DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150899

LONG TERM WEATHERING EFFECTS ON THE THERMAL PERFORMANCE OF THE SUNWORKS (LIQUID) SOLAR COLLECTOR

Prepared by

Wyle Laboratories
Solar Energy Systems Division
Huntsville, Alabama 35805

Under subcontract with

IBM Corporation, Federal Systems Division, Huntsville, Alabama 35805

Contract NAS8-32036

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 38512

For the U. S. Department of Energy

U.S. Department of Energy

Solar Energy

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1.0 SUMMARY

Thermal performance tests were conducted on the Sunworks liquid 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 September 2, 1977, to December 30, 1977, when the collector was integrated into an intermittently active system. The collector remained in intermittently active/stagnant conditions until June 1, 1978, when it was returned to the weathering stand under stagnation conditions through August 15, 1978. The collector was retested at the Marshall Space Flight Center Solar Simulator on August 16, 1978. The total weathering period was approximately eleven and one-half months.

Visual inspection of the collector, prior to the re-test, indicated no noticeable deterioration. The test results also indicated that no detectable degradation in performance had resulted from the weathering. A comparison of the test results for the re-test and the original thermal efficiency test are shown in Figure 1. The necessary supporting data recorded for the re-test are shown in Table 1.

2.0 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 Sunworks (S/N L1158G) single-covered liquid solar collector under simulated conditions (Reference 3.1), following long term exposure to natural weathering conditions. The tests were conducted utilizing the Marshall Space Flight Center Solar Simulator in accordance with the test procedures specified in Reference 3.2 and the test requirements of Reference 3.3.

3.0 REFERENCES

3.1 DOE/NASA CR-150573 Indoor Test for Thermal Performance Evaluation of the Sunworks (Liquid) Solar Collector

3.2 MTCP-FA-SHAC-400 Procedure for Operation of the MSFC Solar Simulator Facility

3.3 ASHRAE-93-77 Method of Testing to Determine the Thermal Performance of Solar Collectors

4.0 TEST REQUIREMENTS AND PROCEDURES

4.1 Collector Thermal Efficiency Test Requirements

Thermal performance evaluation criteria shall be identical to that of Reference 3.1 or as close as possible. Data shall be obtained at inlet temperatures of 0, 25, 50 and 100°F above the ambient temperature at a liquid flow rate of 285 lb/hr (0.57 GPM) at a solar insolation rate of 300 BTU/Hr·Ft^2 and a wind speed of 7.5 mph. 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. Differential pressure across collector.
6. Liquid flow rate.
7. Insolation rate.
8. Wind speed.

4.2 Test Procedure

1. Mount test specimen on test table at a 45° angle with respect to the floor.
2. Assure that simulator lamp array is adjusted to an angle of 45° with respect to the floor.
3. Align the test table so that the test specimen's vertical centerline coincides with the vertical centerline of the lamp array and the distance from the top of the test specimen to the lens plane of the lamp array is 9 feet.
4. Insulate all pipes.
5. Assure that data acquisition system is operational.
6. Start liquid flow loop and establish a flow rate of 285 Lb/Hr (0.57 GPM).
7. Establish the wind speed of 7.5 mph.
8. Power up simulator and establish a solar flux level of 300 BTU/Ft^2·Hr.

4.0 TEST REQUIREMENTS AND PROCEDURES (Continued)

4.2 Test Procedure (Continued)

9. Determine the ambient air temperature.

10. Adjust the inlet temperature of the collector to the ambient air temperature value.

11. After steady state conditions have been established, record data for a minimum of five minutes.

12. Repeat steps 9, 10, and 11, changing the liquid inlet temperature as necessary until data has been obtained for each test condition specified in Paragraph 4.1.

13. Upon completion of testing, power down simulator and liquid loop.

14. Inform data control group that simulator operation has terminated.

5.0 ANALYSIS AND RESULTS

5.1 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:

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

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:

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

Notice that:

$P_i = IA$ = Total Power Incident on the Collector.

$mA = \dot{M}$ = Total Mass Flow Rate through the Collector.

Therefore $\dot{M}\, C_{tf}(t_{f,e} - t_{f,i})$ = Total Power Collected by the Collector.

5.0 ANALYSIS AND RESULTS (Continued)

5.1 Thermal Performance Test (Continued)

Substitution in Equation (2) results in:

$$\eta = \frac{Pabs}{Pinc} \qquad (3)$$

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:

$$\text{Collector Efficiency} = \frac{Pabs}{Pinc} \times 100 \qquad (4)$$

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

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

Each term in Equation (5) was measured and recorded independently during the test. The calculated values of efficiency were determined at sixty-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

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

where:

t_i = Liquid inlet temperature (°F)

t_a = Ambient temperature (°F)

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

The abscissa term $\left((t_i - t_a)/I\right)$ was used to normalize the effect of operating at slightly 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.

