DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150523

LONG-TERM WEATHERING EFFECTS ON THE THERMAL PERFORMANCE OF THE SOLARGENICS (LIQUID) SOLAR COLLECTOR AT OUTDOOR CONDITIONS

Prepared by

Wyle Laboratories
Solar Energy Systems Division
Huntsville, Alabama 35805

Under Subcontract with

IBM Corporation, Federal Systems Division, Huntsville, Alabama 35805

Contract NAS8032036

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

For the U. S. Department of Energy

(NASA-CR-150523) LONG-TERM WEATHERING EFFECTS ON THE THERMAL PERFORMANCE OF THE SOLARGENICS (LIQUID) SOLAR COLLECTOR AT OUTDOOR CONDITIONS (Wyle Labs., Inc.) 13 p HC A02/MF A01 CSCL 10A G3/44

N79-29601

Unclas 31733

U.S. Department of Energy

Solar Energy

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this report is to present the test procedures used and the test results obtained during an evaluation test program. The test program was conducted to obtain thermal performance data on a Solargenics single-covered liquid solar collector under outdoor conditions (Reference 2.1), following long term exposure to natural weathering conditions. The tests were conducted utilizing the Marshall Space Flight Center Breadboard Test Facility in accordance with the outdoor test requirements of Reference 2.2.

2.0 REFERENCES

2.1	CR-150857	Thermal Performance Evaluation of the Solargenics Solar Collector at Outdoor Conditions
2.2	ASHRAE 93-77	Method of Testing to Determine the Thermal Performance of Solar Collectors

3.0 COLLECTOR DESCRIPTION

Manufacturer:	Solargenics
Manufacturer's Address:	808 Gretna Green Way Los Angeles, California
Model Number:	None
Serial Number:	None
Type:	Flat Plate
Working Fluid:	H_2O
Gross Collector Area, ft^2:	63.54
Overall external dimensions:	Width, inches: 38.12 Length, inches: 240.00 Thickness, inches: 3-7/8 Aperture area, ft^2: 53.34 ft^2
Collector glazing:	Single
Weight, lbs:	(Not available)

4.0 SUMMARY

Thermal performance tests were conducted on the Solargenics single-covered liquid solar collector following long term exposure to natural weathering conditions. The collector was mounted on the weathering test stand at the Solar Test Facility at Marshall Space Flight Center, Alabama, with exposure to the natural ambient environment. The collector was under stagnation conditions from August 26, 1978, to June 13, 1979. The collector was retested at the MSFC Breadboard Test Facility under outdoor natural conditions on June 22, 1979. The total weathering period was approximately ten months.

Visual inspection of the collector, prior to retest, indicated that some rain water leakage had occurred at the cover seals leaving water marks on the absorber plate. No other material deficiencies were apparent. The test results indicated that a small change in performance had occurred. A slight increase in the negative slope indicates an increase in the heat loss parameters. The slightly lower intercept on the ordinate axis is likely a result of a slight decrease in the absorptivity of the absorber plate or a decrease in the transmissivity of the cover glass.

5.0 TEST REQUIREMENTS AND PROCEDURES

5.1 Collector Thermal Efficiency Test

Thermal performance evaluation criteria shall correspond to that of reference 2.1. Data shall be obtained at inlet temperatures of 0, 25, 50 and 100°F above the ambient temperature at the liquid flow rate of 1.50 GPM. The test shall be conducted at times having weather conditions such that the integrated average insolation measured in the plane of the collector used for computation of instantaneous efficiency values shall not be less than 200 BTU/Hr·Ft^2. The air velocity across the collector surface shall be measured and recorded as part of the test data. The following data shall be recorded during the test at each test condition.

1. Ambient temperature.
2. Collector inlet liquid temperature.
3. Collector outlet liquid temperature.
4. Collector differential temperature.
5. Total solar flux.
6. Flow rate.
7. Wind speed and direction.

5.2 Test Procedure

1. Mount test specimen and its associated equipment on test bed #2 at a tilt angle of 45°.

2. Assure data acquisition system is operational.

3. Establish the proper flowrate and inlet temperature for each test designation.

4. Continuously adjust the inlet temperature and flow rate to maintain the desired "data point" characteristics, as specified in paragraph 4.1.

5. After steady state conditions have been obtained for each "data point," record data for a minimum of five minutes. Monitor the test parameters by using the data acquisition system at the test site.

6. Once steady state data has been obtained for all specified data points, label and save the printout from teletype as a record.

6.0 ANALYSIS

6.1 Thermal Performance Test

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:

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

where:

q_u = Rate of useful energy extracted from the solar collector (BTU/Hr)

A = Gross collector area (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 transfer liquid through the collector per unit area of the collector ($Lbm/Ft^2 \cdot Hr$)

C_{tf} = Specific heat of the transfer liquid ($BTU/Lb \cdot °F$)

$t_{f,e}$ = Temperature of the transfer liquid leaving the collector (°F)

$t_{f,i}$ = Temperature of the transfer liquid entering the collector (°F)

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

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

Notice that:

$P_i = IA$ = Total power incident on the collector.

