SOLAR/0006-78/20

Test Report on the National Solar Data System Accuracy Test using the MOD 1 SDAS

May 24, 1978

Contract EG-77-C-01-4049

United States Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

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1.0 INTRODUCTION

The basic objective of the National Solar Data System Accuracy Test was to determine the end-to-end accuracy of the Data System, identify sources of data errors and determine their contribution to any data collection inaccuracies. The results reported herein include the tests using the Mod 1 Site Data Acquisition System (SDAS). A subsequent model of the SDAS will be tested and reported on at a later date.

The determination of a representative system accuracy was accomplished by taking "off the shelf" sensors and data system components to an independent testing laboratory for installation and operation as a typical National Solar Data Program site. The Data System was tested with controlled input conditions to determine if the data was sensed correctly and processed accurately.

The testing was performed at Wyle Laboratories, Huntsville, Alabama and all reference data provided by Wyle was obtained by instruments traceable to the National Bureau of Standards.

The test program was divided into three phases: sensors were individually calibrated, static temperature tests were performed to verify the data path, and dynamic tests were performed to determine the accuracy of system level data collection and processing.

The paragraphs that follow will provide a general description of the Data System, describe the test methods, and present the test results. Additionally, the results of a pyranometer verification test by the National Oceanic and Atmospheric Administration will be presented.

2.0 DATA SYSTEM OVERVIEW

A typical instrumented solar energy site in the National Solar Data System is shown in Figure 2-1. The solar energy system at each site in the program is instrumented to provide sufficient measurements to support the thermal performance analysis of the system. The instrumentation generally includes sensor devices to monitor insolation, temperature, fluid flows, and power. The data from these sensors is recorded automatically at prescribed intervals by the Site Data Acquisition System (SDAS).

The communications link between each SDAS and the Central Data Processing System (CDPS) consists of voice-grade telephone lines and telephone data couplers. The recorded data at each remote site is collected periodically (usually daily) by the Communications Processor in the CDPS. The Communications Processor directs the calling of all sites, communicates with the SDAS, and temporarily stores the data until called for by the Host Computer for processing. For each site call, the Communications Processor establishes and verifies correct contact with the site by checking an address code transmitted from the SDAS. Also, the SDAS transmits the reading from its internal timer to insure that the data to be transmitted will be time-tagged correctly. The Communications Processor and Host Computer are located at the IBM Facility in Huntsville, Alabama.

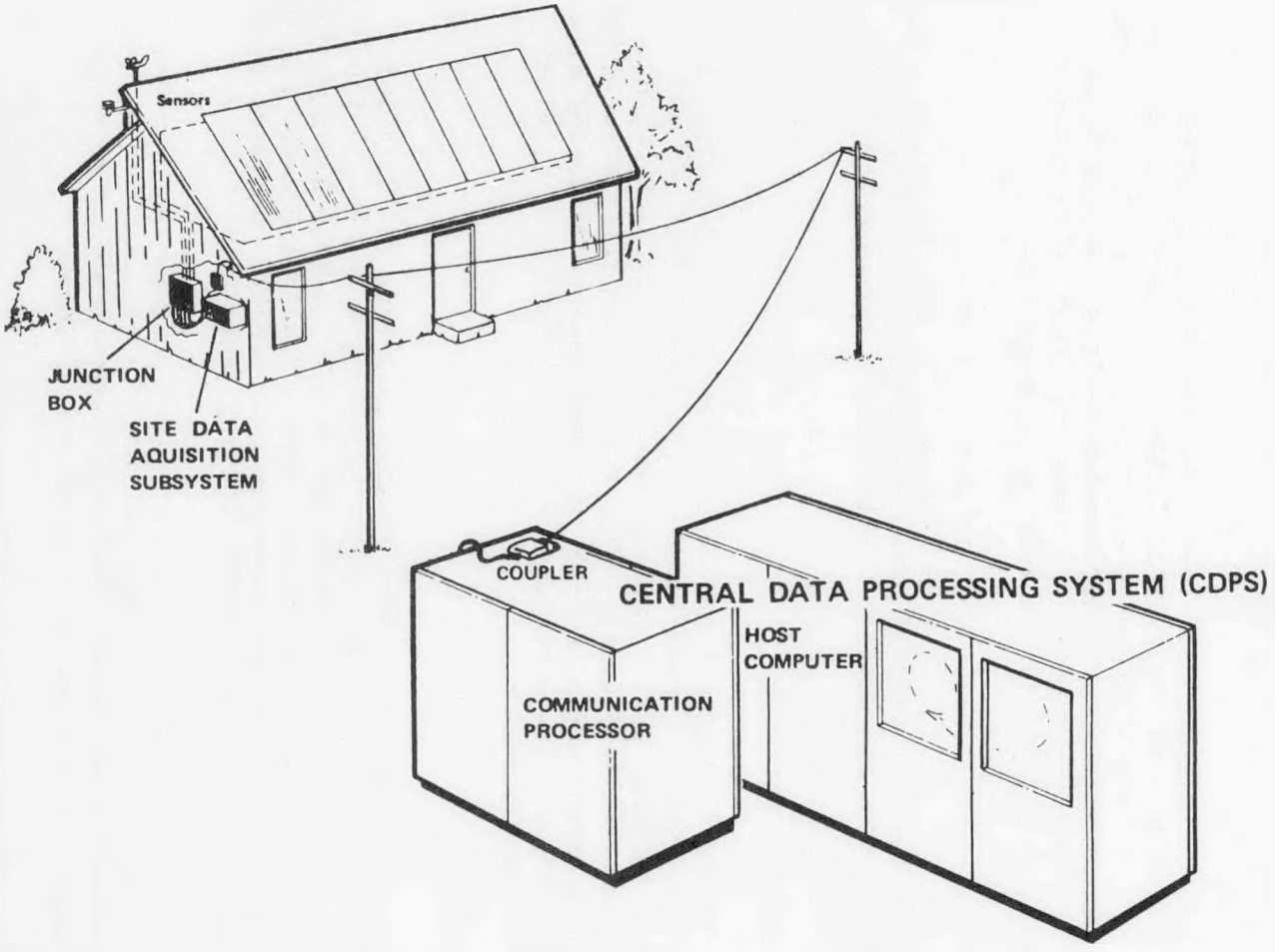


FIGURE 2-1. TYPICAL INSTRUMENTATION INSTALLATION

After the Communications Processor scans the data as it is received, to determine if there are any apparent errors in the transmission process, the measurement data is transferred to the Host Computer where it is converted from the binary transmission format to appropriate values in engineering units. This conversion uses factors which are unique to each site installation. The measurements are then checked to insure that they are reasonable, that is, they are not beyond the known limits of the instrumentation, or that they are not erratic. Data which appears questionable is discarded and is not used further in the site evaluation.

For each site, appropriate equations have been formulated and programmed. These equations define the desired performance factors for the system configuration at that site. All of the valid measurement data is processed using the performance equations to generate hourly performance factors. As sufficient data is accumulated, the hourly performance factors are combined to provide daily performance factors and, finally, monthly performance factors.

3.0 TEST METHODS

The Data System Accuracy Test was divided into three phases: Sensor Calibration, Level 1 System Tests, and Level 2 System Tests. The paragraphs that follow describe each phase.

3.1 SENSOR CALIBRATION

Temperature sensors, liquid flowmeters, and power meters were calibrated in the Wyle Calibration Facilities. Twelve Minco single element (S53P50) and nine Minco dual element (S57P50) Resistance Temperature Devices (RTD) were calibrated in the Wyle Huntsville Facility. Two Ramapo flowmeters (MKV-1-J07) and one Ohio Semitronics watt transducer (PC5-10F) were calibrated in the Wyle Hampton, VA facility. The test equipment used in each calibration is listed on the data sheets in Appendix A.

3.2 LEVEL 1 SYSTEM TEST

The Level 1 System Test utilized temperature sensors to verify the data path through the system and determine the temperature measurement accuracy. Sixteen calibrated temperature sensors were connected to the Junction Box and, in turn, the remainder of the system - SDAS through CDPS. The sensors were placed in a Rosemount 910A Temperature Bath (controllable to $\pm 0.01^{o}F$) and tests were performed at three temperature levels - 100^{o}, 120^{o} and $150^{o}F$.

As shown in Figure 3-1 , the temperature "sensed" at a probe in the bath could be traced through the data path, via the channel to which it was assigned and sampled at specific points in that path. Upon stabilization at the test temperature, the measurement sequence discussed below was followed.

The resistance of each temperature sensor (RTD) was measured and recorded. This "R" value represented a specific temperature for each RTD. The calibration data for each RTD was stored in a programmable desk top calculator for use in the solution of the Calendar Van-Dusen equation. As a resistance was measured, the R value was entered in the equation and the corresponding temperature determined. This was repeated for each of the sixteen sensors.

