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MSFC HOT AIR COLLECTORS - PHASE I TEST REPORT

Prepared by

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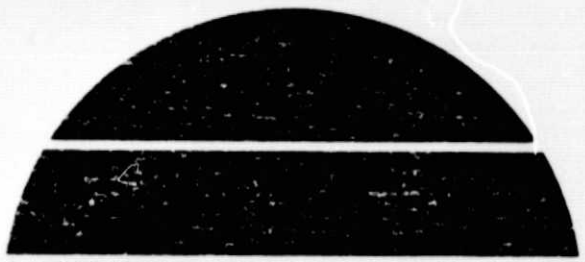
Under sub-contract to

IBM Corporation, Federal Systems Division, Huntsville, Alabama 35805

Contract NAS8-32036

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

for the Department of Energy



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This work was accomplished under the technical supervision of Charles N. Thomas, Marshall Space Flight Center, Alabama.

16. ABSTRACT

Three hot air flat plate solar collectors manufactured by Marshall Space Flight Center (no serial numbers) were subjected to a Development Test Program as described in detail in this report. The pressure drop versus flow rate performance characteristics for these collectors, mounted in series, was determined under fourteen different test conditions each of which was characterized by a unique combination of inlet air temperature and air flow rate. Characteristics of inlet, exit and transfer ducts of these collectors were also determined during this testing. The test results indicate that (1) significant pressure drop occurs at air flow rates greater than 150 Standard Cubic Feet Per Minute (SCFM) and this drop is not heavily dependent upon inlet air temperature, and (2) inlet, exit and transfer duct characteristics differ sufficiently to suggest that system performance may be enhanced through careful design of each type of duct individually.

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1.0 PURPOSE

The purpose of this report is to present the test procedures used and the results obtained during the performance of Phase I of a development test program. Phase I of the test program was conducted to determine the pressure drop across three prototype Hot Air Collectors as a function of air velocity and operating temperature in accordance with references shown in Section 2.0.

2.0 REFERENCES

2.1 MSFC Memorandum EP (76-23), dated June 1, 1976.

MSFC AVO 76-103 from ET-44, dated June 3, 1976, Subject: Testing of MSFC Hot Air Collectors.

2.2 Test Procedure, MTCP-DC-SHAC-400, "MSFC Hot Air Collector - Phase I Test Procedure".

3.0 MANUFACTURER

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

4.0 SUMMARY

Three hot air flat plate solar collectors manufactured by Marshall Space Flight Center (no serial numbers) were subjected to a Development Test Program as described in detail in this report. The pressure drop versus flow rate performance characteristics for these collectors, mounted in series, were determined under fourteen (14) different test conditions each of which was characterized by a unique combination of inlet air temperature and air flow rate. Characteristics of inlet, exit and transfer ducts of these collectors were also determined during this testing. The test results indicate that: 1) significant pressure drop occurs at air flow rates greater than 150 Standard Cubic Feet Per Minute (SCFM) and this drop is not heavily dependent upon inlet air temperature, and 2) inlet, exit and transfer duct characteristics differ sufficiently to suggest that system performance may be enhanced through careful design of each type duct individually.

5.0 TEST CONDITIONS AND TEST EQUIPMENT

5.1 Test Article Description

The test article consisted of three MSFC Hot Air Collectors manifolded in series. Each collector had a surface area of 17.5 ft^2 (1.62 m^2) with air transfer ducts of 0.65 ft^2 (0.06 m^2). Each collector was 3 ft (0.96 m) wide, 6 ft (1.8 m) long, 0.6 ft (0.18 m) deep and weighs approximately 35 lb (15.9 kg). The collector surface was a 0.012 inch 2024-T3 aluminum plate coated dark on the top surface. The collector was covered with a single, 0.125 inch, standard plate glass.

5.2 Ambient Conditions

Unless otherwise specified herein, all tests were performed at an atmospheric pressure of 29.38 $\pm$0.50 inches of mercury absolute, a temperature of 23° $\pm$2°C and a relative humidity of approximately 50 percent.