$\dot{m}A = \dot{M}$ = Total mass flow rate through the collector.

Therefore $\dot{M}\, C_{tf}(t_{f,e} - t_{f,i})$ = Total power collected by the collector.

6.1 Thermal Performance Test (Continued)

Substitution in Equation (2) results in:

$$\eta = \frac{Pabs}{Pinc} \tag{3}$$

where:

Pabs = Total collected power

Pinc = Total incident power

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

$$\text{Collector Efficiency} = \frac{Pabs}{Pinc} \times 100 \tag{4}$$

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

$$\%\ Eff = \frac{\dot{M}\, C_{tf}\, (t_{f,e} - t_{f,i})}{Pinc} \times 100 \tag{5}$$

Each term in Equation (5) was measured and recorded independently during the test.

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

$$\left(t_i - t_a)/I \right)$$

where:

t_i = Liquid inlet temperature (°F)

t_a = Ambient temperature (°F)

I = Incident flux per unit area ($BTU/Hr \cdot Ft^2$)

The abscissa term $\left((t_i - t_a)/I\right)$ was used to normalize the effect of operating at different values of I, t_i and t_a. The results are shown graphically in Figure 1 with the supporting test data given in Table I.

6.0 ANALYSIS AND RESULTS (Continued)

6.1 Thermal Performance Test (Continued)

Reference 2.2 uses the following terms relating to the thermal efficiency graph:

$F_R\alpha\tau$ = intercept of the efficiency curve on the ordinate axis

F_RU_L = the negative of the slope of the efficiency curve

F_R = the solar heat removal factor

$\alpha\tau$ = absorptance of the collector surface for solar radiation

τ = transmittance of the solar collector cover plate

U_L = solar collector heat transfer loss coefficient

A comparison of the before and after weathering efficiency curves indicates that the slope, F_RU_L, did change slightly and that the value of $F_R\alpha\tau$ did drop a marginal amount.

TABLE I

SOLARGENICS LIQUID COLLECTOR PERFORMANCE RECHECK
AFTER LONG TERM EXPOSURE TO NATURAL WEATHERING CONDITIONS

	1	2	3	4	5	6	7	
Ambient Air Temperature (T_a), °F	85.8	89.9	86.5	85.0	86.1	91.1	84.1	
Fluid Inlet Temperature (T_i), °F	87.2	89.9	120.3	109.3	132.4	166.6	151.3	
Fluid Outlet Temperature (T_e), °F	102.2	103.9	131.2	120.4	142.1	173.6	157.3	
Differential Fluid Temperature (ΔT), °F	15.0	14.0	10.9	11.1	9.7	7.0	6.0	
Total Solar Flux (I), BTU/Hr·Ft^2	273.9	263.0	255.0	253.9	260.0	249.6	213.6	
Flow Rate, Lb/Min	11.50	11.71	12.06	12.30	12.13	11.92	11.96	
$(T_i - T_a)/I$ °F·Hr·Ft^2/BTU	0.005	0.000	0.135	0.096	0.178	0.302	0.314	
Efficiency (η), %	59.4	58.9	48.7	50.8	42.7	31.6	31.7	
Date Wind Speed and Direction	6/13 4 SE	6/22 3 SW	6/22 2 SW	6/22 2 SW	6/22 2 SW	6/22 4 SW	6/22 2 SW	

TABLE II

THERMAL PERFORMANCE TEST DATA FOR THE SOLARGENICS COLLECTOR
BEFORE LONG TERM EXPOSURE

Date Wind Speed and Direction	7/18 5E	7/18 5W	7/20 5E	7/20 5W	7/24 7W	7/24 5W	7/24 7E	7/24
Ambient Air Temperature (T_a), °F	89.5	90.0	92.0	92.5	92.0	91.9	91.3	91.6
Fluid Inlet Temperature (T_i), °F	91.8	92.0	91.7	91.9	115.1	115.2	115.4	115.5
Fluid Outlet Temperature (T_e), °F	106.2	106.2	105.4	105.9	129.7	129.6	129.9	129.6
Differential Fluid Temperature (ΔT), °F	14.4	14.2	13.7	14.0	14.6	14.4	14.5	14.1
Total Solar Flux (I), BTU/Hr·Ft^2	303.6	310.3	282.6	283.0	320.6	314.9	316.4	314.1
Flow Rate, GPM	1.58	1.58	1.54	1.54	1.54	1.54	1.55	1.55
$(T_i - T_a)/I$ °F·Hr·Ft^2/BTU	.01	.01	.00	.00	.07	.07	.08	.08
Efficiency (η), %	58.7	56.6	58.4	59.6	54.6	54.8	55.2	54.1
Specific Gravity	0.996	0.996	0.996	0.996	0.989	0.989	0.989	0.989

TABLE II (Continued)

