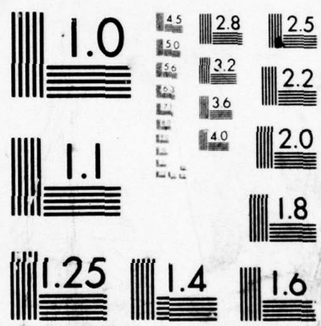
AD-A054 215 CIVIL ENGINEERING LAB (NAVY) PORT HUENEME CALIF F/G 10/2
ANALYSIS OF CHAMBERLIN FLAT PLATE SOLAR COLLECTOR USING NATIONA--ETC(U)
MAR 78 E R DURLAK
UNCLASSIFIED CEL-TN-1517 NL

| OF |

AD
A054215

END
DATE
FILMED
6-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Technical Note

TN no. N-1517

title: ANALYSIS OF CHAMBERLIN FLAT PLATE SOLAR COLLECTOR USING NATIONAL BUREAU OF STANDARDS TEST CRITERIA

author: E. R. Durlak

Technical note Sep-Dec 77

date: March 1978

21p.

sponsor: Chief of Naval Material

program nos: ZF57.571.001.01.010

CEL-TN-1517

F57571

ZF57571001

CIVIL ENGINEERING LABORATORY
NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

Approved for public release; distribution unlimited.

391 111

JOB

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TN-1517	2. GOVT ACCESSION NO. DN687065	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ANALYSIS OF CHAMBERLIN FLAT PLATE SOLAR COLLECTOR USING NATIONAL BUREAU OF STANDARDS TEST CRITERIA		5. TYPE OF REPORT & PERIOD COVERED Not final; Sep 1977 – Dec 1977 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. R. Durlak		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS CIVIL ENGINEERING LABORATORY Naval Construction Battalion Center Port Hueneme, California 93043		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62765N; ZF57.571.001.01.010
11. CONTROLLING OFFICE NAME AND ADDRESS Chief of Naval Material Navy Department Washington, DC 20360		12. REPORT DATE March 1978 13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Solar collector testing, flat plate collector, solar collector efficiency.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Test results are presented for a flat plate, single glazed solar collector tested in accordance with the National Bureau of Standards test criteria. A description of the test apparatus and instrumentation is given. A graph of solar collector efficiency is presented. There was good agreement between test results and data taken from the manufacturer's brochure.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Library Card

Civil Engineering Laboratory
ANALYSIS OF CHAMBERLIN FLAT PLATE SOLAR COLLECTOR USING NATIONAL BUREAU OF STANDARDS TEST CRITERIA, by E. R. Durlak
TN-1517 15 pp illus March 1978 Unclassified

1. Solar collector 2. Flat plate collector I. ZF57.571.001.01.010

Test results are presented for a flat plate, single glazed solar collector tested in accordance with the National Bureau of Standards test criteria. A description of the test apparatus and instrumentation is given. A graph of solar collector efficiency is presented. There was good agreement between test results and data taken from the manufacturer's brochure.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

CONTENTS

INTRODUCTION

As part of the overall energy conservation and self sufficiency program at CEL, the technical evaluation of solar systems is one area being investigated. To aid in this investigation, CEL has constructed an instrumented test stand to conform to and to participate in the National Bureau of Standards and ASHRAE test specifications of references (a) and (b), respectively. The National Bureau of Standards has sent a Chamberlin flat plate solar collector to CEL for investigation under their round robin test program of solar collectors. The results of that investigation are the substance of this report.

DISCUSSION

In general, the conduct of the technical evaluation and the data taken were in accord with the procedures of reference (a). The general test stand configuration is as shown in Figure 1 which is reproduced from reference (a). The only modifications to this configuration are detailed in the following section. Figure 2 is a photograph of the test stand showing the collector at the left being tested.

The Chamberlin collector received at CEL from the National Bureau of Standards was a flat plate, steel absorber, single glazed type. The collector was mounted on the test stand and water was circulated through the collector for about 3 weeks before testing began. After this initial "soak" period, testing was completed within 2 weeks during September 1977.

In keeping with the uniformity of format established by reference (a), the data collected and analyzed will be discussed using this format.

The procedures and data recorded will become obvious as this format is used. The following section, then uses the format of reference (a) to provide a summary of the test data developed.

