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(NASA-TM-X-71689) SOLAR COLLECTOR PERFORMANCE EVALUATED OUTDOORS AT NASA-LEWIS RESEARCH CENTER (NASA)

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SOLAR COLLECTOR PERFORMANCE EVALUATED OUTDOORS AT NASA-LEWIS RESEARCH CENTER

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INTRODUCTION

A facility was constructed at Lewis Research Center to evaluate solar collector performance for conditions that would be encountered by collectors if they were incorporated in a solar heating/cooling system. NASA-Lewis has the responsibility to select and provide solar collectors that will be incorporated in a solar heated and cooled office building at NASA's Langley Research Center in Hampton, Virginia (ref. 1). The solar project at Langley will provide a test bed for determining actual field performance of components that comprise a solar heating/cooling system. Test results obtained from the outdoor test facility at Lewis will provide one of the inputs to the selection process for the collectors to be used on the solar project at Langley.

In addition to providing initial collector performance data, the outdoor facility will enable collector durability and early degradation rates to be evaluated for operating periods of several months. Also, the data obtained from the outdoor tests will be correlated with data obtained using a solar simulator.* This will allow a determination of the extent to which collector performance can be predicted by using data obtained in the simulator facility. This paper describes the outdoor test facility and presents some preliminary performance data.

DESCRIPTION OF FACILITY

A simplified schematic of the flow loop is shown in figure 1. The liquid in the flow loop is a mixture of 50 percent ethylene-glycol and 50 percent water by weight. A conventional home hot-water heater, 80 gallon capacity, is used for storage. The electric heating elements in the storage tank are controlled by a thermostat. The storage tank heaters provide a ready means to raise the temperature of the entire liquid inventory when desired. A centrifugal pump, driven by a 1/4 horsepower electric motor, circulates the liquid. A filter provides

*The solar simulator facility at the Lewis Research Center is described in companion paper authored by Fred Simon elsewhere in this document.

continuous filtration of the liquid. A conventional air-liquid heat exchanger, with an on-off fan control, is used to reject energy when desired. A by-pass around the heat exchanger and the associated proportional control valves permit modulation of the liquid temperature at the outlet of the heat exchanger.

A flow through each collector is manually adjusted with a remotely operated valve. The flow rate through the collector by-pass line is controlled to maintain a constant pressure in the collector inlet manifold. Thus, when the flow rate through one collector is varied, the flow through the remaining collectors remains constant with no adjustment of the flow-control valves. The flow rate through each collector is determined with a calibrated turbine-type flowmeter. Auxiliary heaters with electric immersion elements are located at the inlet of each collector. These heaters provide a controlled variation of inlet temperature from collector to collector. The liquid discharge from the collectors is returned to the storage tank. An expansion tank accommodates volume changes of the liquid inventory.

When completed the outdoor collector facility will include two identical flow loops with a capability of testing ten collectors simultaneously. One of the flow loops is presently completed and is shown in figure 2. The range of possible test conditions is presented in figure 3.

The instrumentation is summarized in figure 4. In addition to the collector performance and solar insolation data, the following weather data are recorded: air temperature, wind speed and direction, and relative humidity. At the present time all temperatures are measured with chromel-constantan thermocouples, ISA type E. The temperature measurement method is being reviewed and may be modified in the future. Presently only a single pyranometer, mounted in the plane of the collectors, is used to measure solar flux. The remaining pyranometers and the pyrheliometer, for direct or beam radiation, will be installed when available. The solar flux will also be integrated continuously in the future.

PRELIMINARY RESULTS

Preliminary results are presented in figure 5 for a collector fabricated at the Lewis Research Center from two copper heat-transfer panels (Thermon Manufacturing Co.). The panels were sprayed with a nonselective black paint ($\alpha = 0.97$). Two glass covers were placed over the panels and four inches of fiberglass insulation beneath. The panels, plumbed in parallel, each measured 22 inches by 45 inches. The outside dimensions of the collector frame are 48 inches by 49 inches. In figure 5, the instantaneous collector efficiency,

$$\frac{\dot{m}\, C_p\, (T_{out} - T_{in})}{q_{solar}\, A_{absorber}}$$

is plotted as a function of the ratio

$$\frac{T_{in} - T_{amb\ air}}{q_{solar}}$$

This format is particularly useful when employing the collector design factors presented in references 2 and 3. A general equation developed therein expresses the collector efficiency as

$$\eta = F_R \left[\alpha\tau - \frac{U_L \ (T_{in} - T_{amb\ air})}{q_{solar}} \right].$$

