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THERMAL PERFORMANCE EVALUATION OF THE NORTHRUP MODEL NSC-01-0732 CONCENTRATING SOLAR COLLECTOR ARRAY AT OUTDOOR CONDITIONS

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George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

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16. ABSTRACT

This report describes the thermal performance tests conducted on the Northrup Model NSC-01-0732 concentrating, tracking solar collector for approximately two months (from the end of August to the first part of October 1979). These tests were made using the Marshall Space Flight Center's Solar House Test Facility.

This Northrup collector was developed under the MSFC Contract NAS8-32251.

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1.0 PURPOSE

The purpose of this document 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 for the Northrup model NSC-01-0732 tracking solar collector array. All testing took place at the Marshall Space Flight Center Solar House Testing Facility under outdoor conditions. The test was conducted, and the data evaluated, using the methods provided in Reference 2.1 as applicable to outdoor testing of concentrating collectors with solar tracking mount.

2.0 REFERENCES

2.1	ASHRAE 93-77	Methods of Testing to Determine the Thermal Performance of Solar Collectors
2.2		Application Manual for Northrup Concentrating Solar Collector Panels, MF-NSC-P "ML" Series, Model NSC-01-0732
2.3	DOE/NASA CR-150804	Thermal Performance Evaluation of the Northrup Concentrating Solar Collector at Outdoor Conditions
2.4		List of Materials for Northrup Concentrating Solar Collector Panels, MF-NSC-0 "ML" Series, Model NSC-01-0732

3.0 COLLECTOR ARRAY ASSEMBLY DESCRIPTION

Manufacturer:	Northrup
Manufacturer's Address:	302 Nichols Drive, Hutchins, Texas 75141
Model Number:	NSC-01-0732
Type:	Concentrating, solar tracking
Working Fluid:	100% Water
Array Aperture Area:	301 Ft^2
Array Gross Area:	780 Ft^2

3.1 Array Configuration

The Northrup NSC-01-0732 tracking collector array consists of seven collector panels positioned at a 32^o tilt angle from horizontal. Each panel has four modules with 10.75 ft^2 of transparent acrylic plastic Fresnel lenses, making a total of 43 ft^2. The complete assembled array is made up of collector panels, supporting framework, insulated fluid manifolding, and a tracking drive system. Collector panels are spaced 10'0" on center. Various components of the array are described as follows:

Collector Housing Material:	Galvanized steel construction

3.0 COLLECTOR ARRAY ASSEMBLY DESCRIPTION (Continued)

3.1 Array Configuration (Continued)

Collector Top Cover:	Modified Fresnel prismatic lens extruded from acrylic. Transmissivity: 0.95
Collector Absorber Tube:	Copper Selective Coating: 0.95 Absorptivity and 0.12 emissivity
Collector Insulation:	Fiberglass, 1.1 lb/ft^3, 1000^{o}F maximum temperature. "K" Factor = .28 at 200^{o}F
Sun Tracker:	A two directional motor is controlled by photovoltaic cells through an integrated circuit. Collector panels are linked by galvanized cable and pulleys. This system is driven by a mechanism consisting of the two directional motor, a chain drive, a stainless steel (Acme) screw, and a "Delvin" drive nut.

4.0 SUMMARY

Thermal performance tests were conducted on the Northrup model NSC-01-0732 concentrating, tracking solar collector at the MSFC Solar House Test Facility. The array tested, shown in Photographs 1 and 2, was operated for about ten months to provide thermal energy for heating and cooling of the MSFC Solar House prior to initiation of thermal performance testing. (Appendix A contains a list of installation comments and Appendix B is a Maintenance Record.) Figure 1 contains a schematic representative of the test configuration. Operation of the array was monitored over a period of approximately two months (from the end of August to the first part of October 1979) to provide sufficient data under clear weather conditions to insure that the data presented is suitable for the purpose intended. On days with intermittent cloud cover or a high density cloud cover, the tracking mechanism would often either lag behind in positioning the collector axis normal to incident solar flux or not track at all. Test data presented in this report was obtained from selected clear days when the collector array was tracking properly. The test conditions and data obtained during the test program are listed in Table I for the thermal performance test and are presented graphically in Figure 2. A performance curve from the Northrup Application Manual for one panel of the array is presented in Figure 3 for comparison with MSFC test results of the total array. The manufacturer's curve is for total beam radiation incident on the single panel and is comparable to the MSFC curve, assuming that data for the manufacturer's curve is from clear days with negligible diffuse radiation.