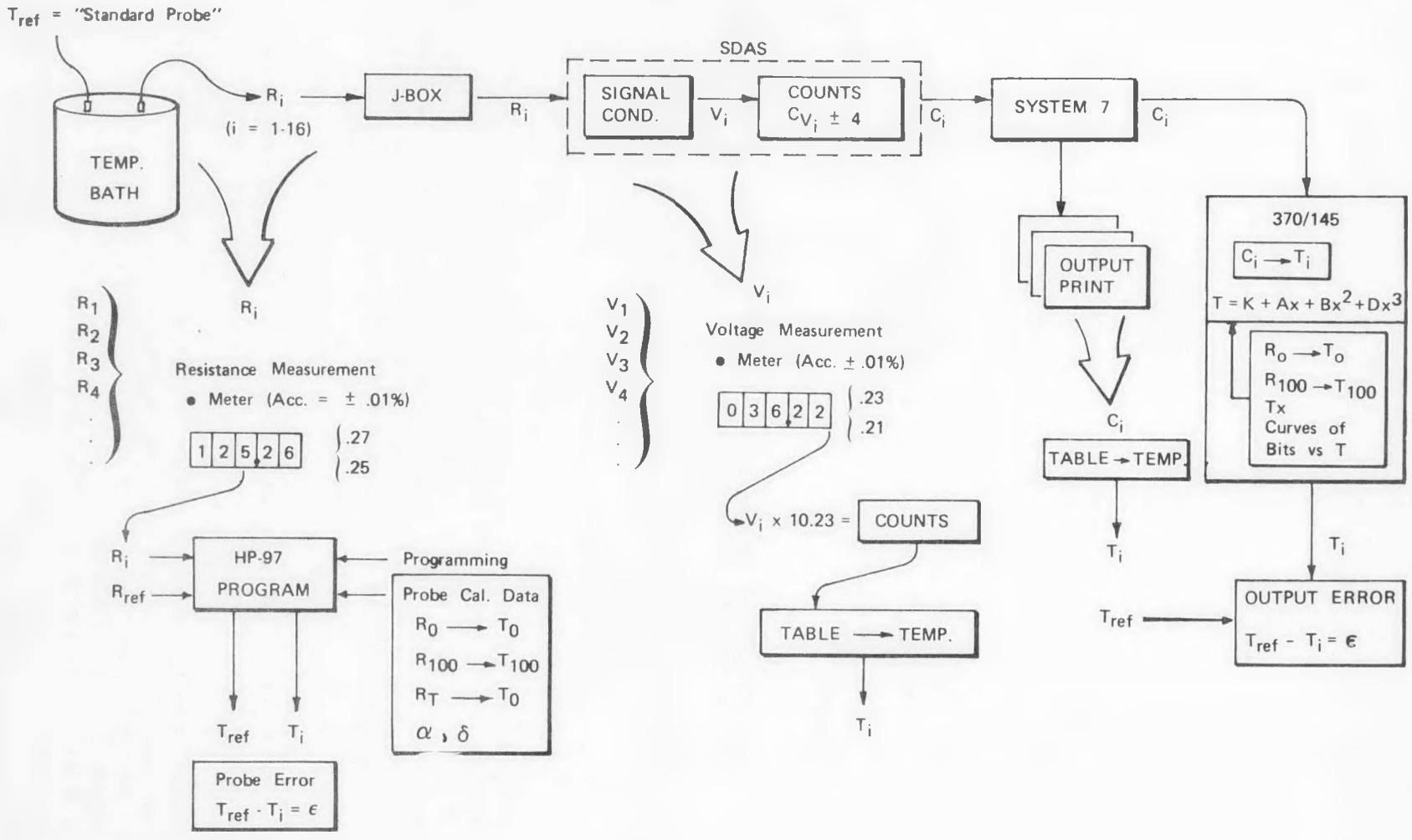


FIGURE 3-1. LEVEL 1 TEST SEQUENCE

The voltage output of the signal conditioning on each channel was measured within the SDAS and recorded. A manual conversion of this voltage to digital counts* and the utilization of a specially generated table of counts (bits) versus temperature yielded the temperature on each channel.

After the analog to digital conversion within the SDAS, the data for each channel is recorded at predetermined intervals for transmission to the Communications Processor (IBM System 7). The output of the System 7 is a tabulation of the data on each channel at specific, identifiable time intervals. This data (in counts) was converted to temperatures for a third data sample point.

The fourth sample point was available at the output of the CDPS. The data transmitted from the Communications Processor to the Host Computer (IBM 370/145) is converted to engineering units and printed out at the same time intervals.

The four data sample points discussed above provided a look at the data path at any specific time during the test. Comparison of the reference temperature and the system output temperature provides the magnitude of the temperature measurement error.

3.3 LEVEL 2 SYSTEM TEST

Following the calibration of the sensors and the verification of the data path, the temperature, flow, and power sensors were installed in a test loop designed and fabricated by Wyle Laboratories. This loop, shown schematically in Figure 3-2, was designed to simulate a typical solar site to the extent that numerous channels (22) were being used to record data at a location remote (200 ft.) from the SDAS. The loop provided combinations of temperature and flow for dynamic test conditions. An 11.25 kilowatt heater simulated solar collectors and a heat exchanger provided variable heat loads. As shown in Figure 3-2, Wyle reference instrumentation was installed in the loop in close proximity to the data system sensors. Thermal instrumentation wells were installed to provide accurate comparison of temperature data. Figures 3-3, 3-4, and 3-5 illustrate the physical configuration of the test loop and the installation of the data system equipment.

The Level 2 Test Sequence is described in Figure 3-6. With the sensors installed in the loop and connected to the SDAS, specific heat loads and flows were established and maintained for extended periods of time. This data, recorded by the SDAS and transmitted to the System 7, was converted to engineering units and used to solve the preprogrammed test loop performance equations by the System 370/145.

The output of the CDPS was verified in three ways. Digital data (counts) from the System 7 was manually converted to temperatures, flows, and power and then compared to the CDPS output. Digital data from the System 7 was entered into the programmable calculator, which was preprogrammed with the performance equations, and the performance factor calculations were compared with the CDPS output. Finally, Wyle reference data was entered into the programmable calculator and performance calculations were made and compared to the CDPS output.

$$*\text{Counts (bits)} = \text{Sig. Cond. Voltage (mv)} \times \frac{1023 \text{ counts}}{100 \text{ mv}}$$

