DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150631

INDOOR THERMAL PERFORMANCE EVALUATION OF THE SEPCO AIR COLLECTOR

Prepared by

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Solar Energy Systems Division
Huntsville, Alabama 35805

Under subcontract to IBM Federal Systems Division, Huntsville, Alabama

Contract NAS8-32036

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

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This work was done under the technical management of Mr. Charles N. Thomas, Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report contains the procedures used and the results obtained during the evaluation test program on the Solar Energy Products Company (SEPCO) Solaron solar air collector, Model EF-212, under simulated conditions for comparison with data collected in outdoor tests on the same collector. The test article was a single-glazed collector with a nonsensitive absorber plate, aluminum box frame, and one-inch isocyanurate foam insulation. The Marshall Space Flight Center's solar simulator was used for these tests.

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1.0 PURPOSE

The purpose of this report is to present the procedures used and the results obtained during the performance of an evaluation test program. The test program was conducted to determine the thermal performance of a SEPCO air collector under simulated conditions for comparison with the data obtained during the outdoor testing of the same collector. The tests were conducted utilizing the Marshall Space Flight Center Solar Simulator in accordance with the test requirements specified in Reference 2.1 and 2.2 and the procedures contained in References 2.3 and 2.4. The outdoor test results are contained in Reference 2.5.

2.0 REFERENCES

2.1 ASHRAE 93-77		Methods of Testing To Determine The Thermal Performance of Solar Collectors
2.2 EP 45 (77-50)		Solar Simulator Testing of the Solar Energy Products Company (SEPCO) Collector
2.3 MTCP-FA-SHAC-400		Procedure for Operation of the MSFC Solar Simulator Facility
2.4 MTCP-DC-SHAC-412		Test Procedure for Thermal Performance Evaluation of Solar Energy Products Company (SEPCO) "Soloron" Collector Under Simulated Conditions
2.5 WYLE-TR-531-08		Test Report for Thermal Performance Evaluation of Solar Energy Products Company (SEPCO) "Soloron" Collector Tested Outdoors

3.0 MANUFACTURER

Solar Energy Product Company
121 Miller Road
Avon Lake, Ohio 44012

3.1 DESCRIPTION OF TEST SPECIMEN

The test article, a Soloron solar collector, Model EF-212, Serial Number 002, is a single glazed collector with a nonselective absorber plate utilizing flowing air as the heat transfer medium. The absorber plate and box frame are aluminum and the insulation is one inch isocyanurate foam. The collector measures 25 inches by 147 inches by 3 5/16 inches, which provides 25.5 square feet of solar collector surface area. The test article weighs 65 pounds. (B)

4.0 SUMMARY

This program was conducted to compare the thermal performance of a SEPCO collector under simulated conditions with that obtained under natural weather conditions. The following tests were conducted at simulated conditions:

1. Thermal Performance Test
2. Time Constant Test
3. Incident Angle Modifier Test

Since the length of the collector is larger than the maximum allowable length that may be accomodated under the solar simulator, a portion of the collector was covered by a irradiation shield. An analysis to be presented in Section 7.1.2 shows that it is feasible to conduct the thermal performance test of an oversized collector under the solar simulator. Further tests are recommended in order to prove the applicability of this analysis.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 Ambient Conditions

Unless otherwise specified herein, all tests shall be performed in the existing environment of Building 4619.

5.2 Instrumentation and Equipment

All test equipment and instrumentation used in the performance of this test program comply with the requirements of MSFC MMI 5300.4C, Metrology and Calibration. Table I contains instrumentation identification and data acquisition connection data. Instrumentation locations are depicted in Figure 1. A listing of the equipment used in each test follows:

Collector Time Constant Test

Apparatus	Manufacturer/Model	Range/Accuracy
Collector Shield	Aluminum Sheet	N/A
Pyranometer	Eppley PSP	0-800 BTU/Hr·Ft^2/±5%
Air Source	MSFC Supplied	50-200 SCFM
Thermopile	Medtherm	0-20°F/±1°F
Thermocouples	Medtherm	32°-200°F/±1°F
Wind Sensor	MSFC Supplied	0-60 MPH
Strip Chart Recorder	Hewlett-Packard	5MV-50V/±0.5%
Flow Sensor	Cox-Turbine C-L-32	20-250 ACFM ±2%
Ice Bath	MSFC Supplied	N/A
Differential Pressure Sensor	MSFC Supplied	0-2 IN. H_2O ±5%

Collector Efficiency Test

Apparatus	Manufacturer	Range/Accuracy
Collector Shield	Aluminum Sheet	N/A
Pyranometer	Eppley PSP	0-800 BTU/Hr·Ft^2/±5%
Air Source	MSFC Supplied	50-200 SCFM
Thermopile	Medtherm	0-20°F/±1°F
Thermocouples	Medtherm	32°-200°F/±1°F
Wind Sensor	MSFC Supplied	0-60 MPH
Flow Sensor	Cox-Turbine C-L-32	20-250 ACFM ±2%
Ice Bath	MSFC Supplied	N/A
Differenctial Pressure Sensor	MSFC Supplied	0-2 IN. H_2O ±5%

5.0 TEST CONDITIONS AND TEST EQUIPMENT (Continued)

5.2 Instrumentation and Equipment (Continued)

Incident Angle Modifier Test

Apparatus	Manufacturer/Model	Range/Accuracy
Collector Shield	Aluminum Sheet	N/A
Pyranometer	Eppley	0-800 BTU/Hr·Ft^2/±5%
Air Source	MSFC Supplied	50-200 SCFM
Thermopile	Medtherm	0-20°F/±1°F
Thermocouples	Medtherm	32°-200°F/±1°F
Wind Sensor	MSFC Supplied	0-60 MPH
Flow Sensor	Cox-Turbine C-L-32	20-250 ACFM ±2%
Ice Bath	MSFC Supplied	N/A
Differential Pressure Sensor	MSFC Supplied	0-2 IN. H_2O

6.0 REQUIREMENTS, PROCEDURES AND RESULTS

6.1 Collector Thermal Performance Test

Tested By Ken C. [illegible]
Started 11 July
Completed 15 July

6.1.1 Requirements

Utilizing the MSFC Solar Simulator and the portable hot air loop, performance evaluation data were obtained at inlet temperatures of 10°F, 25°F, 50°F, and 90°F above ambient temperature at insolation rates of 240 and 290 BTU/Hr·Ft^2, air flow rates of 2 and 5 SCFM/Ft^2 of collector area and with wind speeds of 0 and 4 MPH. The following data were recorded during the test at each test condition:

1.	Collector surface temperature	(°F)
2.	Air temperature at intersection of the shaded area and the irradiated area	(°F)
3.	Inlet air temperature	(°F)
4.	Collector differential temperature	(°F)
5.	Collector differential pressure	("H_2O)
6.	Insolation rate	(BTU/Hr·Ft^2)
7.	Air flow rate	(ACFM)

6.1.2 Procedure

1. Establish the required wind speed.
2. Establish the required air flow rate.
3. Establish the required inlet temperature.
4. Power up solar simulator and establish the required insolation rate.
5. Record data for a minimum of five minutes at these stablized conditions.
6. Repeat above steps as necessary to obtain data for all test conditions.

6.1.3 Results

The results obtained during these tests are contained in Figures 2 and 3 and Table II and III.