Whereas array efficiency from MSFC test results and single panel efficiency presented in the Northrup manual correspond at ambient conditions, array performance at higher inlet temperatures drops significantly in comparison to the single panel curve shown. Increased heat losses of the array as opposed to the single panel are attributed to losses from a large manifold area and from possible weathering effects on the array over exposure of almost one year.

Due to the large surface area, a time constant test was not performed; however, the similarities of the new module to the old should yield a time constant of similar magnitude, which was concluded to be 2 minutes and 3 seconds on the old module from Reference 2.3.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 Ambient Conditions

Unless otherwise specified herein, all tests were performed at ambient conditions existing at the MSFC Solar House Test Facility at the time of the tests.

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. Instrumentation locations on the test loop and collector array are depicted in Figure 1. A listing of the equipment used in the test follows:

Apparatus	Manufacturer/Model	Range/Accuracy
Type T Thermocouples	MSFC Supplied	0-500°F ± 0.5°F
Pyranometer	Eppley - PSP	0-800 BTU/Ft^2·Hr ± 3%
Pyrheliometer	Eppley	0-800 BTU /Ft^2·Hr (Class 1)
Liquid Loop	MSFC Supplied	0 - 10 GPM
Flowmeter	Potter Meter	0 - 9.5 GPM
Data Logger	Model 2240A/John Fluke Company	1 - 30 mv ± .01%

The pyranometer and pyrheliometer were calibrated by the manufacturer.

6.0 TEST REQUIREMENTS AND PROCEDURES

6.1 Collector Array Thermal Efficiency Test

6.1.1 Test Requirements

Thermal performance data from the Northrup model NSC-01-0732 tracking collector array shall be obtained utilizing the MSFC liquid test loop at the MSFC Solar House Test Facility. The collector shall be mounted and installed in a manner consistent with the manufacturer's recommended installation methods. The collector array sun-tracking mechanism shall be operational during the test. The collector shall be mounted in a location such that there will be no significant energy reflected or re-radiated onto the collector from surrounding buildings or any other surfaces in the vicinity of the test for the duration of the test. In addition, the test shall be conducted at times having clear weather conditions such that the integrated average insolation measured in the plane of the collector and used for the computation of instantaneous efficiency values shall not be less than 200 BTU/Ft^2·Hr. Wind speed across the collector at test times should be less than 5 MPH. The following data shall be recorded of test variables and conditions:

1. Ambient air temperature.
2. Collector array inlet liquid temperature.
3. Collector array outlet liquid temperature.
4. Collector array differential temperature.
5. Total insolation from pyranometer.
6. Direct beam insolation from pyrheliometer.

Thermal performance evaluation data shall be obtained at inlet temperatures of approximately 0, 25, 50, 100, and 125°F above the ambient temperature at an array flow rate of 8 GPM. At least four "data points" shall be taken for each value of inlet temperature at the specified flow rate. The efficiency curve shall be established by "data points" that represent efficiency values determined by integrating the data over a time period equal to the time constant or ten minutes, whichever is longer. The integrated value of incident solar energy will be divided into the integrated value of energy obtained from the collector array to obtain an averaged thermal efficiency.

6.1.2 Procedure

1. Assure that the sun tracking mechanism is operational at the beginning of and throughout each test.

2. Initiate operation of the data acquisition system to record data at one minute intervals and check to verify that all necessary channels are operational.