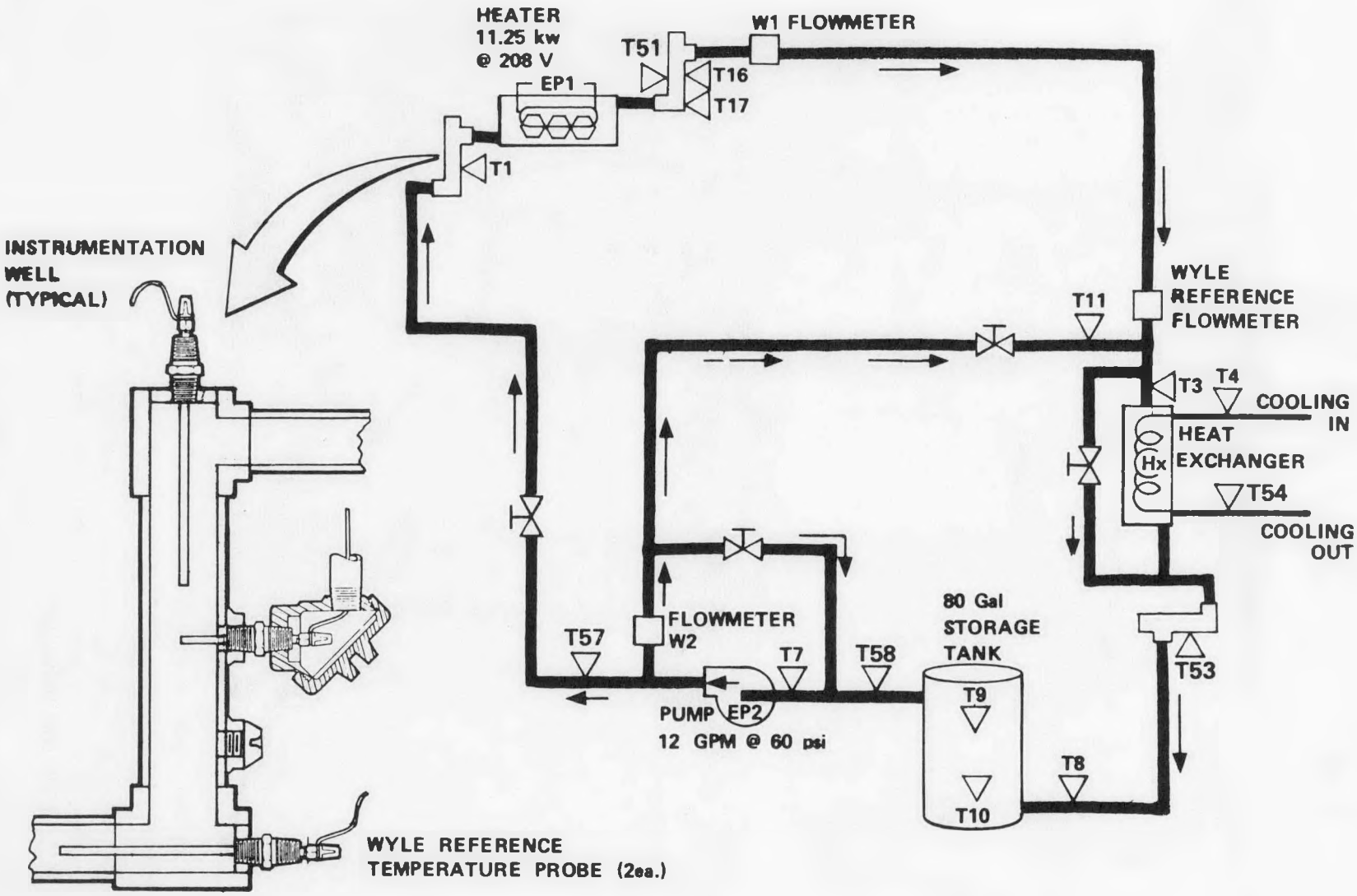


FIGURE 3-2. LEVEL 2 TEST LOOP SCHEMATIC

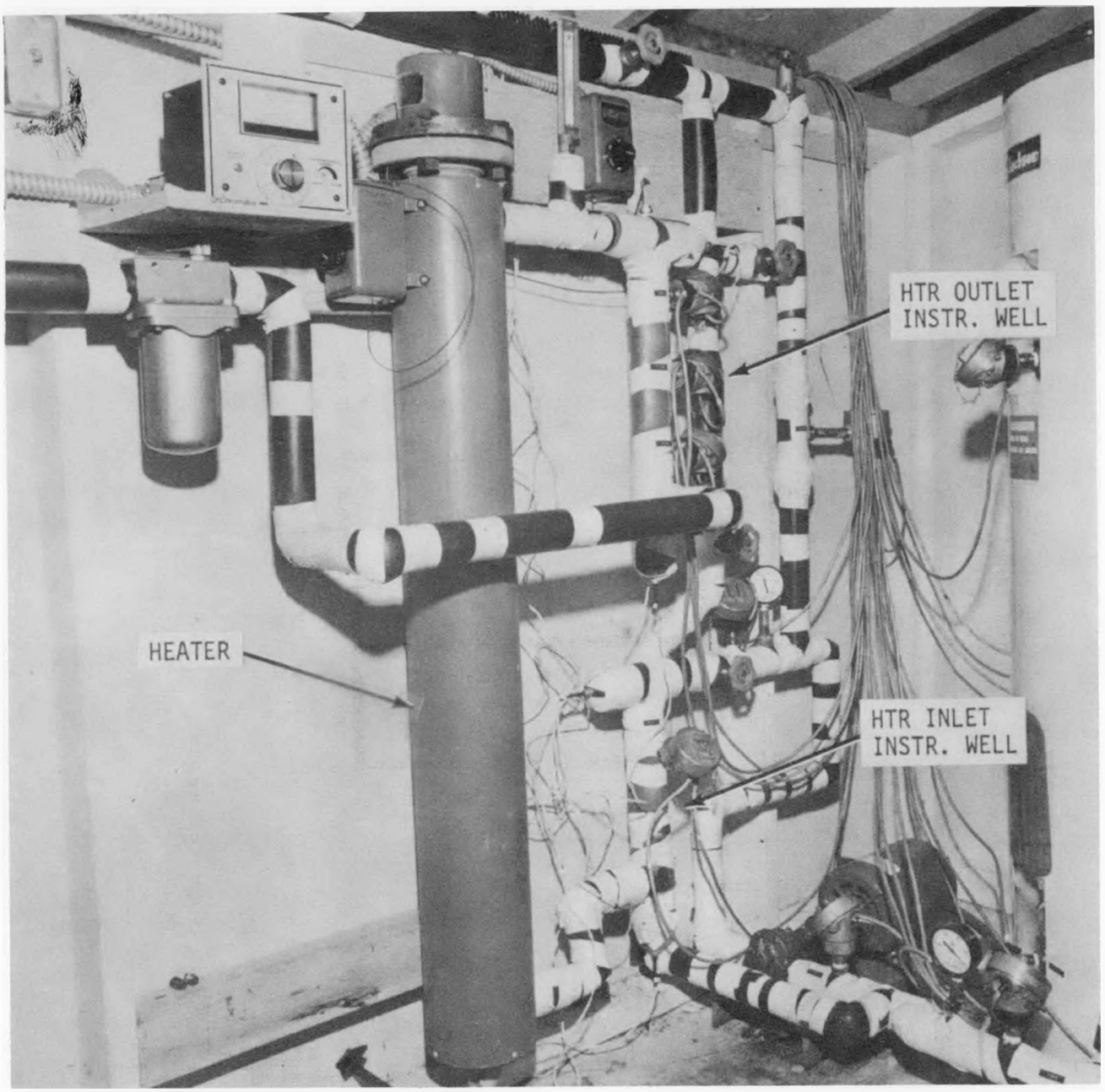


FIGURE 3-3. TEST LOOP CONFIGURATION

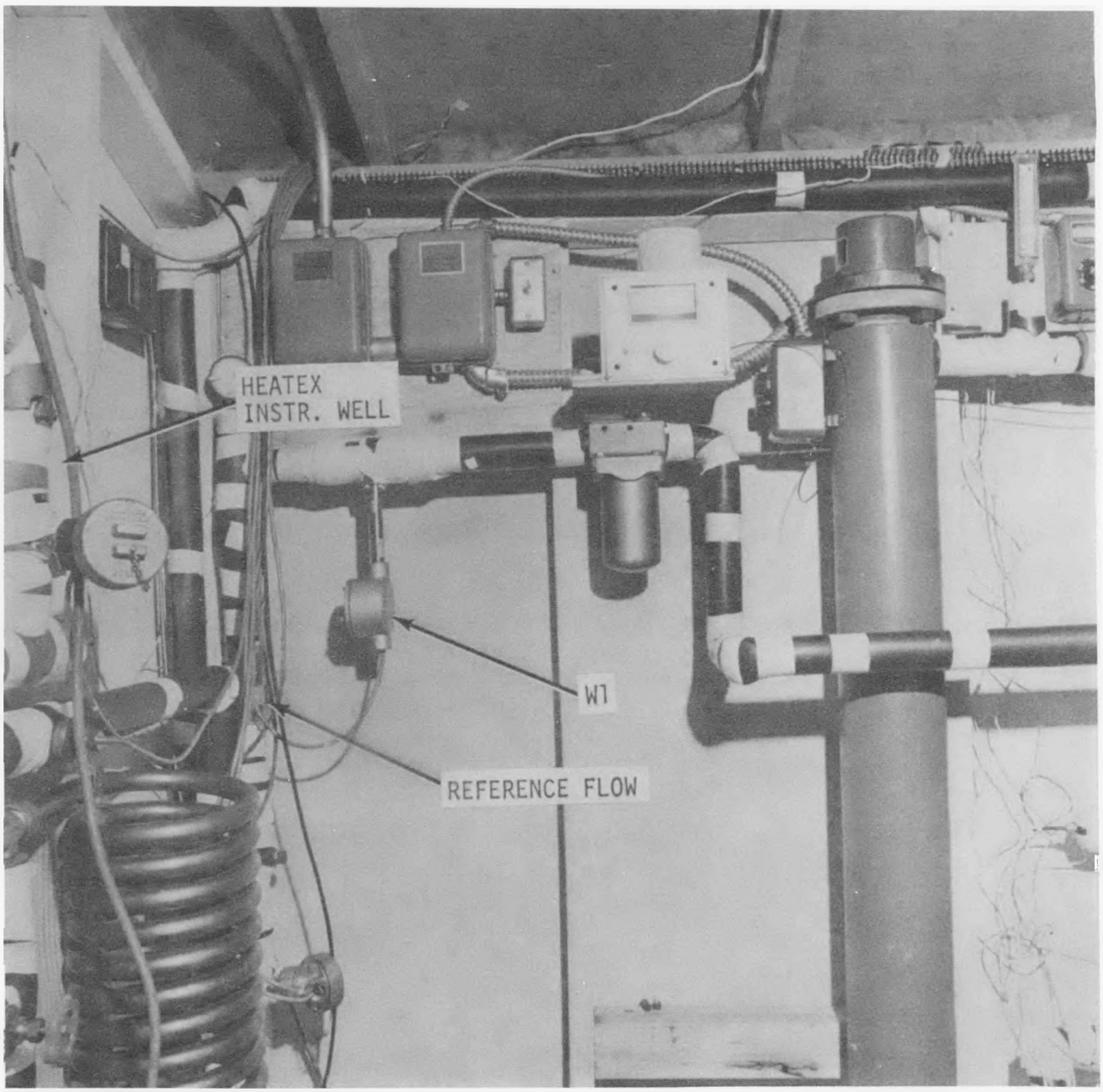


FIGURE 3-4. TEST LOOP CONFIGURATION

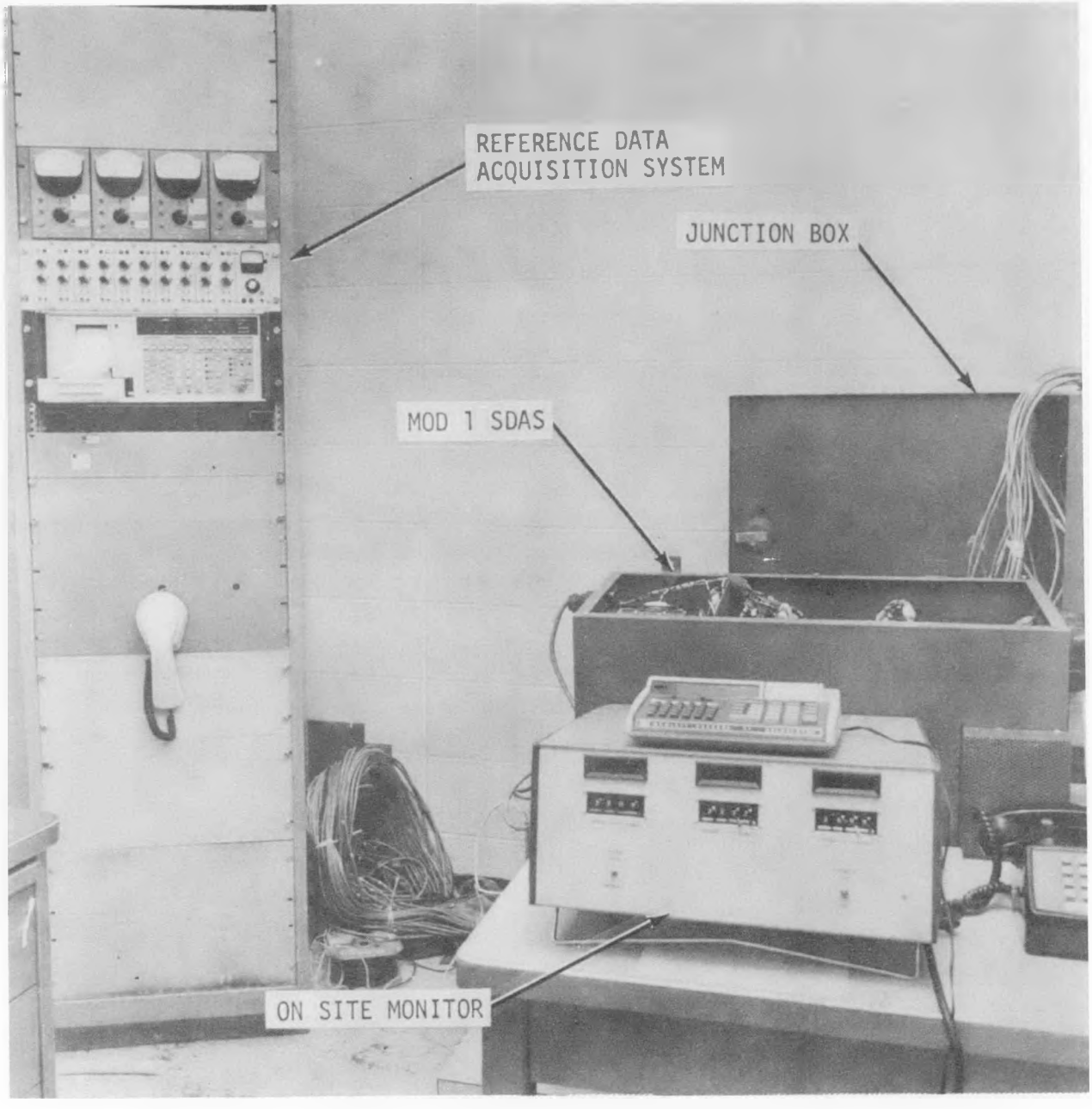


FIGURE 3-5. DATA SYSTEM EQUIPMENT INSTALLATION

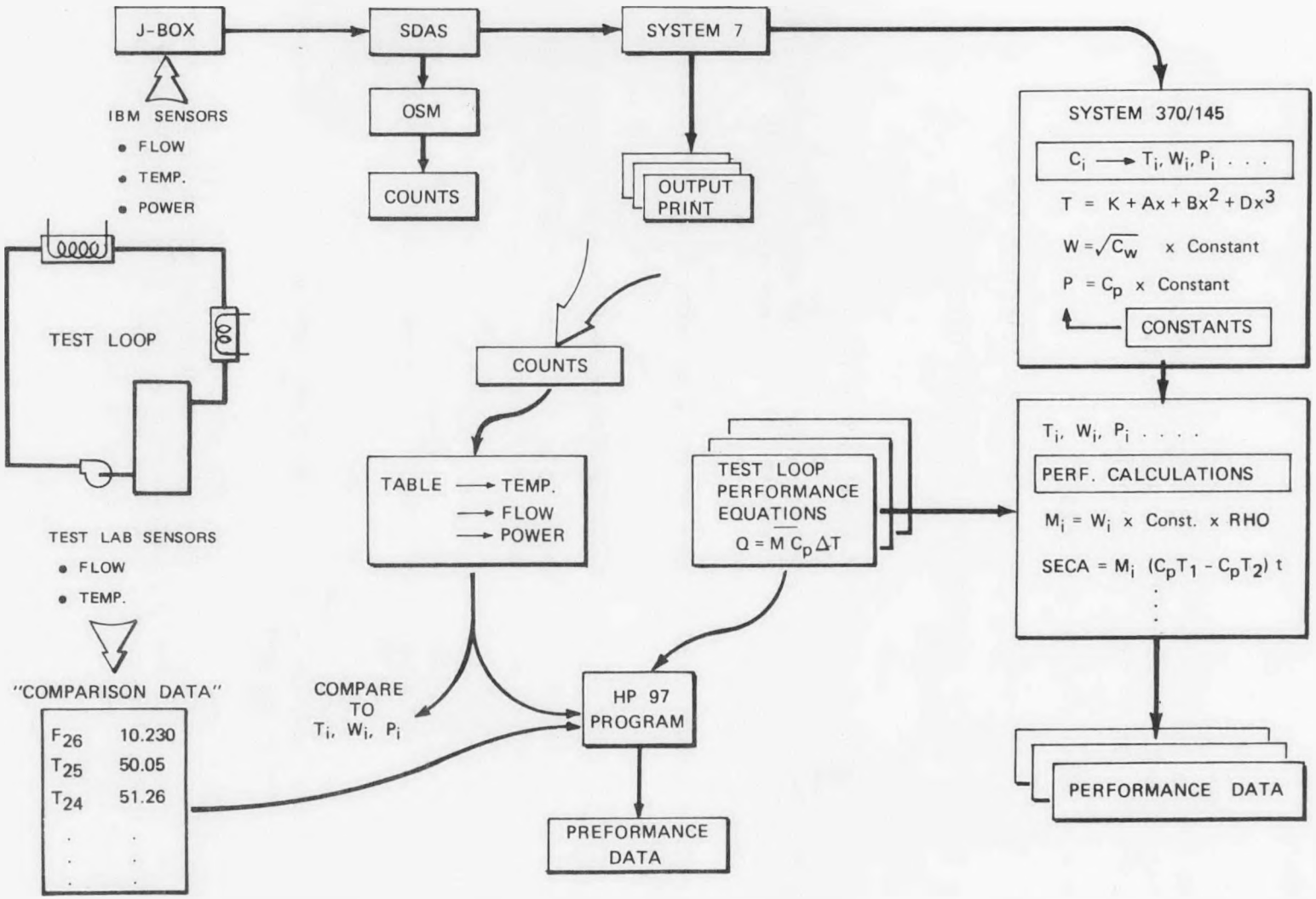


FIGURE 3-6. LEVEL 2 TEST SEQUENCE

4.0 TEST RESULTS

4.1 SENSOR CALIBRATION

The results of the calibration of the Data System sensors are tabulated in the Wyle report included in Appendix A. Additionally, the NOAA Pyranometer Verification results are included in Appendix B.

Analysis of the calibration data indicates:

- All sensors are within the manufacturers tolerance levels
- The manufacturers calibration data is reliable

4.2 LEVEL 1 SYSTEM TEST

The results of the three Level 1 test cases are shown in Tables 4-1 through 4-3. Temperature readings at each of the four sample points in the data path are tabulated for each sensor. The minor variations observed in the temperature along the path are not significant. Temperature readings at the SDAS signal conditioning are not normally recorded during Data System operation and are presented only to verify the data path. Comparison of the system output temperature with the reference temperature is the true indication of temperature measurement accuracy.

Analysis of the data leads to the following conclusions:

- There are no significant variations in the data from the "sensed" value to the CDPS output. CDPS processing of data is accurate.
- The temperature sensors are within $0.25^{o}F$ of the reference temperature in all cases. Utilization of the probe calibration data and the measured resistance in the Calendar Van-Dusen equation should yield a probe difference of zero. The 0.25^{o} difference, a very satisfactory result, is due to slight measurement variations, minor probe calibration inaccuracies, and inconsistencies within the CVD equation. As an example, a variation of 0.05 Ohms (.05% at 100 Ohms) results in a 0.25^{o} change in temperature.
- The system output is within $0.50^{o}F$ of the reference temperature in all cases. Tabulation of the 45 test samples shows the mean system error to be 0.134^{o} with the one sigma value to be 0.126^{o}. Maintaining the output temperature within 0.50^{o} of the reference meets the measurement accuracy requirements of NBSIR 76-1137.*

*Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program.

TABLE 4-1

TEST CASE NUMBER 1

REFERENCE TEMPERATURE = 99.93°F

PROBE NUMBER	TEMP RANGE °F	TEMP @ PROBE	TEMP @ SDAS	TEMP @ SYS. 7	SYSTEM OUTPUT TEMP	SYSTEM* ERROR
1	30 to 230	100.00	99.78	99.83	99.83	0.10
2	30 to 230	99.69	99.75	99.89	99.94	0.01
3	-20 to 120	99.72	99.78	100.05	100.07	0.14
4	30 to 230	100.16	99.89	99.98	99.99	0.06
