Bendix
Aerospace Systems Division

Prototype "A" Thermal Vacuum Test Summary Analysis

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ALSEP THERMAL VACUUM TEST

SUMMARY ANALYSIS

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SECTION 1.0

SCOPE AND OBJECTIVES OF TEST

The scope of the test included all ALSEP Prototype "A" subsystems, the environmental control systems, and the associated test equipment to verify results in each phase of the test. Test Procedures 2333032, 2333040, and 2333035 were used to perform functional tests, setup test equipment, and operate the space simulation chamber respectively. Objectives of the lunar environmental tests were:

1. Functional operation of each ALSEP subsystem
2. Possible interaction between subsystems
3. Power dissipation of each subsystem
4. Thermal control of each subsystem
5. Verification of functional and environmental support test equipment.

SECTION 2.0

BRIEF SUMMARY OF THE TEST

This section contains a general description of the Prototype "A" Thermal Vacuum Test results. It is written to provide a brief discusion of each aspect of the test for those readers whose time may be limited. A detailed description of these results follows in Section 4.0.

2.1 Test sequence. - The basic Prototype "A" Thermal Vacuum Test sequence consisted of:

1. Integrated System Test (IST) at room ambient conditions for reference data
2. Simulation chamber pump down
3. Vacuum room temperature IST
4. Low temperature check of radiometers
5. Simulated lunar morning radioisotope thermoelectric generator (RTG) turn-on
6. IST under simulated lunar noon conditions
7. IST under simulated lunar night conditions
8. Return to room ambient conditions
9. Repeat of IST at room ambient for reference data.

This is the same basic sequence that will be used for qualification and flight model acceptance tests. The only major difference will be the performance of room temperature vacuum IST after radiometer checks to allow more time for out-gassing of the Solar Wind Spectrometer (SWS) and Suprathermal Ion Detector Experiments (SIDE) prior to the turn-on of their high voltage supplies.

2.2 Overall system performance. - In general, the operation and control of the complete test system (i.e., STS, ALSEP Central Station, RTG, Experiments, vacuum chamber, Lunar surface environment simulation, and data monitoring systems) went well throughout the entire test. The ALSEP Central Station including the data, power, and thermal control subsystems operated without significant fault and the telemetry provided adequate information in order to evaluate their status. Minor problems were encountered when the STS computer indicated out-of-tolerance conditions resulting from improper temperature compensation of calibration data and unexpected vacuum induced effects on blank channels.

Each experiment exhibited good aspects of operation either electrically, mechanically or thermally, and at the same time, each experiment encountered significant problems in at least one of these areas. The SIDE encountered mechanical and electrical problems. However, it partially recovered from its electrical problems in lunar night conditions and its thermal control system appeared adequate. LSM functioned well electrically, but encountered thermal and mechanical problems; while PSE operated well electrically, but experienced a thermal problem. SWS had a serious electrical problem but its thermal control system appeared to be operating well in the Standby mode. In all cases modifications to experiments or test setup have been made on the qualification model.

Thus, this test provided some valuable data on each subsystem and has given increased confidence of a successful qual and flight program.

2.3 Central Station and RTG thermal control. - The thermal performance of the ALSEP Central Station for the Prototype "A" model under simulated lunar environmental day and night conditions was in very close agreement with pretest established temperature limits. The results of the thermal vacuum Prototype "A" testing indicated that the average Central Station thermal plate temperature was 105°F for the lunar noon condition and -15°F for lunar night with an overall passive temperature range of 120°F. This temperature range for the Central Station thermal plate compared favorably with the pretest analytical temperature prediction of 129°F and the specification design goal of 125°F for the operational ALSEP temperature swing in the lunar day and night environment.

Central Station component temperatures inside the Central Station were also well within predicted thermal operating limits for the Prototype "A" day and night operation. The maximum electronic component temperature observed was the PCU regulator transistor at 157°F (maximum allowable 210°F) with the remainder of the Central Station components operating within 20°F of the Thermal plate temperature. The 10 watts backup heater was thermostatically initiated during the Prototype "A" tests with a resultant temperature increase inside the Central Station of approximately 20°F. This actuation of the contingency heater reduced the overall Central Station temperature swing to 100°F for day/night operation.

The temperature results for the integrated SNAP-27 RTG/Pallet 2 configuration were near nominal. Maximum generator steady state hot and cold frame temperatures were 1190°F and 440°F for lunar day operation and 1145°F and 380°F for lunar night at an electric fuel capsule power setting of 1400 watts. Pallet 2 equilibrium surface temperatures ranged from 225 to 375°F during lunar noon to -35 to 180°F for lunar night.

2.4 Central Station electronics. - The Central Station electronic components performed all required functions throughout the Prototype "A" Thermal Vacuum Tests without failure of any component to provide the required functions for which intended. Most of the discrepancies written against the Central Station were minor in scope and generally referred to out-of-tolerance indications on housekeeping telemetry data channels or to deviations from the test procedure. Of the 22 discrepancies written, only five indicated a possible requirement for hardware rework. These discrepancies are summarized as follows:

1. Transmitter "A" AGC voltage out-of-tolerance and power input to transmitter "A" is greater than normal. However, transmitter "A" maintained the proper power output throughout the test.

2. Transmitter "B" heat sink temperature sensing channel was inoperative prior to going into test. No other malfunction of transmitter "B" occurred.

3. The signal conditioning circuit monitoring structure temperature #2 (HK 88) was intermittent throughout the test.

4. The receiver prelimiting level telemetry signal indicated an unexpected fluctuation, which was however, within tolerance. Further testing of the component is desirable to determine if this fluctuation is an indication of future degraded performance.

5. On three occasions at various environmental conditions PCU's failed to change over when commanded. A detailed appraisal of this situation is being prepared for the Qual SA model.

All of these items are being investigated and appropriate corrective action will be taken as necessary during the Prototype "A" to Prototype "C" retrofit.

2.5 Radioisotope Thermoelectric Generator. - The model 14 Radioisotope Thermoelectric Generator (RTG) operated admirably well throughout the tests. Lunar morning turn on was accomplished and the RTG output stabilized at 62.5 electrical watts with a thermal input of 1400 watts. At the completion of the lunar night IST, the thermal input was increased to 1500 thermal watts and the RTG electrical output increased to 68.9 watts. No new discrepancies in RTG performance resulted from the test.

2.6 Experiments. -

2.6.1 Passive Seismic Experiment. - Electrical performance of the Passive Seismic Experiment (PSE) was normal throughout test, although the PSE sensor experienced a thermal problem. During the Lunar Noon Test, the sensor temperature approached stabilization below the predicted operating limits. The PSE lunar surface temperature was raised to bring the sensor temperature within operating limits to perform the IST. When the lunar surface temperature was lowered for the Lunar Night IST, the sensor temperature again dropped below the limits. Consequently, the Lunar Night IST was not performed for the PSE. Thermal analysis has shown that there is significant uncompensated heat loss through the Sensor Exciter cable (which will not be present on the lunar surface).

Electrical problems encountered during the test were due to electrical transients from the analog recorder. A low amplitude was observed on the short period signal at the 0 db setting and occasionally, electrical transients reset the Sensor Exciter status.

2.6.2 Lunar Surface Magnetometer. - The electrical performance of the Lunar Surface Magnetometer (LSM) was very satisfactory. Only a few minor discrepancies such as erroneous offset status bits and apparent failure of the Z axis sensor heater control to turn on at the proper temperature were noted.

Significant thermal/structural problems were observed with respect to the Z axis sensor which inhibited the lunar night flip/cal operation. A severe temperature gradient along the boom was the major cause of the malfunction as observed by Dr. P. Dyal. Future LSM models will have a one-watt heater for each sensor (X, Y, and Z) instead of the former 1/3 watt per sensor.

2.6.3 Solar Wind Experiment. - The Solar Wind Experiment (SWS) operated normally during the ambient initial reference IST. However, during the room temperature vacuum IST the SWS failed thirty-one seconds after turn on.

Analysis of the STS printer data indicated the Central Station operation was normal. The problem was believed to be similar to a previous fault in which the experiment failed to sequence properly on turn-on, but with additional turn-ons would eventually start and perform satisfactorily. Therefore, several additional turn-ons were attempted without success. Analysis of the current profile from the power received indicated the experiment was not sequencing and the vacuum IST for the SWS aborted. Additional attempts to turn-on the experiment were performed throughout the remainder of the Thermal Vacuum Test but without success.

Upon completion of the test, the initial paragraphs of the experiment PIA, were performed on the experiment test set; however, this test was also unsuccessful. Data output indicated "all ones" for approximately 40 steps, at which time the data shifted to all zeros.

Post-test examination of experiment at JPL showed that an arc apparently developed in the proton high-voltage circuits of the experiment, causing several failures in other circuits.

The maximum and minimum temperature extremes monitored during the Thermal Vacuum Test, in which the experiment was operated in the Standby mode, were -28°F and +112°F.

2.6.4 Suprathermal Ion Detector Experiment/Cold Cathode Ion Gauge Experiment (SIDE/CCGE). - The basic operation of the experiment was satisfactory over portions of the Thermal Vacuum Test. However, a minor but troublesome design discrepancy caused the SIDE circuit breaker to be tripped many times during phases when the experiment's internal heater was on and commands were sent. The SIDE design has been modified to eliminate this condition. The experiment exhibited signs of arcing during the noon IST but no permanent damage occurred and the SIDE operated properly (with some deviations) during the night IST. The mechanical aspect of the design had a serious problem with the attachment of the legs to the experiment. One leg broke off during the high temperature test. The leg failure made complete evaluation of the thermal control system impractical.

2.6.5 Dust Detector. - The Dust Detector was commanded on for approximately two minutes during each Integrated System Test (IST). An octal printout of the three solar-cell voltages and the three cell temperature voltages was made, both before the Dust Detector was commanded on and during the period when it was on. Thus, little meaningful data could be obtained on solar-cell output or solar cell temperature since the sensors were always below temperature and out of the spectral range at which they come on scale. The test arrangement will be modified on future tests so that more meaningful Dust Detector data is obtained.

2.7 System Test Set and software. - Hardware operation of the System Test Set (STS) over the ten-day period was generally most satisfactory. The system operated continuously and the only malfunction occurred in a high speed Monroe 4000 printer.

Unexpected main-frame or subframe-sync losses occurred 30 times. The cause of each of these sync losses was isolated to several conducted interference sources such as power switching on perpherial equipments and lightning strikes. On future tests sync losses should be reduced due to the incorporation of additional filtering and regeneration of power via a motor generator set.

Computer software operation was highly satisfactory. The limit values applied to Central Station and experiment status monitors were in general adequate. However, a number of out-of-tolerance conditions existed which are attributable to: (1) the lack of temperature dependence in RF component parameters in calibration data originally supplied, (2) errors in limit data provided and (3) peculiar vacuum effects.

SECTION 3.0

DESCRIPTION OF TEST SETUP

3.1 Vacuum chamber test configuration. - Details of the test configuration are given in Procedure 2333040. Salient features are reproduced in this section to minimize cross referencing. The lunar environment simulated in the Bendix 20' x 27' Space Simulation Chamber is keyed to four environment parameters:

(a) Pressure
(b) Cold Sink in Space
(c) Lunar Surface Temperature
(d) Radiant Solar Energy

A pressure of 5×10^{-6} Torr or less was maintained for the duration of this test by the chamber pumping system. The cold sink of space was simulated with a liquid nitrogen cooled shroud, maintained at -300°F and having an infrared absorbtance in excess of 0.90. Lunar surface temperatures of -300°F to +250°F were simulated by flowing liquid nitrogen (LN_2) through the fabricated aluminum floor (lower temperatures) or activating electrical heaters on the floor surface (higher temperatures). A separate lunar surface simulator was constructed for the Passive Seismic Experiment. The damped surface temperatures (+10°F to +70°F), as seen by the PSE sensor under its thermal shroud, were simulated with a temperature controlled flow of trichloroethylene through the surface. Each experiment, the RTG, and the Central Station had independently controlled arrays of lamps to simulate solar energy. The energy absorbed by each irradiated surface was: (1) monitored by a radiometer which was calibrated for that surface; and (2) controlled externally by adjusting the lamp controls associated with the respective surface.

Figure 3-1 shows chamber pressure variations and temperature variations of the chamber cold wall and the Central Station thermal plate and sunshield. The overall test configuration for an ALSEP System Thermal Vacuum Test is presented in Figure 3-2. This figure presents a plan view of the Space Simulation Chamber Room in Bendix' Systems Test Laboratory. All supporting equipment required for this test is identified and the relative positions indicated. An ALSEP functional control center was setup in a semi-clean room environment off the Space Simulation Chamber Room, and an environmental control instrumentation area was established along the right side of the space chamber. A

