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TEST RESULTS ON THE FRENCHMAN'S REEF SOLAR DATA ACQUISITION AND CONTROL SYSTEM

Prepared by

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Under subcontract to IBM Corp., Federal Systems Division, Huntsville, Alabama

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16. ABSTRACT

This report describes the test procedures and the results obtained from an evaluation test program conducted on the Frenchman's Reef Data Acquisition and Control System (DACS), Sunlogger Model 10000-1, produced by Andover Controls Corporation. The purpose of the test program was to verify the accuracy of control functions and to determine the performance of the system in the environment of the planned installation site.

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1.0 INTRODUCTION

A test program has been completed on the Frenchman's Reef Data Acquisition and Control System, DACS, Sunlogger Model 10000-1, produced by Andover Controls Corporation. A complete description of the system can be found in Reference 1. The purpose of the test program was to verify the accuracy of control functions and to determine the performance of the system operating in a severe environment corresponding to conditions of the actual planned installation site as well as meeting the manufacturer's stated specifications in References 1 and 2.

The intended environment at Frenchman's Reef in St. Thomas, Virgin Islands, is an uncontrolled enclosed area near surfaces with higher than ambient temperatures and high relative humidity. Also, the supply voltage in the area varies in magnitude and frequency. The following environmental criteria used as test parameters were assembled from the projected environment at Frenchman's Reef and the manufacturer's specification limits:

Temperature $0^{o}C$ ($32^{o}F$) to $50^{o}C$ ($122^{o}F$)

Relative Humidity 0 to 90 per cent

Frequency 54 to 66 cycles/second

Voltage 103 to 127 volts

Temporary voltage drop out 10 milliseconds

The components comprising the system which were subjected to testing were the Sunlogger, the Interface Wiring Unit, the Power Controller, and the tape recorder. All components except the tape recorder were tested in an environmental chamber as shown in Photograph 1 (13).

2.0 SUMMARY

The performance of this test program required the development of a custom system simulator to provide the DACS with a simulated solar collector system for interactive communication. The simulator provided circuitry for 48 thermistor (resistance) type inputs, 16 discrete digital inputs, two independent variable analog voltage inputs, a 0/30/60 Hz selectable oscillator input, and 16 LED channels for monitoring discrete digital outputs from the Sunlogger. A complete description of the simulator is included in Section 3.0.

A bench test was conducted to determine the accuracy of the Sunlogger in recording temperatures measured by typical thermistors. Ten Fenwal UUT43J1 and 25 Midwest AP-1H-303 thermistors, both types to be utilized in the Frenchman's Reef project, were tested utilizing the Sunlogger preprogrammed lookup table for Fenwal thermistors. The results of this test are shown in Table 1. The Fenwal sensors are deemed accurate ($\pm$ 0.6°F deviation between sensors and 2.6°F maximum deviation from the reference table) for control and analysis purposes, but the Midwest sensors require a separate lookup table, deviating as much as 14.6°F from the reference table used by the DACS.

Following the temperature accuracy test, the Sunlogger and the Interface Wiring Unit and Power Controller were installed in an environmental chamber for controlling humidity and temperature. The intended environment was to begin at 72°F and 50% relative humidity and steadily increase the temperature to 120°F and 90% relative humidity during a four hour period. Additional tests were planned, but the Sunlogger failed during the initial phase of the test. An Andover Controls field engineer corrected this failure and testing resumed with an environment of 100°F and 50% relative humidity. The Sunlogger again failed after approximately one-half hour. Apparently this failure was a hardware failure, and the unit was returned to the manufacturer.

The Sunlogger was again returned to the environmental chamber at 100°F and 87% relative humidity and performed without failures.

