 (38)	115 (36)	56 (18)	39 (12)
AUG								
Available energy	230 (73)	210 (67)	188 (59)	193 (61)	239 (76)	219 (69)	110 (35)	115 (37)
Collected energy E-W	105 (33)	82 (26)	78 (25)	80 (25)	102 (32)	94 (30)	39 (13)	41 (13)
Collected energy N-S	119 (38)	91 (29)	90 (28)	91 (29)	116 (37)	107 (34)	45 (14)	46 (15)
SEP								
Available energy	212 (67)	158 (50)	159 (50)	137 (43)	218 (69)	182 (58)	108 (34)	93 (29)
Collected energy E-W	96 (31)	61 (19)	64 (20)	56 (18)	89 (28)	74 (23)	41 (13)	31 (10)
Collected energy N-S	106 (34)	64 (20)	71 (23)	61 (19)	99 (31)	80 (26)	45 (14)	34 (11)

Table 3 (Continued)

Predicted Monthly Thermal Output for an Output Temperature of 60°C (140°F)
(Thermal output is given in kWh/m^2 with conversion to kBtu/ft^2, shown in parentheses.)

	Phoenix, AZ	Santa Maria, CA	Ft. Worth, TX	Brownsville, TX	Albuquerque, NM	Dodge City, KS	Lake Charles, LA	Miami, FL
OCT								
Available energy	206 (65)	160 (51)	154 (49)	132 (42)	228 (72)	181 (57)	114 (36)	118 (37)
Collected energy E-W	91 (29)	61 (19)	63 (20)	54 (17)	95 (30)	72 (23)	41 (13)	44 (14)
Collected energy N-S	93 (30)	61 (19)	65 (20)	56 (18)	97 (31)	74 (23)	42 (13)	48 (15)
NOV								
Available energy	179 (57)	133 (42)	127 (40)	104 (33)	192 (61)	126 (40)	95 (30)	129 (41)
Collected energy E-W	75 (24)	50 (16)	51 (16)	39 (12)	71 (22)	47 (15)	34 (11)	50 (16)
Collected energy N-S	74 (23)	48 (15)	50 (16)	39 (12)	69 (22)	46 (15)	33 (11)	50 (16)
DEC								
Available energy	147 (46)	129 (41)	112 (35)	82 (26)	175 (55)	126 (40)	86 (27)	117 (37)
Collected energy E-W	56 (18)	47 (15)	41 (13)	28 (9)	63 (20)	43 (14)	30 (9)	42 (13)
Collected energy N-S	55 (17)	45 (14)	40 (13)	27 (8)	61 (19)	41 (13)	28 (9)	41 (13)
ANNUAL								
Available energy	2477 (785)	1958 (621)	1733 (549)	1584 (502)	2583 (819)	2080 (659)	1275 (404)	1401 (444)
Collected energy E-W	1064 (337)	743 (235)	682 (216)	619 (196)	1027 (325)	811 (257)	456 (145)	506 (160)
Collected energy N-S	1157 (367)	783 (248)	735 (233)	671 (213)	1112 (353)	879 (279)	490 (155)	544 (172)

Reference

[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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