6.0 TEST REQUIREMENTS AND PROCEDURES (Continued)

6.1 Collector Array Thermal Efficiency Test (Continued)

6.1.2 Procedure (Continued)

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

4. Monitor the test parameters by examining the data logger printout at the test site.

5. Upon completion of testing, save the printout as a record.

6.1.3 Test Results

The results obtained during these tests are contained in Table I and in Figure 2 for thermal performance data. The array thermal performance from Figure 2 is compared with the manufacturer's single panel performance curve from Reference 2.2 in Figure 3.

7.0 ANALYSIS

7.1 Array Thermal Performance Test

The analysis of data contained in this report is consistent with the procedure of Reference 2.1. The thermal efficiency of the Northrup model NSC-01-0732 collector array determined from test data contained in Table I is given by the following equations:

$$\eta = 0.814 - 0.852\left(\frac{T_i - T_a}{I}\right) \quad \text{based on aperture area}$$

$$\eta = 0.306 - 0.302\left(\frac{T_i - T_a}{I}\right) \quad \text{based on gross area}$$

The calculated values of efficiency were determined at sixty second intervals and averaged over a ten minute period when test conditions remained in a quasi-steady state. Each ten minute average constitutes one data point shown graphically in Figure 2. Total solar insolation in the collector plane was used rather than only direct beam insolation for calculating collector efficiency. The nature of the modified Fresnel prismatic lens cover allows the collection of an undetermined amount of the diffuse component of insolation. It was observed that on days of relatively high diffuse insolation, efficiencies greater than 100% would occur when only the direct beam component was used for calculations. Data points presented were calculated from clear day data with a small percentage of diffuse insolation. The best curve fit for data obtained is a first order polynomial of the form:

$$\eta = a_0 + a_1 \tau$$

where:

$$\tau = (T_i - T_a)/I$$

The coefficients were determined to be

$$\left.\begin{aligned} a_0 &= 0.814 \\ a_1 &= -0.852 \end{aligned}\right\} \text{based on aperture area} \qquad \left.\begin{aligned} a_0 &= 0.306 \\ a_1 &= -0.302 \end{aligned}\right\} \text{based on gross area}$$

with a flow rate of 8 GPM for the collector array.

TABLE I

THERMAL PERFORMANCE TEST DATA FOR THE
NORTHRUP MODEL NSC-01-0732 TRACKING SOLAR COLLECTOR ARRAY

Ambient Air Temp. (T_a), °F	81.4	85.4	86.6	86.3	64.1	61.4	67.1	67.8	70.3		
Fluid Inlet Temp. (T_i), °F	92.0	124.5	148.5	180.0	106.2	193.0	178.5	185.2	179.6		
Fluid Outlet Temp. (T_e), °F	106.3	136.9	161.6	192.7	120.7	200.7	190.3	197.4	190.4		
Differential Fluid Temp. (ΔT), °F	14.3	12.4	13.1	12.7	14.5	7.7	11.8	12.2	11.2		
Total Solar Flux (I), BTU/Hr·Ft^2	244.7	263.6	277.7	297.7	287.6	274.3	301.6	299.3	298.3		
% of Diffuse Flux	15	15	15	15	15	12	7	7	8		
Flow Rate, of Collector Array, GPM	8.03	8.67	7.94	7.94	8.03	8.04	8.03	8.08	8.03		
$(T_i - T_a)/I$ °F·Hr·Ft^2/BTU	.043	.148	.223	.315	.146	.480	.369	.392	.365		
Array Efficiency (η), % (Aperture Area of 301 ft^2)	.810	.663	.610	.548	.667	.362	.505	.529	.488		