3.0 DACS OPERATIONAL SIMULATOR

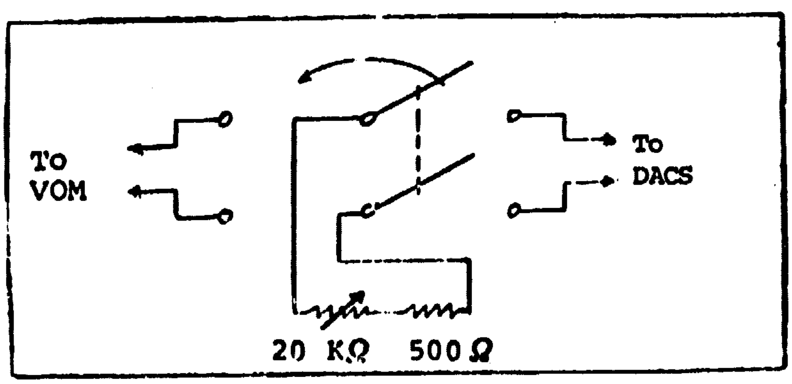
Simulation of instrumentation I/O with the DACS was accomplished by the development of a custom test fixture entitled Solar System Simulator (SSS). Photograph 2 shows the SSS packaged into a portable module planned to support checkout activities at Frenchman's Reef.

This fixture provided circuitry for 48 thermistor type inputs; 16 discrete digital inputs; 2 independently variable analog voltages; a selectable 0/30/60 Hz oscillator output; and monitoring for 16 discrete digital outputs.

The theory of the SSS operation is as follows:

Thermistor Inputs

Inputs for forty-eight 30,000 OHM thermistors (as per Fenwal # UUT-43 J1 or Midwest Components # AP-41303) were provided by a 20K OHM potentiometer offset with 500 Ω. (See Figure 1.) This provided a continuously variable resistance corresponding to a temperature range of 84 through 282 degrees Fahrenheit. Calibration and off line/emergency disconnect modes were also implemented.



Thermistor Simulator Circuit (48 each)

PT	RK Ω	°C	°F
1	20	28.9	84.0
2	15	33.9	93.0
3	10	40.5	104.9
4	2	94.4	122.4
5	1	116.8	201.9
6	.6	134.8	242.2

Resistance/Temperature Correlation

Figure 1. Thermistor Inputs

Analog Voltage Inputs

Two Analog voltages from 0 - 5.1 volts DC were provided by a simple voltage divider (See Figure 2). Each channel can be calibrated separately.

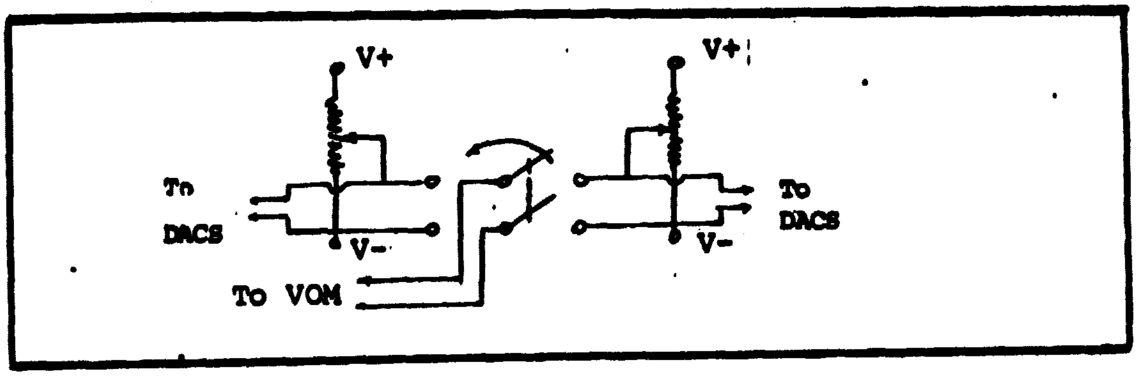


Figure 2. Analog Voltage Inputs

Hardware Counter Inputs

Counter input frequencies were provided by a switch selectable 0/30/60 Hz oscillator, shown schematically in Figure 3, driving a set of mechanical contacts. The duty cycle was fixed for each frequency at 50%.