5.3 Instrumentation and Equipment

Instrumentation consisted of two copper-constantan thermocouples monitored by a Mity-Mite T.C. meter and a water-filled inclined manometer with a resolution of 0.01 inches of water.

The air supply system used for the test was a 3500 psi missile air supply system available at Building 4619. This supply was regulated and heated through the use of a three-stage regulator stand equipped with an 18 kW proportional controlled heater stage.

6.0 REQUIREMENTS, PROCEDURES AND RESULTS

6.1 Test Title: MSFC HOT AIR COLLECTOR TEST - PHASE I

6.1.1 Requirements

Determine pressure drop over the collectors under the following conditions:

Air Flow Rate (SCFM)	Temperature (°F)
30	80° and 110°
100	80° and 110°
120	80° and 110°
200	80° and 110°

6.1.2 Procedures

6.1.2.1 Principles of Operation

The test articles were arranged as indicated in Figure 1. Air from the regulator/heater system was allowed to expand and pass through a six foot by eight-inch diameter chamber to facilitate equalization prior to passing into the collectors. From this expansion chamber the air was routed through the entrance duct to the first collector. This intake manifold was instrumented for static air measurements. The air passed through all three collectors in series before exiting to ambient pressure through an exhaust duct identical to the entrance duct.

Air flow was measured in Actual Cubic Feet Per Minute (ACFM) after passing through the heater and converted to Standard Cubic Feet Per Minute (SCFM) for test purposes. The temperature sensing for the controller was located at the flowmeter section and concurrently monitored at the first collector inlet port for test parameter determination.

6.1.2.2 Initial Test Procedure Modifications

During the process of system performance verification, it was determined that the initial pressure sensing port locations were inadequate. Due to their orientation they were producing erroneous results. They were relocated as shown in Figure 1 upon approval of Mr. F. zurBurg. It was also decided to drop the proposed data format and use a new format which does not include individual differential measurement for each collector, since it was agreed that those measurements would not obtain further pertinent data.

6.1.2.3 Test Procedure

1. Set up proper test parameters -- This required setting a temperature/air flow configuration; allowing for system stabilization; determining true SCFM/inlet temperature parameters; adjusting to new ACFM/temperature configuration if required by test parameters; and computing new true SCFM/inlet temperature conditions. This process was repeated until correct test parameters were obtained.

2. Manometer was tested for zero offset -- This was done by exposing both differential sensing lines to ambient pressure.

3. Flowmeter frequency, temperature, pressure, inlet and outlet air temperature, and manometer zero offset were recorded on data sheet. (A)

4. The static pressure at Test Port 1, see Figure 1, referenced to ambient pressure was measured and recorded -- This was done by attaching one sense line to Port No. 1 and exposing the second line to ambient pressure. Caution was required to determine correct sign of the pressure value (+ or - reference to ambient).

5. The static pressure at Test Port 2, see Figure 1, reference to Test Port (1) was measured and recorded. (A)

   Caution was required to determine correct sign of the pressure value (+ or - Reference to ambient).

6. The static pressure at Test Ports 3 through 14 referenced to Test Port (1) were measured and recorded in the same manner as in Step 5 above.

7. Inlet and outlet air temperature were noted -- If either temperature changed by more than one degree Fahrenheit, that temperature was recorded as the original temperature plus one-half the change in temperature.

8. The flowmeter frequency was monitored and the average deviation from the initial recorded frequency was recorded.

6.1.2.4 Data Analysis

Before complete data evaluation was possible, it was necessary to accurately determine the true test parameters. This was done by correcting the indicated flow for temperature and pressure deviations from standard conditions using the following equation:

$$SCFM = ACFM \times K \times P_A/T_K$$

where: SCFM = Standard cubic feet per minute

ACFM = Actual cubic feet per minute (Interpreted from the frequency versus ACFM curve of the flowmeter)

K = 19.948 (conversion factor obtained from EC23)

P_A = Meter pressure in psia

T_K = Meter temperature in °K (degrees Kelvin)

Correction was also made on the fluctuations of the flowmeter to determine their detrimental effect on the accuracy of the test parameters.