5	30 to 230	100.04	99.94	100.08	100.11	0.18
6	-20 to 120	100.08	99.86	100.10	100.11	0.18
7	30 to 230	100.00	99.81	99.89	99.94	0.01
8	30 to 230	99.77	99.86	100.00	100.03	0.10
9	30 to 160	99.82	99.74	99.87	99.93	0.00
10	30 to 160	100.04	99.95	100.07	100.09	0.16
11	30 to 160	99.93	99.97	100.11	100.17	0.24
12	30 to 160	99.91	99.80	99.89	99.91	0.02
13	30 to 160	99.93	99.84	99.90	99.94	0.01
14	-20 to 120	99.97	99.87	100.18	100.20	0.27
15	30 to 450	99.93	99.97	100.13	100.15	0.22
16	30 to 450	99.86	99.81	99.89	99.89	0.04
		Tmean=99.93°	Tmean=99.85°	Tmean=99.99°	Tmean=100.02°	

Range=+.23°
-.24°

*SYSTEM ERROR = $T_{REF} - T_{SYSTEM\ OUTPUT}$

TABLE 4-2

TEST CASE NUMBER 2

REFERENCE TEMPERATURE = 120.00°F

PROBE NUMBER	TEMP RANGE °F	TEMP @ PROBE	TEMP @ SDAS	TEMP @ SYS 7	SYSTEM OUTPUT TEMP	SYSTEM* ERROR
1	30 to 230	119.88	119.80	120.08	120.04	0.04
2	30 to 230	119.80	119.78	119.97	119.96	0.04
3	-20 to 120	119.75	119.82	120.16	120.17	0.17
4	30 to 230	120.18	119.86	120.00	119.97	0.03
5	30 to 230	120.11	119.94	120.32	120.31	0.31
6	-20 to 120	120.12	119.87	120.29	120.27	0.27
7	30 to 230	120.11	119.83	120.02	120.04	0.04
8	30 to 230	119.93	119.90	120.18	120.14	0.14
9	30 to 160	119.89	119.75	120.05	120.04	0.04
10	30 to 160	120.06	120.00	120.18	120.17	0.17
11	30 to 160	120.03	120.00	120.19	120.21	0.21
12	30 to 160	120.03	119.81	120.04	120.01	0.01
13	30 to 160	120.07	119.87	120.11	120.10	0.10
14	-20 to 120	119.93	119.96	120.26	120.26	0.26
15	30 to 450	120.00	120.00	120.11	120.15	0.15
16	30 to 450	119.94	119.88	119.99	119.99	0.01

Tmean=119.99° Tmean=119.88° Tmean=120.12° Tmean=120.11°
Range=+.18°
-.25°

*SYSTEM ERROR = $T_{REF} - T_{SYSTEM\ OUTPUT}$

TABLE 4-3

TEST CASE NUMBER 3

REFERENCE TEMPERATURE = 149.97°F

PROBE NUMBER	TEMP RANGE °F	TEMP @ PROBE	TEMP @ SDAS	TEMP @ SYS 7	SYSTEM OUTPUT TEMP	SYSTEM* ERROR
1	30 to 230	149.83	149.80	150.05	150.03	0.06
2	30 to 230	149.75	149.78	150.15	150.18	0.21
3	-20 to 120	149.78	--	--	--	--
4	30 to 230	150.17	149.76	150.04	150.05	0.08
5	30 to 230	150.16	149.87	150.24	150.23	0.26
6	-20 to 120	150.08	--	--	--	--
7	30 to 230	150.09	149.75	150.10	150.09	0.12
8	30 to 230	149.92	149.88	150.17	150.17	0.20
9	30 to 160	149.93	149.68	150.05	150.06	0.09
10	30 to 160	150.04	149.90	150.26	150.26	0.29
11	30 to 160	150.02	149.99	150.36	150.36	0.39
12	30 to 160	149.88	149.74	150.13	150.10	0.13
13	30 to 160	150.06	149.82	150.25	150.23	0.16
14	-20 to 120	149.89	--	--	--	--
15	30 to 450	149.97	149.91	150.48	150.46	0.49
16	30 to 450	149.90	149.83	150.25	150.19	0.22

Tmean=149.97° Tmean=149.82° Tmean=150.19° Tmean=150.18°

Range=+.20°
-.22°

*SYSTEM ERROR = $T_{REF} - T_{SYSTEM\ OUTPUT}$

4.3 LEVEL 2 SYSTEM TEST

Table 4-4 shows the comparison between the output at the CDPS and the manual conversion of temperatures, flow, and power based on System 7 digital counts. No significant differences can be seen.