All the data was computer analyzed to provide the tabulated data and the solar collector efficiency curve is a computer plot with a computer analyzed least squares line drawn through the data points.

TEST RESULTS

The following results are given in the format of reference (a):

Test Data Recorded - Section I
Test Data Reported - Section II

Section II further contains:

Figure 3 - Efficiency Plot of Chamberlin Solar Collector
Figure 4 - Comparison of Test Results to Manufacturer's Predictions for Chamberlin Solar Collector

Table 1 - Tabulated values for test data.

TEST RESULTS

Section I

Test Data Recorded

Item	Test Involving Air as the Transfer Fluid	Test Involving Liquid as the Transfer Fluid	CEL Test Conditions
Date	X	X	yes
Observer(s)	X	X	yes
Equipment name plate data	X	X	yes
Collector tile angle	X	X	yes
Collector azimuth angle (as a function of time if movable)	X	X	yes
Collector aperture area or frontal transparent area	X	X	yes
Local standard time, at the beginning of collector warm-up and at the beginning and end of each 15 minute test period	X	X	yes
Barometric pressure	X		N/A
Ambient air temperature (at the beginning and end of each 15 minute test period)	X	X	yes
$\Delta t = t_{f,e} - t_{f,i}$ across solar collector (either as a continuous function of time or as a 15 minute integrated quantity)	X	X	yes
Inlet temperature, $t_{f,i}$ (as a continuous function of time	X	X	yes
Outlet temperature, $t_{f,e}$ (as a continuous function of time	X	X	yes

N/A = Not Applicable

Section I continued

Item	Test Involving Air as the Transfer Fluid	Test Involving Liquid as the Transfer Fluid	CEL Test Conditions
Liquid flow rate		X	yes
Gauge pressure at solar collector inlet		X	monitored but not recorded
Gauge pressure at nozzle throat	X		N/A
Nozzle throat diameter	X		N/A
Velocity pressure at nozzle throat or static pressure difference across nozzle	X		N/A
Dry bulb temperature at nozzle throat	X		N/A
Wet bulb temperature at nozzle throat	X		N/A
Pressure drop across solar collector	X	X	no
Height of the collector outlet above the collector inlet	X	X	yes
Wind velocity near the collector surface or aperture (15 minute average)	X	X	estimated not measured
I, the incident solar radiation onto the collector (as a continuous function of time and as a 15 minute integrated quantity if desired)	X	X	yes
I_d, the diffuse component of the solar radiation onto the collector (at the beginning of the 15 minute period and after the completion of the 15 minute period)	X	X	yes but not every test

Section II

Test Data Reported

General Information

Manufacturer or Project Name - Chamberlin flat plate solar collector, single glazed, steel absorber plate

Collector Model No. - Model No. 711101, Assembly No. 44-6206, Ser, No. 00622

Construction Details of Collector - Typical flat plate collector using carbon steel as the absorber plate and a metal edge retainer. The absorber plate is backed by about 2 inches of rigid foam insulation all contained in a galvanized metal pan housing.

Gross Dimensions and Area - 3 ft x 7 ft x 4-7/16 in.
- 21 ft^2

Area of Absorbing Surface (i.e. frontal aperature area)
- 82 in. x 33-7/8 in., 2,778 $in.^2$ or 19.3 ft^2

Cover Plate

Dimensions - 81 in. x 32-7/8 in.
Materials - 1/8 in. Low Iron Glass
Optical Properties - Glass transmittance, 90%
Reflectance - about 8-10%

Absorber Plate

Dimensional Layout and Configuration of Flow Path - Typical "Roll Bond" Type

Absorptivity to Short Wave Radiation - 0.95

Emissivity for Long Wave Radiation - 0.2

Coating - Selective

Maximum Temperature - Not Known

Air Space - 1/2 in. - 7/8 in. constrained air

Insulation

Material - Rigid Foam

Thickness - About 2 in.