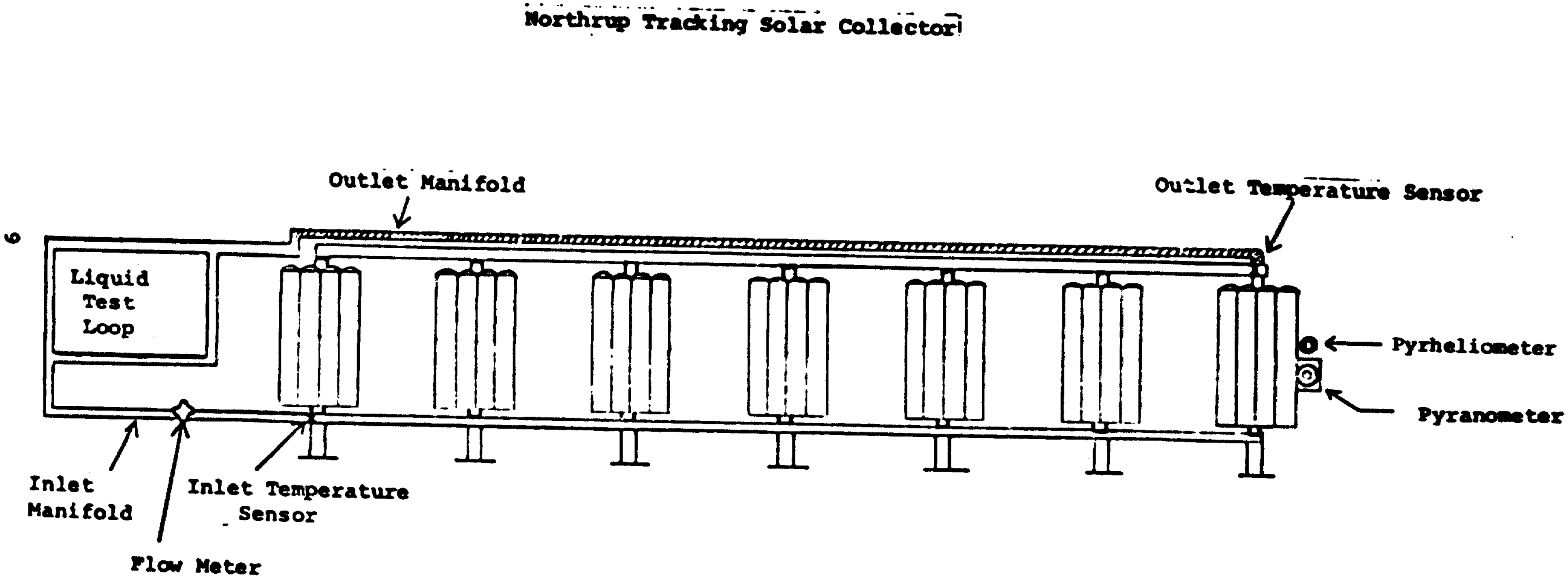


Figure 1. Test Loop Schematic of the Northrup Model NSC-01-0732 Solar Collector Array.