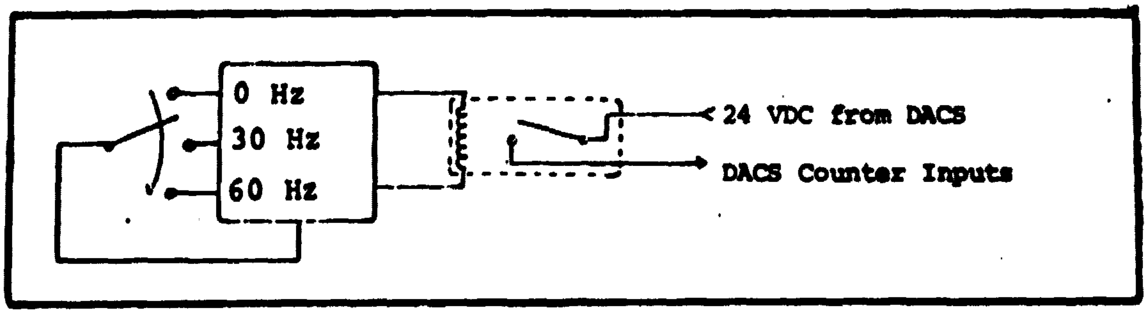


Figure 3. Counter Input Oscillator

Discrete Inputs

Discrete inputs were implemented as shown in Figure 4.

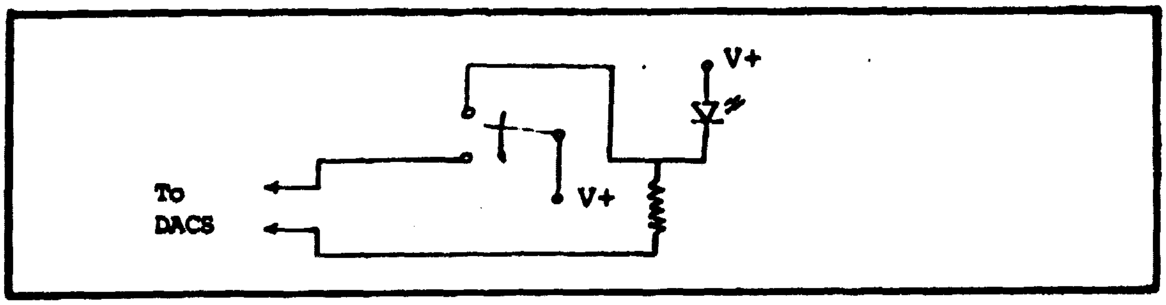


Figure 4. Discrete Inputs (16 each)

Discrete Outputs

The DACS outputs are effected as relay contact closures. These closures were monitored by the circuit shown in Figure 5.

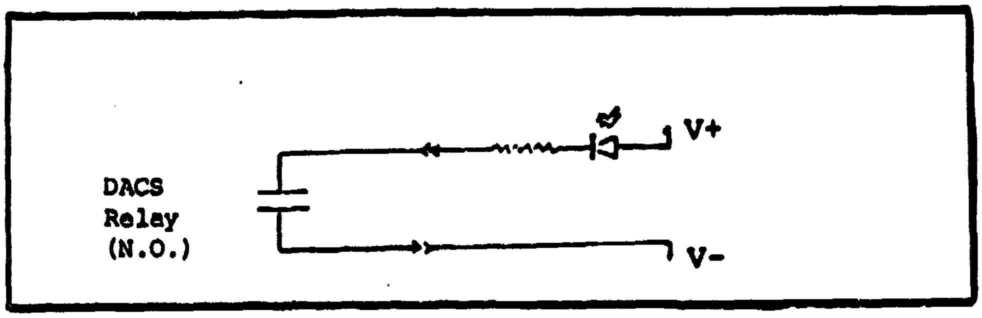


Figure 5. Discrete Output Monitor (16 each)

3.1 DACS Test Software

Two programs were written for the DACS testing.