Thermal Conductivity - Not Given

Transfer Fluid - Water - Specific Heat = 1 BTU/lbm - ^{o}F

Section II continued

Weight of Collector - Approximately 8.8 lb/ft^2 with fluid
- Approximately 7.6 lb/ft^2 without fluid

Volumetric Capacity of Collector - About 0.4 gal

Normal Operating Temperature Range - Not known what is "normal". Data is shown in brochure up to 220^{o}F inlet temperature

Minimum Transfer Fluid Flow Rate - 0.35 GPM (typical design flow)

Maximum Transfer Fluid Flow Rate - Not known

Maximum Operating Pressure - Not known, working pressure is 50 psi.

Description of Apparatus

The test stand configuration, shown in Figure 1 reproduced from reference (a), follows very closely that given in reference (a), except for the following:

(1) The manometer was not used.
(2) The valve for adjusting the flow is in series with the pump.
(3) An extra valve was installed at the top of the collector to provide a vent and/or purge path.

The data recording instrumentation consisted of the following:

(1) Data Logger - A.D. Data Systems, Inc., with Dana D.C. amplifiers
(2) Data Recorder (on magnetic cassette tape) - Techtran 4100 communications terminal. Compatible with most time-share computer terminals.
(3) Insolation - Eppley Radiometer and Rho Sigma photovoltaic pyranometer.
(4) Ambient Temperature - Weather measure T621 remote temperature indicator
(5) Collector Temperatures - Hy-Cal Engineering platinum resistance thermometers.
(6) Flow Rate - Flow Technology 1/2-73B, NA-88 Flowmeter

Description of the Mounting of the Collector for Testing

The collector was positioned in a wooden box such that the entire collector and its metal housing was enclosed in the box and the front glass plate was not in any way shaded from the sun. The wooden box and collector were mounted on the test stand board which was tilted at the latitude angle of 34°. The surface of the test stand is painted black. Figure 2 shows the test configuration. The test stand faces due south.

Location of Tests

Latitude - 34.14°N

Longitude - 119.21°W

Elevation - less than 10 ft

Efficiency Tests

Figure 3 is a plot of efficiency versus $\dfrac{\left(\dfrac{t_{f,i} + t_{f,e}}{2} - ta\right)}{I}$

Where $t_{f,i}$ = temp at collector inlet

$t_{f,e}$ = temp at collector exit (outlet)

ta = Ambient Temperature

I = Solar Insolation in plane of collector

Note $\dfrac{t_{f,i} + t_{f,e}}{2}$ is defined as t average in Figure 3.

The efficiency is calculated from the equation:

$$\text{Efficiency} = \frac{\left[\dot{m}C_p \int_{T1}^{T2} (t_{f,e} - t_{f,i})dT\right] \Big/ Aa}{\int_{T1}^{T2} IdT}$$

where $\dot{m}$ = flowrate

Cp = specific heat = 1 BTU/lbm - °F

Aa = Collector transparent frontal area

T = Time

An equation for the efficiency curve in Figure 3 is y = 71.7 - 411X which is a least squares first degree line approximation calculated from the data points.

The values for each data point comprising the efficiency curve are given in Table 1.

To calculate efficiencies from Table 1, follow this procedure:

$$(\text{Flowrate in GPM}) \times \left(\int_{T1}^{T2} (t_{f,e} - t_{f,i})dT\right) \times (147.26) \div \left(\int_{T1}^{T2} IdT\right)$$

The constant (147.26) is used to account for the collector area, the specific heat (Cp), and the proper units.

SUMMARY

The data reported in Figure 3 represent the summary of tests conducted during September 1977. The equation for the least squares approximation of the efficiency curve in Figure 3 is y = 71.7 - 411X.

As a comparison Figure 4 is shown which compares the test results to the manufacturer's predictions as computed from his brochure. As shown, the CEL test results agree well with the predictions giving slightly lower overall efficiencies. The manufacturers' data were given for slightly higher ambient temperatures (32.2°C versus 23°C) which might account for the slight variation. The average value of solar insolation for the CEL tests was about 900 watts/M^2, whereas, the manufacturer presented data for about 945 watts/M^2.

REFERENCES

a. Method of Testing for Rating Solar collectors Based on Thermal Performance, NBSIR74-635, by J. E. Hill and T. Kasuda, December 1974.

b. Method of Testing Solar Collectors Based on Thermal Performance, ASHRAE Proposed Standard 93-P, June 1976.