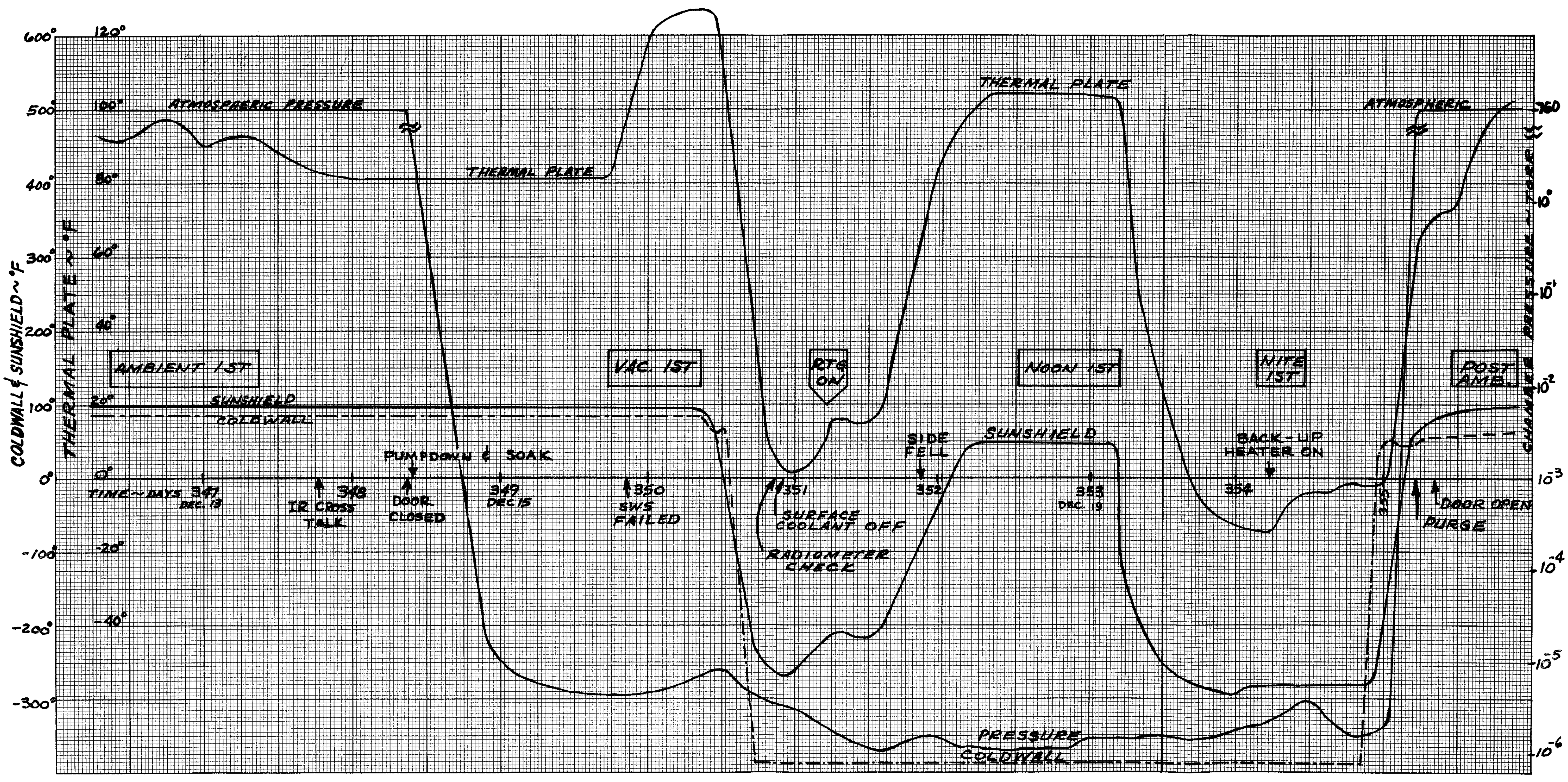


Figure 3-1 Chamber Environments During Thermal Vacuum Tests

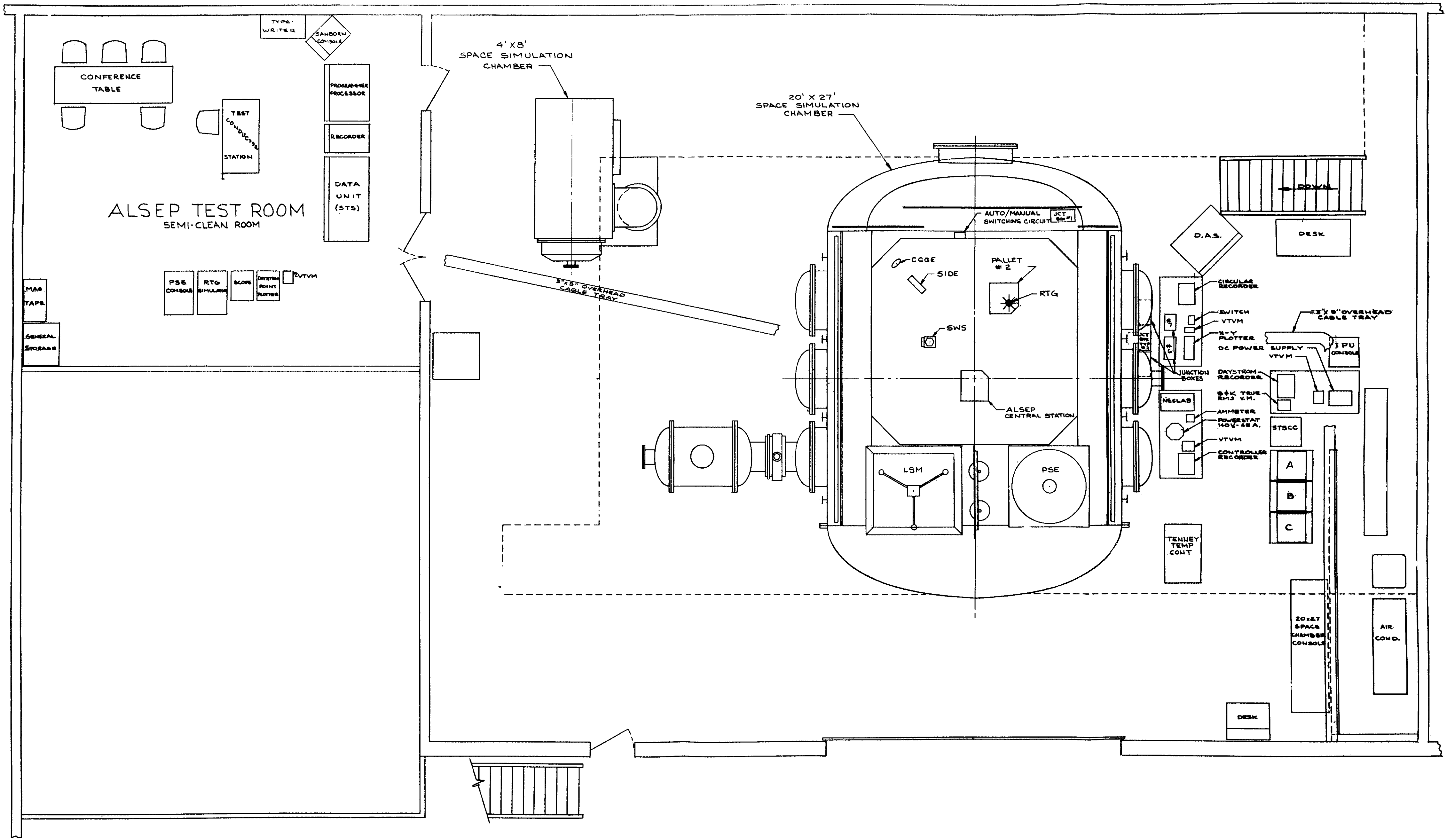


Figure 3-2 ALSEP Thermal Vacuum Test Configuration

direct communication link between these two areas was maintained throughout the performance of this test.

Figure 3-3 is an intercabling block diagram of units under test and the test equipment. Figure 3-4 details the solar simulation, and Figure 3-5 shows the radiometer locations. Surface temperature control and its relationship to the monitoring system is shown in Figures 3-6, 3-7, and 3-8. Figures 3-9 through 3-12 illustrate System Deployment and Instrumentation.

3.2 System Test Set and auxiliary instrumentation. -

3.2.1 System Test Set. -

3.2.1.1 Function. - The STS, for purposes of thermal vacuum testing, is equivalent to the MSFN ground station. The principal difference in these two equipments is their handling of science data. In thermal vacuum, the science data is of no real significance and great emphasis is placed upon engineering performance. The DPS-2000 decommutator checks the received data against programmed limits. It also attempts to track the operating modes of experiments with respect to executed commands.

3.2.1.2 Hardware discrepancies. - Hardware operation of the test set over the ten-day period was generally most satisfactory. The only discrepancy occurred in the Monroe 4000 printer.

Conducted interference from a number of sources caused mainframe and subframe lock losses. Analysis of these failures on replaying the video recordings indicated that the STS was susceptible to the following:

Power Switching of the DURA Teletype (2 sync losses)
Lightning Strikes (8 sync losses)
Power Switching of the AMPEX FR 1300 Recorder (1 sync loss)
Other Power Borne Interference (12 sync losses)

A parallel effort on STS #3 to reduce susceptibility by changing to a better grade of power filters indicates that a complete solution is available and will be incorporated.

3.2.1.3 Software discrepancies. - Software operation was also highly satisfactory with a single exception. Command tracking of the SIDE experiment broke down when the experiment did not respond in the predicted manner to commands.

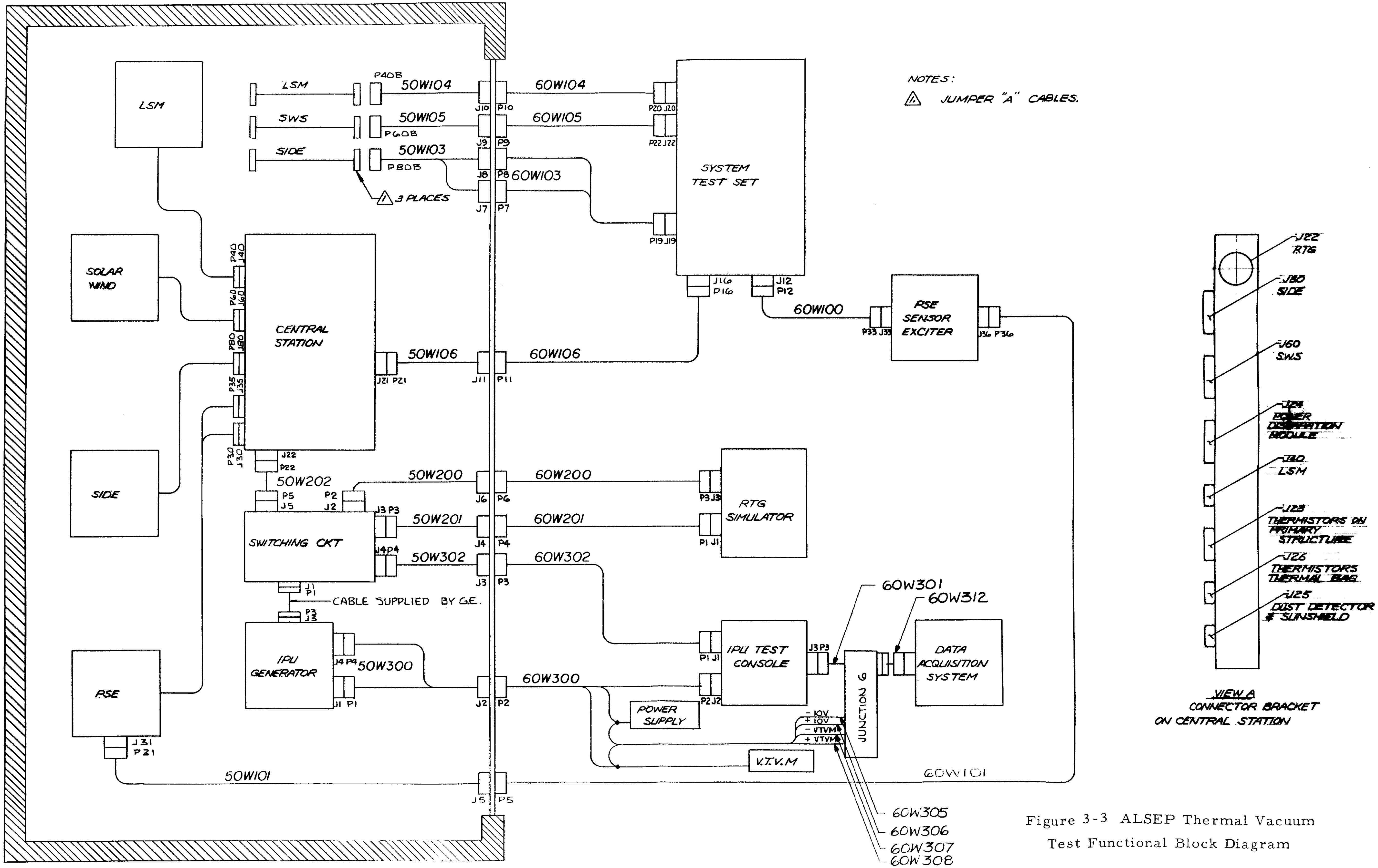


Figure 3-3 ALSEP Thermal Vacuum Test Functional Block Diagram

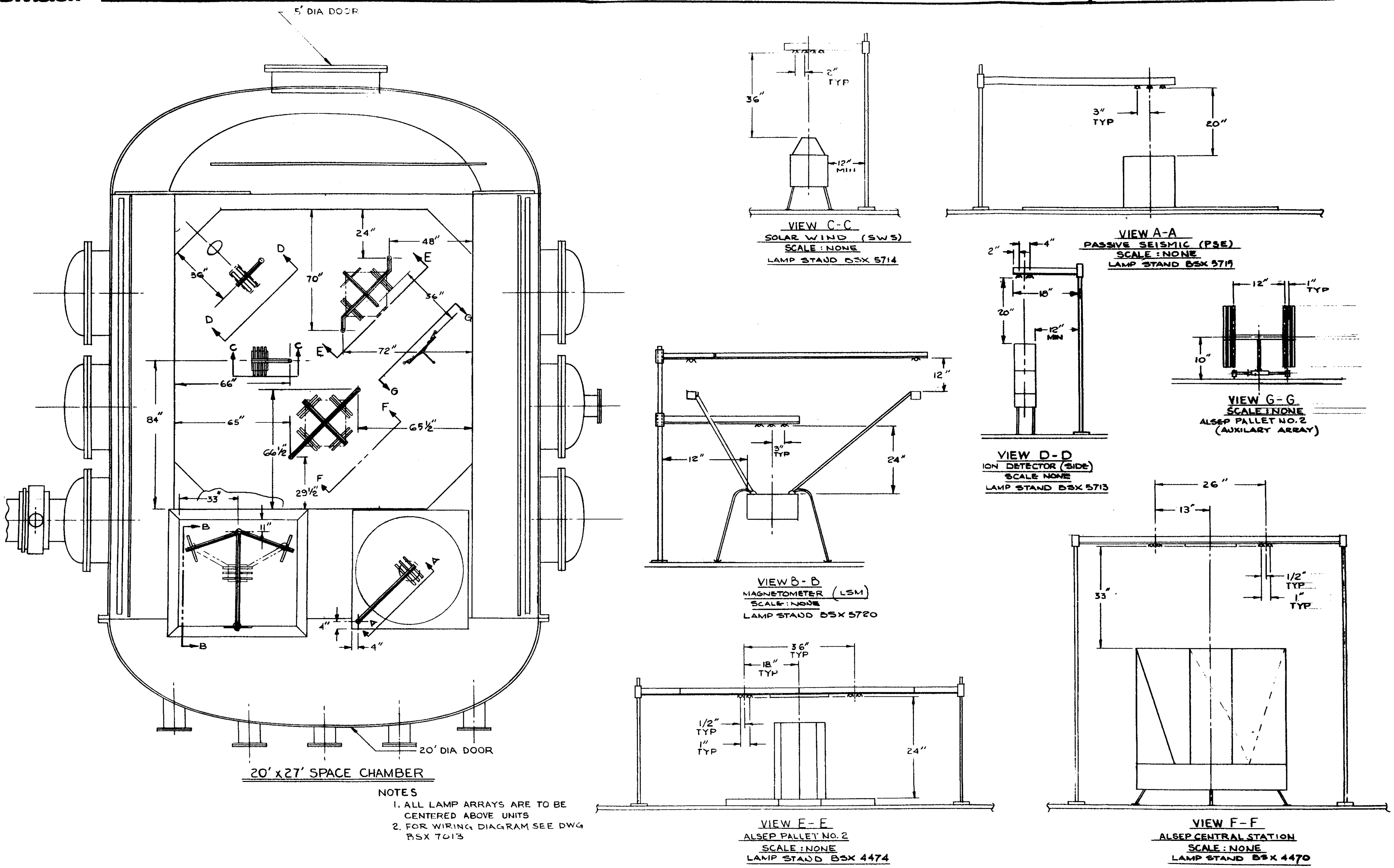
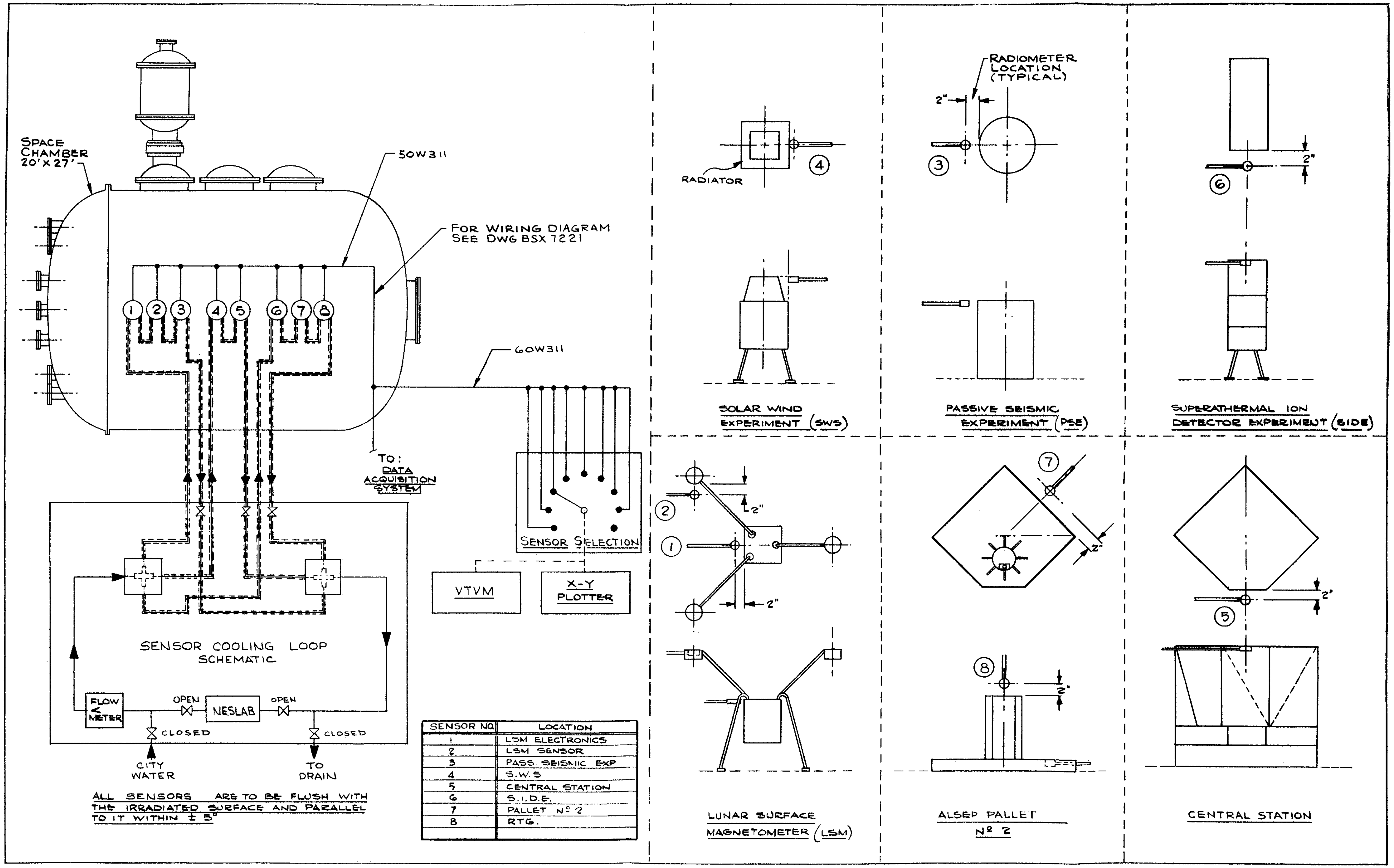