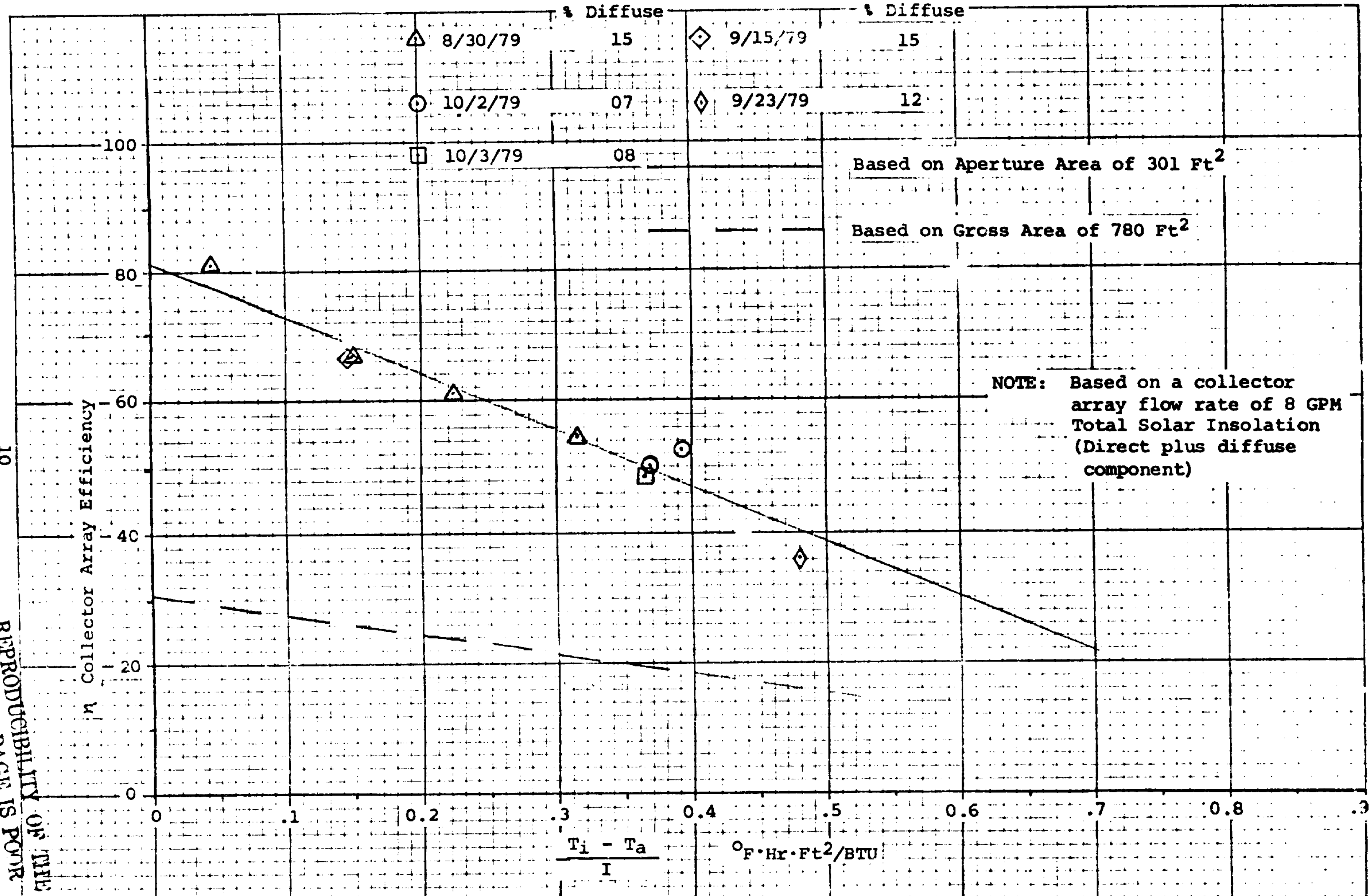


Figure 2. Thermal Performance of the