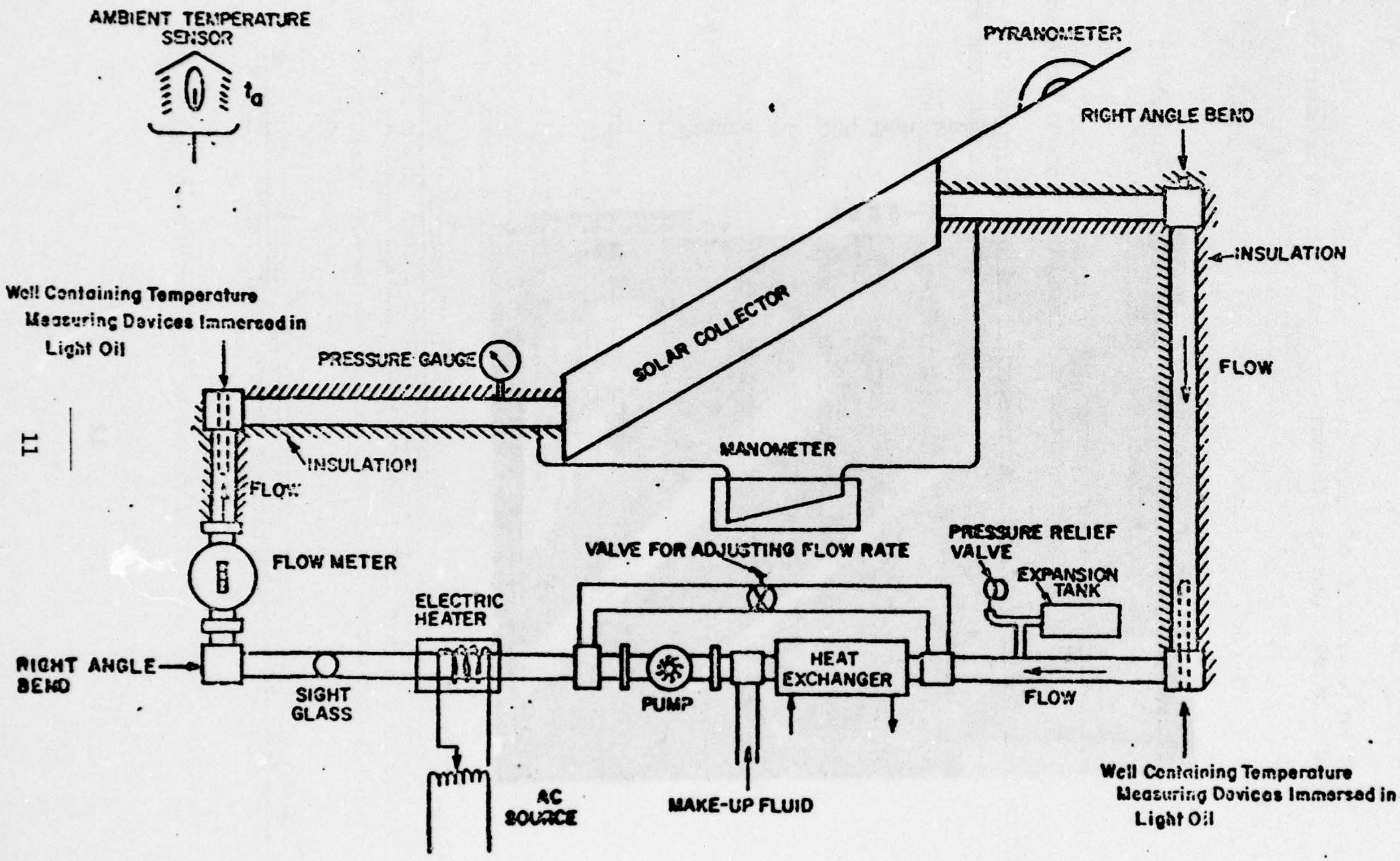
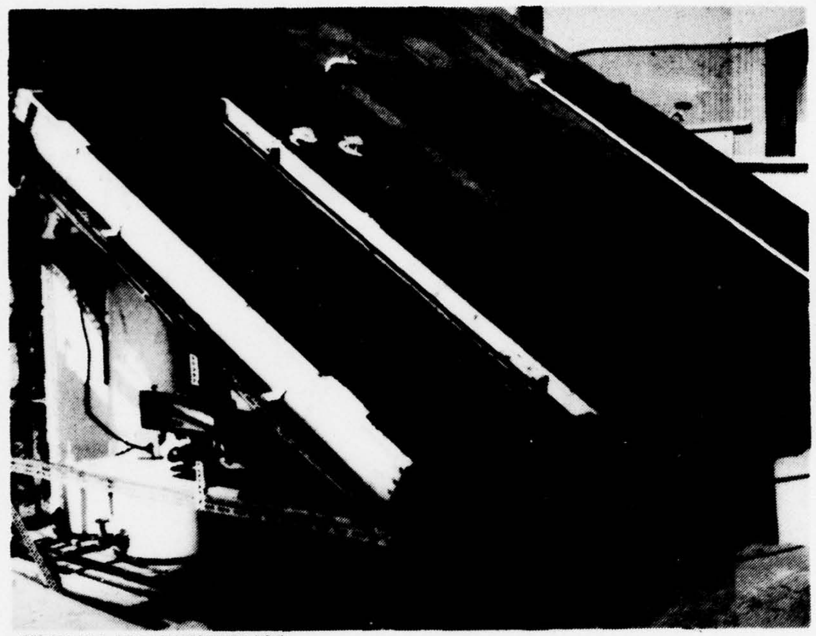