6.0 REQUIREMENTS, PROCEDURES AND RESULTS (Continued

6.2 Collector Time Constant Test (Continued)

Tested By Ken C. Ekirk
Started 18 July
Completed 22 July

6.2.1 Requirements

According to ASHRAE 93-77, the time constant test is conducted by abruptly reducing the flux level to zero. The inlet shall be kept to within ±2°F of ambient, or the best achievable with the existing system, with the air flow rate of 50 SCFM. The differential air temperature across the collector were recorded to determine the time required to reach the condition of

$$\frac{T_{e,\tau} - T_i}{T_{e,ini} - T_i} = .368$$

where

$T_{e,\tau}$ = Outlet temperature at time τ

T_i = Inlet temperature

$T_{e,ini}$ = Initial inlet temperature

The following data were recorded during the test:

1. Absorber plate temperature - 6 locations (°F)
2. Air temperature at intersection of the shaded area and the irradiated area (°F)
3. Inlet air temperature (°F)
4. Collector differential temperature (°F)
5. Air flow rate (SCFM)
6. Insolation rate ($BTU/Hr \cdot Ft^2$)

6.2.2 Procedures

1. Mount the collector at 45° from the floor.
2. Adjust the air flow rate to 50 SCFM.
3. Adjust the flux level to 250 $BTU/Hr \cdot Ft^2$.
4. Monitor the differential temperature on strip chart recorder.
5. Allow the system to stabilize for at least 5 minutes.
6. Turn off the solar simulator.

6.2.2 Procedures (Continued)

7. Monitor the differential temperature until the ratio of $\frac{T_e - T_i}{T_{e,ini} - T_i}$ is less than .30.

6.2.3 Results

The result obtained during this test is contained in Figure 5 and Table IV. The time constant was determined to be 6 minutes and 12 seconds.

6.0 REQUIREMENTS, PROCEDURES AND RESULTS (Continued)

6.3 Collector Incident Angle Modifier Test

Tested By Ken C. Ehik

Started 25 July

Completed 29 July

6.3.1 Requirements

The collector incident angle modifier shall be conducted at incident angles of 45°, 60° and 75°. The air flow rate will be 50 SCFM with the inlet temperature controlled to within ±2°F of ambient, or the best achievable with the existing system, at the insolation rate of 240 BTU/Hr·Ft^2, normal to the collector plane. The following data were recorded during the test:

1. Absorber surface temperature - 6 locations (°F)
2. Air temperature at intersection of shaded area and the irradiated area (°F)
3. Inlet air temperature (°F)
4. Collector differential temperature (°F)
5. Insolation rate (BTU/Hr·Ft^2)
6. Air flow rate (SCFM)

6.3.2 Procedures

1. Mount the collector on the test table at the required incident angle.
2. Establish the required air flow rate.
3. Establish the required inlet temperature.
4. Power up solar simulator and establish the required insolation rate.
5. Record data for a minimum of five minutes at these stabilized conditions.
6. Repeat above steps as necessary to obtain data for all incident angles.

6.3.3 Results

The results obtained during these tests are contained in Figures 6 and 7 and Table V.

7.0 ANALYSIS

7.1 Thermal Performance Test

7.1.1 Efficiency Calculation

The analysis of data contained in this report is in accordance with the National Bureau of Standards recommended approach. This approach is outlined below.

The efficiency of a collector is stated as:

$$\eta = \frac{q_u/A}{I} = \frac{\dot{m}\, C_{tf}\,(t_{f,e} - t_{f,i})}{IA} \tag{1}$$

where:

q_u	=	Rate of useful energy extracted from the Solar Collector (BTU/Hr)
A	=	Overall cross-sectional area 25.52 Ft^2
I	=	Total solar energy incident upon the plane of the Solar Collector per unit time per unit area ($BTU/Hr\cdot Ft^2$)
$\dot{m}$	=	Mass flow rate of the air through the collector per unit cross-sectional area of the collector
C_{tf}	=	Specific heat of BTU/Lb·°F
$t_{f,e}$	=	Air temperature leaving the collector (°F)
$t_{f,i}$	=	Air temperature entering the collector (°F)

Rewriting Equation (1) in terms of the total collector area yields:

$$\eta = \frac{(\dot{m}A)\, C_{tf}\,(t_{f,e} - t_{f,i})}{(IA)} = \frac{\dot{M}\, C_{tf}\,(t_{f,e} - t_{f,i})}{P_i} \tag{2}$$

Notice that:

P_i = IA = Total Power Incident on the Collector

$\dot{m}A$ = M = Total Mass Flow Rate through the Collector

For an air collector system, the mass flow rate is obtained by multiplying the density of the air with the volume flow rate of air through the collector.

7.0 ANALYSIS (Continued)

7.1.1 Efficiency Calculation (Continued)

$$\dot{M} = \rho_{tf} \dot{V}$$

where:

ρ_{tf} = Density of air (Lb/Ft^3) (A)

$\dot{V}$ = Volume flow rate (SCFM)

Substitution in Equation (2) results in:

$$\eta = \frac{P_{abs}}{P_{inc}} \quad (3)$$

where:

P_{abs} = Total collected power

P_{inc} = Total incident power

This value of efficiency is expressed as a percentage by multiplying by 100. This expression for percent efficiency is:

$$\text{Collector Efficiency} = \frac{P_{abs}}{P_{inc}} \times 100 \quad (4)$$

or from Equation (2), collector efficiency is defined by the equation:

$$\%\ \text{Eff.} = \frac{\dot{M}\, C_{tf}\, (t_{f,e} - t_{f,i}) \times 100}{P_i} \quad (5)$$

Each term in Equation (5) was measured and recorded independently during the test. The calculated values of efficiency were determined at eighty-second intervals. The mean value of efficiency was determined over a five-minute period during which the test conditions remained in a quasi-steady state. Each five-minute period constitutes one "data point" as is graphically depicted on a plot of percent efficiency versus

$$(t_{f,i} - t_a)/I \quad \text{and} \quad \frac{\frac{t_{f,i} + t_{f,e}}{2} - t_a}{I}$$

These thermal performance parameters are presented in Figures 2 and 3.

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7.0 ANALYSIS (Continued)

7.1.1 Efficiency Calculation (Continued)

where:

$t_{f,i}$ = Inlet air temperature (°F)

$t_{e,i}$ = Outlet air temperature (°F)

t_a = Ambient temperature (°F)

I = Incident flux per unit area (BTU/Hr·Ft^2)

The abscissa terms $(t_{f,i} - t_a)/I$ and $\left(\frac{t_{f,i} + t_{f,e}}{2} - t_a\right)/I$

were used to normalize the effect of operating at different values of I, $t_{f,i}$, $t_{f,e}$ and t_a.