Table 4-5 shows the comparison between the manual calculation of performance factors and the CDPS output. The minor differences noted, such as the Solar Energy to Load (SEL) calculation, are attributable to round off in the data processing. The maximum difference noted in all calculations was 0.10%. The data presented in Table 4-4 and 4-5 was taken at a single 64-second time scan. The method of calculating data on one scan essentially removed the effect of reference temperature variations and measurement noise.

Table 4-6 shows the comparison between the data system output and calculations based on the reference instrumentation. The comparison was made at the inlet and outlet to the system heater. As shown in Figure 3-2, instrumentation wells and the reference flowmeter provide an accurate indication of data at this point. The time span of fifteen readings was chosen for ease of data handling - any number of scans could be chosen within these test conditions with no significant change in results. Analysis of the data and the sample calculation shows the CDPS output to be within the limits set forth in NBSIR 76-1137.

The data presented in this report was obtained in short duration time scans to enhance manual conversion and reduce test time and, as such, represents the worst case situation. The nature of the digital data implies that variations will be less as more samples are taken. Typical solar site data is scanned at five minute intervals and collected daily for monthly performance reporting.

5.0 CONCLUSIONS

A review of the data presented in Section 4 substantiates the conclusion that the Data System, with the Mod 1 SDAS, provides accurate measurement of system parameters, error free data processing, and accurate performance evaluation. The instrumentation met the required accuracy goals, the SDAS maintained that accuracy through collection and formatting for transmission, and the accuracy was not degraded by CDPS processing.

TABLE 4-4

ENGINEERING UNIT CONVERSION VERIFICATION

TIME: 13:00:25

MEASUREMENT NUMBER	SYS. 7 DIGITAL COUNTS	MANUAL CONV.	CDPS OUTPUT
W1	112	10.45	10.459
T53	394	109.89	109.888
EP1	443	8.65	8.652
T54	807	92.20	92.199
EP2	120	0.23	0.234
T1	389	108.77	108.773
T3	402	112.80	112.801
T4	587	60.90	60.900
T7	371	107.11	107.113
T57	388	110.05	110.050
T9	618	109.91	109.907
T8	605	109.00	108.997
RH1	209	20.40	20.430
T58	615	109.78	109.781
T10	618	109.86	109.861
T11	626	111.21	111.211
T14	462	44.13	44.130
T17	208	115.43	115.431
T16	209	115.77	115.771

TABLE 4-5

PERFORMANCE EQUATION VERIFICATION

TIME: 13:00:25

PERFORMANCE FACTOR*	MANUAL CALCULATION	CDPS OUTPUT	EQUATION*
RHO(T17)	8.25	8.25	$8.3T1467-3.26x10^{-4}T-6.801x10^{-6}T^2$
RHO(T4)	8.33	8.33	"
M1	86.75	86.72	$W1x\sqrt{8.338xRHO(T)}$
M3	15.00	15.00	"
HWT1	109.08	109.08	$1.01146T-1.17403x10^{-4}T^2+.3457x10^{-6}T^3$
HWT3	113.10	113.10	
HWT4	61.24	61.24	
HWT7	107.42	107.42	
HWT8	109.30	109.30	
HWT17	115.72	115.72	
HWT53	110.19	110.19	
HWT54	92.53	92.53	
HWT57	110.35	110.35	
HWT58	110.08	110.08	
HWL	5,205.00	5,203.33	M1x60
SEA	29,529.28	29,530.34	3413xEP1
SECA	34,561.20	34,576.70	M1x(HWT17-HWT1)x60
SEL	15,146.55	15,128.61	(M1+M2)x(HWT3-HWT53)x60
SYSL	28,161.00	28,161.07	M3x(HWT54-HWT4)x60
SFR	.54	.54	SEL/SYSL
CSOPE	798.64	799.91	3413xEP2
HSE	15,250.65	15,250.72	M1x(HWT57-HWT7)x60
HL	798.64	799.91	CSOPE
STEI	9,785.40	9,786.49	M1x(HWT8-HWT7)x60
TST	109.88	109.88	T9+T10/2

*Performance factors and equations are derived from NBSIR76-1137 and modified by IBM for use in the CDPS. Refer to the following page for a definition listing.

TABLE 4-5 (Continued)

PERFORMANCE FACTOR AND EQUATION DEFINITION

RHO(TXX)	-	FLUID DENSITY AT TEMPERATURE XX
MX	-	MASS FLOWRATE - LBS/MIN
WX	-	VOLUMETRIC FLOWRATE - GAL/MIN
HWTX	-	ENTHALPY AT TEMPERATURE X-BTU/LB
Q	-	HEAT TRANSFER ENERGY - BTU
HWL	-	HOT WATER LOAD
SEA	-	INCIDENT SOLAR ENERGY ON COLLECTOR ARRAY
SECA	-	COLLECTED SOLAR ENERGY BY ARRAY
SEL	-	SOLAR ENERGY TO LOAD
SYSL	-	SYSTEM LOAD
SFR	-	SOLAR FRACTION
CSOPE	-	ECSS OPERATING ENERGY
HSE	-	SOLAR ENERGY TO SPACE HEATING
HL	-	SPACE HEATING LOAD
STEI	-	ENERGY DELIVERED TO STORAGE
TST	-	STORAGE TEMPERATURE

TABLE 4-6
PERFORMANCE COMPARISON

TIME INCREMENT	HEATER INLET TEMP (T1)	REFERENCE TEMP	HTR OUTLET TEMP (T16)	REFERENCE TEMP	SYSTEM FLOW W1 - GPM	REFERENCE FLOW - GPM
1	109.87	110.27	115.37	115.81	10.46	10.26
2	109.87	110.27	115.37	115.81	10.46	10.26
3	109.67	110.28	115.37	115.81	10.51	10.17
4	110.07	110.30	115.77	115.85	10.46	10.20
5	109.87	110.30	115.37	115.84	10.46	10.23
6	110.07	110.26	115.17	115.73	10.41	10.21
7	109.67	110.27	115.37	115.88	10.46	10.22
8	109.87	110.27	115.77	115.82	10.46	10.17
9	109.87	110.27	115.77	115.86	10.46	10.22
10	109.87	110.27	115.37	115.79	10.46	10.23
11	109.87	110.26	115.77	115.98	10.37	10.23
12	110.07	110.26	115.77	115.79	10.55	10.22
13	109.87	110.26	115.77	115.89	10.55	10.18
14	110.07	110.28	115.37	115.86	10.46	10.26
15	109.67	110.28	115.77	115.84	10.41	10.20
MEAN	109.87^{o}	110.27^{o}	115.60^{o}	115.83^{o}	10.46 GPM	10.21 GPM

ENERGY CALCULATION EXAMPLE: $Q = M \times (HWT_o - HWT_i) \times \Delta t$

SYSTEM		REFERENCE	
T_{IN}	$= 109.87^{o}$	T_{IN}	$= 110.27^{o}$
T_{OUT}	$= 115.60^{o}$	T_{OUT}	$= 115.83^{o}$
W	= 10.46 GPM	W	= 10.21 GPM
Q	= 7,442 BTU	Q	= 7,048 BTU

DIFFERENCE = 5.58%

APPENDIX A

Test Report

REPORT NO. _____

WYLE JOB NO. IBM 17176

CUSTOMER P. O. NO. 827310

DATE 2 March 1978

SPECIFICATION (S) _____

1.0 CUSTOMER IBM

ADDRESS 150 Sparkman Drive, Huntsville, Ala. 35806

2.0 TEST SPECIMEN _____

3.0 MANUFACTURER _____

4.0 SUMMARY

Wyle Laboratories designed and constructed a test loop to be used by IBM to determine the end-to-end accuracy of their Site Data Acquisition System (SDAS). The test loop and an SDAS are located at Wyle's Huntsville facility.

In addition, Wyle's calibration laboratory provided traceable calibration of the SDAS's sensors.

Attached are the following:

- Calibration sheet for the test loop flowmeter.
- Calibration sheets for the IBM sensors.
- Appendix A - Calibration sheets for the test loops temperature sensors.

STATE OF ALABAMA
COUNTY OF MADISON } ss.

Ralph Barber, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Ralph Barber

SUBSCRIBED and sworn to before me this 3 day of Mar 19 78

Lisa B. Barnett

Notary Public in and for the ~~County of Madison~~, State of Alabama at large.

My Commission expires June 17 19 80

PREPARED BY L. L. Pahst

APPROVED BY L. L. Pahst

WYLE Q. A. R. M. Davies

WYLE LABORATORIES
SCIENTIFIC SERVICES AND SYSTEMS GROUP
HUNTSVILLE, ALABAMA

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HAMPTON, VIRGINIA

Wyle Job No. 28532

Customer P.O. No. 17176-91

Wyle Laboratories
7800 Governor's Drive West
Huntsville, Alabama 35805

Date 11-15-77

Reference No. N/A

Manufacturer Bearingless — Calibration schedule N/A Days

Model No. E-100 — Serial No. N/A — Calibration date 11-15-77

Instrument Flowmeter — Type of calib. N/A

Type Bearingless — Range 0-10 GPM — Accuracy +/-0.5% FS

DESCRIPTION OF CALIBRATION

SEE ATTACHED DATA SHEET

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
High Flow Stand	9910	GFE-394	+/-0.3 % IND.	7-11-77

Test Engineer

Quality Control

REPORT OF CALIBRATION-WYLE LABORATORIES

CALIBRATION OF TURBINE METER

MANUFACTURER BEARINGLES
MODEL NUMBER E-100
RANGE 0-10 GPM

INV #N/A
SER # N/A
JOB # 28532

DATE 11-15-77
CAL BY W-1784
ORDER #

TEMP DEG F	TOTAL CYCLES	TIME (SEC)	WEIGHT (LBS)	K (CPG)	FREQ. (CPS)	FLOW (GPM)
74	19241	31.60	45	3559.292	608.892	10.2643
74	19211	35.57	45	3553.743	540.090	9.1187
74	19292	40.02	45	3568.726	482.059	8.1047
75	19201	45.89	45	3551.302	418.414	7.0692
75	19200	53.65	45	3551.117	357.875	6.0467
75	12839	43.46	30	3561.936	295.421	4.9763
75	10756	44.68	25	3580.857	240.734	4.0337
75	8590	47.13	20	3574.698	182.262	3.0592
75	6460	54.61	15	3584.408	118.293	1.9801
75	4273	66.83	10	3556.388	63.938	1.0787
75	2132	56.56	5	3548.897	37.694	0.6373

LINEARITY +/- 0.50 PERCENT AVERAGE K= 3562.851 CYCLES/GAL.