Figure 1. Test Configuration



OFFICIAL U.S. NAVY PHOTOGRAPH (LDH)
PORT HUENEME, CALIFORNIA

9980-77

Figure 2. CEL Test Stand

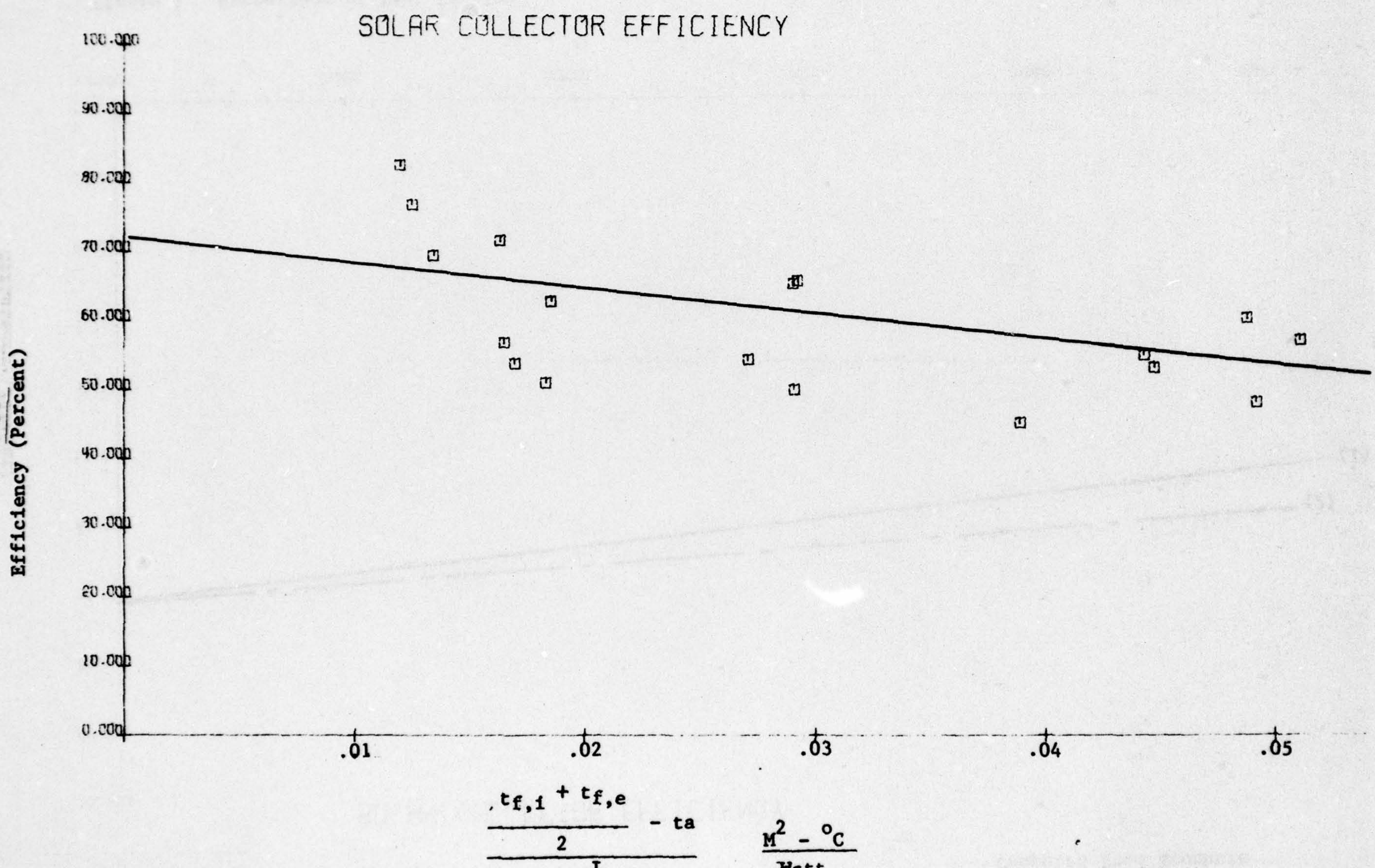


Figure 3 Efficiency Plot of Chamberlin Solar Collector

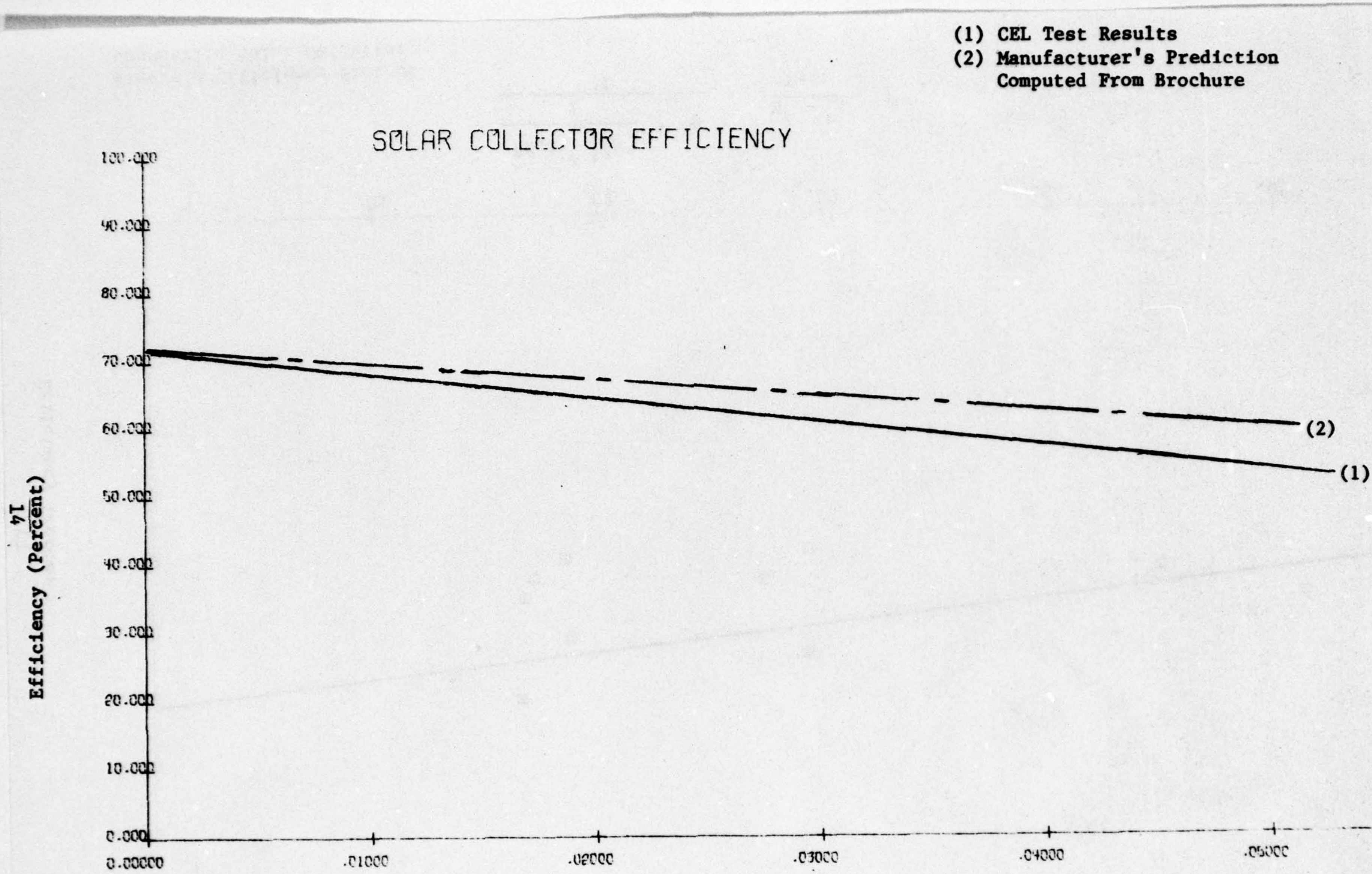


Figure 4. Comparison of Test Results to Manufacturer's Predictions for Chamberlin Solar Collector

$$\frac{\frac{t_{f,i} + t_{f,e}}{2} - t_a}{I} \qquad \frac{M^2 - {}^oC}{Watt}$$

Table 1. Tabulated Values for Te

Efficiency (%)	Z ① $\left(\frac{M^2 \text{-} {}^\circ C}{watt}\right)$	Flowrate (gpm)	$\int_{T1}^{T2} (t_{f,e} - t_{f,i})dT$	$\int_{T1}^{T2} I\,dT$ $\left(\frac{watt}{M^2}\right)$	Sol Inci Ang (de
62.72	0.01858	0.514	731.34	88264.9	
65.69	0.02928	0.700	61.21	9605.9	
65.22	0.02908	0.699	60.45	9541.3	