Northrup Model NSC-01-0732 Collector Array

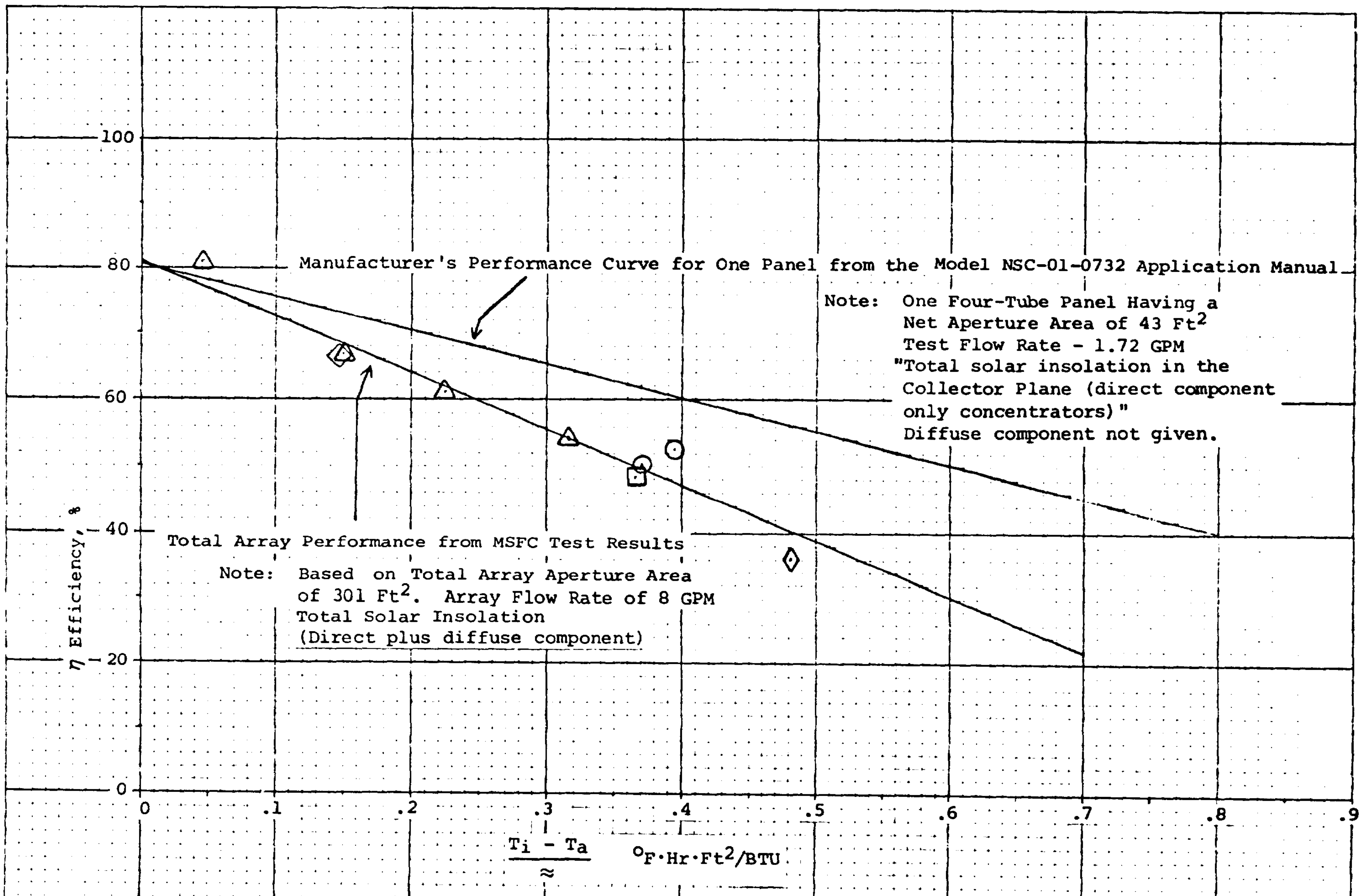