The first and second order polynomial to best describe the test results are

$$\text{Efficiency} = a_0 + a_1 \mathcal{I}$$

and $$\text{Efficiency} = a_2 + a_3 \mathcal{I} + a_4 \mathcal{I}^2$$

where:

$$\mathcal{I} = (t_{f,i} - t_a)/I \text{ or } \left(\frac{t_{f,i} + t_{f,e}}{2} - t_a\right)/I$$

and the coefficients are determined to be:

$\mathcal{I}$	$(t_{f,i} - t_a)/I$				$\left[(t_{f,i} + t_{f,e})/2 - t_a\right]/I$			
FLOW	50 SCFM		125 SCFM		50 SCFM		125 SCFM	
WIND	0	4	0	4	0	4	0	4
a_0	.396	.360	.533	.517	.482	.455	.590	.585
a_1	-.757	-.891	-1.033	-1.229	-.920	-1.124	-1.146	-1.391
a_2	.392	.360	.518	.519	.467	.456	.560	.589
a_3	-.699	-.896	-.819	-1.271	-.784	-1.114	-.818	-1.437
a_4	-.132	.012	-.492	.112	-.250	.030	-.668	.109

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7.1.1 Efficiency Calculation (Continued)

The performance of a flat-plate solar collector under steady state conditions can be described as

$$q_u = A_i I (\alpha\tau)_e - A_i U_L (t_p - t_a) \quad (6)$$

where:

A_i is the absorber plate area

$(\alpha\tau)_e$ is the product of transmissivity and absorptivity at normal incident angle

Since the efficiency is defined as the ratio of the useful energy extracted from the collector to the total incident energy, equation 6 becomes

$$\eta = \frac{q_u}{IA} = \frac{A_i}{A} (\alpha\tau)_e - \frac{A_i}{A} U_L \frac{(\bar{t}_p - t_a)}{I} \quad (7)$$

It is convenient to introduce two parameters F_R and F'

where:

F_R = $\frac{\text{actual useful energy collected}}{\text{useful energy collected if the entire collector surface were at the inlet liquid temperature}}$

$$q_u = F_R \left[A_i I (\alpha\tau)_e - U_L A_i (t_{f,i} - t_a)\right]$$

or

$$\eta = \frac{q_u}{AI} = \frac{A_i}{A} F_R (\alpha\tau)_e - \frac{A_i}{A} F_R U_L \frac{(t_{f,i} - t_a)}{I} \quad (8)$$

and

F' = $\frac{\text{actual useful energy collected}}{\text{useful energy collected if the entire collector surface were at the average liquid temperature}}$

$$q_u = F' \left[A_i I (\alpha\tau)_e - A_i U_L \left(\frac{t_{f,i} + t_{f,e}}{2} - t_a\right)\right]$$

or

$$\eta = \frac{q_u}{AI} = \frac{A_i}{A} F' (\alpha\tau)_e - \frac{A_i}{A} F' U_L \frac{\left(\frac{t_{f,i} + t_{f,e}}{2} - t_a\right)}{I} \quad (9)$$

7.1.1 Efficiency Calculation (Continued)

When the efficiency is plotted against $\frac{t_{f,i}-t_a}{I}$ and $\frac{\frac{t_{f,i}+t_{f,e}}{2}-t_a}{I}$, as shown in Figures 2 and 3, a linear regression can be applied to determine the coefficients in equations 8, and 9.

7.1.2 Shading Effect

The maximum length of the collector that can be accomodated under the solar simulator is 8 feet. For collectors longer than 8 feet the overhanging part must be shaded. Performance data obtained with part of the collector shaded can be corrected to predict the efficiency of the collector without shading.

Assuming that the shaded area is A_s, and the irradiated area is A_i, and the gross area of the collector is A_o. If q_u is the useful energy collected by the partially shaded collector

$$q_u = F_R A_i(\alpha\tau)I - F_R U_L(A_i+A_s)(t_{f,i}-t_a)$$

and the efficiency can be expressed as

$$\eta = \frac{q_u}{IA_o} = F_R\frac{A_i}{A_o}(\alpha\tau) - F_R U_L \frac{A_i+A_s}{A_o} (t_{f,i}-t_a).$$

Now, if the collector is not shaded,

$$q'_u = F'_R(A_i+A_s)(\alpha\tau)I - F'_R U'_L (A_i+A_s)(t_{f,i}-t_a).$$

and the efficiency can be expressed as

$$\eta' = \frac{q_u'}{IA_o} = F'_R\frac{A_i+A_s}{A_o}(\alpha\tau) - F'_R U'_L \frac{A_i+A_s}{A_o} (t_{f,i}-t_a).$$

Assuming that

$$F_R \simeq F_{R'} \text{ and } U_L \simeq U_{L'}$$

then

$$\eta' = F_R \frac{A_i}{A_o}(\alpha\tau) - F_R U_L \frac{A_i+A_s}{A_o}(t_{f,i}-t_a) + F_R \frac{A_s}{A_o}(\alpha\tau)$$

$$= \eta + F_R \frac{A_s}{A_o}(\alpha\tau)$$

From this equation, it is obvious that the difference between these two efficiencies is

$$F_R \frac{A_s}{A_o}(\alpha\tau)$$

7.1.2 Shading Effect (Continued)

$$F_R \frac{A_s}{A_o} (\alpha\tau) = F_R \frac{A_i}{A_o} (\alpha\tau) \cdot \frac{A_s}{A_i}$$

where $F_R \frac{A_i}{A_o} (\alpha\tau)$ is the intercept at $\frac{t_{f,i} - t_a}{I}$ equals zero, and

$\frac{A_s}{A_i}$ is the area ratio of the shaded area to the irradiated area.

Results of simulated solar collector testing, when corrected for the shaded area, show good agreement with outdoor test data obtained from Reference 2.5. Correlated results of these two test conditions on the SEPCO Collector are shown graphically in Figure 4.

7.0 ANALYSIS (Continued)

7.2 Time Constant Test

Two methods are proposed by ASHRAE 93-77 conducting a time constant test. However, due to facility limitations, only the first method could be used. This method consisted of shutting down the simulator and maintaining a constant flow rate and inlet temperature while obtaining data.

According to the definition of time constant given in 93-77, it is the time required for the ratio of the differential temperature at time τ to the initial differential temperature to reach .368. It can be expressed as:

$$\frac{T_{f,e,\tau} - T_{f,i}}{T_{f,e,ini} - T_{f,i}} = .368 \qquad (1)$$

If the inlet liquid temperature can not be controlled to equal the ambient air temperature, then the following equation must be used

$$\frac{F_R U_L \,(t_{f,i} - t_a) + \frac{\dot{m}C_p}{A_i}\,(t_{f,e,\tau} - t_{f,i})}{F_R U_L \,(t_{f,i} - t_a) + \frac{\dot{m}C_p}{A_i}\,(t_{f,e,ini} - t_{f,i})} = .368 \qquad (2)$$

where:

$T_{f,e,\tau}$	Exit air temperature at time τ
$T_{f,i}$	Inlet air temperature
$T_{f,e,ini}$	Initial exit air temperature
$\dot{m}$	Air mass flow rate 227.7 Lb/Hr
C_p	Specific heat of air = .24 BTU/Lb·°F
A_i	Absorber area = 16.73 Ft^2
$F_R U_L$	Negative of the slope determined from the thermal efficiency curve

During the time constant test, the inlet liquid temperature can not be controlled to within ±2°F of ambient air temperature, hence equation (2) was used for evaluation. From the performance curve, it is found that $F_R U_L$ = 1.15. Substitution of $F_R U_L$ = 1.15 in equation (2) yields.

$$\frac{1.15\,(87.2-79.7) + 3.159\,(t_{f,e,\tau} - 87.2)}{1.15\,(87.2-79.7) + 3.159\,(\quad 44.4 \quad)} = .368$$

7.2 Time Constant Test (Continued)

or

$$\frac{t_{f,e,\tau} - t_{f,i}}{t_{f,e,ini} - t_{f,i}} = .329$$

From Figure 5 the time constant was determined to be 6 minutes and 12 seconds.