Once the data was corrected for non-standard conditions, pressure profile trends were generated for each type of transfer duct as well as a centerline profile.

6.1.3 Results

The results of the tests are depicted in Tables I, II and III, and form the basis for the following conclusions:

1. The pressure drop becomes significant above 150 SCFM.

2. Pressure gradients across the transfer ducts are significant and could be altered through better design.

3. Pressure gradients across the transfer ducts are not strongly temperature dependent.

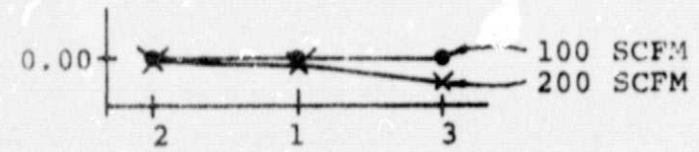
4. Pressure gradients across the transfer ducts are velocity dependent.

5. The pressure drop across the collector is heavily velocity dependent and slightly temperature dependent.

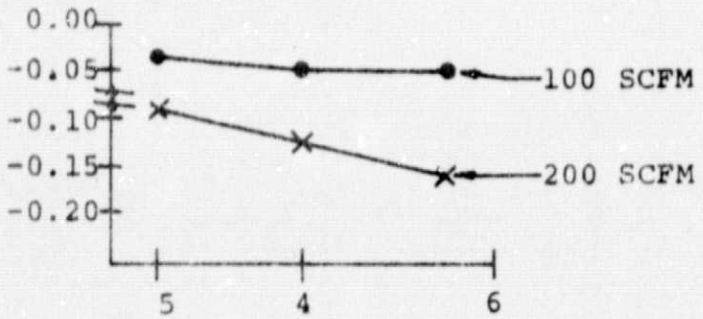
6. For conditions up to 200 SCFM at 200°F, pressure drops of greater than 0.17 inches of water should not be encountered for an individual collector.

7. More reliable data should be obtainable through the use of a lower pressure air supply, and better designed inlet air ducts.