The first, Program I, was a program to exercise the discrete outputs at five minute intervals. At the end of each cycle, the time and system status were printed; all outputs were monitored via L.E.D.'s on the test fixture. The first eight channels were also monitored for momentary dropouts by way of a strip chart recorder. This program was executed throughout the test.

The second, Program II, initiated comprehensive tests of the thermistor inputs in two modes, test of the analog voltage channels in two modes, exercised the internal counters, the discrete inputs, discrete outputs, and caused the time and system status to be printed. This program was executed at half hour intervals throughout the test and was followed by a manually initiated examination of the hardware counters at 30 and 60 Hertz.

Annotated listings of both tests are shown on the following pages.

PROGRAM I

RELAY DRIVER PROGRAM

```
DRUM --  2
                         A015    79 AUG  1 WED   7 34 55

  1   FB *           XL  2          Reset all bits and drivers.
      FD *

  2   OD *           XL  3 OD *     All drivers on; exit line
                           TM = 5   if all drivers on in five
                                    minutes.
  3   FD *           XL  4 FD *     All drivers off; exit line
                           TM = 5   if all drivers off after
                                    five minutes.
  4   OB 43,46,47,48,50,51,52 XL  1
                                    Set print control and print;
                                    start over.
```

PROGRAM II

COMPREHENSIVE SUNLOGGER STATUS TEST

DRUM -- 1

A015 79 AUG 1 WED 7 33 54

1	OD 11,16 OB 53,55,57,59	XL 2 TM = 1	Reset hardware counters; exit line after timer set.
2	FD 16 OD 15 FB ¤	XL 3 V9 > 104.9	Reset all bits; exit line when A-variable 9 look-up greater than 104.9°F.
3	OD 16 OB 54,56,58,60	XL 4 V10 - V9 > 10	Toggle internal counters; exit when difference in V-variables 9 & 10 greater than 10°F.
4	FD 15,16 OD 14 FB 54,56,58,60	XL 5 OI ¤	Toggle internal counters; exit line when all inputs true.
5	OD 16 OB 54,56,58,60	XL 6 FI ¤	Toggle internal counters; exit line when all inputs false.
6	FD 16 OD 15 FD 54,56,58,60	XL 7 V41 - V48 > 2.5	Toggle internal counters; exit line when difference in V41 & V48 greater than 2.5 VDC.
7	OD ¤ OB 54,56,58,60	XL 8 V48 > 4	Toggle internal counters; set all drivers;exit line V48 greater than 4 volts.
8	FD ¤ OB 43,47,52		Set bits for print control; all drivers reset; wait for manual exit.

Note 1. Setting and resetting of bits 11 - 16 enabled operator to track drum and line number execution.

Note 2. V1 - V40 are defined as A1 through A40 referenced to internal look up table. V41 through V48 are defined as A41 through A48 multiplied by .001 (normalized to read in volts).

4.0 TEST SEQUENCE AND RESULTS

The DACS was installed in the chamber, and the test sequence was initiated at approximately 0730 hours. Status prints were provided at five minute intervals by Program I and ten minute intervals by Program II. The last correct status print occurred at 1015 hours. A copy of the "V-Variables" list from this print is reproduced in Figure 6, with channels 1 through 8 on the first line, with succeeding channels in the same order. It should be stated that the first three channels were not connected to the simulator but tied to thermistors in the chamber. Channel 1 was placed to read the temperature of the Sunlogger J-box power supply; Channel 2, the Sunlogger power supply; and Channel 3, the chamber ambient. It should also be noted that the erroneous reading on Channel 4 was caused by a broken wire in the simulator interconnect. The first error occurred at 1025 hours at a temperature of 107°F and a relative humidity of 80%. This error manifested itself as a failure of channels 33 - 48. Channels 33 - 48 (thermistor inputs) had a range of from -16.6°F to -18.4°F as opposed to a correct nominal value of 83.5°F. Channels 41 - 48 (0 - 5.1 volt) were hardwired at the J-box in two groups of four (41 - 44 and 45 - 48). Channels 41 through 44 read 5.115 volt and channels 45 - 48, although with the same input voltage, ranged from 5.115 volts to 2.14 volts. The true input for all channels was 4.98 volts. At this point, several printouts were manually requested in rapid succession. These prints show the analog values to be totally erroneous and constantly changing without regard to actual input (See Figure 7). This continued until 1050 hours, when print control errors such as failure to space, spurious line feeds, carriage returns, and overtyping occurred as shown in Figure 8. The chamber temperature was now 112.8°F at 82.8% relative humidity.