PRESSURE 30 PSIG APPROVED WYLE 3

CAL. FLUID-WATER SG 0.99850 VISCOSITY-CENTISTOKES 1.0

STANDARDS USED IN THIS CALIBRATON HAVE BEEN CERTIFIED BY, OR ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS, WASHINGTON D.C.

INVENTORY NUMBER OF STANDARD USED: 121731

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HUNTSVILLE, ALABAMA

Wyle Job No. 17176

Customer P.O. No. 827310

I. B. M. Corporation
150 Sparkman Dr.
Huntsville, AL 35805

Date 12/2/77

Reference No. 77-244

Manufacturer Weather Measure Corporation

Calibration schedule 365 Days

Model No. HM14-V Serial No. 1005

Calibration date 12/2/77

Instrument Humidity Probe

Type of calib. Transfer

Type

Range 0-100 Accuracy ± 3%

DESCRIPTION OF CALIBRATION

This instrument was calibrated in accordance with MIL-C-45662A specifications and manufacturer's procedures:

1. LICl - 13% - 25.0°C Adj 3% H
2. K2504 = 97% - 25.0°C Adj 2% H
3. Comparison 28% = 28% (HM14-V SN1079)

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
Thermometer	63F	136421	± .2°F	3/4/77
Humidity Indicator	HM111	1167	± 2%	11/19/77
Humidity Probe	HM14-V	11190	± 2%	11/29/77

Test Engineer

Quality Control

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HAMPTON, VIRGINIA

Wyle Job No. 17176

Customer P.O. No. 827310

I. B. M. Corporation
150 Sparkman Drive
Huntsville, AL 35805

Date 11/21/77

Reference No. 77-239

Manufacturer Ohio Semitronics, Inc.

Calibration schedule 365 Days

Model No. PC5-10F Serial No. 1319

Calibration date 11/18/77

Instrument Watt Transducer

Type of calib. Transfer

Type

Range 1.2KW Accuracy ± .5%

DESCRIPTION OF CALIBRATION

The above instrument was received at .75% tol and calibrated to better than .5% in accordance with MIL-C-45662A specifications and M. F. C. procedures.

	Volts	Amps.	Watts.	Calculated	Actual Reading	MV Diff.
1.	115.90	8.60	996.7	49.83	49.74	.097
2.	118.40	2.30	272.3	13.61	13.60	.01
3.	117.50	4.57	536.98	26.84	26.77	.07
4.	116.75	6.78	791.56	39.58	39.61	.03
5.	115.75	8.91	1031.33	51.57	51.68	.11

Average Diff = .0634 mv
In tol. Diff = .250 mv

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
Ampmeter	370	80458	± .25%	11/11/77
Voltmeter	3465A	96140	± .15%	10/10/77
Voltmeter	8200A	96123	± .1%	7/22/77

Test Engineer

Quality Control

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HAMPTON, VIRGINIA

Wyle Job No. 28532

Customer P.O. No. 17176-91

Wyle Laboratories
7800 Governor's Drive West
Huntsville, Alabama 35805

Date 11-10-77

Reference No. N/A

Manufacturer Ramapo — Calibration schedule N/A Days

Model No. V-1-J07 — Serial No. 5511 — Calibration date 11-10-77

Instrument Flowmeter — Type of calib. N/A

Type Strain Gage — Range 1-10 GPM — Accuracy See Curve.

DESCRIPTION OF CALIBRATION

ATTACHED DATA SHEETS

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
High Flow Stand	9910	GFE-394	+/-0.3% IND.	7-11-77

Test Engineer

Quality Control

WYLE LABORATORIES

REPORT ON

FLOWMETER

MAKE Ramapo SER. 5511 MOD. V-1-J07 INV. NO. N/A

RANGE 1 TO 10 gpm

TEMP °F		TIME (SEC)	WEIGHT (LBS)		TEST INDICATION (MVDC)	FLOW (GPM)
78		32.70	45		20.69	9.92
78		35.48	45		17.45	9.15
78		37.10	45		16.05	8.75
78		37.76	40		12.14	7.64
78		34.76	30		8.14	6.22
78		35.09	25		5.50	5.14
78		41.80	25		4.02	4.31
78		32.42	15		2.45	3.34
78		27.69	10		1.39	2.60
78		45.35	10		0.685	1.59
78		33.73	5		0.400	1.07

CAL. FLUID-WATER SG 0.99688 @ 78°F

VISCOSITY-CENTISTOKES 1.0

DATE 11-10-77

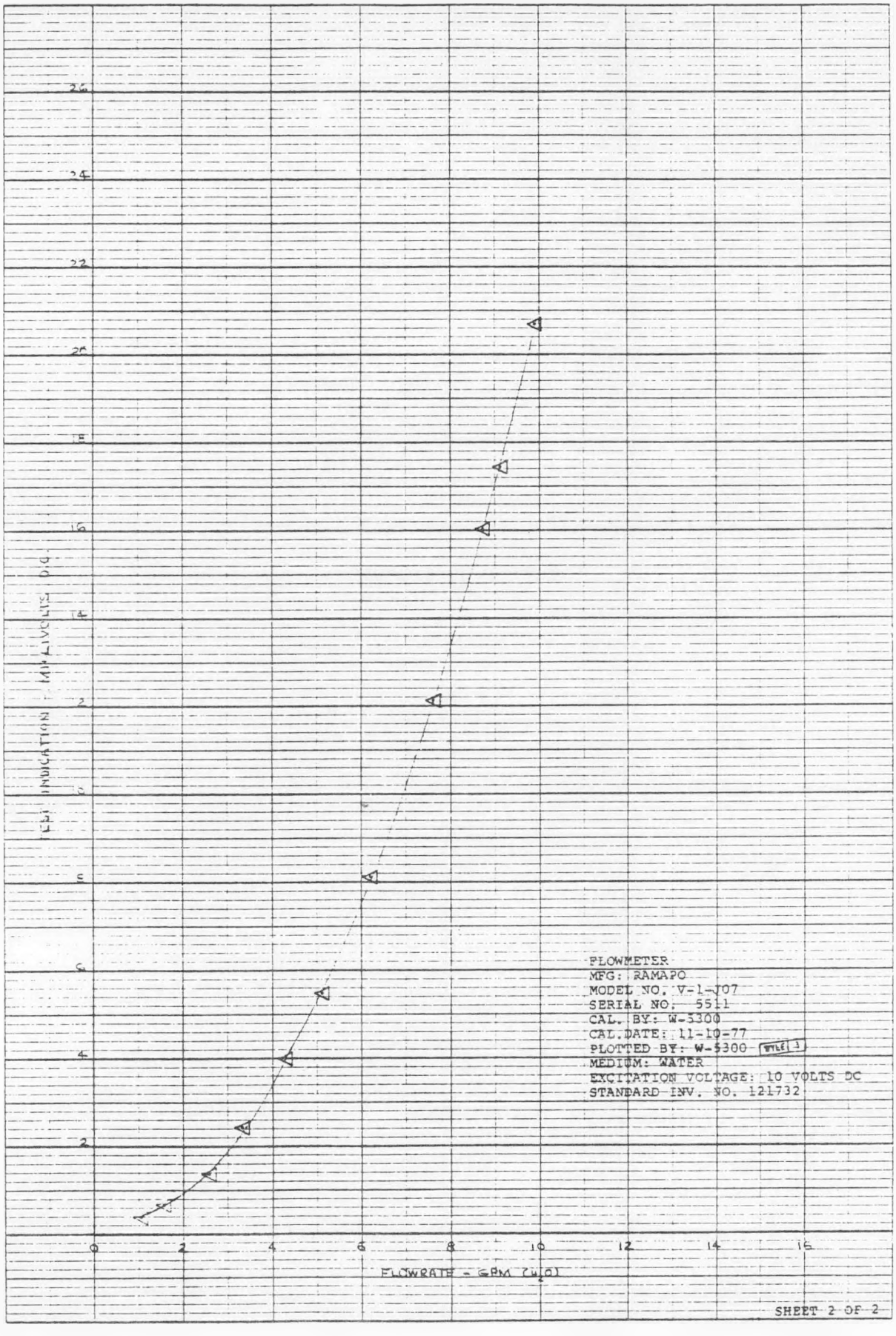
CALIBRATED BY W-5300

PRESS 30 PSIG

APPROVED BY WYLE [3]

NOTE: STANDARDS USED IN THIS CALIBRATION HAVE BEEN CERTIFIED BY, OR ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS, WASHINGTON D. C.