7.0 ANALYSIS (Continued)

7.3 Incident Angle Modifier Test

Two methods are proposed by ASHRAE 93-77 for incident angle modifier tests. For the MSFC Solar Simulator Facility, only method 1, (tilting the collector) is applicable. The collector was adjusted so that the incident angles were 45, 60 and 75°.

According to 93-77, the performance of a flat-plate solar collector at incident radiation angles other than normal is defined as

$$\eta = \frac{q_u}{AI} = \frac{A_i}{A} F_R K(\alpha\tau)_n - \frac{A_i}{A} F_R U_L \frac{(t_{f,i} - t_a)}{I} \qquad (1)$$

By rearranging equation (1), the incident angle modifier, $K_{\alpha\tau}$, can be expressed as

$$K_{\alpha\tau} = \frac{\eta + \frac{A_i}{A} F_R U_L \frac{(t_{f,i} - t_a)}{I}}{\frac{A_i}{A} F_R (\alpha\tau)_n} \qquad (2)$$

If the inlet liquid temperature is controlled to within ±2°F of ambient temperature, equation (2) becomes

$$K_{\alpha\tau} = \frac{\eta}{\frac{A_i}{A} F_R (\alpha\tau)_n} \qquad (3)$$

Table IV shows that the inlet liquid temperatures were not within ±2°F of ambient air temperatures. Hence, equation (2) was used for evaluation.

$$K_{\alpha\tau} = \frac{\eta + .757 \frac{t_{f,i} - t_a}{I}}{.396}$$

The results of this computation are shown on Table V. The incident angle modifier, $K_{\alpha\tau}$, is shown plotted versus incident angles in Figure 6 and plotted versus $\left[\frac{1}{\cos \theta i} - 1\right]$ in Figure 7.