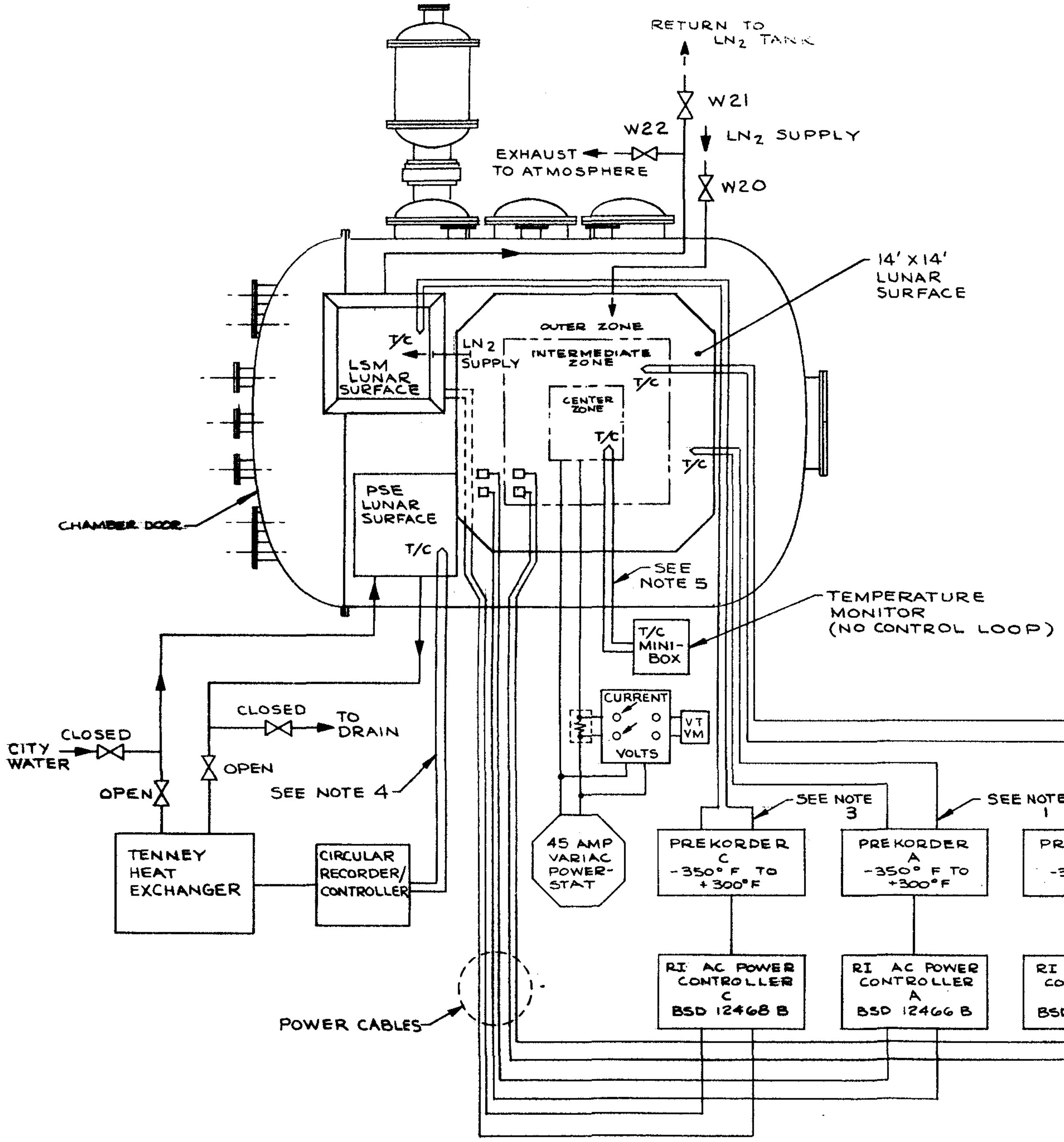
Figure 3-4 IR Lamp Array Locations



ALL SENSORS ARE TO BE FLUSH WITH THE IRRADIATED SURFACE AND PARALLEL TO IT WITHIN ± 5°

SENSOR NO.	LOCATION
1	LSM ELECTRONICS
2	LSM SENSOR
3	PASS. SEISMIC EXP
4	S.W.S
5	CENTRAL STATION
6	S.I.D.E.
7	PALLET Nº 2
8	RTG.

Figure 3-5 IR Sensor Function Diagram



NOTES:

1. THERMOCOUPLES LS 46, 50, 51, 55 ARE TO BE WIRED IN PARALLEL TO PREKORDER A.
2. THERMOCOUPLES LS 47, 48, 53, 54 ARE TO BE WIRED IN PARALLEL TO PREKORDER B.
3. THERMOCOUPLES MLS 5, 11 ARE TO BE WIRED IN PARALLEL TO PREKORDER C.
4. THERMOCOUPLES PSLS 4, 9 ARE TO BE WIRED IN PARALLEL TO THE TENNEY CIRCULAR RECORDER / CONTROLLER.
5. THERMOCOUPLES LS 49, 52 ARE TO BE WIRED IN PARALLEL TO THE T/C MINIBOX.
6. ALL THERMOCOUPLES ARE MADE FROM NO. 28 AWG COPPER CONSTANTAN THERMOCOUPLE WIRE.
7. FOR BLOCK DIAGRAM SEE BSX 7010.

Figure 3-6 Lunar Surface Temperature Control System

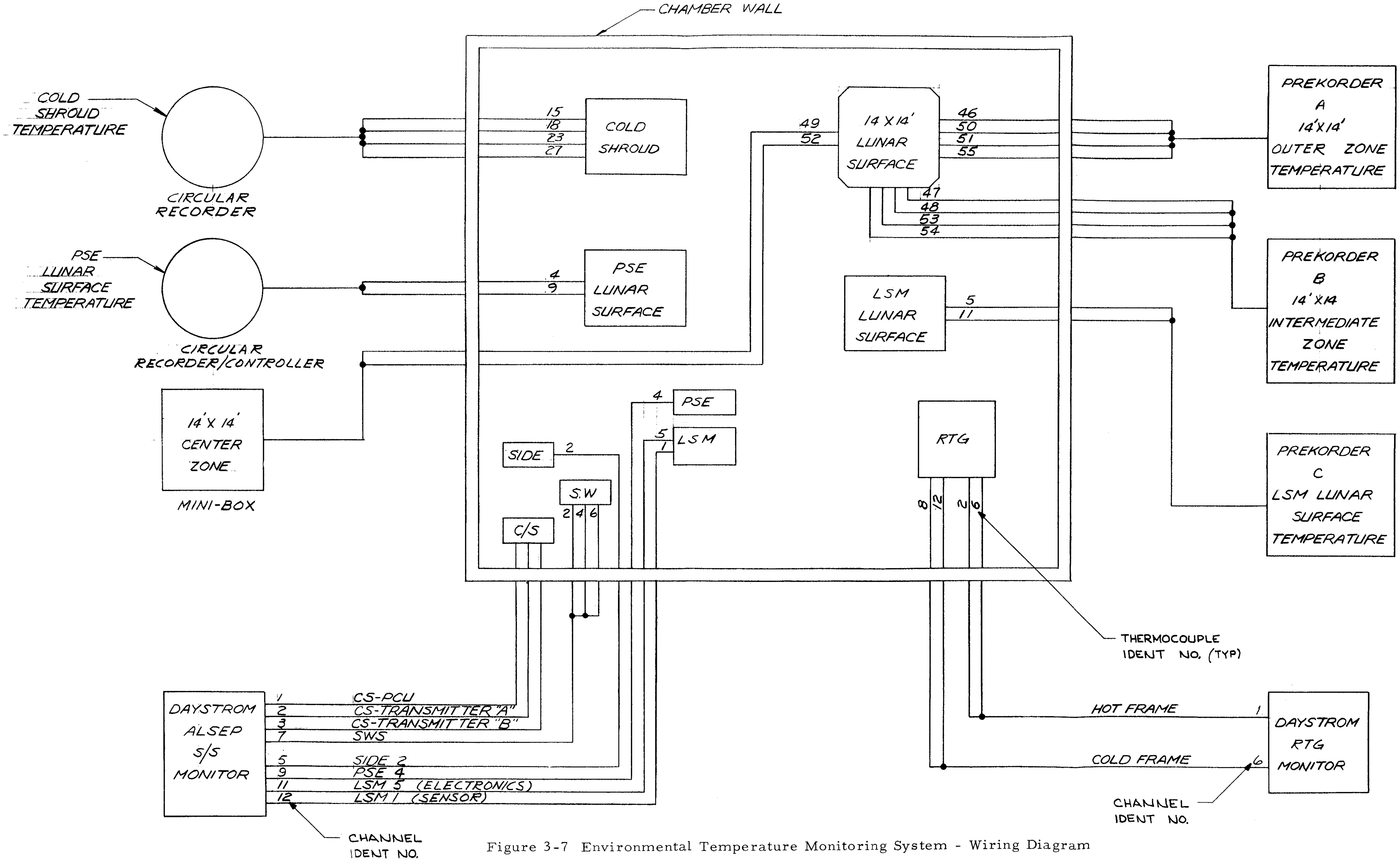


Figure 3-7 Environmental Temperature Monitoring System - Wiring Diagram

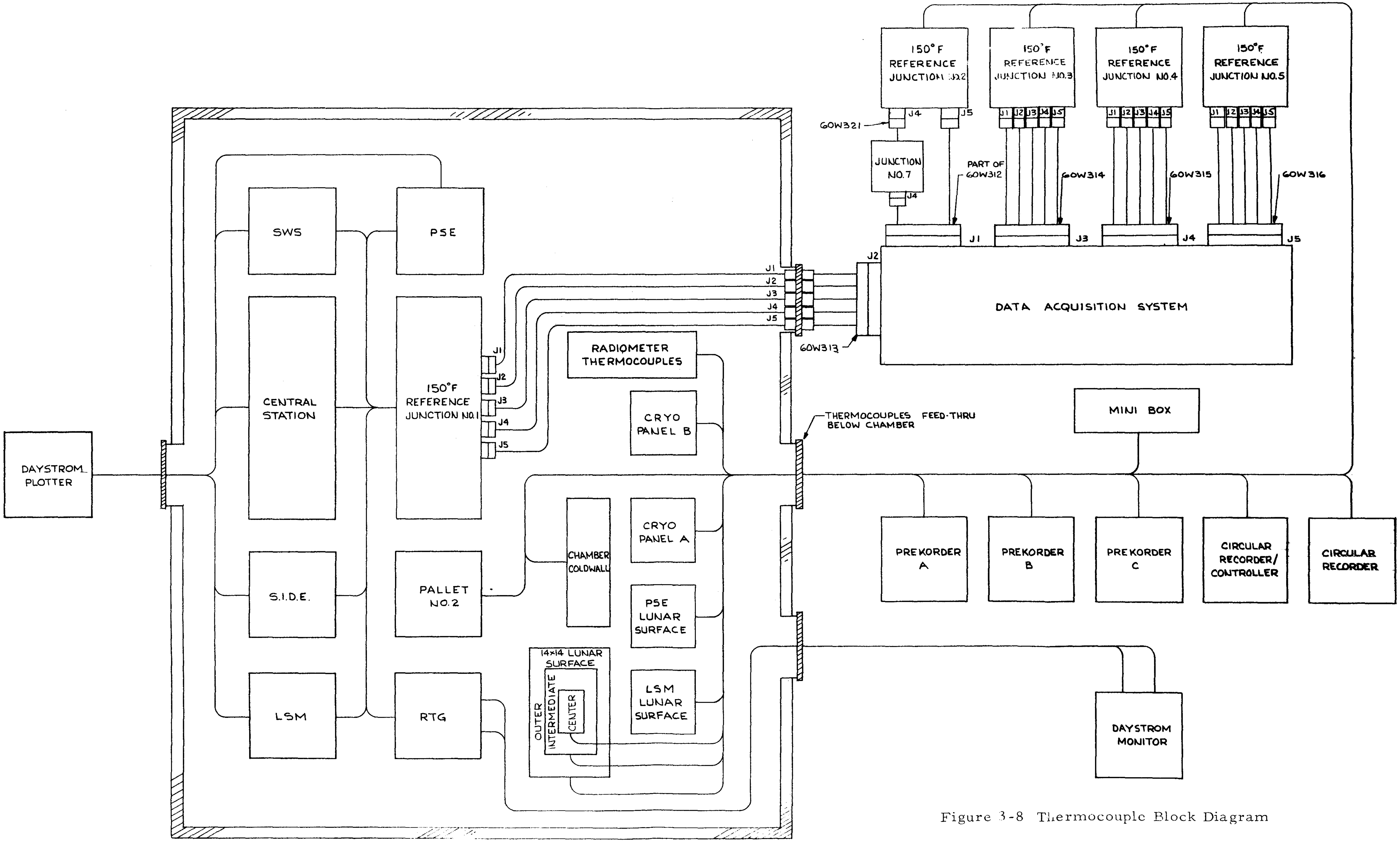


Figure 3-8 Thermocouple Block Diagram

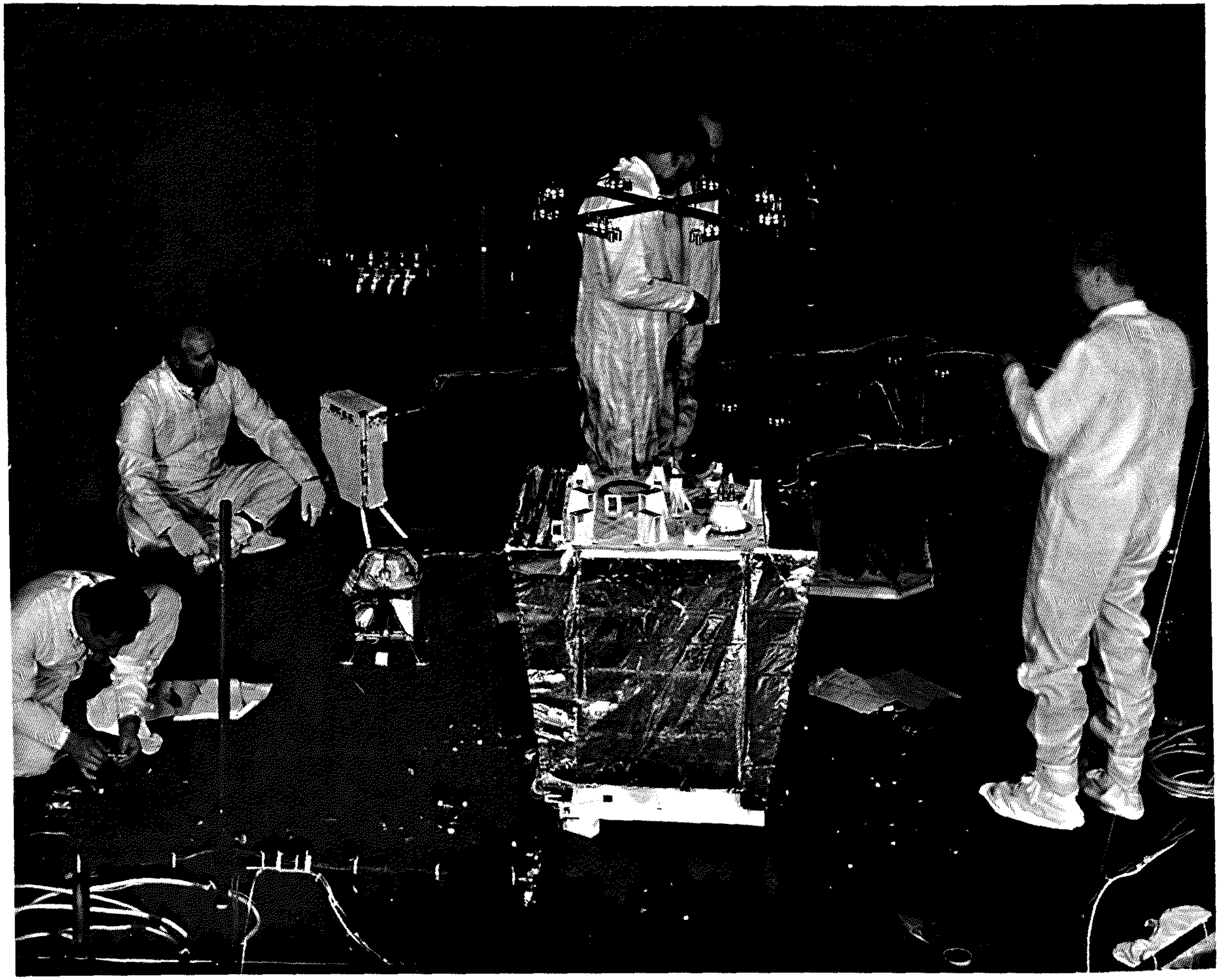


Figure 3-9 **ALSEP Prototype A System Deployed in T/V Chamber.**

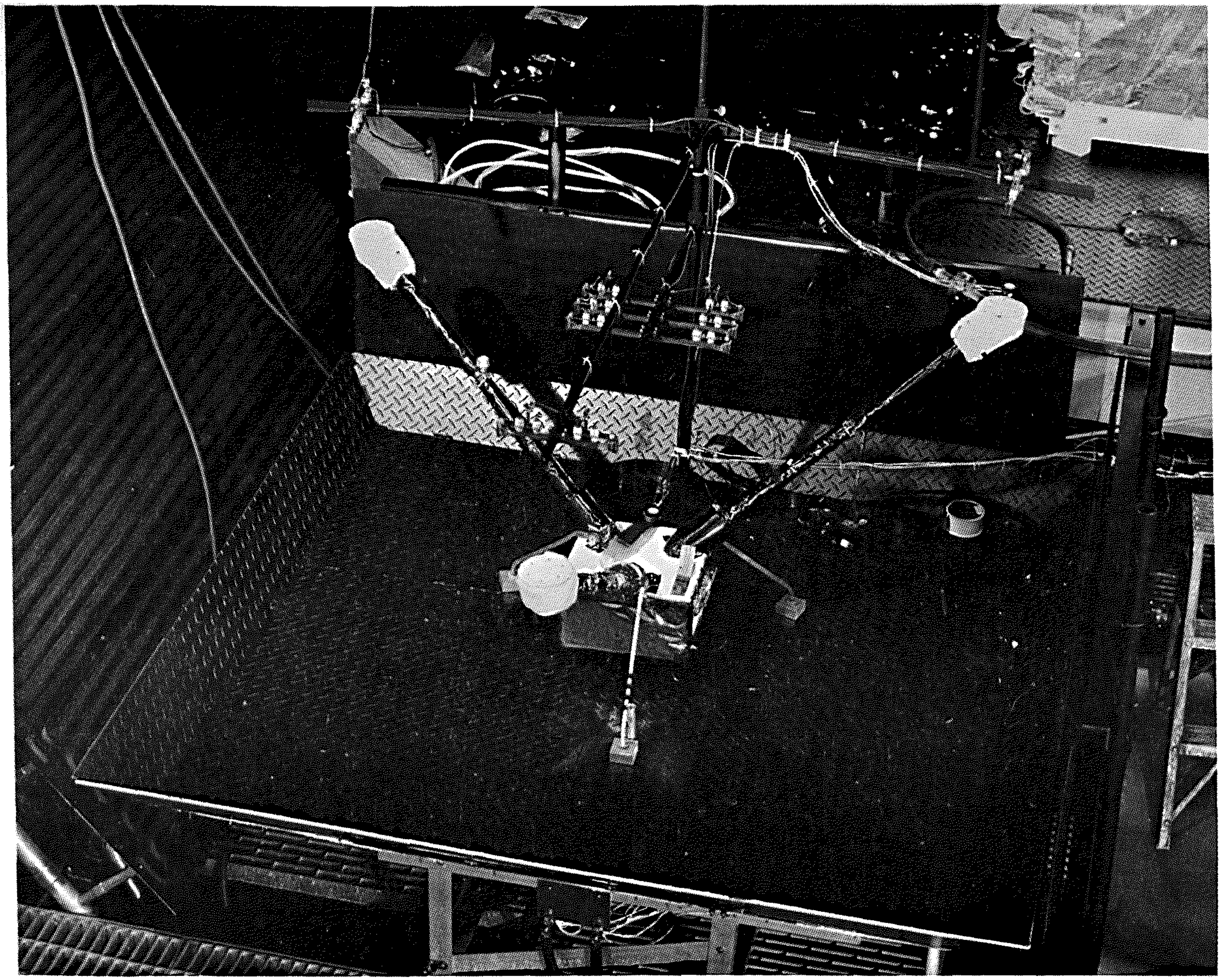


Figure 3-10 **LSM Prototype Deployed for T/V Testing**

Figure 3-11 PSE Prototype Deployed for T/V Testing.