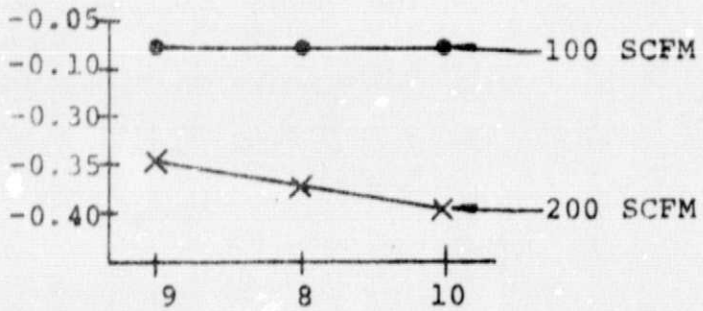
TABLE I. DATA GENERATED PRESSURE PROFILES
100, 200 SCFM AT 80°F



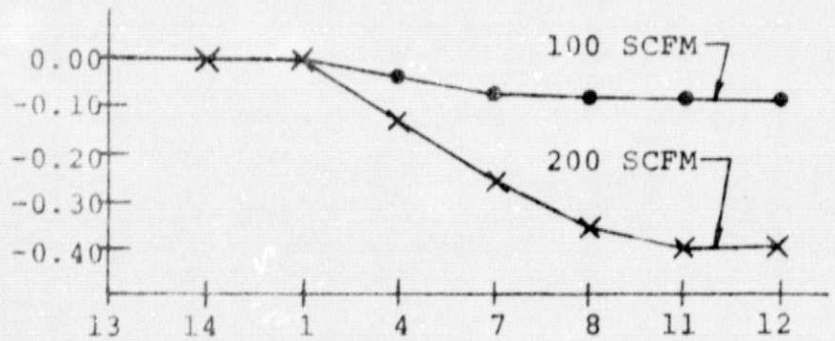
INLET PROFILE



TRANSFER PROFILE



EXIT PROFILE



CENTERLINE
PRESSURE PROFILE

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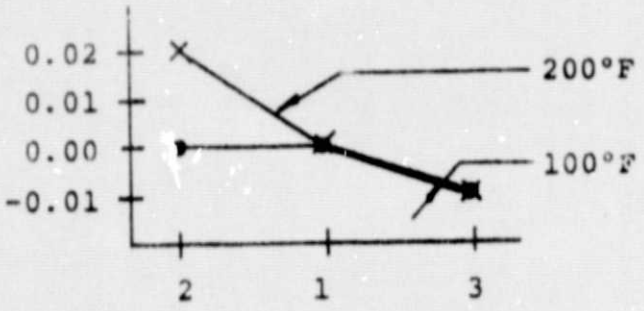
OF POOR QUALITY

TABLE I. DATA GENERATED PRESSURE PROFILES
200 SCFM AT 100°F, 200°F



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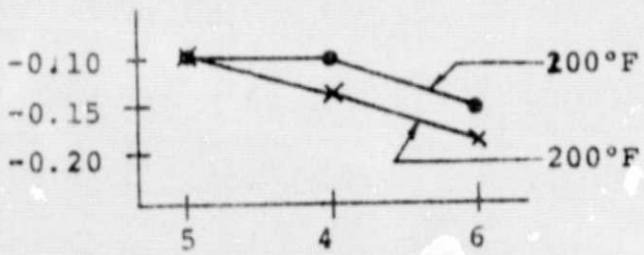

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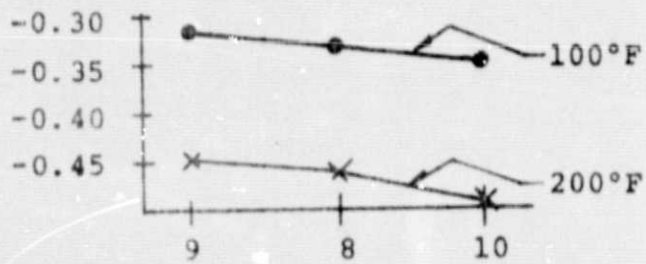

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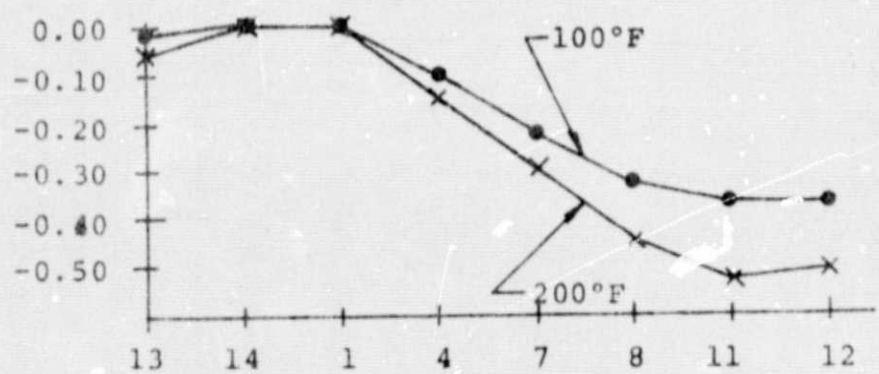


CENTERLINE PRESSURE PROFILE

TABLE III. HOT AIR COLLECTOR ΔP DATA

DATE	7/23	7/23	7/23	7/23	7/23	7/23
TEST #	1	2	3	4	5	6
TEMP °F	81	72	60	54	80	80
SCFM (*)	45(44.3)	115(95.7)	140(144.8)	227(226)	30	100
FREQ Hz	225	475	700	900	150	475
TEMP °F	76	64	58	57	70	72
PRESS psia	AMB	AMB	AMB	17.7	AMB	AMB
INLET °F	81	72	60	54	80	79
OUTLET °F	87	76	62	58	80	80
ZERO "H_2O	0.00	0.00	0.00	0.00	0.00	0.00
#1 REF "H_2O to AMB	0.025	0.10	0.23	0.45	0.00	0.10