At 1203 hours the Sunlogger stopped echoing characters to the terminal even though transmissions were being correctly decoded. Fearing total loss of communication, Program I was started at 1205 hours. At approximately 1242 hours the Sunlogger failed to decode commands and suspended sending status prints generated by Program I. Chamber temperature was now 115°F at a relative humidity of 89.9%. The chamber cycle was discontinued and the chamber allowed to return to room conditions over the next several hours. Program I continued to toggle the drivers correctly throughout this period, although no status prints were transmitted.

The next attempt to log on was made the following morning. The Log On was correctly decoded and a sign on message transmitted; however, transmitted characters failed to echo, and the Sign On format was incorrect. In addition, the Sign On message was not printed in its entirety.

Transmission of a carriage return resulted in the printing of the next eight characters. Successive carriage returns resulted in the completion of the Sign On and monitor prompt in eight character increments. V-variables were then requested, showing the analog variables V-1 through V-48 to be operating correctly, although the printed format was slightly in error (the last line printed twice). At this point, the Sunlogger resumed printing Program I status at the prescribed intervals. Testing was now suspended pending arrival of an Andover Controls Corporation engineering representative.

The failure analysis is as follows. Two types were evident: (1) failure to correctly interpret analog inputs, and (2) failure of the serial interface.

In an actual operating situation, the failure to correctly interpret the analog inputs and the rapid rate and wide disparity of apparent change within the Sunlogger of these inputs could result not only in the inability of a control program to run (best case) but also in a condition where the output drivers, though operating correctly, could be falsely toggled on or off at random, possibly at a very rapid rate, pending control program specifics (worst case).

The failure of the serial interface in an operating situation would result in an inability to read machine status, issue diagnostic or operating commands, modify, enable, or terminate a previously running program either via local keyboard or remote telephone modem.

With both conditions occurring simultaneously, the system would be at best inoperable. The worst case failure would result in false triggering of the output drivers with the user's only recourse to disconnect AC power from the Sunlogger and set the drivers manually to a safe condition from the J-Box.

Following the failure of the Sunlogger to operate at 120°F a decision was made to return the Sunlogger to Andover for repair and, on its return, retest in a 100°F environment.

The test was run as before, ramping to 100°F at 87% relative humidity over a four hour period and sustaining these conditions for fifteen additional hours. On evaluation of test data, no significant problems were found.

Due to fluctuations in line voltage and frequency at the projected installation site, and the dependence of the Sunlogger on line frequency for clocking a constant voltage, a frequency synthesizer was purchased and tested.

This device outputs a constant 115 VAC/60Hz for an input range of 114V ± 10% and 60 Hz ± 10%. The synthesizer was tested by inputting the permutations of the voltage/frequency range to the unit by use of a variable voltage/frequency supply and measuring the synthesizer output to a resistive load. The load power was fixed at 25 watts as the variable supply was limited to a 500 VA output for both synthesizer "Q" and load. The synthesizer output was valid over the rated range.