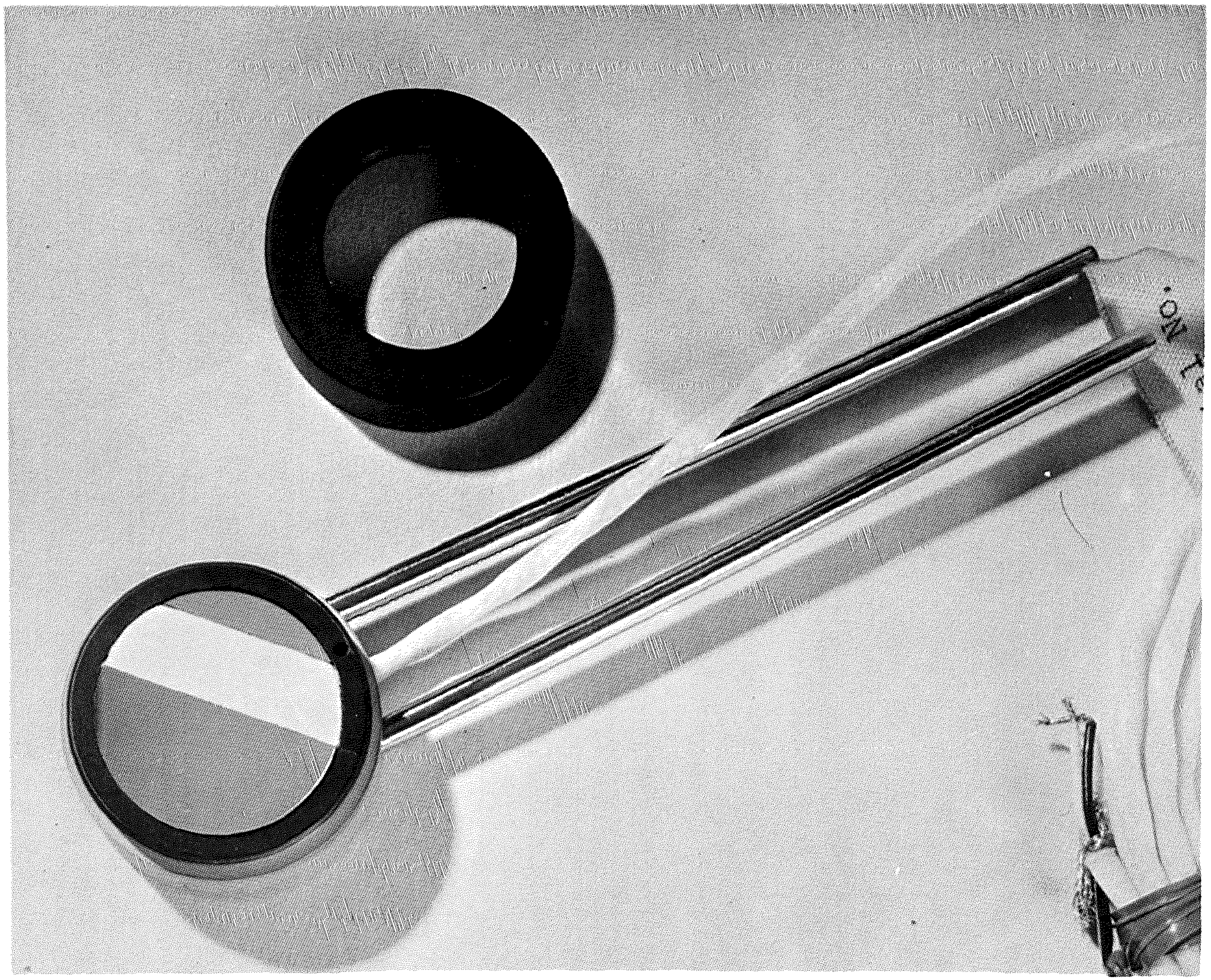


Figure 3-12 **Special Radiometer Used in T/V Test**

Mode alterations, which were not commanded, also caused a loss of tracking. The limited capability of the STS and the insufficient operational data concerning SIDE (to software programmers) was the principal cause of the sync losses. The ground station software should not be operated by command execution alone but should also be capable of analyzing the telemetered data and verifying status. Additional information concerning SIDE operation has made it possible to write a new program to alleviate some of the sync loss problems.

3.2.1.4 Limit values. - The limit values applied to various HK channels were in general, satisfactory. Channels which were not assigned to a function and RTG channels were found to wander in vacuum. (RTG hot and cold junction thermistors were burned out prior to test and resistors were substituted.) Analysis attributed this unforeseen wandering on the unassigned channels, to the cessation of surface migration at the FET input gates of the analog multiplexer which was caused by the vacuum. The RTG channels wandered due to noise pickup on the long unshielded lines. Prediction of the RF equipment telemetry outputs was complicated by the temperature sensitivity of the measurements. The limits will be revised in view of thermal vacuum experience.

3.2.2 Additional instrumentation. - The normal capability of the STS was extended by the addition of special instrumentation to the system test set. This was necessary to confirm the operation of thermal sensors within the various subsystems and to provide an adequate basis for decision making by the Test Conductor. Outputs of much of this instrumentation was monitored and recorded throughout the test to indicate trends.

3.2.2.1 Sanborn hot stylus recorder. - This recorder was used to record critical aspects of the power system such as: (1) 12 volts, (2) reserve power 1 and 2, (3) input voltage, and (4) input current. The data obtained was of the greatest importance in establishing events that occurred without command. Without this information, it would be impossible to estimate accurately the duration of events. For lunar operation it may be of some value to increase the data rate of the reserve power channels (HK 8 and HK 13) by duplicating the data on unallocated or unused channels in word 33. For future tests of a similar nature, it would be advantageous to use a recorder with an increased frequency response and a greater full-scale displacement.

3.2.2.2 Daystrom chart recorder. - This recorder plotted numbered points which fed from some of the chamber instrumentation sensors and was placed near the test conductor to give quick access to environmental data. To accommodate external temperature sensors, a scale of -300, 0, +300°F was chosen. This gave poor resolution to less exposed sensors. The sample rate was very low and the chart was difficult to read with any accuracy. More appropriate methods of displaying this data will be established before qual thermal vacuum test.

3.2.2.3 Digital voltmeter and panel meters. - Early in the test sequence, the ALSEP power was derived from an RTG simulator which had permanent wiring to vital power points. A digital voltmeter and panel meters constantly monitored this data in parallel with the Sanborn hot stylus recorder.

3.2.2.4 Sanborn 4524 optical recorder. - This recorder was employed to monitor data from the DPS 2000 from the Passive Seismic Experiment. The eight traces recorded were: (1) short period, (2) X axis long period, (3) Y axis long period, (4) Z axis long period, (5) X axis tidal, (6) Y axis tidal, (7) Z axis tidal, and (8) temperature.

3.2.2.5 Data Acquisition System. - The Electro-Instruments Data Acquisition System (DAS) recorded approximately 239 channels of data. A description of each channel and drawings which illustrate thermocouple locations are shown in Table 3-1.

TABLE 3-1

DESCRIPTION OF DATA ACQUISITION SYSTEM (DAS) CHANNELS

Chan. No.	Type	Description of Channel	Transducer Location Bendix Ref. Doc.		
			No.		
000	5	Calib Volt 1			
001	14	Press X +10V Power Supply			
002	7	EFCS Power			
003	9	EFCS Volts IPU Console			
004	10	EFCS Amp IPU Console			
005	11	IPU Power IPU Console			
006	12	IPU Volts IPU Console			
007	13	IPU Amps IPU Console			
008	8	Press to VTVM			
009	0	CS IR Volts Sol/Therm Sim Cont Console			
010	0	CS IR Amps ↑ ↑ ↑			
011	0	Pal IR Volts			
012	0	Pal IR Amps			
013	0	RTG IR Volts			
014	0	RTG IR Amps			
015	0	LSM-E IR Volts			
016	0	LSM-E IR Amps			
017	0	LSM-S IR Volts			
018	0	LSM-S IR Amps			
019	0	SIDE IR Volts			
020	0	SIDE IR Amps			
021	0	SWS IR Volts			
022	0	SWS IR Amps			
023	0	PSE IR Volts ↓ ↓ ↓			
024	0	PSE IR Amps Sol/Therm Sim Cont Console			
025	0	CS RR Radiometer Response			
026	0	Pal RR Radiometer Response			
027	0	RTG RR Radiometer Response			
028	0	LSM-E RR Radiometer Response			
029	0	LSM-S RR Radiometer Response			
030	0	SIDE RR Radiometer Response			
031	0	SWS RR Radiometer Response			
032	0	PSE RR Radiometer Response			
033	6	Calib Volt 2			

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc. No.	Page	Figure
034	4	CS RT1 Radiometer			
035	4	CS RT2 Radiometer			
036	4	Pal RT1 Radiometer			
037	4	Pal RT2 Radiometer			
038	4	RTG RT1 Radiometer			
039	4	RTG RT2 Radiometer			
040	4	LSM-E RT1 Radiometer			
041	4	LSM-E RT2 Radiometer			
042	4	LSM-S RT1 Radiometer			
043	4	LSM-S RT2 Radiometer			
044	4	SIDE RT1 Radiometer			
045	4	SIDE RT2 Radiometer			
046	4	SWS RT1 Radiometer			
047	4	SWS RT2 Radiometer			
048	4	PSE RT1 Radiometer			
049	4	PSE RT2 Radiometer			
050	2	CS 26 Central Station	2333040	174	23
051	2	CS 1 Central Station	2333040	172	21
052	2	CS 2 Central Station	"	"	"
053	2	CS 3 Central Station	"	"	"
054	2	CS 4 Central Station	2333040	173	22
055	2	CS 5 Central Station	"	"	"
056	2	CS 6 Central Station	"	"	"
057	2	CS 7 Central Station	"	"	"
058	2	CS 8 Central Station	"	"	"
059	2	CS 9 Central Station	"	"	"
060	2	CS 10 Central Station	"	"	"
061	2	CS 11 Central Station	"	"	"
062	2	CS 12 Central Station	" "	"	"
063	2	CS 13 Central Station	"	"	"
064	2	CS 14 Central Station	2333040	173,174	22, 23
065	2	CS 15 Central Station	"	" "	" "
066	2	CS 16 Central Station	"	" "	" "
067	2	CS 17 Central Station	2333040	174	23
068	2	CS 18 Central Station	"	"	"
069	2	CS 19 Central Station	"	"	"
070	2	CS 20 Central Station	"	"	"

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc. No.	Page	Figure
071	2	CS 21 Central Station	2333040	174	23
072	2	CS 22 Central Station	"	"	"
073	2	CS 23 Central Station	"	"	"
074	2	CS 24 Central Station	"	"	"
075	2	CS 25 Central Station	"	"	"
076	2	SIDE 1 SIDE	2333040	178	27
077	2	SIDE 3 SIDE	"	"	"
078	2	SIDE 4 SIDE	"	"	"
079	2	SWS 1 SWS	"	"	"
080	2	SWS 3 SWS	"	"	"
081	2	SWS 5 SWS	"	"	"
082	2	PSE 1 PSE	2333040	177	26
083	2	PSE 2 PSE	"	"	"
084	2	PSE 3 PSE	"	"	"
085	2	LSM 2 LSM	"	"	"
086	2	LSM 3 LSM	"	"	"
087	2	LSM 4 LSM	"	"	"
088	3	RTG 1 RTG	2333040	176	25
089	3	RTG 3 RTG	"	"	"
090	3	RTG 4 RTG	"	"	"
091	3	RTG 5 RTG	"	"	"
092	3	RTG 7 RTG	"	"	"
093	3	RTG 9 RTG	"	"	"
094	3	RTG 10 RTG	"	"	"
095	3	RTG 11 RTG	"	"	"
096	2	RTG 13 RTG	"	"	"
097	2	RTG 14 RTG	"	"	"
098	2	RTG 15 RTG	"	"	"
099	3	RTG 16 RTG	"	"	"

Chan. No.	Type	Description of Channel	Transducer Location Bendix Ref. Doc. No.	Page	Figure
100	4	Switch on Relay L/S			

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc.		
			No.	Page	Figure
101	4	Pal 1 Pallet Assy No. 2	2333040	175	24
102	4	Pal 2 Pallet Assy No. 2	"	"	"
103	4	Pal 3 Pallet Assy No. 2	"	"	"
104	4	Pal 4 Pallet Assy No. 2	"	"	"
105	4	Pal 5 Pallet Assy No. 2	"	"	"
106	4	Pal 6 Pallet Assy No. 2	"	"	"
107	4	Pal 7 Pallet Assy No. 2	"	"	"
108	4	Pal 8 Pallet Assy No. 2	"	"	"
109	4	Pal 9 Pallet Assy No. 2	"	"	"
110	4	Pal 10 Pallet Assy No. 2	"	"	"
111	4	Pal 11 Pallet Assy No. 2	"	"	"
112	4	Pal 12 Pallet Assy No. 2	"	"	"
113	4	Pal 13 Pallet Assy No. 2	"	"	"
114	4	Pal 14 Pallet Assy No. 2	"	"	"
115	4	Pal 15 Pallet Assy No. 2	"	"	"
116	4	PSE LS 1	2333040	179	28
117	4	PSE LS 2	"	"	"
118	4	PSE LS 3	"	"	"
119	4	PSE LS 5	"	"	"
120	4	PSE LS 6	"	"	"
121	4	PSE LS 7	"	"	"
122	4	PSE LS 8	"	"	"
123	4	PSE LS 10	"	"	"
124	4	PSE LS 11	"	"	"
125	4	PSE LS 12	"	"	"
126	4	LSM LS 1	"	"	"
127	4	LSM LS 2	"	"	"
128	4	LSM LS 3	"	"	"
129	4	LSM LS 4	"	"	"
130	4	LSM LS 6	"	"	"
131	4	LSM LS 7	"	"	"
132	4	LSM LS 8	"	"	"
133	4	LSM LS 9	"	"	"
134	4	LSM LS 10	"	"	"
135	4	LSM LS 12	"	"	"
136	4	LSM LS 13	"	"	"

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc. No.	Page	Figure
137	4	LSM LS 14	2333040	179	28
138	4	LSM LS 15	"	"	"
139	0	Not Used	2333040	179	28
140	4	Ref 5	"	"	"
141	4	LS 1	2333040	179	28
142	4	LS 2	"	"	"
143	4	LS 3	"	"	"
144	4	LS 4	"	"	"
145	4	LS 5	"	"	"
146	4	LS 6	"	"	"
147	4	LS 7	"	"	"
148	4	LS 8	"	"	"
149	4	LS 9	"	"	"
150	4	LS 10	"	"	"
151	4	LS 11	"	"	"
152	4	LS 12	"	"	"
153	4	LS 13	"	"	"
154	4	LS 14	"	"	"
155	4	LS 15	"	"	"
156	4	LS 16	"	"	"
157	4	LS 17	"	"	"
158	4	LS 18	"	"	"
159	4	LS 19	"	"	"
160	4	LS 20	"	"	"
161	4	LS 21	"	"	"
162	4	LS 22	"	"	"
163	4	LS 23	"	"	"
164	4	LS 24	"	"	"
165	4	LS 25	"	"	"
166	4	LS 26	"	"	"
167	4	LS 27	"	"	"
168	4	LS 28	"	"	"
169	4	LS 29	"	"	"
170	4	LS 30	"	"	"
171	4	LS 31	"	"	"
172	4	LS 32	"	"	"
173	4	LS 33	"	"	"
174	4	LS 34	"	"	"
175	4	LS 35	"	"	"

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc.		
			No.	Page	Figure
176	4	LS 36	2333040	179	28
177	4	LS 37	"	"	"
178	4	LS 38	"	"	"
179	4	LS 39	"	"	"
180	4	LS 40	"	"	"
181	4	LS 41	"	"	"
182	4	LS 42	"	"	"
183	4	LS 43	"	"	"
184	4	LS 44	"	"	"
185	4	LS 45	"	"	"
186	4	CPA 1	"	"	"
187	4	CPA 2	"	"	"
188	4	CPB 1	"	"	"
189	4	CPB 2	"	"	"
190	0	Not Used			
191	4	CW 1	2333040	180	29
192	4	CW 2	"	"	"
193	4	CW 3	"	"	"
194	4	CW 4	"	"	"
195	4	CW 5	"	"	"
196	4	CW 6	"	"	"
197	4	CW 7	"	"	"
198	4	CW 8	"	"	"
199	4	CW 9	"	"	"
200	4	CW 10	"	"	"
201	4	CW 11	"	"	"
202	4	CW 12	"	"	"
203	4	CW 13	"	"	"
204	4	CW 14	"	"	"
205	4	CW 16	"	"	"
206	4	CW 17	"	"	"
207	4	CW 19	"	"	"
208	4	CW 20	"	"	"
209	4	CW 21	"	"	"
210	4	CW 22	"	"	"
211	4	CW 24	"	"	"

TABLE 3-1 (CONT.)