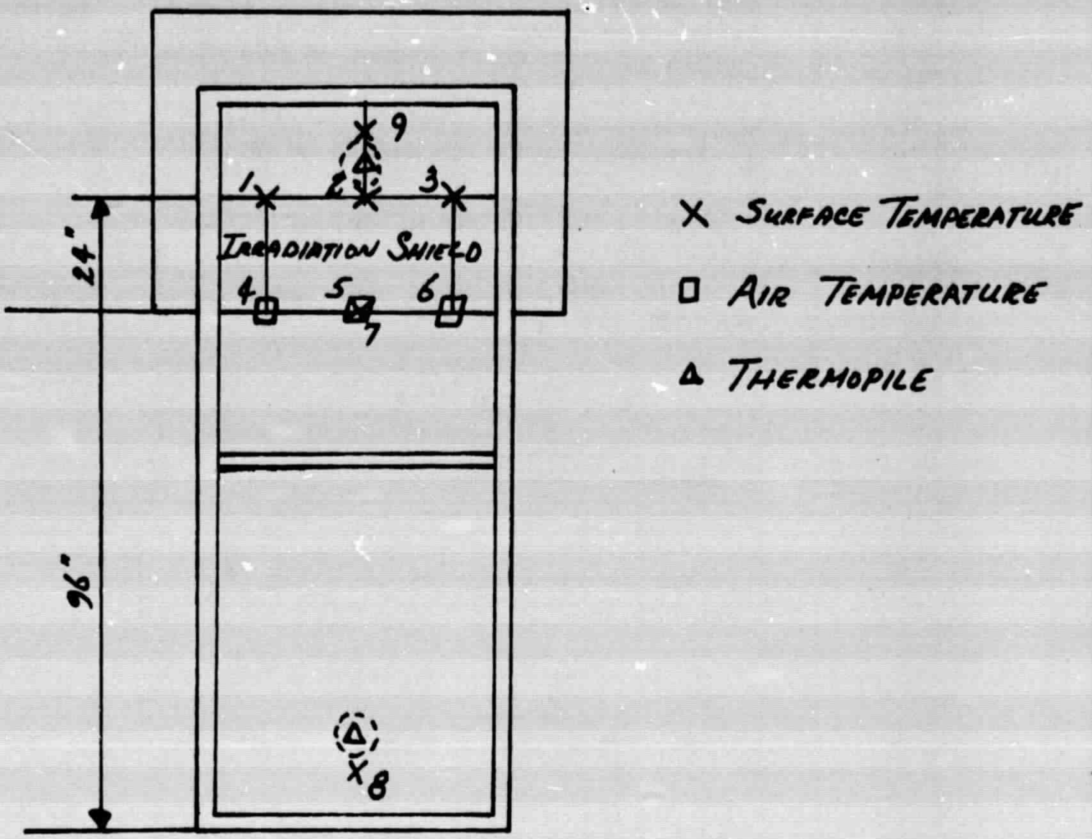

Figure 1. SEPCO Collector Instrumentation Locations

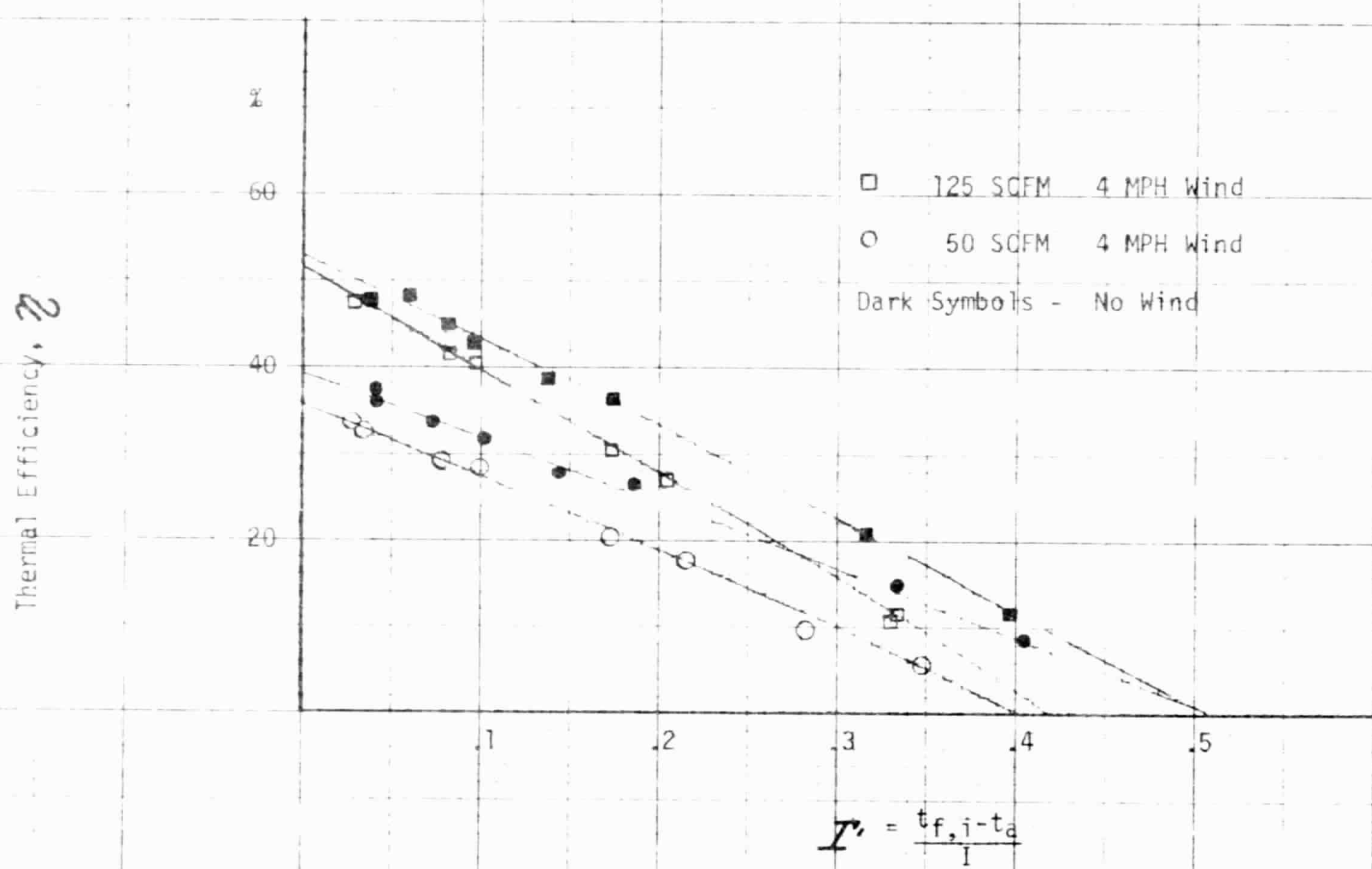

Figure 2. Thermal Performance of SEPCO Collector

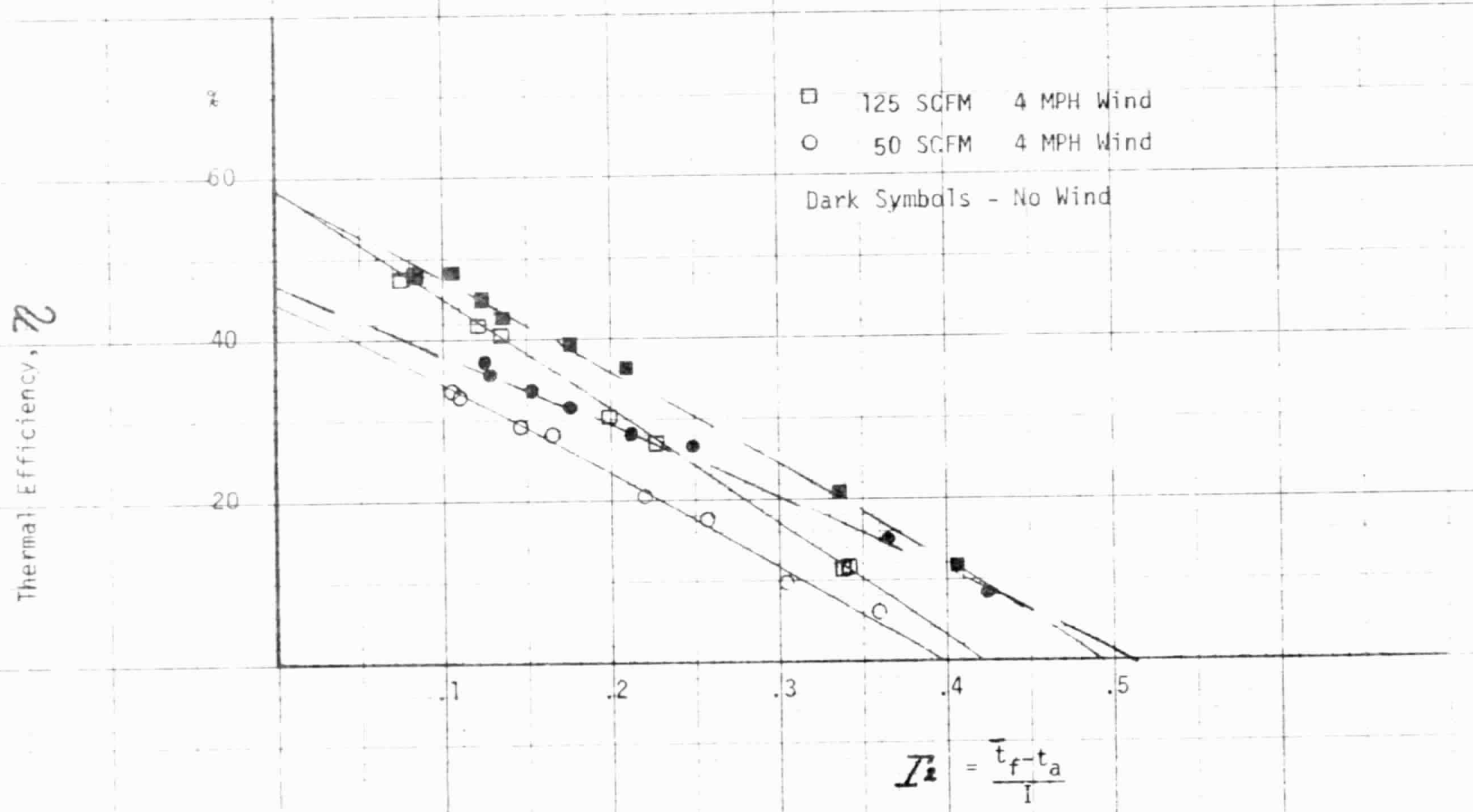

Figure 3. Thermal Performance of SEPCO Collector

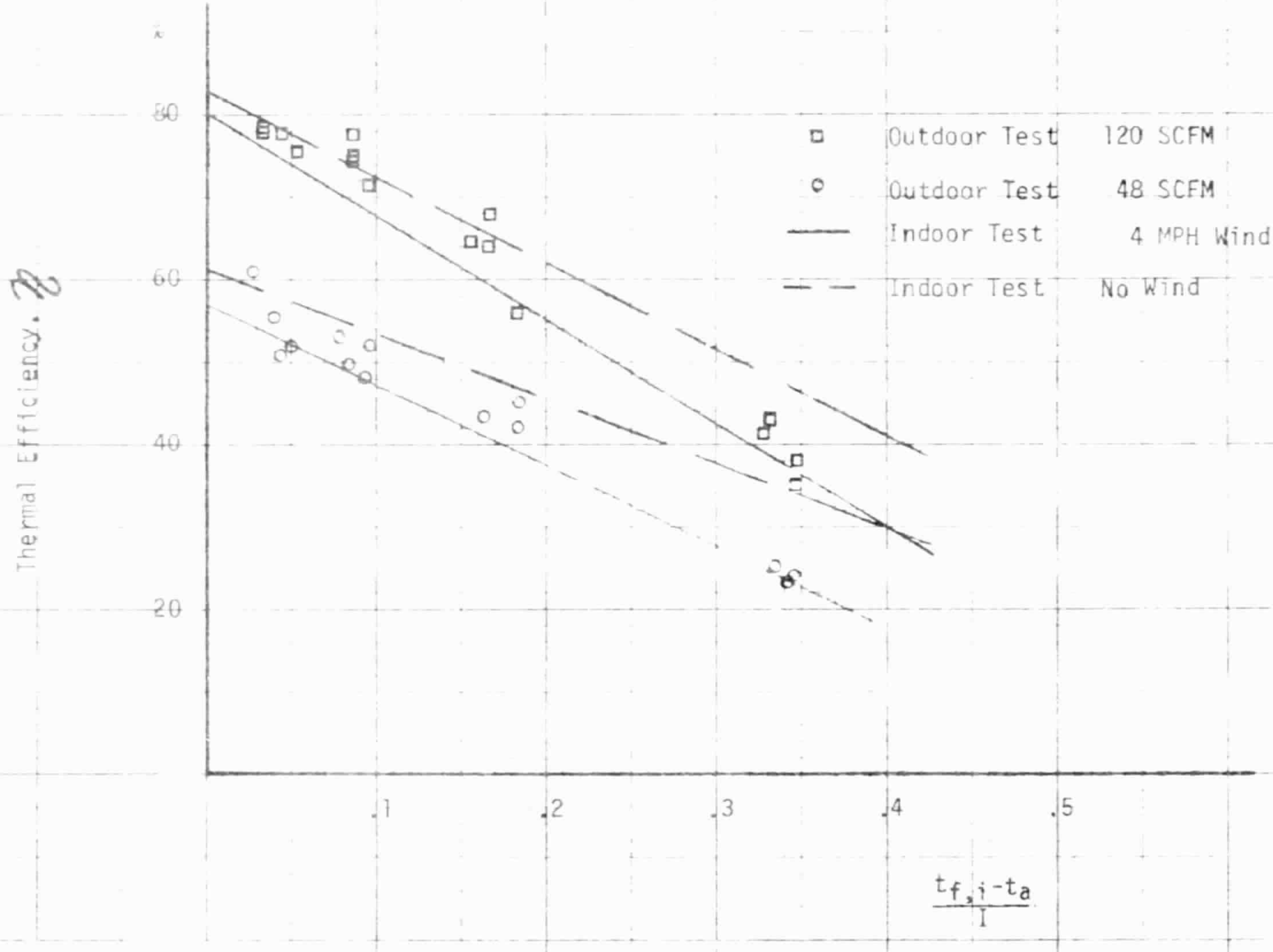