SERIAL NUMBERS OF STANDARDS USED: 121732


FLOWMETER
MFG: RAMAPO
MODEL NO. V-1-J07
SERIAL NO. 5511
CAL. BY: W-5300
CAL. DATE: 11-10-77
PLOTTED BY: W-5300
MEDIUM: WATER
EXCITATION VOLTAGE: 10 VOLTS DC
STANDARD INV. NO. 121732
FLOWRATE - GPM (H2O)
SHEET 2 OF 2

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HAMPTON, VIRGINIA

Wyle Job No. 28532

Customer P.O. No. 17176-91

Wyle Laboratories
7800 Governor's Drive West
Huntsville, Alabama 35805

Date 11-10-77

Reference No. N/A

Manufacturer Ramapo — Calibration schedule N/A Days

Model No. V-1-J07 — Serial No. 5512 — Calibration date 10-9-77

Instrument Flowmeter — Type of calib. N/A

Type Strain Gage — Range 1-10 GPM — Accuracy See Curve

DESCRIPTION OF CALIBRATION

ATTACHED DATA SHEETS

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
High Flow Stand	9910	GFE-394	+/-0.3% IND.	7-11-77

Test Engineer

Quality Control

WYLE LABORATORIES

REPORT ON

FLOWMETER

MAKE Ramapo SER. 5512 MOD. V-1-J07 INV. NO. N/A

RANGE 1 TO 10 gpm

TEMP °F		TIME (SEC)	WEIGHT (LBS)		TEST INDICATION (MVDC)	FLOW (GPM)
78		32.00	45		20.93	10.14
78		34.81	45		17.64	9.32
78		36.63	45		15.93	8.86
78		37.60	40		11.98	7.67
78		34.85	30		7.91	6.20
78		35.10	25		5.46	5.14
78		40.62	25		4.08	4.44
78		31.56	15		2.54	3.43
78		27.78	10		1.48	2.60
79		46.05	5		0.725	1.57
78		35.14	5		0.420	1.03

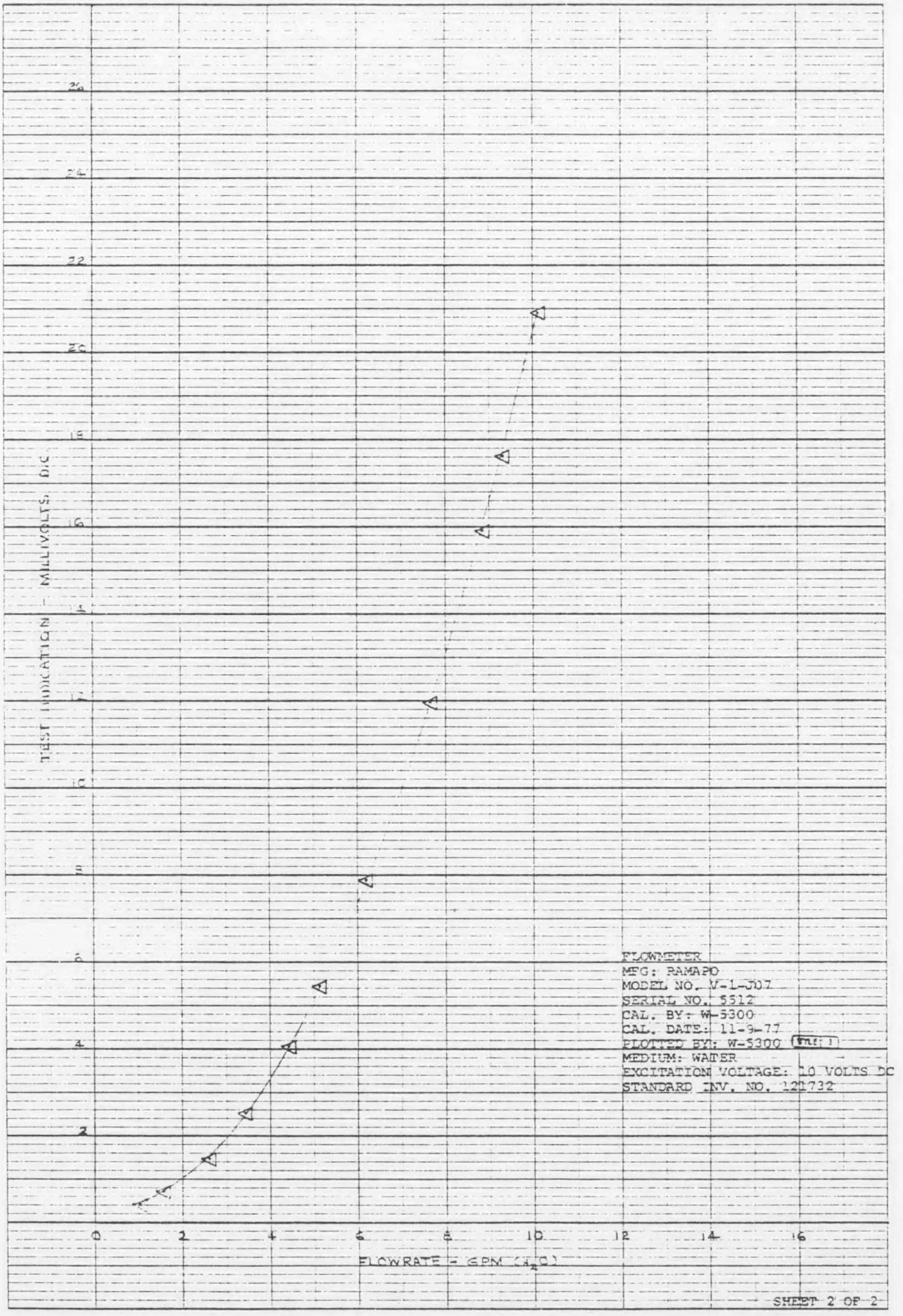
CAL. FLUID-WATER SG 0.99688 @ 78°F CALIBRATED BY W-5300

VISCOSITY-CENTISTOKES 1.0 PRESS 30 PSIG

DATE 11-9-77 APPROVED BY WYLE 3

NOTE: STANDARDS USED IN THIS CALIBRATION HAVE BEEN CERTIFIED BY, OR ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS, WASHINGTON D. C.

SERIAL NUMBERS OF STANDARDS USED: 121732


TEST INDICATION - MILLIVOLTS, D.C.
FLOWRATE - GPM (H2O)
0
2
4
6
8
10
12
14
16
FLOWMETER
MFG: RAMAPO
MODEL NO. V-1-507
SERIAL NO.: 5512
CAL. BY: W-5300
CAL. DATE: 11-9-77
PLOTTED BY: W-5300
MEDIUM: WATER
EXCITATION VOLTAGE: 10 VOLTS DC
STANDARD INV. NO. 120732
SHEET 2 OF 2

CERTIFICATE OF CALIBRATION

WYLE LABORATORIES
HUNTSVILLE, ALABAMA

Wyle Job No. 17176

Customer P.O. No. 827310

IBM Corporation
150 Sparkman Drive
Huntsville, Ala. 35805

Date 12-12-77

Reference No. 78-1

Manufacturer Minco — Calibration schedule 365 Days

Model No. N/A — Serial No. * See Data — Calibration date 12-12-77

Instrument Platinum Resistance Thermometer — Type of calib. Transfer

Type — Range 32° - 212°F — Accuracy See Data

DESCRIPTION OF CALIBRATION

The above P.R.Ts were calibrated in accordance with MIL-C-45662A specifications and manufacturers procedures. A Rosemount 910A bath was used for a control bath and a STD P.R.T. was used to give reference temperature.

This is to certify that the above instrument was calibrated using state-of-the-art techniques with standards listed below whose calibration is traceable to the National Bureau of Standards.

STANDARDS USED

Instrument	Model No.	Wyle No.	Accuracy	Date of Last Calibration
Platinum Resistance Thermometer	8164	N/A	±.01°C	11-1-77
Muller Bridge	8067	80044	See Cert.	7-11-77

Richard C. Lobe — W CALIB
Test Engineer

L. M. Davies
Quality Control

DATA SHEET

Customer IBM
Specimen Platinum Resistance Thermometers
Part No. _____ Amb. Temp. _____
Spec. _____ Photo _____
Para. _____ Test Med. _____
S/N _____ Specimen Temp. _____
GSI _____

WYLE LABORATORIES

Job No. 17176
Report No. _____
Start Date 12-12-77

CALIB

Test Title PRT Calibration

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
1 (1)				
	32.00	99.63	100.00	30.32
	94.91	113.40	113.80	93.07
	121.91	119.28	119.68	119.82
	166.84	129.04	129.41	165.13
	212.01	138.66	139.11	209.90
2 (13)				
	32.00	99.96	100.00	31.82
	94.91	113.78	113.80	94.81
	121.91	119.66	119.68	121.81
	166.84	129.42	129.41	166.90
	212.01	139.12	139.11	212.05
3 (15)				
	32.00	99.95	100.00	31.77
	94.91	113.76	113.80	94.72
	121.91	119.65	119.68	121.76
	166.84	129.40	129.41	166.80
	212.01	139.10	139.11	211.95

Specimen Failed _____
Specimen Passed _____
NOD Written _____

Tested By RB Dahl Date: 12-12-77
Witness _____ Date: _____
Sheet No. 1 of 7
Approved _____

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

W CALIB

Description of Test (Continued):

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
4				
	32.00	99.97	100.00	31.86
	94.91	113.79	113.80	94.85
	121.91	119.68	119.68	121.90
	166.84	129.38	129.41	166.71
	212.01	139.10	139.11	211.95
5 (16)				
	32.00	100.07	100.00	32.32
	94.91	113.90	113.80	95.36
	121.91	119.79	119.68	122.41
	166.84	129.54	129.41	167.45
	212.01	139.26	139.11	212.70
6 (11)				
	32.00	99.97	100.00	31.86
	94.91	113.79	113.80	94.85
	121.91	119.67	119.68	121.86
	166.84	129.41	129.41	166.85
	212.01	139.12	139.11	212.05
7 (14)				
	32.00	99.96	100.00	31.82
	94.91	113.77	113.80	94.76
	121.91	119.66	119.68	121.81
	166.84	129.39	129.41	166.76
	212.01	139.10	139.11	211.95

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

Description of Test (Continued):

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
8 (2)				
	32.00	100.10	100.00	32.45
	94.91	113.93	113.80	95.50
	121.91	119.84	119.68	122.64
	166.84	129.59	129.41	167.68
	212.01	139.31	139.11	212.93
9 (3)				
	32.00	99.89	100.00	31.50
	94.91	113.68	113.80	94.35
	121.91	119.57	119.68	121.39
	166.84	129.29	129.41	166.29
	212.01	138.99	139.11	211.44
10 (12)				
	32.00	100.01	100.00	32.05
	94.91	113.84	113.80	95.08
	121.91	119.74	119.68	122.18
	166.84	129.50	129.41	167.27
	212.01	139.22	139.11	212.51
11 (9)				
	32.00	100.00	100.00	32.00
	94.91	113.83	113.80	95.04
	121.91	119.73	119.68	122.13
	166.84	129.48	129.41	167.17
	212.01	139.21	139.11	212.47

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

Description of Test (Continued):