A cassette tape recorder for use as a mass storage device for the Sunlogger data was also supplied. The unit was to have been subjected to an environmental test as were the other system components, but a failure of the supplied data cartridge prohibited test before the specified deadline for shipment back to the manufacturer.

```
V-VARIABLES     A015     79 AUG   1 WED   10 15 37

     107     117.2     105.4   -    40      83.8        83      83.2      82.2
      83     119.8      83.2      83.2      82.8      80.8      81.6        83
    83.8        84      83.2      79.6      83.8        81      84.2        84
      83      83.6      83.2      82.8      82.8      82.8      83.2      82.8
    81.4      83.4      83.2      83.8      82.8        83      83.6        83
   4.975     4.975     4.975      4.98      4.97      4.97      4.97      4.97
       0         0         0         0         0         0         0         0
       0         0         0         0         0         0         0
```

Figure 6. Last Correct Print (105.4°F @ ≈ 79% RH)

```
V-VARIABLES     A015     79 AUG   1 WED   10 25 37

   108.6       119     107.6   -    40      83.8        83      83.2      82.2
    82.8     119.8      83.2      83.2      82.8      80.8      83.2      83.6
    83.2      83.6      83.2      82.8      82.8      82.8      83.2      82.8
    81.4      83.4      83.2      83.8      82.8        83      83.4        83
  - 18.4    - 18.4    - 18.4    - 18.4    - 17.4    - 17.4    - 17.4    - 16.6
   5.115     5.115     5.115     5.115     5.115      2.14      2.48     3.205
       0         0         0         0         0         0         0         0
       0         0         0         0         0         0         0
```

Figure 7. First Error Print (107.6°F @ 80% RH)

```
12.>PV
V-VARIABLES     A015
79 AUG   1 WED   10 50 58
 -       114       302      83.8     112.2          82   84.  40     123     1  84.6
  -    40   123..6    84.6  -    40   123.8      84      -    40   123.6
   844.6      40   123.6      84.6  -    40   123.6      84    11    40
  82  123.4      84.6  -    40   -   40   84.6  -     40   123.4 5.115
  - 0 48.01523.4      2.54115  822.82  48.22123.4 02184.62.84  48.225
0       0       0       0
  0       0       0       0
     0       0       0       0       0       0       0
```

Figure 8. Last Error Print (112.8°F @ 82.8% RH)

5.0 CONCLUSIONS AND RECOMMENDATIONS

Although the Sunlogger system has been verified to perform normally in an environment of 100°F and approximately 90% humidity, it is recommended that the Sunlogger be installed in a controlled environment with temperatures and humidity significantly lower than those referenced above. The failure mode of the Sunlogger should be thoroughly studied to determine whether special precautions need to be taken to shut down the system in the event of a failure by the Sunlogger.