Chan. No.	Type	Description of Thermocouple Channel	Transducer Location Bendix Ref. Doc. No.	Page	Figure
212	4	CW 25	2333040	180	29
213	4	CW 26	"	"	"
214	4	CW 28	"	"	"
215	4	CW 29	"	"	"
216	4	CW 30	"	"	"
217	4	CW 31	"	"	"
218	4	CW 32	"	"	"
219	4	CW 33	"	"	"
220	4	CW 34	"	"	"
221	4	CW 35	"	"	"
222	4	CW 36	"	"	"
223	4	CW 37	"	"	"
224	4	CW 38	"	"	"
225	4	CW 39	"	"	"
226	4	CW 40	"	"	"
227	4	CW 41			
228	4	CW 42			
229	4	CW 43			
230	4	CW 44			
231	4	CW 45			
232	4	CW 46			
233	4	CW 47			
234	4	CW 48			
235	4	Ref 1			
236	4	Ref 2			
237	4	Ref 3			
238	4	Ref 4			

SECTION 4.0

DESCRIPTION OF TEST RESULTS

This section is a step-by-step detailed description of the events, environmental test setup, and results of each phase of the test.

4.1 Detailed sequence of events. -

TABLE 4-1

SEQUENCE OF EVENTS

Event	ALSEP Clock Reading	Calendar Day
Environmental Test Setup Verification		12/12/67
ALSEP System Test Setup		12/12/67
Ambient Pressure and Temperature Tests		12/12/67
Ambient IST		
System Test Set Turn-On Using RTG Simulator	346-08-44-00	12/12/67
Central Station Verification	346-13-12-06	
SWS Turn-On	346-14-34-28	
PSE Turn-On	346-20-09-19	
SIDE Turn-On	347-04-21-50	12/13/67
LSM Turn-On	347-06-58-22	
Central Station Turn-Off	347-10-00-00	

Event	ALSEP Clock Reading	Calendar Day
System Test Set Turn-Off	347-10-30-00	12/13/67
Pre-Test Environmental Systems Verification		12/14/67
Vacuum IST		
Pump Down Initiated	348-15-50-00	12/14/67
Vacuum Less Than 10^{-5} Torr	348-22-50-00	
17-Hour Soak Completed Pressure = 4.7×10^{-5}	349-15-50-00	12/15/67
System Test Set Turn-On	349-16-00-00	
Central Station Verification	349-19-34-09	
SWS Failed to Turn-On	349-20-12-51	
SIDE Turn-On	349-23-20-14	
PSE Turn-On	350-02-58-40	12/16/67
LSM Turn-On	350-07-06-00	
Environmental Reference Test	350-21-36-00	
Lunar Morning Turn-On		
Lunar Morning Initiated	351-06-50-15	12/17/67
Power to ALSEP Switched From RTG Simulator to IPU	351-07-44-00	
Lunar Morning Turn-On Completed	351-12-30-00	

Event	ALSEP Clock Reading	Calendar Day
Lunar Noon IST		
Thermal Equilibrium reached	352-12-00-00	12/18/67
Central Station Verification	352-14-19-26	
SWS Failed Turn-On	352-14-44-15	
SIDE IST	352-18-25-47	12/18/67
SIDE Tripped Over	352-22-50-00	
LSM IST	352-22-48-07	
PSE IST	353-02-13-00	12/19/67
Lunar Night IST		
Thermal Equilibrium Reached	354-04-00-00	12/20/67
Central Station Verification	354-06-42-33	
SWS Failed Turn-On	354-07-00-00	
LSM IST	354-11-06-00	
SIDE IST Started	355-04-52-10	12/21/67
PSE IST - Abort Per Engineering Dept.		
Vacuum Shut Down		
ALSEP Turned Off	355-04-58-20	
Shut Down of IPU	355-06-00-00	
System Returned to Ambient Pressure and Temperature	355-08-15-00	

Event	ALSEP Clock Reading	Calendar Day
ALSEP Post-Test Ambient IST		
Central Station Verification	355-13-51-30	12-21-67
SWS - Abort		
SIDE IST Completed	355-16-35-36	
PSE IST Completed	355-19-17-05	
LSM IST Completed	355-20-44-40	
Proto Thermal Vacuum Test Completed	355-21-00-00	

4.1.1 Unit Status - Table 4.2, which follows, is a chronological event log that lists each command and time of transmission regarding the Data Processors X & Y, Back-up Heater, Transmitters A & B, PDM's 1 & 2, PCU's 1 & 2, Dust Detector and all experiment power commands during the Prototype A Thermal Vacuum Test.

TABLE 4-2

UNIT STATUS DURING PROTOTYPE A THERMAL VACUUM TEST

<table>
<tr><th>Data Processor Y</th><th>Data Processor X</th><th rowspan="2">Back-Up Heater
On = 024
Off = 025</th><th colspan="2">Transmitter On = 13, Off = 14</th></tr>
<tr><th>On = 035</th><th>On = 034</th><th>Transmitter A
Select = 012</th><th>Transmitter B
Select - 015</th></tr>
<tr><td>349-17-32-40</td><td>------------</td><td>349-19-23-50 ON</td><td>------------</td><td>349-17-32-40</td></tr>
<tr><td>------------</td><td>349-18-22-32</td><td>349-19-26-48 OFF</td><td>349-18-32-12</td><td>------------</td></tr>
<tr><td>349-18-31-11</td><td>------------</td><td>349-21-21-59 ON</td><td>------------</td><td>349-18-17-59</td></tr>
<tr><td>------------</td><td>352-13-41-34</td><td>349-21-22-57 OFF</td><td></td><td></td></tr>
<tr><td>349-13-49-31</td><td>------------</td><td>349-22-29-44 ON</td><td colspan="2">349 - 18 - 20 - 15 Off</td></tr>
<tr><td></td><td></td><td>349-22-29-51 OFF</td><td></td><td></td></tr>
<tr><td></td><td></td><td>351-06-26-16 OFF</td><td>------------</td><td>349-18-20-36</td></tr>
<tr><td></td><td></td><td>351-06-26-24 ON</td><td></td><td></td></tr>
<tr><td></td><td></td><td>353-19-50-24 OFF</td><td colspan="2">351 - 06 - 39 - 27 Off</td></tr>
<tr><td></td><td></td><td>353-19-54-35 ON</td><td></td><td></td></tr>
<tr><td></td><td></td><td>353-19-54-35 ON</td><td>351-7-44-01</td><td>------------</td></tr>
<tr><td></td><td></td><td>353-21-37-40 T'STAT</td><td>------------</td><td>351-07-49-57</td></tr>
<tr><td></td><td></td><td>353-21-39-01 OFF</td><td>351-07-56-31</td><td>------------</td></tr>
<tr><td></td><td></td><td>354-06-23-04 ON</td><td>------------</td><td>352-13-20-32</td></tr>
<tr><td></td><td></td><td>354-06-25-07 OFF</td><td>352-13-27-33</td><td>------------</td></tr>
<tr><td></td><td></td><td>354-06-26-20 ON</td><td></td><td></td></tr>
<tr><td></td><td></td><td>354-06-31-10 OFF</td><td colspan="2">352 - 13 - 32 - 36 Off</td></tr>
<tr><td></td><td></td><td>354-06-43-41 ON</td><td></td><td></td></tr>
<tr><td></td><td></td><td>354-06-46-00 OFF</td><td>352-13-33-39</td><td>------------</td></tr>
<tr><td></td><td></td><td>354-09-45-55 ON</td><td>------------</td><td>354-05-16-53</td></tr>
<tr><td></td><td></td><td>354-14-00-40 OFF</td><td>354-05-22-08</td><td>------------</td></tr>
<tr><td></td><td></td><td>354-14-10-03 ON</td><td>-------------</td><td>354-05-28-07</td></tr>
<tr><td></td><td></td><td></td><td>354-05-31-00</td><td>------------</td></tr>
<tr><td></td><td></td><td></td><td>------------</td><td>354-05-35-43</td></tr>
<tr><td></td><td></td><td></td><td>354-05-36-42</td><td>------------</td></tr>
<tr><td></td><td></td><td></td><td>------------</td><td>354-08-44-15</td></tr>
<tr><td></td><td></td><td></td><td>354-09-54-18</td><td>------------</td></tr>
</table>

TABLE 4-2 (CONT.)

PDM 1 On = 017 Off = 021	PDM 2 On = 022 Off = 023	PCU 1 On = 060	PCU 2 On = 062	Dust Detector On = 027 Off = 031
349-18-40-53 ON	349-19-19-22 ON	349-17-32-40	--------------	349-19-29-30 ON
-19-12-47 OFF	-19-20-47 OFF	------------	349-19-34-09	-19-31-09 OFF
350-19-46-36 ON	354-01-02-49 ON	-19-38-33	------------	352-14-14-18 ON
-21-21-32 OFF	-01-03-22 OFF	------------	351-06-39-43	-14-19-26 OFF
352-07-46-44 ON	-06-19-28 ON	------------		354-06-37-00 ON
353-19-53-23 OFF	-06-21-13 OFF	351-07-43-05	------------	-06-42-33 OFF
354-01-06-42 ON		------------	352-14-10-20	
-01-07-07 OFF		352-14-12-01	------------	
-06-08-01 ON		------------	354-06-32-00	
-06-17-39 OFF		354-06-38-00	------------	
		------------	-15-18-03	
		-15-47-39	------------	

TABLE 4-2 (CONT.)

PSE	LSM	SWE	SIDE BB = Blow Breaker RO = Ripple Off		
ON = 036 SB = 037 OFF = 041	ON = 042 SB = 043 OFF = 044	ON = 045 SB = 046 OFF = 050	ON = 052 SB = 053 OFF = 054	CCGE High Volts	Channeltron
350-2-58-41 ON	350-07-06-00 ON	349-20-12-51 ON	349-22-18-05 ON	ON	ON
350-6-12-47 SB	350-07-07-39 OFF	(No Lock)		349-22-18-45 OFF	349-22-18-57 OFF
350-6-13-44 OFF	350-07-07-53 ON	349-20-14-21	349-23-18-55 SB		
350-6-14-39 ON	350-07-09-44 OFF	349-20-17-23 ON	349-23-20-14 ON	ON	ON
350-9-17-40 SB	350-07-10-06 ON	349-20-18-33 SB		350-01-38-20 OFF	349-23-58-30 OFF
350-9-31-12 ON	350-07-10-45 OFF	349-20-18-06 ON	350-02-00-00 SB		
351-6-39-20 SB	350-07-11-36 ON	(7 Attempts)	350-02-01-21 OFF		
351-9-26-12 ON	350-08-32-06 SB	349-21-11-08 OFF	350-02-02-20 ON	ON	ON
353-14-58-22 Armed	350-08-33-10 OFF	349-21-51-35 ON		350-02-10-33 OFF	350-02-10-55 OFF
353-15-17-42 SB	350-08-34-10 ON	(3 Attempts)	350-09-17-27 SB		
353-15-48-10 ON	350-09-17-33 SB	349-21-33-32 OFF	350-09-51-51 ON	ON	ON
	350-09-31-39 ON	350-09-11-35 ON		350-09-54-46 OFF	350-09-55-15 OFF
	351-06-39-15 SB	(10 Attempts)	351-06-39-09 SB		
	351-08-15-03 ON	350-09-25-21 SB	351-08-32-58 ON	ON	ON
	352-14-43-50 SB	350-17-08-59 OFF	351-08-37-37 BB		
	352-14-51-17 ON	350-17-09-29 ON	351-09-41-44 ON	ON	ON
	352-22-45-56 SB	350-17-10-46 SB	351-10-05-03 BB		
	352-22-47-15 OFF	351-06-39-03 SB	351-10-23-06 ON	ON	ON
	352-22-48-07 ON	351-13-18-31 ON	351-10-05-08 BB		
	353-01-54-20 SB	(2 Attempts)	351-10-45-32 ON	ON	ON
	353-01-54-37 OFF	351-13-20-24 SB		351-11-41-01 OFF	351-11-42-09 OFF
	353-01-54-50 ON	351-14-03-50 OFF	351-19-44-19 SB		
		(4 Attempts)	351-19-44-22 ON	ON	ON
		351-14-09-34 SB		351-19-44-49 OFF	351-19-45-00 OFF
		352-14-14-15 ON	SIDE Fell 22-50		
		(2 Attempts)	352-07-47-12 SB		
		352-14-47-31 SB	352-15-30-51 ON	ON	ON
		353-07-22-18 ON		352-15-46-03 OFF	352-15-51-07 OFF
		(10 Attempts)	352-17-45-57 BB		
		354-01-59-43 OFF	352-18-08-05 ON	ON	ON
		(10 Attempts)		352-18-14-09 OFF	352-18-09-06 OFF
		354-02-05-21 SB	352-18-15-18 BB		
		354-06-52-24 ON	352-18-18-10 ON	ON	ON
		(2 Attempts)	352-18-25-02 SB		
		354-06-55-31-SB	352-18-25-57 OFF		

TABLE 4-2 (CONT.)

PSE ON = 036 SB = 037 OFF = 041	LSM ON = 042 SB = 043 OFF = 044	SWE ON = 045 SB = 046 OFF = 050	SIDE BB = Blow Breaker RO = Ripple Off		
			ON = 052 SB = 046 OFF = 054	CCGE High Volts	Channeltron
			353-03-42-55 ON	ON	ON
			353-03-44-50 ON	ON	ON
				353-3-46-03 OFF	353-3-46-30 OFF
			354-04-52-35 SB		
			354-4-53-35 ON	ON	ON
			354-4-54-25 BB		
			354-4-56-57 ON	ON	ON
			354-4-58-10 BB		
			354-4-59-15 ON	ON	ON
			354-5-06-30 BB		
			354-5-06-49 ON	ON	ON
			354-8-23-22 BB		
			354-8-25-01 ON	ON	ON
			354-8-41-35 SB		
			354-13-59-08 ON	ON	ON
			354-13-59-48 RO		
			354-14-02-19 ON	ON	ON
			354-14-09-41 SB		

4.2. Lunar environments. - The following discussion describes the results of the lunar environmental parameters simulated during the Prototype "A" Thermal Vacuum Test. These parameters included, (1) lunar surface temperatures, (2) cold sink of deep space, (3) pressure, and (4) radiant solar/thermal energy.

4.2.1 Lunar surface temperatures. - The temperature performance of the simulated lunar surfaces was extremely good throughout the test. The average surface temperatures for each test phase were all within the required test specification of -300°F ± 20° for lunar night and + 250°F ± 10° for lunar noon. See Figure 4.2.1-1. Irregularities are explained by notes on the figure. During the lunar night tests, both the 14' x 14' and the LSM lunar surfaces were at -303°F, the temperature of liquid nitrogen. During the lunar noon tests, the average temperature of the 14' x 14' lunar surface was +248°F and that of the LSM lunar surface was +244°F. The damped temperature extremes expected under the PSE thermal shroud were to be +10°F and +40°F respectively, for lunar night and lunar noon. These values were changed during the performance of the test several times in order to gain added engineering thermal data. However, for each lunar surface temperature selected by Engineering, the average temperature varied by no more than ± 2°F with respect to time and by no more than ± 1/2°F in uniformity under the seismometer.

● Lamps Missing

▲ Inoperative Thermocouple

■ Thermocouple Probably Not Affixed Properly

	203 -303	---- ▲ ----	239 -303	● 213 -303	---- ▲ ----	
236 -303	265 -303	245 -303	264 -303	270 -303	268 -302	248 -302
242 -302	264 -302	237 -302	252 -302	271 -300	264 -302	242 -302
■ 216 -303	■ 272 -303	■ 248 -301	■ 246 -301	■ 236 -303	■ 221 -303	---- ▲ ----
230 -303	255 -303	248 -302	286 -303	257 -302	254 -303	217 -303
239 -303	262 -303	278 -303	328 -303	250 -303	256 -303	---- ▲ ----
	250 -303	245 -303	259 -303	● 222 -302	241 -303	

Figure 4.2.1-1 Lunar Surface Temperatures

4.2.2 Cold sink of deep space. - The cold sink of deep space was simulated with the chamber's liquid nitrogen cold shroud. The average temperature of this shroud remained at -265°F and lower for the duration of the test. This average temperature, which is slightly warmer than the test specification of -300°F ± 20°F, was due, primarily, to a few random cold shroud panels. These panels never received an adequate flow of liquid nitrogen during the test. It should be emphasized, however, that the cold shroud's arch, which provides the primary view of space for the ALSEP subsystems, maintained an average temperature of -290°F or less throughout the test. The effect of the few, random "warm" panels of the chamber's cold shroud would have a very minimal effect on the ALSEP subsystems.