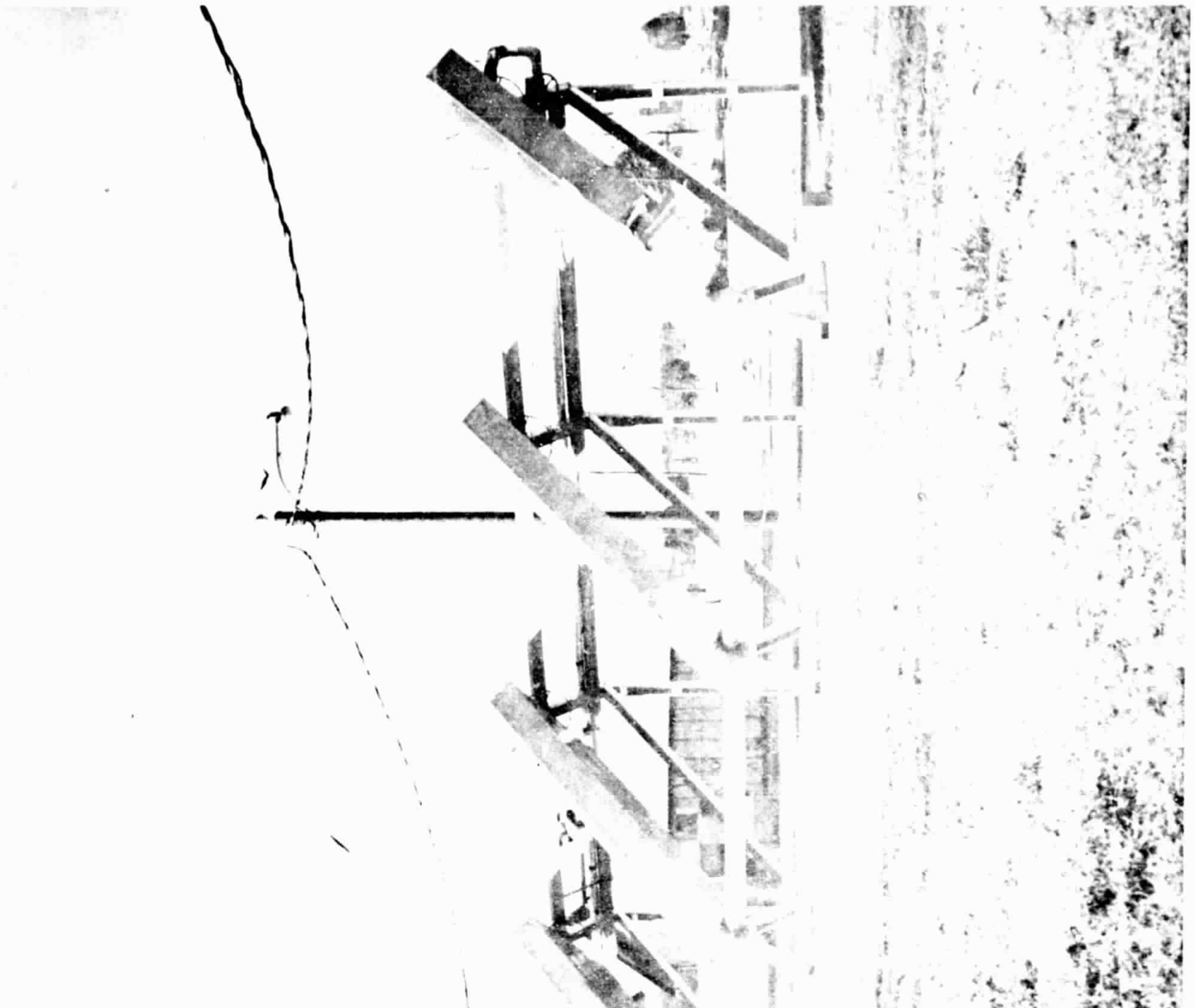
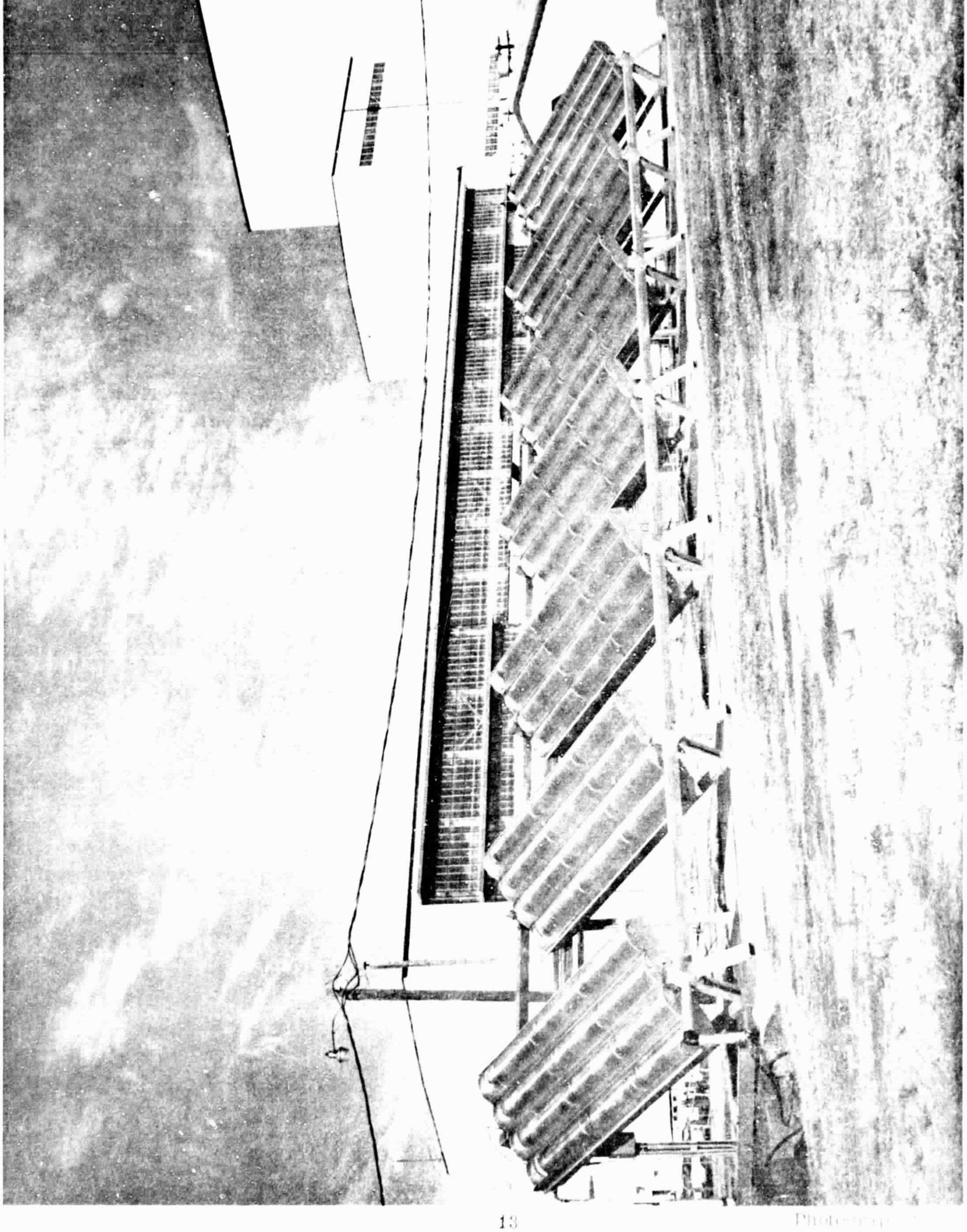