57.19	0.05114	0.527	65.54	8897.6	1
54.29	0.02713	0.553	33.56	5034.7	
53.71	0.01700	0.548	76.57	11506.1	
60.26	0.04883	0.553	912.0	123244.5	
71.46	0.01636	0.523	194.70	20986.5	
50.99	0.01834	0.501	1101.3	159333.3	
53.13	0.04479	0.514	95.29	13575.4	
54.92	0.04434	0.492	70.12	9250.3	
49.97	0.02911	0.536	981.7	155064.5	
56.65	0.01651	0.601	76.35	11928.6	
48.16	0.04920	0.551	79.62	13416.6	
45.04	0.03894	0.669	181.51	39707.4	
76.71	0.01255	0.530	113.42	11537.7	
82.42	0.01204	0.702	71.99	9030.4	
69.32	0.01350	0.741	119.34	18785.4	

① $Z = \dfrac{\dfrac{(t_{f,i} + t_{f,e})}{2} - t_a}{I}$

② Collector Tilt Angle = 34°
Collector Facing Due South

③ Very light - 0-5 mph
Light - 5-10 mph
Heavy - 10-20 mph

* Not measured

able 1. Tabulated Values for Test Data

,e $- t_{f,i})dT$	$\int_{T1}^{T2} I\,dT$ $\left(\frac{watt}{M^2}\right)$	Solar (2) Incident Angle (deg)	Fluid Inlet Temperature (°C)	Estimated Percentage of Diffuse Radiation (%)	Estimated Wind Speed (3)
731.34	88264.9	1	36.7	*	Very light
61.21	9605.9	1	47.7	14	Very light
60.45	9541.3	0	47.6	14	Very light
65.54	8897.6	10	65.3	23	Light
33.56	5034.7	5	42.8	23	Light
76.57	11506.1	4	34.1	*	Light
912.0	123244.5	8	63.8	19	Very light
194.70	20986.5	5	31.7	23	Light
1101.3	159333.3	6	33.1	23	Light
95.29	13575.4	9	61.0	*	Light
70.12	9250.3	8	61.0	*	Light
981.7	155064.5	5	45.1	*	Light
76.35	11928.6	2	34.3	*	Light
79.62	13416.6	8	64.6	19	Very light
181.51	39707.4	4	54.5	19	Very light
113.42	11537.7	4	29.0	19	Very light
71.99	9030.4	6	30.6	13	Light wind
119.34	18785.4	6	32.4	13	Light wind

t - 0-5 mph
-10 mph
0-20 mph

sured