4.2.3 Pressure. - The performance of the chamber's vacuum system was excellent throughout the test. The vacuum specification of 5×10^{-6} torr was reached approximately 15 hours after pumpdown initiation and was then maintained for the duration of the test. See Figure 4.2.3-1 for a pressure profile of the chamber during the test. The only vacuum system difficuly occurring during the test was due to a minute, high pressure leak in the LN_2 line pressure for the lunar surfaces to near ambient pressure. This pressure reduction, reduced the leak sufficiently to enable the chamber's pumping system to maintain an internal chamber pressure of approximately 2×10^{-6} torr and less for the duration of the lunar night tests.

4.2.4 Radiant solar/thermal energy. - The incident solar radiation was simulated with several arrays of infrared lamps; each ALSEP subsystem having its own, individually controlled array. Each array was provided with a matched set of GE 1000-T3 infrared lamps. These lamps were arrayed so as to provide the best possible uniformity patterns over the irradiated surfaces (approximately ±5% uniformity achieved). The Lunar Surface Magnetometer louvers were positioned such that IR radiation was directed into the experiment so baffles will be placed over the IR lamps during future tests to direct the IR radiation. The only significant problem arising during the test performance was due to a power supply drift. This problem was examined and found to be due to: (1) an interaction between high current power supplies and (2) a controller instability associated with low voltage operations. The first cause was alleviated by changing the operating procedure and the latter, by raising the operating voltage for the IR lamp arrays.

Because of the spectral mismatch between infrared radiation sources and a true solar spectrum, the level of energy absorbed by each irradiated surface was monitored, rather than the incident energy. Special radiometers were built and calibrated to read the absorbed energy for each ALSEP subsystem.

There was a problem associated with the determination of the background radiation level for the radiometer used with ALSEP Pallet No. 2. During

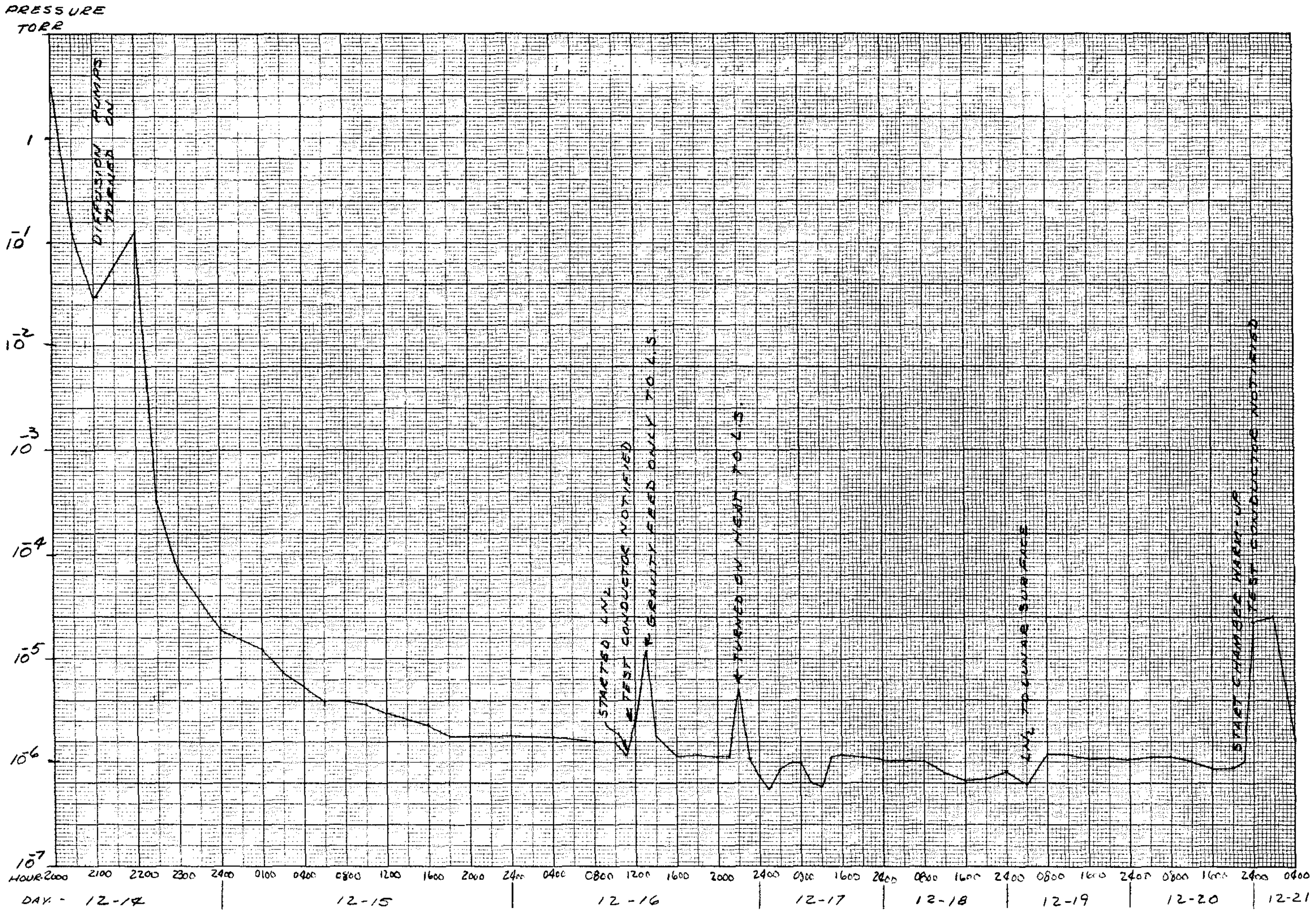


Figure 4.2.3-1 Chamber Pressure During Test

the performance of the environmental reference test, the near-zero thermal background radiation inside the chamber was measured. These data provided the "zero-level" reading or the "zero-offset" reading for the radiometer. This data did not, however, include the radiation "seen" by the Pallet No. 2 radiometer from the RTG, because the RTG was not energized at the time the background measurements were made. Therefore, the true radiometer zero-offset was in error by that amount of radiated thermal energy coming from the RTG, An attempt to calculate this energy error was made during the test and the IR lamp array output adjusted accordingly. The test procedure has been changed so this problem will not occur in future tests.

4.3 System electrical performance. - The ALSEP Prototype "A" system integrity was demonstrated during the Thermal Vacuum Test. Although some malfunctions occurred within the subsystems, no malfunctions were attributed to a lack of balance or integrity between the subsystems.

4.3.1 Power. - The test conductor was able to control power readily and sufficient power was available at all times for electrical and thermal control. Power dumps were adequate for maintaining regulation. Changeover from RTG simulator to IPU was achieved smoothly and operation was as predicted.

4.3.2 Subsystem interaction. - No interaction was observed between experiments during the test. Malfunctions in SWS and SIDE caused the central station to malfunction but it resumed normal operation following the interruption.

4.3.3 System design improvements. - All design improvements are discussed in other sections of this report since each improvement is unique to subsystem level and not system level. No system level defects were found in the ALSEP system.

4.4 Central Station thermal performance. - The primary and secondary Central Station thermal test objectives for the prototype A tests were:

Primary

Design verification of ALSEP Central Station thermal control under simulated lunar day and night conditions, confirming established limits and present predicted values.

Secondary

1.) Determine the internal and external temperature gradients and levels on the Central Station radiator plate, primary structure, super-insulation, sunshield, electronic components and cables for simulated lunar day and night environment.

2.) Assess the heat leaks into and out of the Central Station due to radiation and conduction from specular reflector, cables, thermal plate and structure for lunar day/night conditions.

3.) Determine the temperature gradients between the Central Station thermal plate and internal electronic components to provide comparison with pre-test predicted levels.

4.) Evaluate the overall performance of the Central Station thermal design to maintain 125^{o} temperature swing at Proto A Experiment dissipation levels and 63 watt RTG input power.

4.4.1 Test results. - This section discusses the results of the Proto A Thermal Vacuum (T/V) tests for the Central Station (C/S) lunar day and night testing. Figure 4.4-1 shows the lunar day/night temperature results for the Proto A primary structure, thermal bag, thermal plate, dump resistors and sunshield. Temperature's values, shown in small boxes on Figure 4.4-1, are predicted while other temperatures noted are average recorded values. Sunshield temperatures ranged from 40 to 42°F as compared to a predicted value of 42°F. C/S primary structure temperatures ranged from 165°F to 185°F for the lunar day and -133°F to -161°F for night as compared to predicted values of 148°F and -125°F respectively. The maximum PCU dump resistor plate temperature observed was 350°F at a PCU reserve power reading of 29 watts.

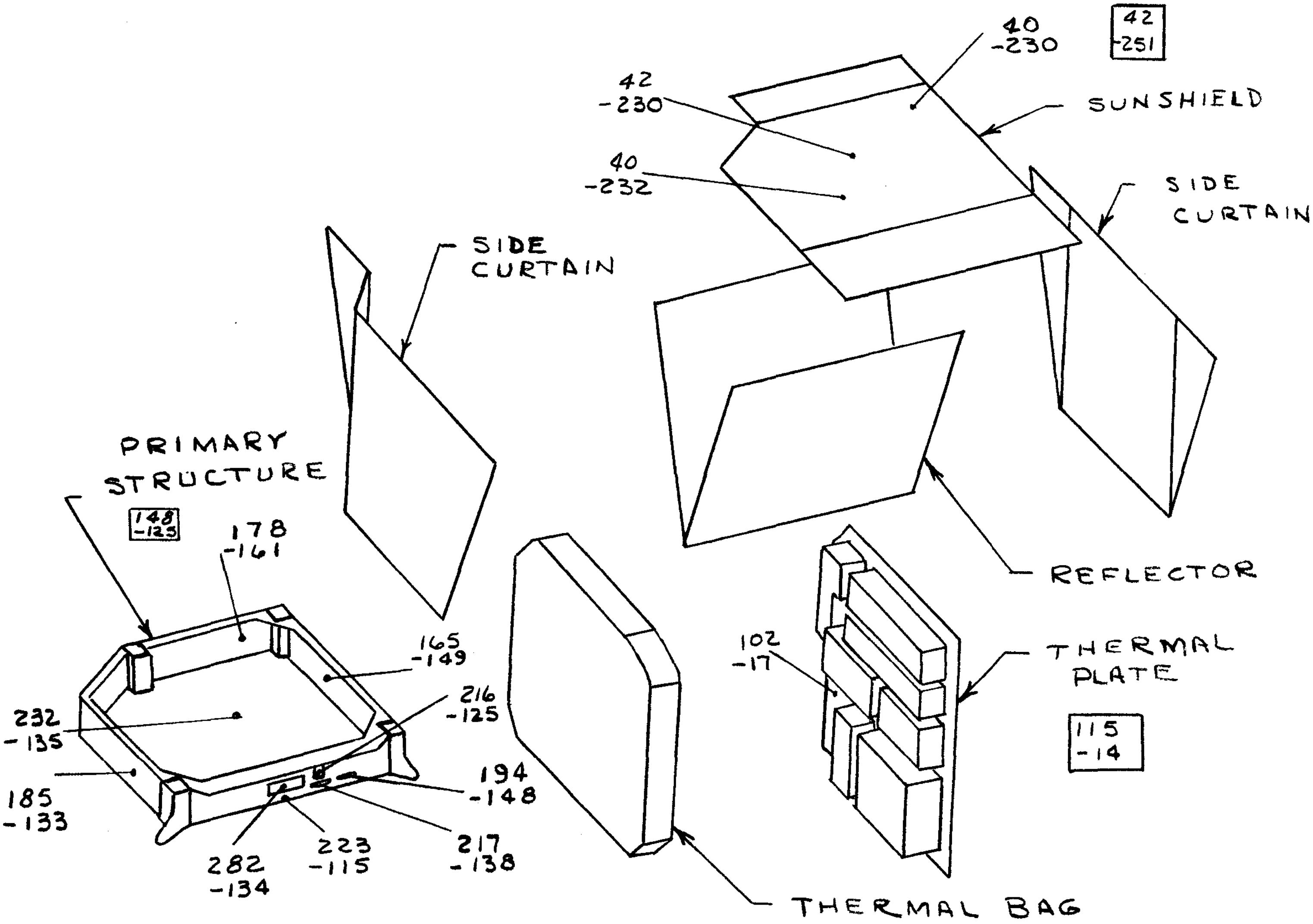


Figure 4.4-1 Temperature Results on Subpackage No. 1
For Lunar Noon and Lunar Night

4.4.1.1 Thermal plate. - The time history of the ALSEP Central Station thermal plate temperature results from the Prototype tests are shown in Figure 4.4-2. The maximum steady state temperatures observed on the thermal plate were as expected across from the Power Conditioning Unit (PCU). Temperatures of 135°F for the pre-test ambient IST and 114°F for the lunar noon vacuum test were obtained.

The Central Station ten watt backup heater was initiated after thermal stabilization for lunar night at 09:45 on 20 December 1967. The average Central Station component base plate temperature increased from -15°F to +5°F during the time period when the heater was activated. The ten-watt heater under normal operation is thermostatically controlled on when the thermal plate temperature reaches -10°F and switches off at 0°F. For the steady portion of the lunar night test the heater was intentionally commanded to the off position prior to the above activation in order to obtain the Central Station passive temperature swing of the overall system.

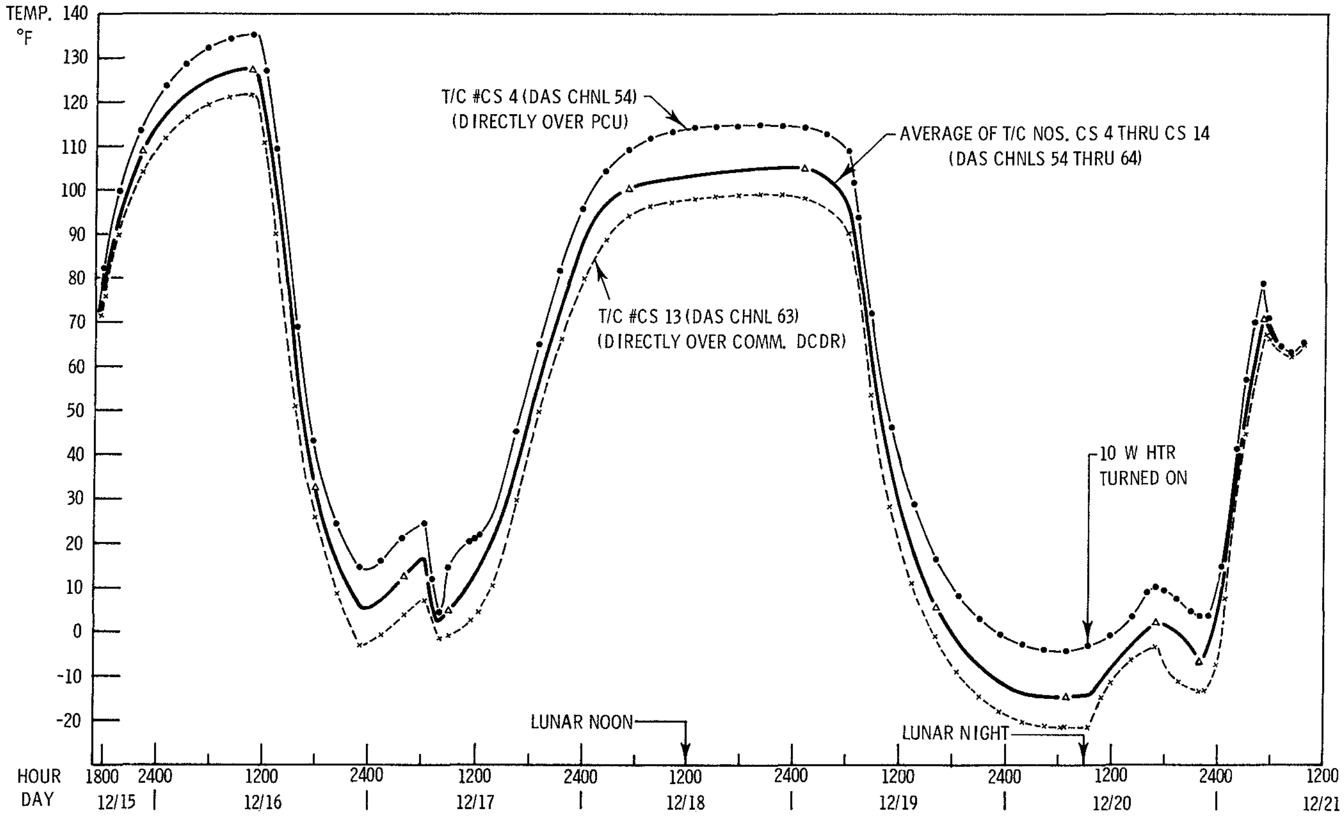


Figure 4.4-2 Central Station Thermal Plate Temperature

4.4.1.2 Primary structure. - The Central Station primary structure temperature profiles for the Prototype test are shown in Figures 4.4-3 and 4.4-4. The sides of the Central Station primary structure ranged from 165° to 190°F during lunar day and -133°F to -172°F during lunar night. The structure temperatures as seen in Figure 4.4-3 were dependent on the reserve power being dissipated on the front panel of the Central Station. The average temperature drop across the thermal isolation springs between the thermal plate and the primary structure was 77°F and 144°F during lunar day and lunar night respectively. The temperatures of the reserve power resistor panel, the dump power resistor, the RTG connector and the Central Station sunshield during the prototype tests are described in Figure 4.4-4. The large fluctuation in the Central Station primary structure panel temperature is caused by the variation in the PCU reserve power dissipation external to the Central Station.