By plotting the data as shown in figure 5, the values F_R and U_L are readily obtained. Knowing the effective $\alpha\tau$ product, F_R can be determined knowing the vertical intercept. Then, knowing F_R and the slope of the curve, U_L can be determined. These early data are presented primarily to demonstrate the approach to be taken for presenting data. No correction was incorporated for the effects of wind, incident angle, sky temperature, etc. In the future, using the integrated values of solar flux, the collector efficiency will be determined on both an hourly and daily basis. The collector performance determined outdoors will be correlated with data obtained using a solar simulator (ref. 4 and 5) to confirm the simulator approach to acquiring performance data.

CONCLUDING REMARKS

A facility to determine solar collector performance outdoors has been constructed. Preliminary performance data have been obtained. Performance data obtained from the outdoor tests will be employed as one of the bases for selecting collectors for installation on the solar project at NASA-Langley. The solar simulator approach to obtaining collector performance will hopefully by confirmed by correlation of data acquired outdoors with data previously measured in a solar simulator facility.

REFERENCES

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2. Hottel, H.C. and Whillier, A., "Evaluation of Flat-Plate Solar Collector Performance", in Trans. Conf. on the Use of Solar Energy - The Scientific Basis, Vol. 2, Oct. 31 - Nov. 1, 1955, p. 74, Tucson, Arizona.

3. Bliss, R.W., Jr., <u>Solar Energy</u>, <u>3</u>, 55 (1959).

4. Simon, F.F. and Harlamert, P., "Flat-Plate Collector Performance Evaluation", paper presented at International Solar Energy Society, Annual Meeting, Oct. 3-4, 1973, Cleveland, Ohio.

5. Vernon, R.W. and Simon, F.F., "Flat-Plate Collector Performance Determined Experimental with a Solar Simulator", paper presented at International Solar Energy Society, Annual Meeting, Aug. 19-23, 1974, Fort Collins, Colorado.

SYMBOLS

$A_{absorber}$	Area of absorber, ft^2
C_p	Specific heat of fluid, Btu/lb°F
F_R	Overall collector plate heat removal efficiency, dimensionless
q_{solar}	Total flux in plane of collector, Btu/hr ft^2
$\dot{m}$	Fluid mass flow rate, lb/hr
$T_{amb\ air}$	Ambient air temperature, °F
T_{in}	Fluid temperature at collector inlet, °F
T_{out}	Fluid temperature at collector outlet, °F
U_L	Overall heat loss coefficient, Btu/hr ft^2°F
α	Absorptivity of collector absorber, dimensionless
η	Collector efficiency, dimensionless
τ	Transmittance of collector cover system, dimensionless

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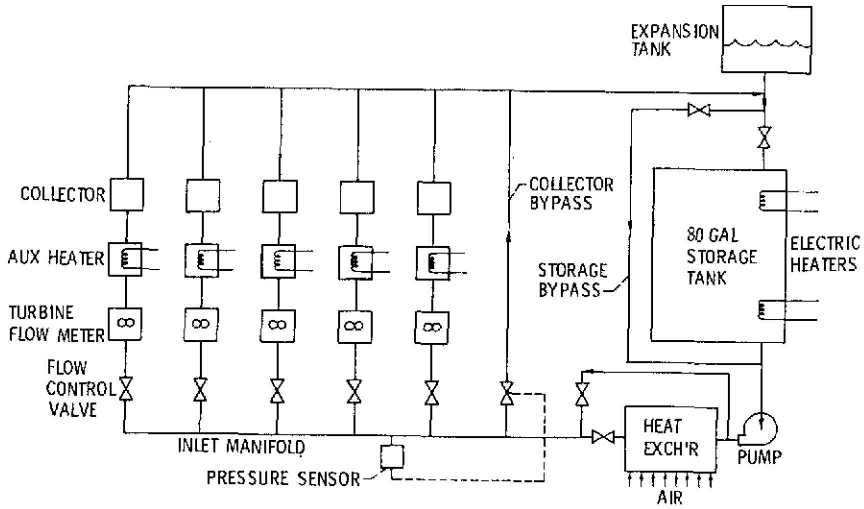

Figure 1. - Schematic of outdoor collector facility.