TABLE I

DACS THERMISTOR TEMPERATURE TEST RESULTS

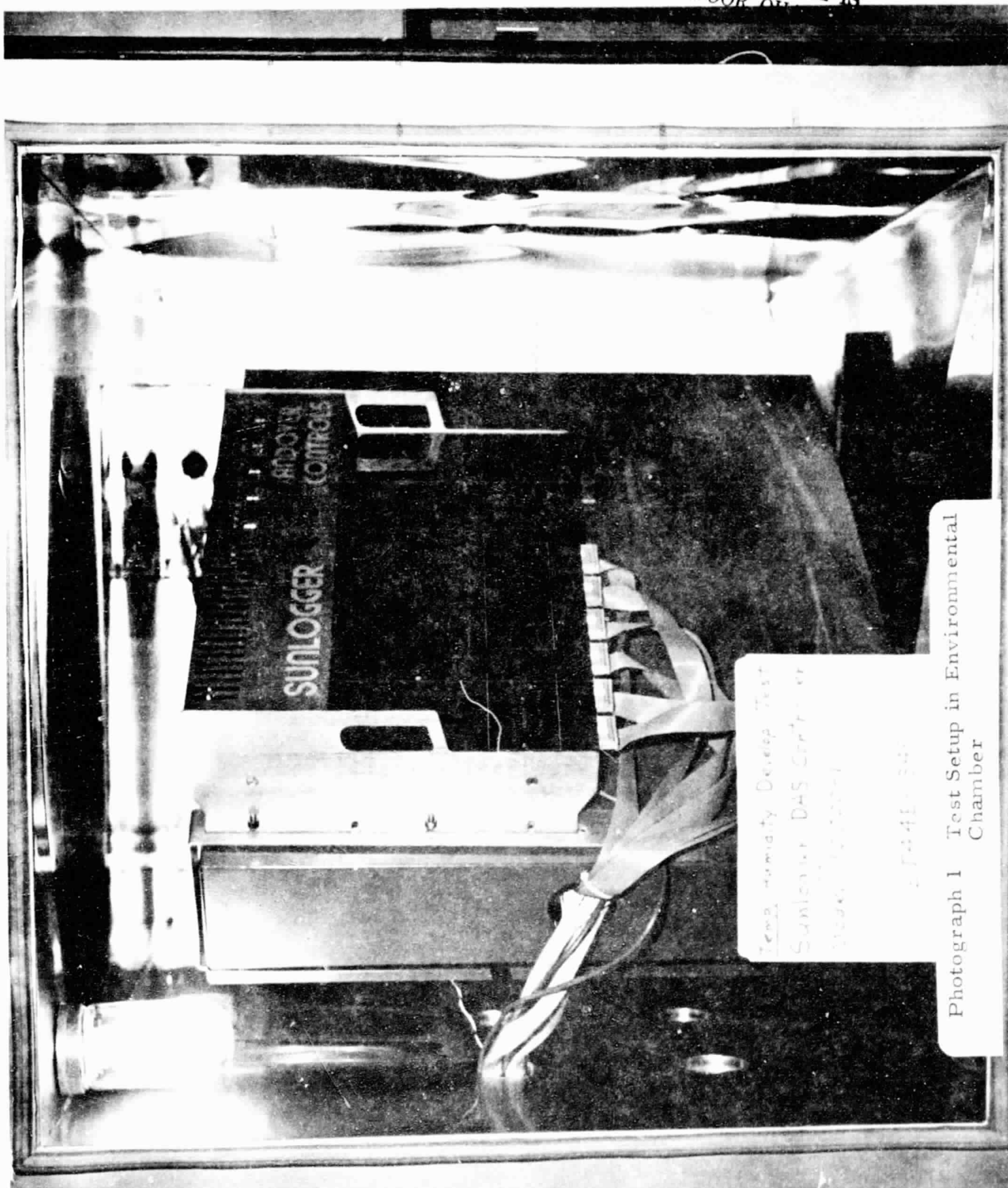
Fenwal UUT43J1 (10 samples)

Temp.	Avg. of Sensor Reading	Deviation From Avg.	Sensor Reading Lowest	Sensor Reading Highest
32.0°F	33.4	± .5 °F	32.6	33.6
82.0°F	82.1	± .1 °F	81.0	82.6
126.0°F	126.3	± .6 °F	125.4	126.6
146.5°F	146.2	± .2 °F	146.0	146.4
200.0°F	200.1	± .5 °F	199.4	200.4
250.0°F	252.1	± .6 °F	251.6	252.6