Figure 3. Single Panel Performance Vs. Total Array Performance of the Northrup NSC-01-0732 Collector



Photograph 1



Photograph

APPENDIX A

INSTALLATION COMMENTS

1. The first shipment of collector lenses contained four lenses with edges cracked in transit. A subsequent shipment of lenses also evidenced some cracks from rough treatment while in route. Only lenses free of damage were installed.

2. Upon delivery, welds were discovered to be cracked on four of the fourteen flanged shaft assembly parts shown in Reference 2.4. Uncorrected, a safety hazard would have existed for personnel installing the collector panels.

3. Placement of the collector panels in the framework was difficult. Installation instructions first direct the installation of collector lenses in the proper grooves but later detail a method of hoisting the collectors in place by using four eye bolts in collector corners, which requires removal of the lenses.

4. It was necessary to shift the location of wind bracing rods on the end manifold support struts to prevent overstraining of the structure so that cable could be tightened (as installation instructions recommend) until less than a one-half inch sag exists between supports.

APPENDIX B

MAINTENANCE RECORD

1. The original "O" rings in swivels were dried out and deformed and had to be replaced. The newly installed "O" rings worked well for several months until testing the collector with water at temperatures slightly over 200°F caused some leakage to occur. "O" rings were again replaced and the transfer fluid in the system was later changed to 100% ethylene glycol. Some occasional leakage has been noticed when ambient temperature drops below freezing.

2. The tracking mechanism drive gear comes loose on the shaft requiring periodic retightening of the set screw.

3. No other maintenance has been required during the operation of the collector array.

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