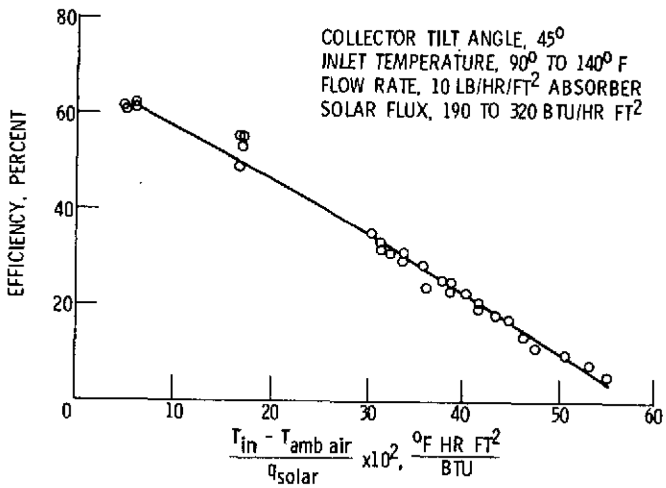

Figure 2. - Performance of Lewis collector, preliminary data.

- FLOW -- TO 3 GAL/MIN
- INLET FLUID TEMPERATURE ---------------------- AMBIENT TO 200°F
- TILT ANGLE --------------------------------------- 20 TO 60 DEGREES
- COLLECTOR SIZE --------------------------------- UP TO 4 X 8 FT

FIGURE 3. - RANGE OF OUTDOOR TEST CONDITIONS

- COLLECTOR

    FLOW RATE

    TEMPERATURE
    - IN
    - OUT
    - PLATE
    - GLASS

    PRESSURE
    - IN
    - DELTA P

- SOLAR FLUX

    TOTAL IN PLANE OF COLLECTOR (PRESENT)

    TOTAL HORIZONTAL, DIFFUSE HORIZONTAL, DIRECT (FUTURE)

FIGURE 4. - INSTRUMENTATION FOR OUTDOOR COLLECTOR TESTS

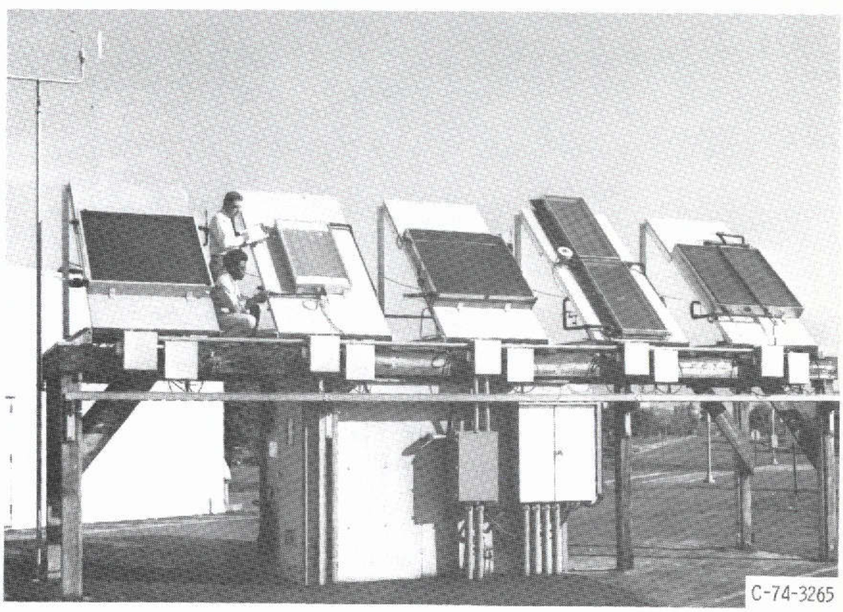

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Figure 5. - Outdoor collector facility.