REFERENCE TO #1 POSITION

"H_2O						
	2	- 0.01	0.00	0.00	0.00	0.00	0.00
	3	- 0.00	0.00	0.00	0.00	0.00	0.00
	4	- 0.01	0.05	0.08	0.15	0.00	0.05
	5	- 0.01	0.05	0.06	0.10	0.00	0.04
	6	- 0.01	0.05	0.10	0.20	0.00	0.05
	7	- 0.01	0.07	0.15	0.28	0.00	0.08
	8	- 0.02	0.08	0.20	0.43	0.00	0.08
	9	- 0.02	0.08	0.20	0.40	0.00	0.08
	10	- 0.02	0.10	0.23	0.45	0.00	0.08
	11	- 0.02	0.10	0.23	0.47	0.00	0.09
	12	- 0.03	0.09	0.23	0.47	0.00	0.00
	13	- 0.00	0.20	0.00	0.00	0.00	0.00
	14	- 0.01	0.30	0.00	0.00	0.00	0.00

* Numbers in parentheses ( ) indicate true test values as determined by T, P flow correction which were different from desired test parameters.

DATA RESOLUTION IS [0.01 inches of H_2O]

TABLE III. (CONTINUED)

DATE	7/23	7/23	7/27	7/27
TEST #	7	8	9	10
TEMP °F	80	80	100	100
SCFM (*)	120(118±6)	200(228±5)	100(103.7)	115(111.3±7)
FREQ Hz	580 ±30	950 ±5	550	580 ±40
TEMP °F	74	78	100	100
PRESS psia	14.7	17.7	14.7	14.7
INLET °F	80	80	96	97
OUTLET °F	80	80	98	94
ZERO "H_2O	0.00	0.00	0.00	0.00
#1 REF "H_2O to AMB	0.11	0.40	0.10	0.13

