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DOE/NASA CONTRACTOR
REPORT

14. 2297

DOE/NASA CR-150899

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

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Under subcontract with

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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

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1. REPORT NO. DOE/NASA CR-150899	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Long Term Weathering Effects on the Thermal Performance of the Sunworks (Liquid) Solar Collector		5. REPORT DATE January 1979	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT #	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Wyle Laboratories Solar Energy Systems Division Huntsville, Alabama 35805		10. WORK UNIT NO.	
		11. CONTRACT OR GRANT NO. NAS8-32036	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		13. TYPE OF REPORT & PERIOD COVERED Contractor Report	
		14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. Norman Thomas, George C. Marshall Space Flight Center, Alabama.			
16. ABSTRACT This report presents the test procedures used and the results obtained during the evaluation test program of the Sunworks single-covered liquid solar collector. The tests were performed under simulated conditions, following long-term exposure to natural weathering conditions. The Sunworks collector is a flat-plate solar collector. The absorber plate is copper with copper tubes bonded by soft solder, and is coated with Enthon selective black with an absorptivity factor of .87 ~ .92 and an emissivity factor of .10 ~ .20. It has a single glass cover of 3/16" tempered glass and weighs about 115 pounds. The overall dimensions of the collector are 36" x 84" x 4". For further information on the Sunworks collector test procedures and performance evaluation, see DOE/NASA CR-150573. The Sunworks solar collector is manufactured by Sunworks, P. O. Box 1004, New Haven, Connecticut 06508.			
17. KEY WORDS		18. DISTRIBUTION STATEMENT UC-59c Unclassified-Unlimited WILLIAM A. BROOKSBANK, JR. Mgr, Solar Heating and Cooling Project Office	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 10	22. PRICE NTIS

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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·Ft² 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/Ft²·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:

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

where:

q_u = rate of useful energy extracted from the Solar Collector (BTU/Hr)

A = Gross collector area (Ft²)

I = Total solar energy incident upon the plane of the solar collector per unit time per unit area (BTU/Hr·Ft²)

$\dot{m}$ = Mass flow rate of the transfer liquid through the collector per unit area of the collector (Lbm/Ft²·Hr)

C_{tf} = Specific heat of the transfer liquid (BTU/Lb·°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:

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

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.

5.0 ANALYSIS AND RESULTS (Continued)

5.1 Thermal Performance Test (Continued)

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:

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

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 ($^{\circ}\text{F}$)

t_a = Ambient temperature ($^{\circ}\text{F}$)

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

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·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·Hr·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

NASA-MSFC