Figure 4. Comparison of Indoor Tests with Outdoor Data

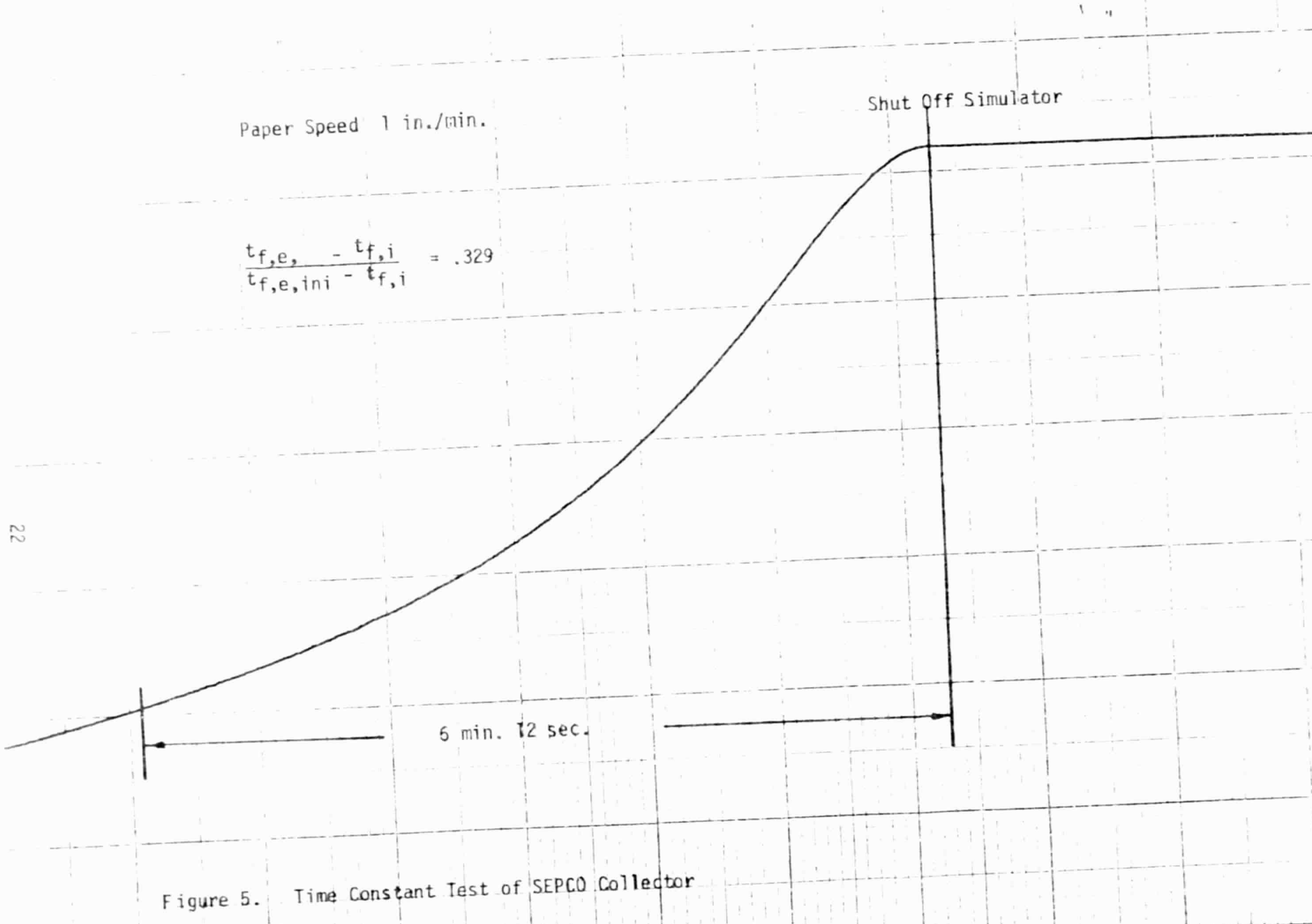

Figure 5. Time Constant Test of SEPCO Collector

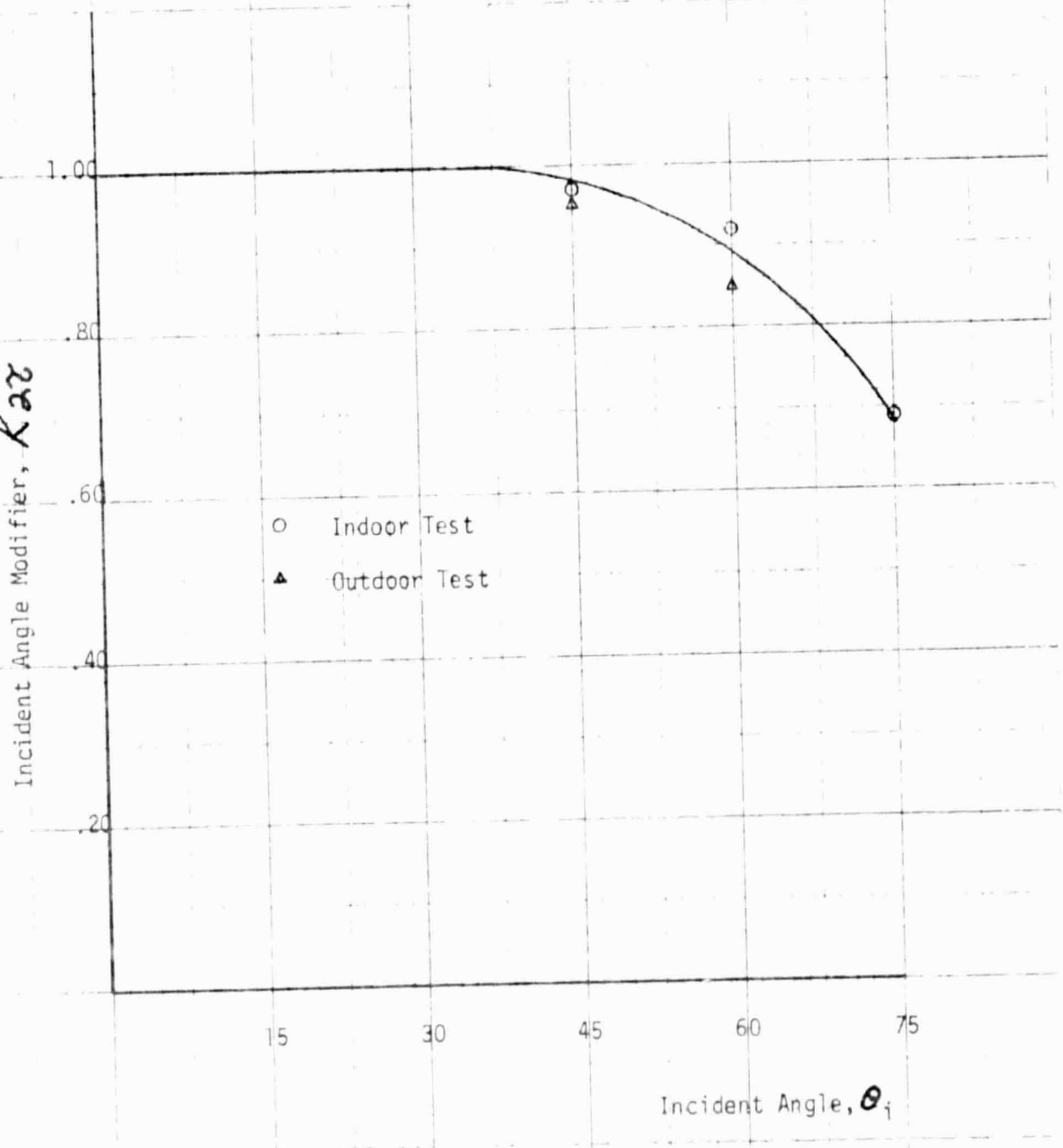

Figure 6. Incident Angle Modifier, $K_{\tau\alpha}$ for SEPCO Collector

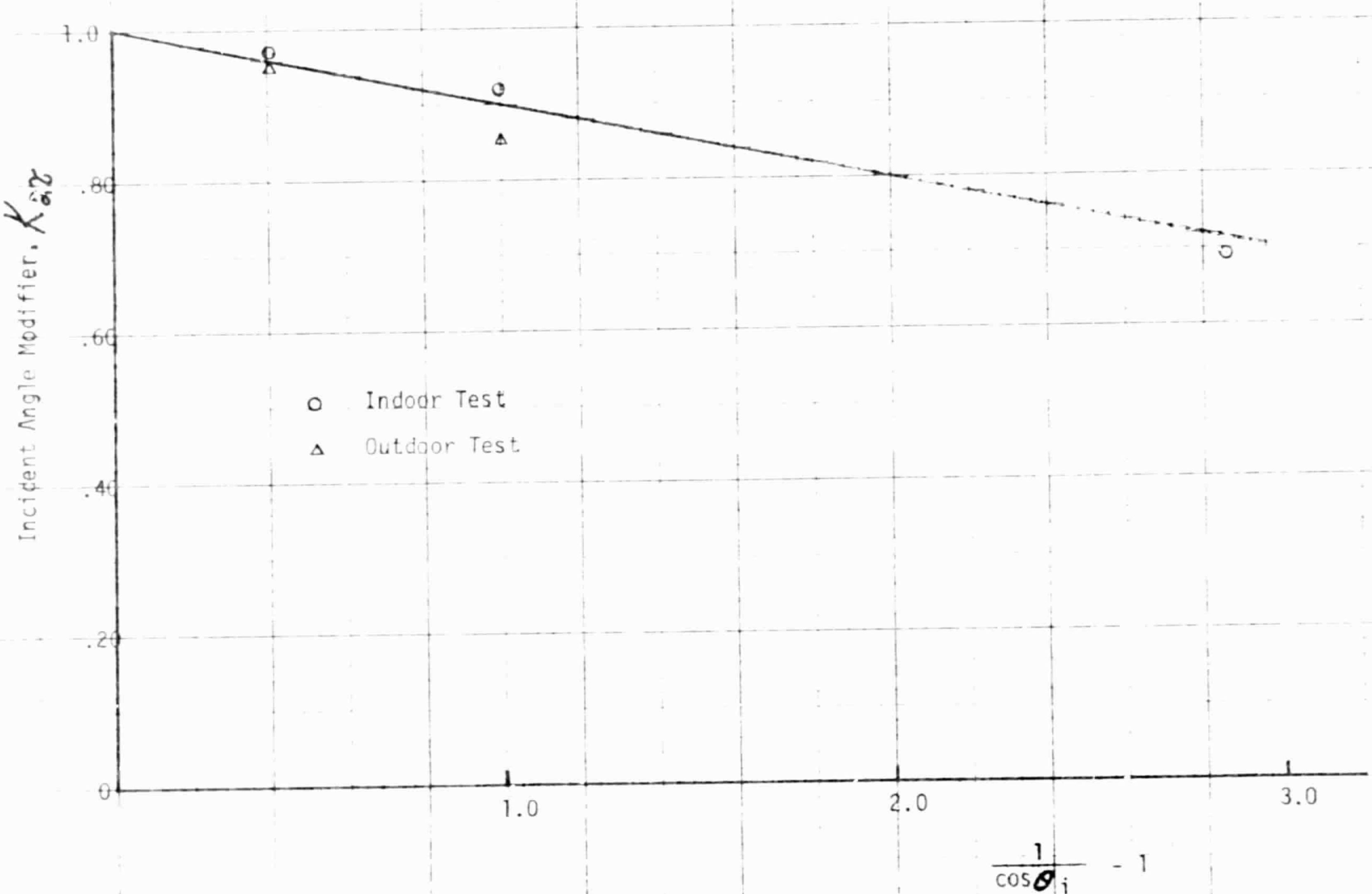

Figure 7. Incident Angle Modifier, K_{az} for SEPCO Collector

TABLE I

SEPCO COLLECTOR INSTRUMENTATION

HP Number	Computer Line	Inst. ID	Function
2	109 B	TC-1	Surface Temp. - W
3	110 A	TC-2	Surface Temp. - C
4	110 B	TC-3	Surface Temp. - E
5	111 A	TC-4	Average Air Temp.
6	111 B	TC-7	Surface Temp.
7	112 A	TC-8	Surface Temp. - S
8	112 B	TC-9	Surface Temp. - N
9	113 A		Flowmeter
10	113 B		Ambient