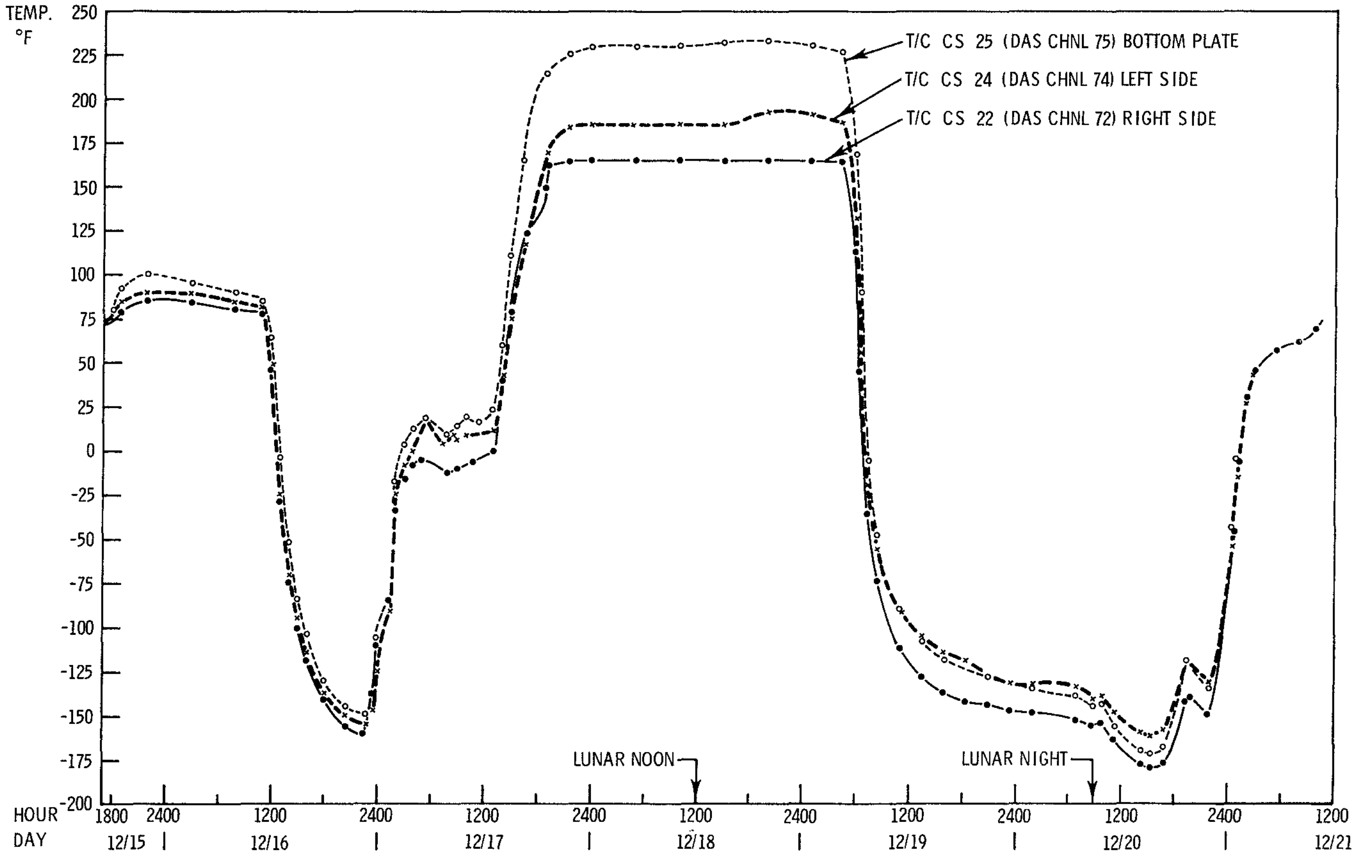


Figure 4.4-3 Central Station Structure Temperatures

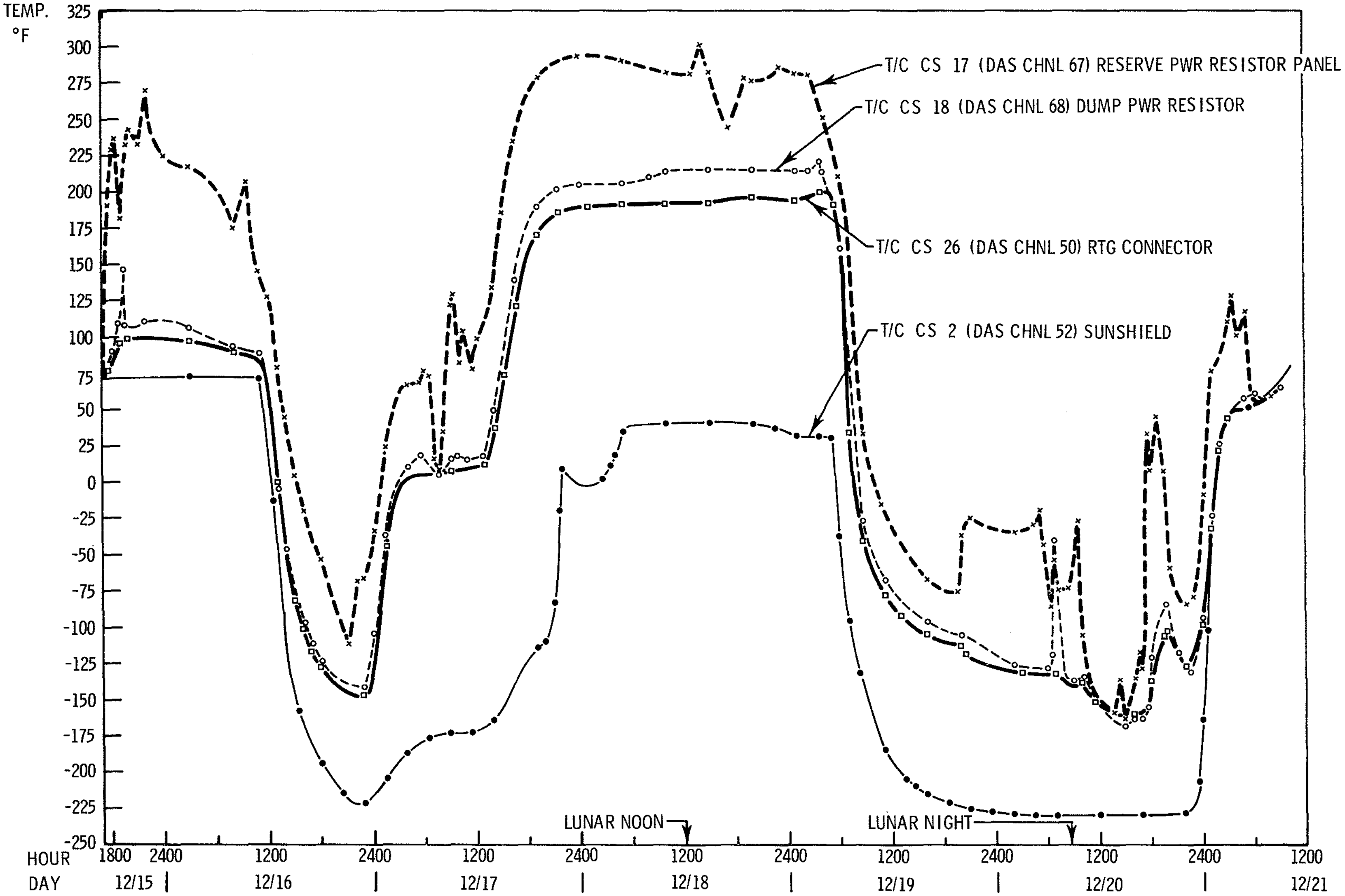


Figure 4.4-4 Central Station Structure Temperatures

4.4.1.3 Central Station components. - Figure 4.4-5 summarizes the component temperatures inside the Central Station for the Proto A lunar noon/night tests. The maximum component temperature observed inside C/S was the PCU transistor at 157°F. All other components temperatures ranged approximately from 1°F to 20°F above the base plate temperature and were within the operating range predicted from pre-test component acceptance tests results.

Component	Component Base Temp, °F Day/Night		Component Temp, °F Day/Night		Delta Temp, °F Day/Night		Predicted Delta Temp, °F Day/Night
1. PCU Transistor #1	114	-5	157	38	43	43	60
2. PCU Transistor #2	114	-5	124	5	10	10	10
3. Transmitter A	105	-14	117	10	13	18	20
4. Comm. Receiver	103	-19	110	-8	5	6	5
5. PDU	112	-10	129	10	20	21	20
6. Command Decoder	98	-22	104	16	5	6	5
7. Digital Data Processor	103	-15	108	14	5	2	5
8. Analog Multiplexer	106	-17	114	-6	11	16	20

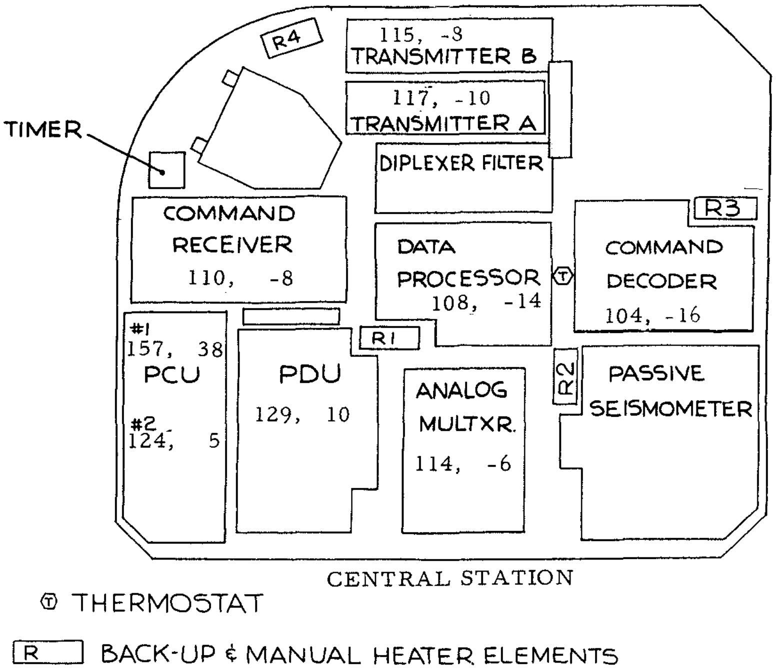


Figure 4.4-5 Component Temperature Results
For Lunar Noon and Lunar Night

4.4.1.4 Radiator temperatures. - Figure 4.4-6 shows the results of the measured C/S radiation plate steady-state temperature from the Proto A lunar noon/night tests. The average lunar noon temperature for the C/S thermal plate was 105°F and -15°F for lunar night, thereby having an overall swing of 120°F. These temperatures compared favorably with the analytical predicted average C/S thermal plate temperatures of 115°F for day, -14°F for night and an overall swing of 129°F. The temperature gradients on the thermal plate ranged approximately ± 7°F from the average values. Figures 4.4-7 and 4.4-8 show a comparison of the predicted versus the measured test result values for the lunar noon and lunar night cases, respectively. The predicted value appears first and is followed by the measured value.

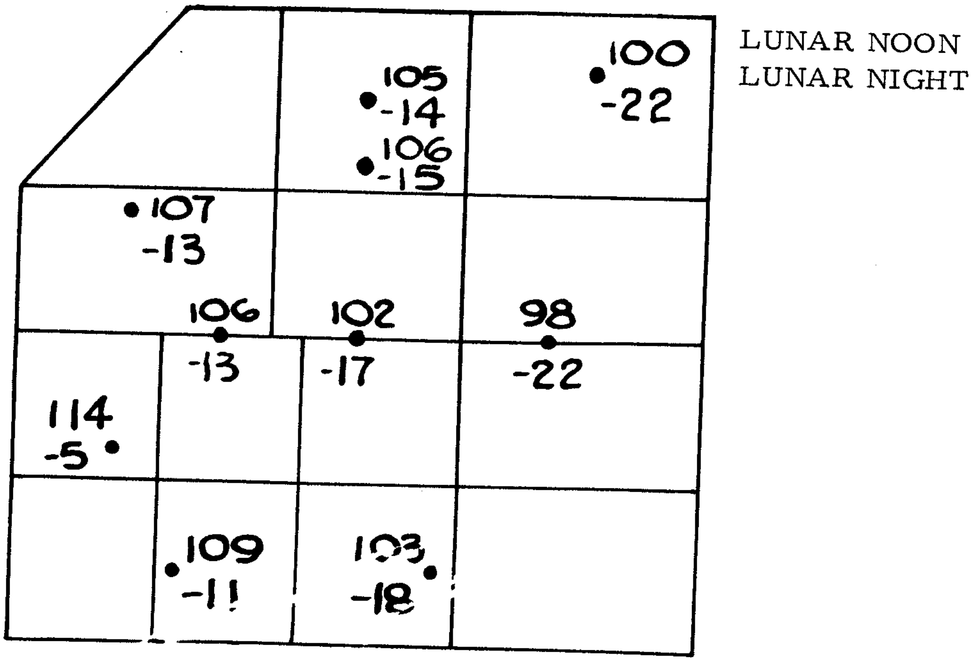
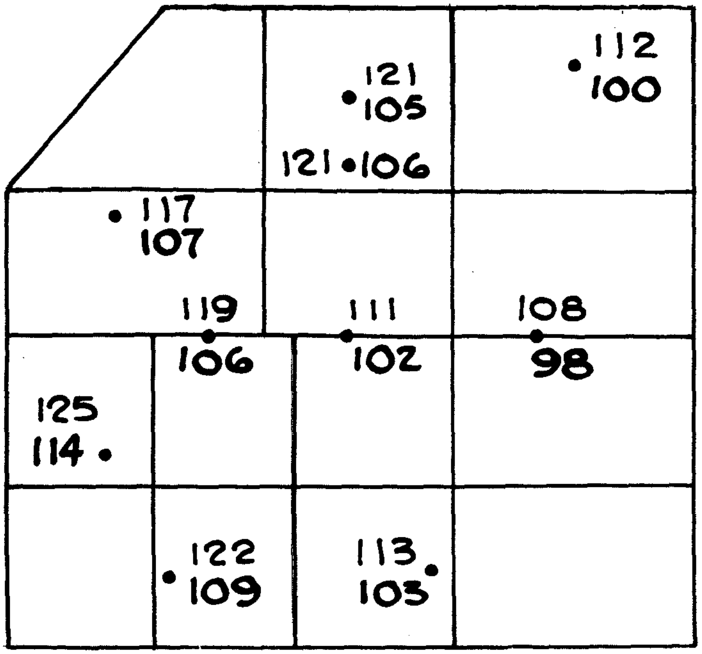
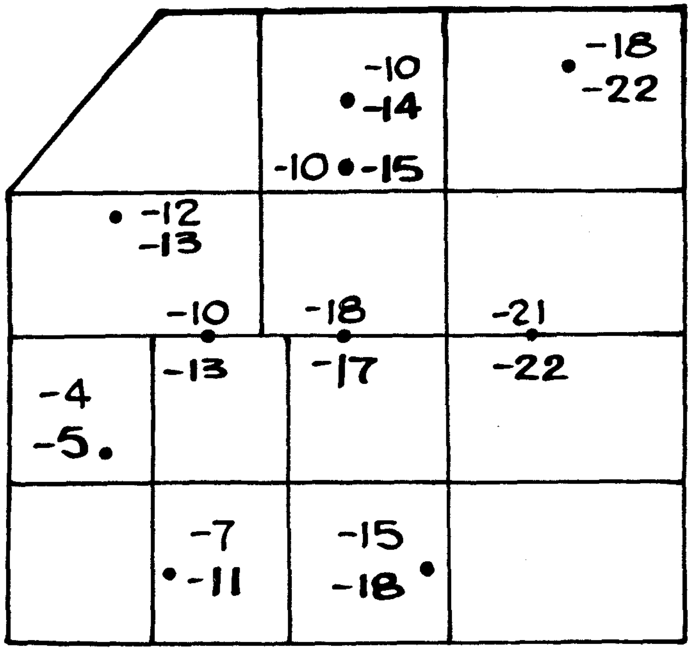


Figure 4.4-6 Measured Radiator Temperatures for Lunar Noon and Lunar Night



$T_{pred.}$ = 115°F
$T_{meas.}$ = 105°F

Figure 4.4-7 Predicted vs Measured Radiator Temperatures for Lunar Noon



$T_{pred.}$ = 14°F
$T_{meas.}$ = 15°F

Figure 4.4-8 Predicted vs Measured Radiator Temperatures for Lunar Night

4.4.1.5 Thermal balance. - Figure 4.4-9 summarizes the noon/night C/S calculated heat balance from the thermal plate to surrounding sink conditions. As noted, electrical dissipation of the C/S electronics was 35.1 ± 1 watts during both lunar noon and lunar night testing. The average lunar noon reading for each component is shown first and the lunar night reading is below. A plus (+) sign means "watts into the radiator" and a minus (-) sign means "watts from the radiator".