REFERENCE TO #1 POSITION

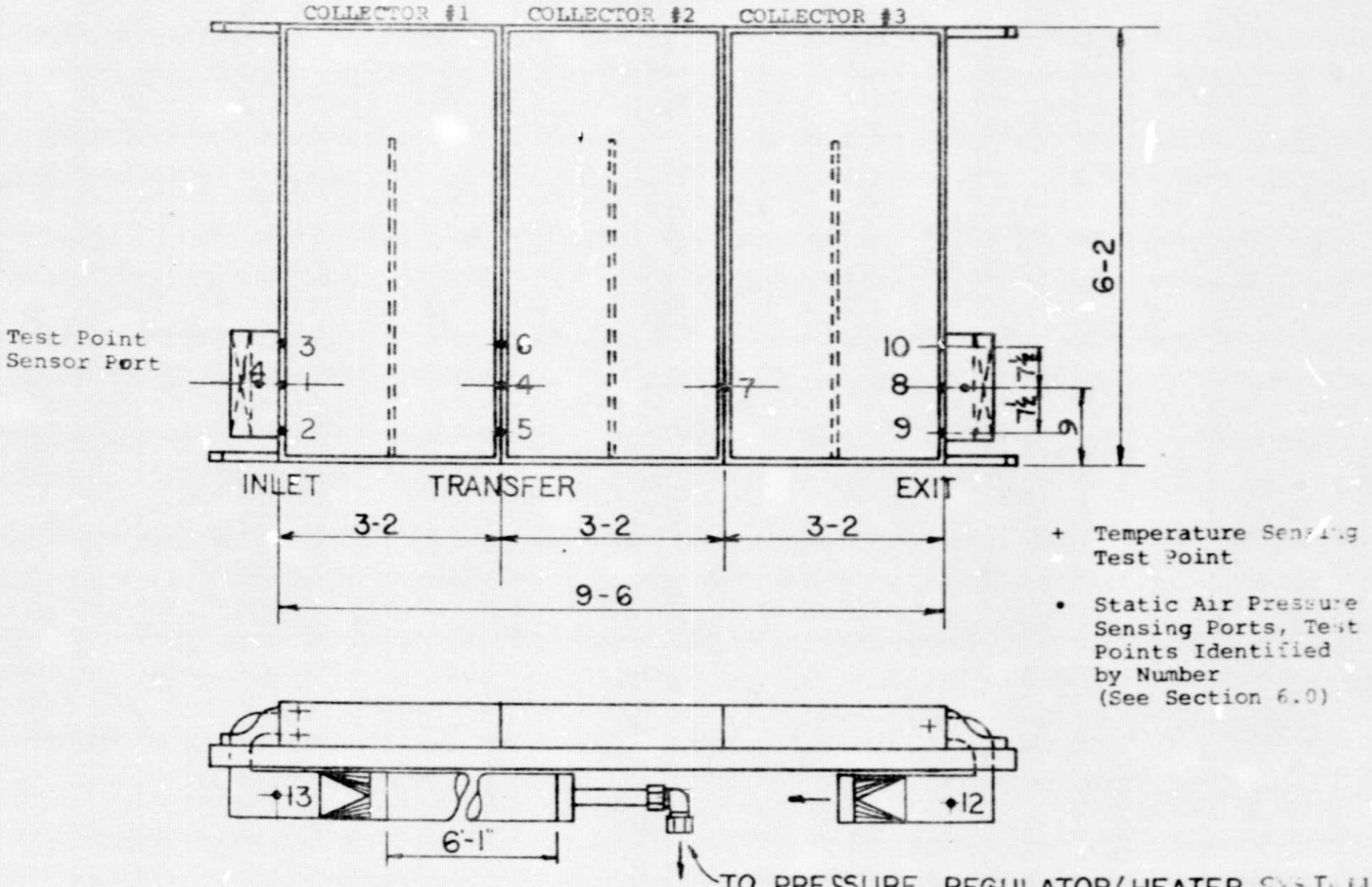
"H_2O	2	0.00	0.00	0.00	0.00
	3	0.00	-0.01	-0.01	-0.01
	4	-0.05	-0.13	-0.05	-0.05
	5	-0.04	-0.09	-0.04	-0.05
	6	-0.06	-0.16	-0.05	-0.06
	7	-0.08	-0.27	-0.08	-0.08
	8	-0.10	-0.37	-0.10	-0.10
	9	-0.10	-0.35	-0.10	-0.10
	10	-0.10	-0.40	-0.10	-0.10
	11	-0.10	-0.40	-0.10	-0.10
	12	-0.10	-0.40	-0.10	-0.10
	13	-0.00	-0.00	-0.10	-0.00
	14	-0.00	-0.00	-0.00	-0.01

TABLE III. (CONCLUDED)

DATE	7/27	7/27	7/27	7/27
TEST #	11	12	13	14
TEMP °F	100	200	200	200
SCFM (*)	200(211±10)	100(100.9±7)	115(115.9±7)	200(228.7±4)
FREQ Hz	970±50	680±50	775±50	1150±20
TEMP °F	100	257	255	230
PRESS psia	16.7	14.7	14.7	18.7
INLET °F	100	205	209	195
OUTLET °F	98	164	169	174
ZERO "H_2O	0.00	0.00	0.00	0.00
#1 REF "H_2O to AMB	0.36	0.12	0.16	0.52

REFERENCE TO #1 POSITION

"H_2O	2	0.00	0.00	0.00	0.02
	3	-0.01	0.00	0.00	-0.01
	4	-0.10	-0.05	-0.05	-0.14
	5	-0.10	-0.05	-0.05	-0.10
	6	-0.15	-0.06	-0.06	-0.19
	7	-0.23	-0.08	-0.09	-0.30
	8	-0.33	-0.10	-0.12	-0.46
	9	-0.31	-0.10	-0.12	-0.45
	10	-0.35	-0.10	-0.13	-0.50
	11	-0.36	-0.10	-0.13	-0.53
	12	-0.36	-0.10	-0.13	-0.51
	13	0.01	-0.01	0.00	0.05
	14	0.00	0.00	0.00	0.00



STATIC PRESSURE MEASUREMENT IDENTIFICATION

FIGURE 1

N O T I C E

When government drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the United States government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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