CALCULATION OR DATA SHEET

TABLE II

THERMAL PERFORMANCE TEST DATA - NO WIND

	#1	#2	#3	#4	#5	#6	#7	#8	#9
1	139.7	118.4	124.7	144.7	148.4	153.8	170.7	166.4	197.8
2	141.3	119.8	126.4	146.2	150.1	158.9	172.9	169.0	200.9
3	142.3	119.8	126.3	147.1	150.8	159.7	173.8	150.1	201.6
4	132.0	116.7	122.2	134.7	137.7	146.4	156.7	151.3	174.9
7	154.9	125.7	133.5	162.6	163.8	174.8	189.3	182.1	215.0
8	—	—	—	—	—	—	—	—	—
9	137.9	118.9	125.1	142.1	145.7	154.1	166.9	162.6	191.2
T_a	87.1	84.3	87.0	83.8	88.1	89.3	90.2	91.6	92.5
T_{in}	97.2	98.6	98.0	96.1	112.5	110.4	132.4	136.4	189.7
ΔT	41.9	22.2	26.7	48.6	36.1	46.6	38.5	30.0	9.66
Q	240	240	290	290	240	290	290	240	240
F ACFM	51.5	130.5	130.1	52.6	54.3	53.9	55.9	55.9	60.5
SCFM	48.6	122.9	122.4	49.6	49.8	49.6	49.6	49.2	48.8
η	35.9	48.1	47.7	37.3	31.7	33.7	27.9	26.5	8.5
I'_1	.042	.060	.038	.042	.102	.073	.146	.187	.405
I'_2	.129	.106	.084	.126	.177	.153	.212	.249	.425

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TABLE II (Continued)

THERMAL PERFORMANCE TEST DATA - NO WIND

	#11	#12	#10	#13	#14	#15	#16
1	132.1	135.2	208.4	153.3	158.0	188.9	196.5
2	133.4	137.0	212.2	154.8	159.9	189.6	198.4
3	133.1	136.7	212.9	154.6	159.7	189.8	198.4
4	124.7	129.6	184.8	143.7	148.8	164.4	175.3
7	139.4	143.9	229.4	160.9	167.2	198.3	206.2
8	—	—	—	—	—	—	—
9	131.5	135.1	201.4	152.1	157.2	184.4	193.1
Ta	88.7	88.6	93.1	93.2	95.2	87.3	93.8
Tin	112.1	112.0	189.8	135.3	135.2	182.6	185.6
ΔT	19.4	24.6	20.2	16.5	21.6	5.2	11.3
Q	240	290	290	240	290	240	290
F ACFM	136.4	136.2	60.5	141.4	141.6	154.0	154.8
SCFM	125.3	125.1	48.9	124.5	124.6	125.5	125.8
η	42.8	44.9	14.8	36.2	39.3	11.6	20.7
I_1	.098	.081	.333	.175	.138	.397	.317
I_2	.138	.123	.368	.210	.175	.408	.336

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TABLE III

THERMAL PERFORMANCE TEST DATA - 4 MPH WIND

	#17	#18	#19	#20	#21	#22	#23	#24	#25
1	134.9	143.6	143.2	151.8	154.7	162.8	175.8	182.6	118.9
2	135.6	144.4	143.9	152.7	155.6	163.6	176.6	183.3	119.9
3	136.5	145.5	145.1	154.1	157.0	165.4	178.8	185.7	119.3
4	125.0	133.2	132.7	139.9	138.0	146.3	155.5	160.7	115.9
7	152.0	163.8	160.4	172.5	172.8	183.8	194.7	204.8	127.5
8	—	—	—	—	—	—	—	—	—
9	132.1	140.6	140.1	148.3	150.1	157.9	109.9	175.8	118.3
Ta	88.7	89.3	88.4	90.1	83.7	85.4	86.0	87.4	88.3
TIN	96.5	97.0	112.1	112.6	135.3	135.3	169.0	169.0	97.3
ΔT	37.2	45.5	31.9	34.9	19.9	27.9	6.65	13.3	21.8
Q	240	290	240	290	240	290	240	290	240
FACFM	53.0	13.4	54.5	54.4	56.5	56.6	60.0	60.4	131.8
SCFM	50.0	50.4	50.0	49.9	49.7	49.8	49.9	50.2	124.3
η_c	32.8	33.4	28.1	29.0	17.4	20.3	5.8	9.7	47.8
I'_1	.033	.027	.099	.078	.215	.172	.346	.281	.038
I'_2	.110	.105	.165	.147	.256	.220	.360	.304	.082

TABLE III (Continued)

THERMAL PERFORMANCE TEST DATA - 4 MPH WIND

	#26	#27	#28	#29	#30	#31	#32		
1	123.6	129.9	135.0	146.2	150.9	173.3	188.9		
2	124.7	130.8	136.2	147.3	152.1	174.2	189.9		
3	124.1	130.4	135.7	147.2	152.0	174.7	190.6		
4	119.1	122.2	127.1	131.4	136.1	154.2	165.3		
7	134.0	138.8	145.8	155.7	162.0	183.0	200.5		
8	—	—	—	—	—	—	—		—
9	122.8	128.4	133.5	143.9	148.4	169.8	184.6		
Ta	89.0	88.9	88.6	84.6	84.8	88.5	86.9		
Tin	97.3	112.0	112.0	134.4	134.4	168.0	182.6		
ΔT	26.3	18.6	23.1	12.1	16.5	5.1	5.9		
Q	290	240	290	240	290	240	290		
FACFM	131.6	133.7	133.9	142.9	142.6	151.6	153.9		
SCFM	124.1	122.6	122.8	125.9	125.9	126.1	125.4		
η	47.7	40.2	41.4	26.8	30.2	11.4	10.9		
I_1	.029	.096	.081	.203	.171	.331	.330		
I_2	.074	.135	.121	.229	.199	.342	.340		

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TABLE IV

TIME CONSTANT TEST DATA

ID \ Time	9:9:25	9:10:25	9:11:26	9:12:26	9:13:27	9:14:27	9:15:28	9:16:28	9:17:28
1	131.7	131.7	131.9	131.9	152.0	132.1	132.1	127.4	119.8
2	132.3	132.4	132.5	132.6	132.6	132.7	132.8	127.7	119.0
3	133.0	133.1	133.2	133.3	133.3	133.5	133.3	126.3	118.2
4	123.4	123.5	123.7	123.8	123.9	124.1	123.7	118.6	114.4
7	148.9	149.0	149.1	149.1	149.2	149.3	149.1	136.0	120.8
8	—	—	—	—	—	—	—	—	—
9	139.9	141.1	140.0	139.9	140.7	140.5	140.2	137.7	134.8
Ta	79.5	79.6	79.7	79.8	79.8	79.8	79.8	79.4	79.5
Tin	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Q	250	250	250	250	250	250	0	0	0
F_{SCFM}	49.6	48.9	49.8	49.0	49.6	49.3	49.2	49.5	49.1

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TABLE IV (Continued)

TIME CONSTANT TEST DATA

ID \ Time	19:18:29	9:19:29	9:20:29
1	113.3	108.6	105.2
2	111.8	106.8	103.6
3	112.0	107.6	104.4
4	111.5	109.2	107.2
7	111.0	105.1	101.4
8	—	—	—
9	132.5	130.9	129.5
Ta	79.6	79.8	79.7
Tin	87.5	87.5	87.5
Q	0	0	0
F SCFM	49.9	50.2	49.8

TABLE V

INCIDENT ANGLE MODIFIER TEST DATA

	45°	60°	75°
1	123.1	115.7	106.4
2	123.6	114.7	105.0
3	124.0	113.9	103.7
4	118.5	111.0	—
7	133.5	121.0	108.1
8	—	—	—
9	—	112.6	103.3
Ta	87.2	89.1	89.7
Tin	94.0	96.0	95.5
ΔT	28.9	18.4	8.52
Q	169.7	126.5	82.8
FACFM	51.4	52.6	52.4
SCFM	48.9	50.0	49.8
η	35.2	32.4	21.9
$K_{\alpha\tau}$	.97	.92	.69

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