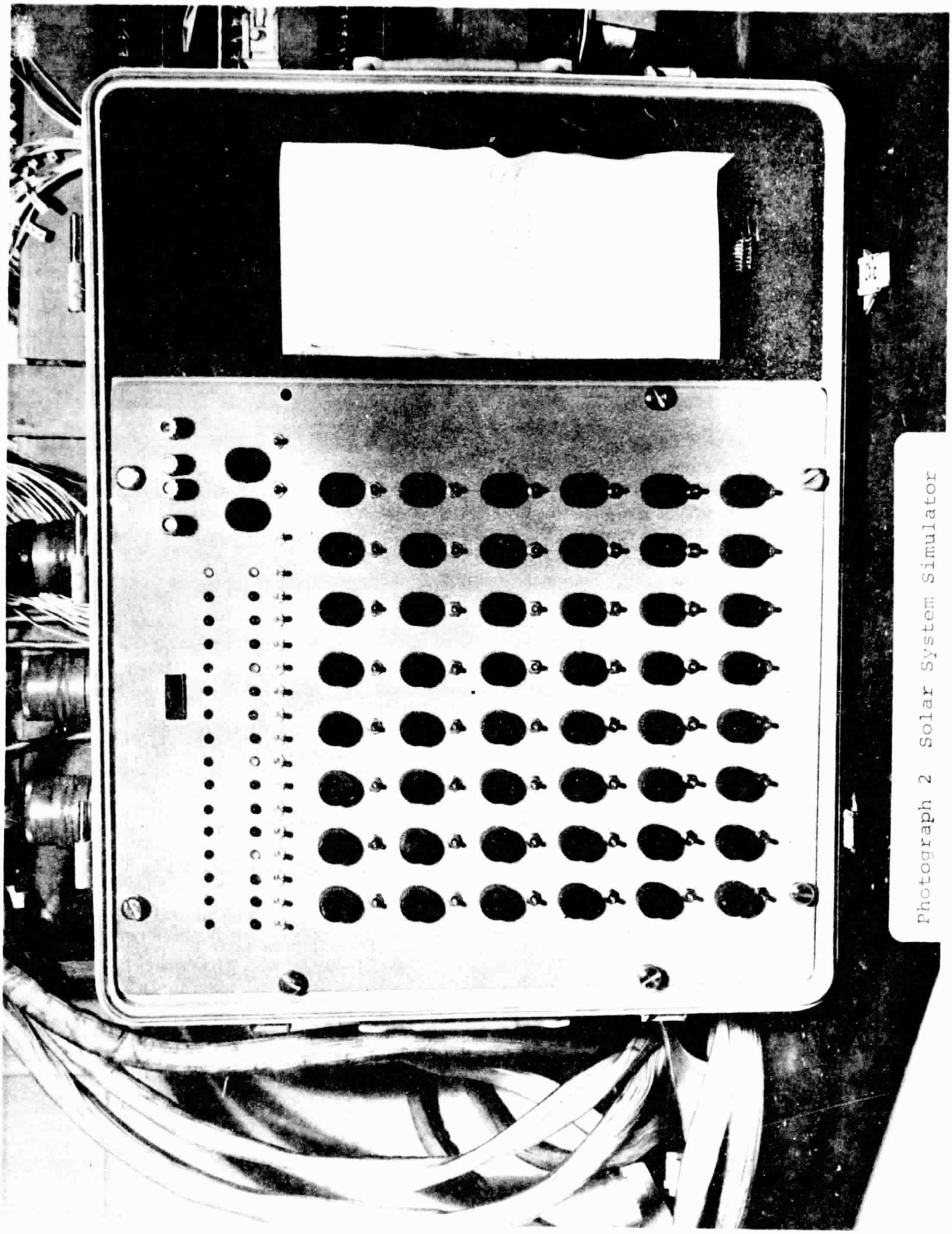
Midwest AP-1H-303 (25 samples)

Temp.	Avg. of Sensor Reading	Deviation From Avg.	Sensor Reading Lowest	Sensor Reading Highest
32.0°F	35.2	± 0.8°F	35.1	36.8
82.0°F	81.9	± 1.1°F	80.6	82.4
126.0°F	122.1	± 1.0°F	120.8	122.8
146.5°F	140.2	± .9°F	139.8	141.6
200.0°F	189.4	± 1.1°F	188.4	190.8
250.0°F	238.1	± 1.8°F	235.4	239.0

The above results were obtained with the sensors connected to the Interface Wiring Unit with 10 feet of #18 shielded instrumentation wire utilizing the Sunlogger conversions lookup table as received.



Photograph 1 Test Setup in Environmental Chamber



Photograph 2 Solar System Simulator

REFERENCES

1. Sunlogger Functional Specification, Andover Controls Corporation, Rev. F, 9/5/78

2. Final Design Package for Contract No. DEN8-000005, Sunmaster Corporation

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