TABLE I

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

	1	2	3	4	5			
Ambient Air Temperature (T_a), °F	79.1	80.8	82.0	83.5	83.1			
Fluid Inlet Temperature (T_i), °F	87.3	107.7	132.5	153.0	184.2			
Fluid Outlet Temperature (T_e), °F	101.2	120.3	143.9	162.2	190.0			
Differential Fluid Temperature (ΔT), °F	13.9	12.6	11.4	9.2	5.8			
Total Solar Flux (I), $BTU/Hr \cdot Ft^2$	303.4	303.4	303.4	303.4	300.0			
Flow Rate, GPM	0.587	0.581	0.572	0.582	0.570			
$(T_i - T_a)/I$ $°F \cdot Hr \cdot Ft^2/BTU$	0.03	0.09	0.166	0.229	0.34			
Efficiency (η), %	63.8	57.0	50.4	41.2	25.4			
Specific Gravity	0.999	0.993	0.986	0.981	0.970			

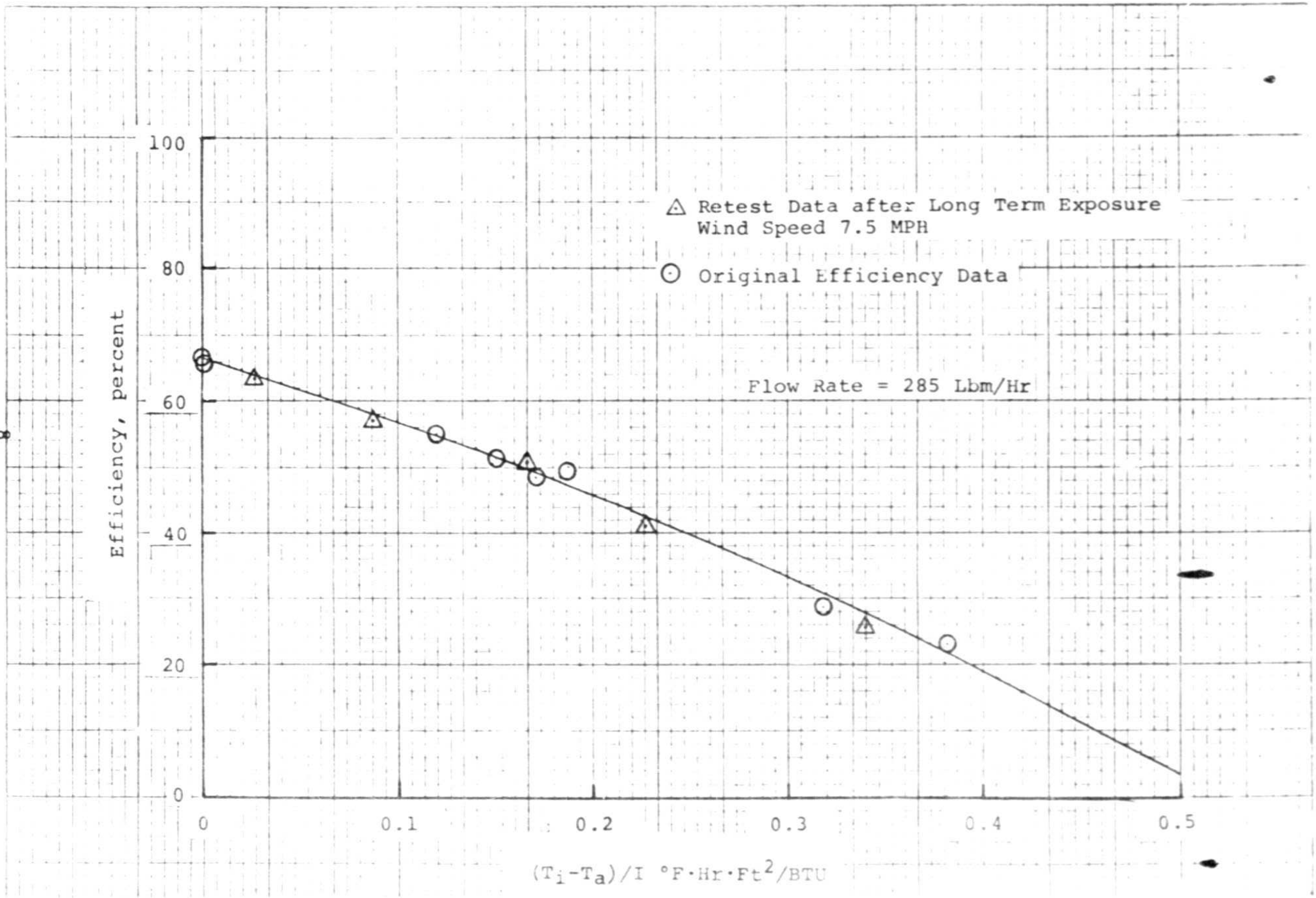

Figure 1. Comparison of Thermal Performance of Sunworks Liquid Collector Before and After Long Term Exposure to Natural Weathering Conditions