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
12				
	32.00	100.11	100.00	32.50
	94.91	113.93	113.80	95.50
	121.91	119.81	119.68	122.50
	166.84	129.57	129.41	167.59
	212.01	139.28	139.11	212.79
13				
	32.00	100.02	100.00	32.09
	94.91	113.84	113.80	95.08
	121.91	119.73	119.68	122.13
	166.84	129.49	129.41	167.22
	212.01	139.20	139.11	212.42
14				
	32.00	99.87	100.00	31.41
	94.91	113.65	113.80	94.21
	121.91	119.49	119.68	121.03
	166.84	129.24	129.41	166.06
	212.01	138.90	139.11	211.02
15				
	32.00	100.09	100.00	32.41
	94.91	113.92	113.80	95.45
	121.91	119.79	119.68	122.41
	166.84	129.56	129.41	167.55
	212.01	139.26	139.11	212.70

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

Description of Test (Continued):

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
16				
	32.00	99.99	100.00	31.95
	94.91	113.79	113.80	94.85
	121.91	119.65	119.68	121.76
	166.84	129.40	129.41	166.80
	212.01	139.11	139.11	212.00
17				
	32.00	99.56	100.00	30.01
	94.91	113.31	113.80	92.66
	121.91	119.17	119.68	119.55
	166.84	128.89	129.41	164.44
	212.01	138.56	139.11	209.43
18 (6)				
	32.00	100.05	100.00	32.23
	94.91	113.87	113.80	95.22
	121.91	119.75	119.68	122.22
	166.84	129.95	129.41	169.35
	212.01	139.23	139.11	212.56
19				
	32.00	99.98	100.00	31.91
	94.91	113.79	113.80	94.85
	121.91	119.68	119.68	121.90
	166.84	129.43	129.41	166.94
	212.01	139.15	139.11	212.19

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

Description of Test (Continued):

PRT No.	Temp- F(Cal)	Resistance- Ω(Cal)	Temp- F(12-100)	Resistance- Ω(12-100)
20				
	32.00	100.09	100.00	32.41
	94.91	113.92	113.80	95.45
	121.91	119.80	119.68	122.45
	166.84	129.57	129.41	167.59
	212.01	139.28	139.11	212.79
21				
	32.00	99.83	100.00	31.23
	94.91	113.63	113.80	94.12
	121.91	119.50	119.68	121.07
	166.84	129.24	129.41	166.06
	212.01	138.93	139.11	211.16
1A (8)	32.00	99.85	100.00	31.32
	94.91	113.65	113.80	94.21
	121.91	119.54	119.68	121.26
	166.84	129.29	129.41	166.29
	212.01	138.95	139.11	211.25
12A (7)				
	32.00	99.77	100.00	30.96
	94.91	113.54	113.80	93.71
	121.91	119.40	119.68	120.61
	166.84	129.12	129.41	165.51
	212.01	138.81	139.11	210.60

DATA SHEET

WYLE LABORATORIES

Specimen Platinum Resistance Thermometers
Part No. _____
S/N _____

Job No. 17176
Report No. _____
Date 12-12-77

Test Title PRT Calibration

Description of Test (Continued):

PRT No.	Temp-°F (Cal)	Resistance-Ω (Cal)	Temp-°F (12-100)	Resistance-Ω (12-100)
13A				
	32.00	99.82	100.00	31.18
	94.91	113.61	113.80	94.03
	121.91	119.48	119.68	120.98
	166.84	129.21	129.41	165.92
	212.01	138.91	139.11	211.07

CALTB

DATA SHEET

Customer IBM
Specimen P.R.T.
Part No. _____ Amb. Temp. _____
Spec. _____ Photo _____
Para. _____ Test Med. _____
S/N As Listed Specimen Temp. _____
GSI _____

WYLE LABORATORIES
Job No. 17176
Report No. _____
Date 2-2-78

Test Title _____

212.045 35.58977 PRT 8164 ±.01°C Cal Date 11-1-77

PRT NO.	Resistance (Cal)	PRT No.	Resistance (Cal)
1	138.47	22 (5)	138.97
2	139.06	23	139.31
3	139.04	24 (16)	138.99
7	139.06	25	139.09
5	139.15	26 (4)	139.34
6	138.98	27	139.164
8	139.204	1A	138.93
9	138.88		
10	139.21		
11	139.19		
12A	138.83		
13A	138.90		
18	139.224		
19	139.12		

Note 1* Lead Resistance was subtracted out of all readings

Note 2* Resistance was measured with the 3455A on two wire input W11210

R. A. DOKE

Specimen Failed _____
Specimen Passed _____
NOA Written _____

Tested By [signature] Date: 2-2-78
Witness _____ Date: _____
Sheet No. _____ of _____
Approved [signature]

DATA SHEET

Customer IBM
Specimen P.R.T.
Part No. _____
Spec. _____
Para. _____
S/N As Listed
GSI _____

Amb. Temp. _____
Photo _____
Test Med. _____
Specimen Temp. _____

WYLE LABORATORIES

Job No. 17176
Report No. _____
Start Date 2-2-78

Test Title _____

32.00°F 25.55650 PRT 8164 ±.01°C Cal Date 11-1-77

PRT No.	Res (Cal)		Res (Cal)
1	99.61	22	99.86
2	99.96	23	100.09
3	99.94	24	99.88
7	99.96	25	99.94
5	100.093	26	100.12
6	99.97	27	99.98
8	100.07	1A	99.85
9	99.86		
10	100.01		
11	100.00		
12A	99.79		
13A	99.79		
18	100.05		
19	99.98		

Note 1* Lead Resistance was subtracted out of all readings

Note 2* Resistance was measured with the 3455A on two wire input W11210

W CALIB

R. A. DOKE

Specimen Failed _____
Specimen Passed _____
NOA Written _____

Tested By _____ Date: 02-02-78
Witness _____ Date: _____
Sheet No. _____ of _____
Approved _____

DATA SHEET

Customer IBM
Specimen P.R.T.
Part No. _____ Amb. Temp. _____
Spec. _____ Photo _____
Para. _____ Test Med. _____
S/N As Listed Specimen Temp. _____
GSI _____

WYLE LABORATORIES
Job No. 17176
Report No. _____
Start Date 2-7-78

Test Title _____
212.01°F 35.5874 PRT 8164 ± .01°C Cal Date 11-1-77

PRT No.	1st Cal	(A-B) Diff	B 2nd Cal	(B-C) Diff	C 3rd Cal	(A-C) Diff
1	138.66	-.19	138.47	+.07	138.54	-.12
5	139.26	-.11	139.15	+.04	139.193	-.067
6	139.12	-.14	138.98	+.11	139.095	-.025
7	139.10	-.04	139.06	.00	139.06	-.04
8	139.31	-.10	139.204	+.017	139.221	-.089
9	138.99	-.11	138.88	.00	138.88	-.11
1A	138.95	- 02	138.93	+ 01	138.94	-.01

W
CALIB

R. A. DOKE

Specimen Failed _____
Specimen Passed _____
NOA Written _____

Tested By _____ Date: 02-07-78
Witness _____ Date: _____
Sheet No. _____ of _____
Approved _____

CERTIFICATE OF CALIBRATION AND TESTING

Customer Wyle Labs P.O. No. 4-7268

Model ESD-9050-A-A-B-(0 to 100°C)-6-X5 with RTS-31-B-100-B-6-3-120 System s/n: 63644 Rtd. Serial No. 63645, 46, 47, 48, 49 and 50

Part Name Linearized Bridge Amplifier System and Resistance Temperature Sensors

This is to certify that the above part(s) was (were) calibrated in accordance with applicable requirements. The tests were successfully conducted and records are on file subject to examination.

Specific calibration and test data are recorded on the reverse side of this form.

Oct. 19, 1977
Date of Certification

Engineer

Quality Control

HY-CAL ENGINEERING
12109 LOS NIETOS ROAD
SANTA FE SPRINGS, CALIFORNIA
PHONE (213) 698-7785

CALIBRATION SHEET

Model Number	Serial Number	True Temperature ° ____	Thermocouple Indicated Temp. ° ____	Correction ° ____
SYSTEM CALIBRATION DATA ATTACHED				

Tested by Mike Vincent Date 10-17-77

Remarks: Traceable to National Bureau of Standards. Reports of calibration of test equipment employed on above tests is attached. Digital Multimeter = NBS Tst. #213185-212285-213693. Mueller Bridge = NBS Tst. #212285. RTD Standard = Navy Lab calibration traceable to NBS.

HY-CAL ENGINEERING
12106 LOS NIETOS ROAD
SANTA FE SPRINGS, CALIFORNIA
PHONE (213) 698-7788

HY-CAL ENGINEERING
12105 Los Nietos Rd. • Santa Fe Springs, Ca. U.S.A. 90670 • (213) 698-7785 • Telex 67-4494

SYSTEM CALIBRATION TEST DATA SUMMARY

Hy-Cal Model No. ESD-9050-A-A-B-(0 to 100°C)-6-X5 (serial number 63644)

With Platinum Resistance Sensors, Hy-Cal Model No. RTS-31-B-100-B-6-3-120

Channel No.	1	2	3	4	5	6	
Probe Serial No.	63645	63646	63647	63648	63649	63650	
Lead Cable Length*	150'	150'	150'	150'	150'	150'	
Test Temp. °C	Error °C	Error °C	Error °C	Error °C	Error °C	Error °C	
0	-.02	-.01	+.01	+.01	+.01	.00	
25	-.03	-.03	-.03	-.02	-.02	-.02	
50	-.03	-.04	-.02	-.03	-.03	-.01	
75	-.02	-.04	-.03	-.03	-.02	-.01	
100	+.01	-.01	+.01	.00	.00	.00	

*Does not include the 120 inches on probe.

APPENDIX B

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

PYRANOMETER VERIFICATION

FOR

SOLAR DEMONSTRATION PROGRAM

EPPLEY SERIAL NUMBER	EPPLEY CAL DATA (ISP)**	NOAA (ISP) CONV TO (ABS)*	EPPLEY CAL (ABS)*	NOAA CAL DATA (ABS)*	% ERROR
15107F3	8.77	.975	8.551	8.42	+1.55
15280F3	9.93	.975	9.682	9.6	+ .85
15814F3	10.59	.975	10.325	10.32	+ .051
15816F3	9.81	.975	9.56	9.64	- .781
15833F3	8.78	.975	8.561	8.6	- .453
15910F3	11.07	.975	10.793	10.94	-1.3

*(ABS) - Absolute pyrheliometric scale (X 10^{-6} volts per watt per meter^2)

**(ISP) - International pyrheliometric scale (X 10^{-6} volts per watt per meter^2)