Date Wind Speed and Direction	7/24 10W	7/24 8W	7/24 6W	7/24 8W	7/18 5E	7/18 3E	7/18 8W	7/18 10W
Ambient Air Temperature (T_a), °F	93.5	93.0	92.5	92.3	93.9	93.9	94.5	95.2
Fluid Inlet Temperature (T_i), °F	145.4	145.4	145.3	145.1	187.8	189.4	189.9	189.9
Fluid Outlet Temperature (T_e), °F	158.3	158.2	158.6	158.4	195.4	197.5	199.4	199.4
Differential Fluid Temperature (ΔT), °F	12.9	12.8	13.3	13.3	7.6	8.1	9.5	9.5
Total Solar Flux (I), BTU/Hr·Ft^2	322.4	3[illegible]4.6	323.4	331.4	300.4	302.4	315.8	308.0
Flow Rate, GPM	1.51	1.51	1.51	1.51	1.57	1.57	1.57	1.57
$(T_i - T_a)/I$ °F·Hr·Ft^2/BTU	.16	.16	.16	.16	.31	.32	.30	.31
Efficiency (η), %	46.8	46.1	48.0	46.9	30.2	31.9	35.9	36.8
Specific Gravity	.984	.984	.984	.984	.966	.966	.966	.966

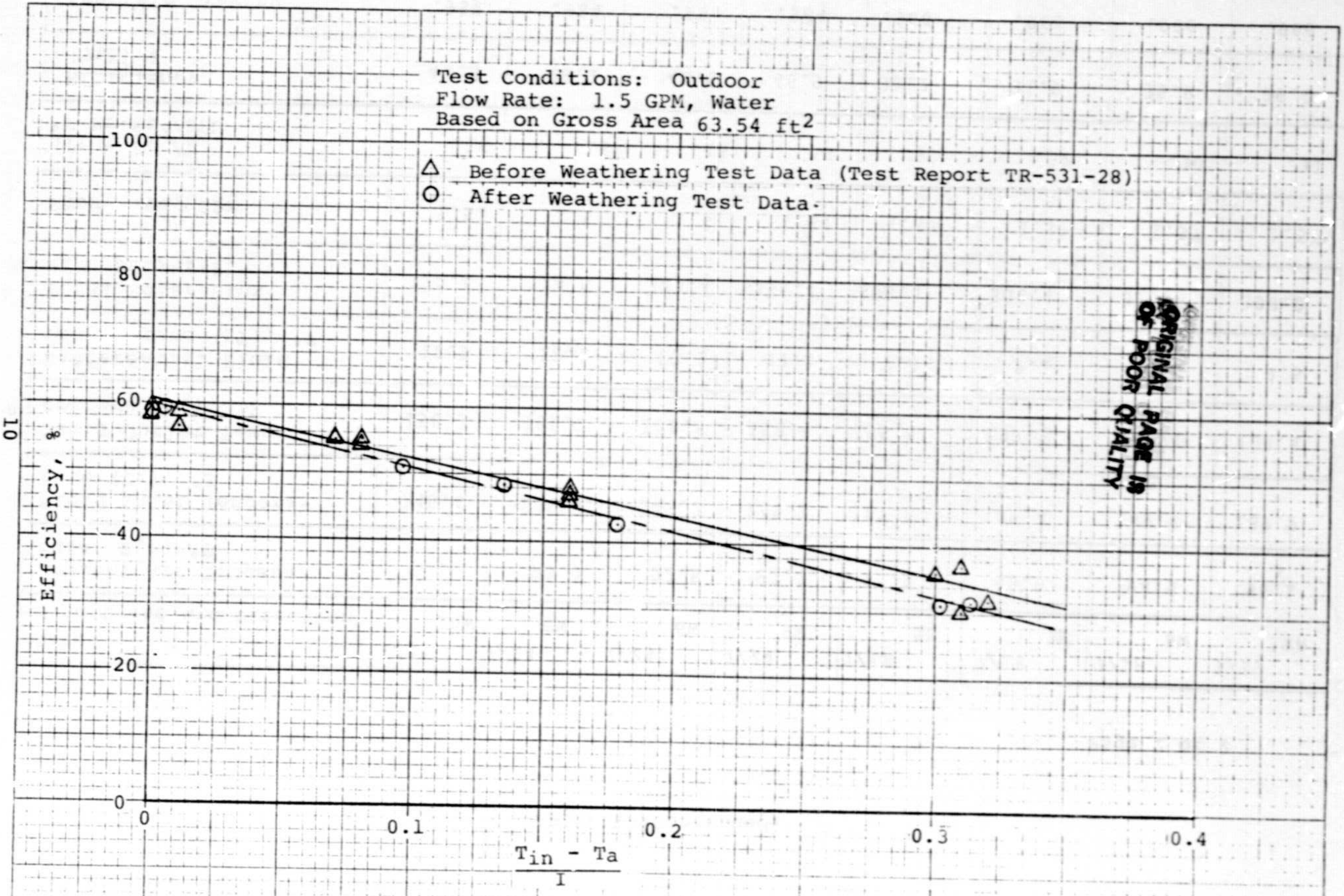

Figure 1. Solargenics Collector Thermal Performance Test Results