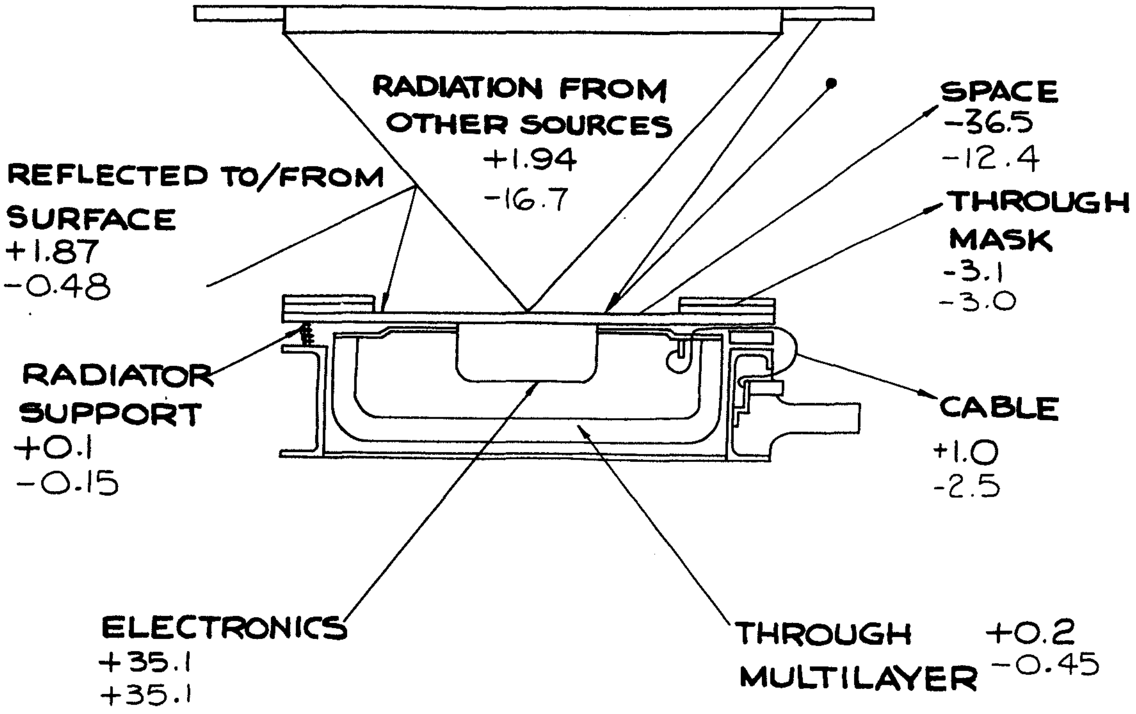


Figure 4.4-9 Central Station Heat Balance For Lunar Noon and Lunar Night

Figure 4.4-10 shows the post-test thermal analysis correlation for the C/S together with the pre-test predicted values. Initial pre-test predictions indicated a passive temperature swing of 147°F for the noon/night conditions. From the BxA post-test correlation of the test results, the C/S thermal model was modified to bring the pre-test assumptions in line with actual chamber conditions. The post-test correlation changes included a reduction in view factors to the lunar surface, elimination of the lunar surface solar impingement, an increase in the reflector specular reflectivity, and modification of the Proto A actual component power dissipation levels. The final post-test analytical temperature predicted range was 129°F which compared favorably with the actual test results of 120°F.

ORIGINAL ASSUMPTION	CHANGE	T_D (°F)	T_N (°F)	ΔT_{D-N} (°F)	$\Delta(\Delta T_{D-N})$ (°F)
• INITIAL CHAMBER PREDICTION	--------	131	-16	147	---
• VIEW FACTORS TO LUNAR SURFACE	REDUCE TO REALISTIC VALUES	125	-16	141	6
• SOLAR IMPINGEMENT ON MOON	ACCOUNT FOR NO SOLAR	121	-16	137	4
• REFLECTOR $\rho_s = 0.8$	$\rho_s = 0.9$	117	-17	134	3
• $Q_D = 36$ W, $Q_N = 34$ W	$Q_D = 35.1$ W, $Q_N = 35.1$ W	115	-14	129	5
COMPARISON WITH TEST					
FINAL PREDICTION		115	-14	129	
PROTO "A" TEST RESULTS		105	-15	120	

Figure 4.4-10 Post-Test Correlation of Test Results and Predictions

4.4.1.6 Subpackage No. 2 - Figures 4.4-11 and 4.4-12 illustrate the temperature distribution on subpackage No. 2. The surface temperature of Pallet 2 below the RTG ranged from a maximum of 375° F during lunar noon to 177°F during lunar night compared to predicted temperature limits of 394°F and 187°F respectively. The differences between pretest predictions and the Prototype test results are attributed to the lower RTG power setting of 1400 watts instead of the 1500 watt RTG dissipation used in the analyses.

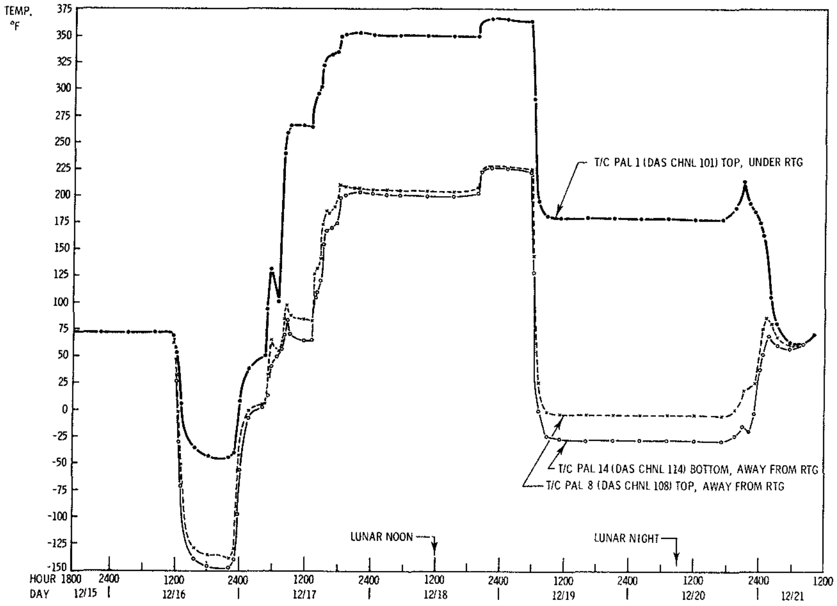


Figure 4.4-11 Temperature Distribution on Pallet 2

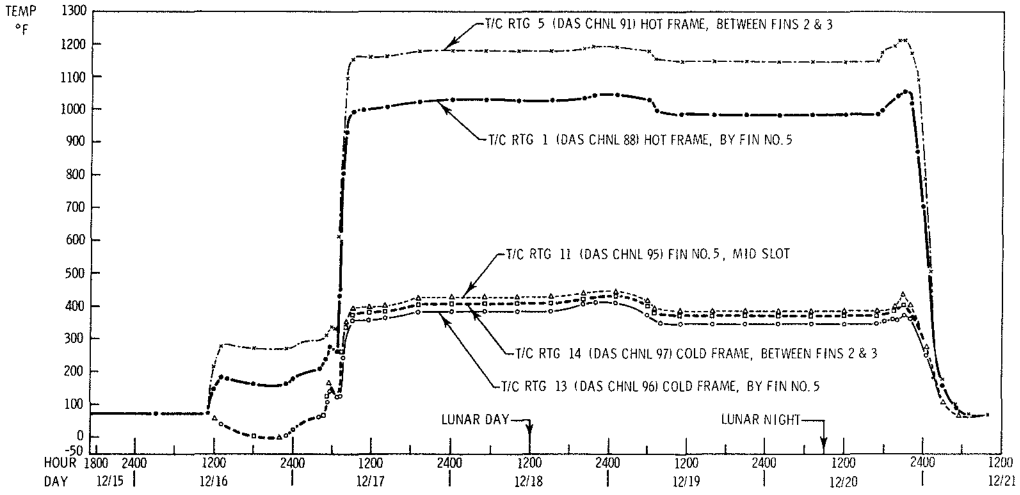


Figure 4.4-12 Temperature Distribution on the RTG

4.4.2 Central Station thermal control design improvements. - Figure 4.4-13 lists the C/S thermal design improvements and changes for the Qual SA design. Preliminary thermal studies completed on the C/S during January 1968 have shown that a 15°F to 20°F improvement can be obtained by removing the current awning and the attaching side curtains. This modification together with the deletion of the thermal isolation blocks (net change -12°F to -15°F) will be incorporated into the Qual SA model.

	IMPROVEMENT IN TEMPERATURE SWING
● REMOVE ISOLATORS	-3° TO -5°F
● REMOVE AWNING AND MODIFY RADIATOR MASK	15° TO 20°F
● NET IMPROVEMENT	12° TO 15°F

Figure 4.4-13 Central Station Thermal Control Improvements and Changes

Additional design changes for Qual SA and subsequent ALSEP C/S models include the addition of both five and ten watt commandable heaters to the C/S thermal plate, the increase in the PCU regulator range from 40 to 55 watts, and the revision of the C/S super-insulation radiator mask width from six to seven inches to accommodate the wider range in C/S internal power dissipation.

Figure 4.4-14 summarizes the Proto A and Qual SA Central Station temperature swing as a function of the RTG power level, the PCU loads, the current and revised design with both commandable dumps and active heater power. The revised Qual SA design with new awnings and Proto A experiment loads is predicted to operate on the moon within the specification allowable of 125°F. With the change in experiment nighttime power loads by eight watts from Proto to Qual, the total temperature swing for Qual, Flight 1, and Flight 2 is predicted to increase to a maximum of 148°F for a 63 to 74-watt RTG power range and a 40-watt PCU regulator range. The Central Station temperature swing can be reduced by active thermal control to a maximum value of 132°F through the use of commandable dumps during the day and the +10 watt backup heater at night. The use of the 10-watt heater results in the ripple off of at least one or more experiments depending on the RTG input power, due to the already high 51-watt PCU nighttime loads. The ripple off of the experiment(s) occurs due to the reserve power being lower than the ten-watt minimum value required. As shown in Figure 4.4-14 the use of a 68-watt RTG reduces the swing to 140°F for the (passive) case and 124°F for the active case.

				Temperature Swing, °F		
Model	Location	Power, W	Loads	Passive	Active With Daytime Comm Dumps	Active with Daytime Dumps and Nighttime 10 W Heater
Proto A	Chamber	62	Proto	120	---	100
Proto A	Moon	62	Proto	140	130	115
Qual SA	Moon ①	63	Proto	125	115	100
Qual SA	Moon ①	63	Qual	148	137	132 ②
Qual SA	Moon ①	68	Qual	140	130	124 ③
Qual SA	Moon ①	74	Qual	129	121	110

① Qual SA with revised awning design and Proto A loads.

② +10 W heater command ripples off SIDE and S/W. Reserve power ∼3 watts.

③ +10 W heater command ripples off SIDE. Reserve power ∼8 watts.

Figure 4.4-14 Comparison of ALSEP Proto "A" C/S Temperature Range vs Predicted Proto "A" And Qual "A" Lunar Performance

Figure 4.4-15 shows the PCU power dissipation inside the C/S versus PCU electrical load for RTG input powers of 63, 68 and 74 watts and a 40 W regulator range. As seen from Figure 4.4-15, any increase in nighttime PCU loads at high total levels reduces the total power dissipated inside the C/S almost proportionally for low RTG power levels.

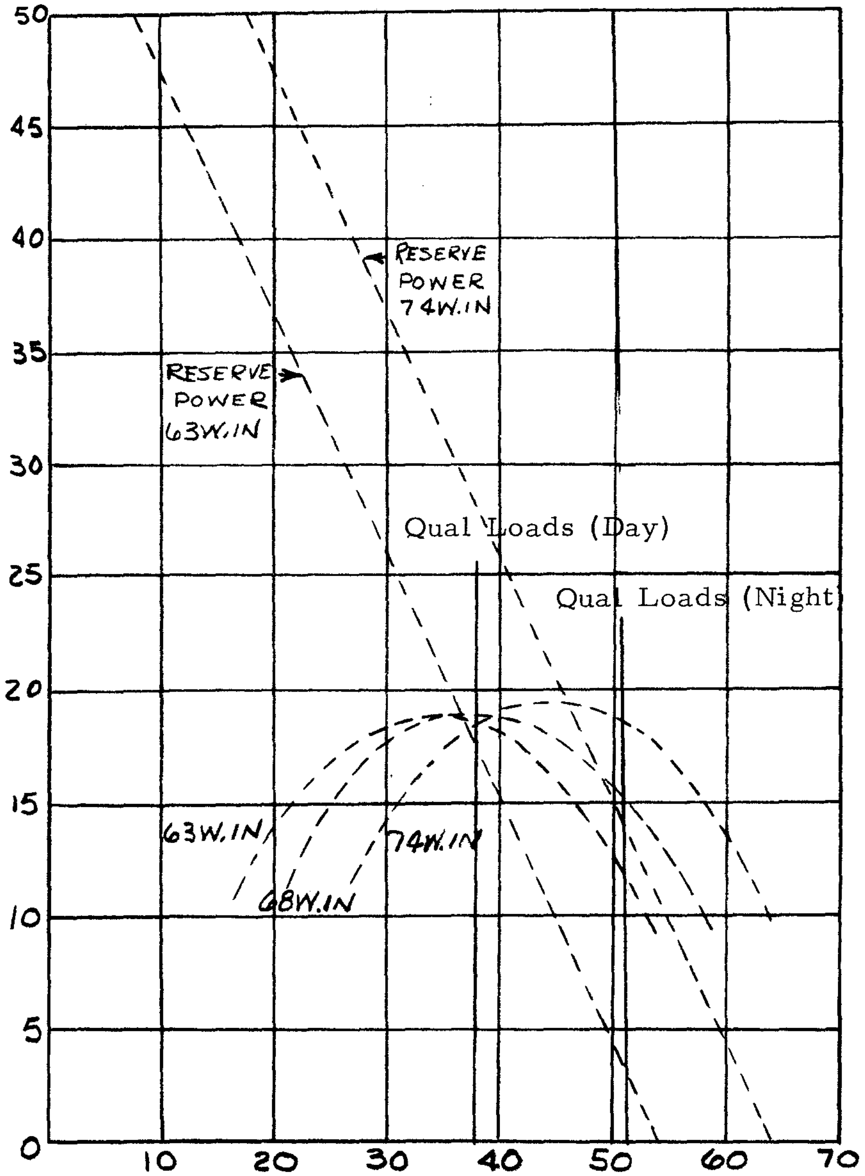


Figure 4.4-15 PCU Power Dissipated Inside C/S Station vs Load on PCU

Figure 4.4-16 summarizes the predicted temperature range for the improved Proto A system, Qual SA, and Flights 1, 2, 3 and 4. The temperature swing for Flights 3 and 4 does not appear at the present time to be a problem unless the nighttime experiment power increases from today's current estimates. Flights 1 and 2 temperature swing can be reduced by increasing the RTG power above 63 watts with a predicted passive swing of 129°F for a 74 W generator. The off-loading of one experiment for Flights 1 and 2 brings the passive range down to approximately 130°F due to the overall reduction in total PCU experiment load and the resultant increase in C/S nighttime thermal dissipation.

	Specification	
Design Action (Test/Flight Model)	Maximum Temp. Range Passive, °F	Maximum Temp. Range Active, °F
● IMPROVED PROTO A C/S DESIGN WITH 63 TO 74 W RTG AND PROTO EXPERIMENT LOADS (38/43)	0 TO 125	0 TO 100
● IMPROVED QUAL A, FLIGHTS 1 AND 2 DESIGN WITH 63 TO 74 W RTG AND QUAL SA EXPERIMENT LOADS (38/51)	0 TO 148	0 TO 132
● IMPROVED FLIGHT 3 DESIGN WITH 63 TO 74 W RTG AND FLIGHT 3 EXPERIMENT LOADS (32/44)	0 TO 130	0 TO 110
● IMPROVED FLIGHT 4 DESIGN WITH 63 TO 74 W RTG AND FLIGHT 4 EXPERIMENT LOADS (37.41)	0 TO 125	0 TO 100

Figure 4.4-16 Summary of ALSEP C/S Thermal Design Status

4.5 Central Station (C/S) electrical performance. - Each component part of the C/S operated very well throughout the Thermal Vacuum Tests. The following sections describe the functional operation of the RTG, PCU, and Data Subsystem with a brief explanation of Discrepancy Reports (DR's) written during the tests.

4.5.1 Radioisotope Thermoelectric Generator (RTG). - The performance of the RTG was admirable throughout the Prototype "A" Thermal Vacuum Tests. No new discrepancies in generator performance were observed. The RTG used in this test was the Model 14 generator. The generator was attached to the prototype pallet Number 2 and deployed on the simulated lunar surface in the 20' x 27' space simulation chamber. The generator was heated with an Electric Fuel Capsule Simulator (EFCS) which was powered from the Model 14 IPU Test Console located immediately adjacent to the test chamber.

The RTG was connected to a switching box which allowed it to be connected to the C/S or the IPU test console. The same switching circuitry allowed the C/S to be powered by the RTG or the RTG Simulator.

The Model 14 generator has some physical differences from the subsequent models. The platinum wire temperature sensors, which had previously failed, were all replaced with thermocouples. In this test twelve thermocouples were connected to the DAS and four were connected to a Daystrom recorder. Figure 4.4-12 is a plot of five of the DAS channels showing two hot and three cold frame temperatures throughout the test. Two hot frame and two cold frame thermocouples were combined to give a continuous printout of average temperatures on the Daystrom recorders.

The generator pressure transducer which is absent on later models was used throughout the entire test to monitor internal generator pressure. The excitation and output voltages were recorded on DAS channels. The transducer output voltage, proportional to pressure, was also displayed on two VTVM's and recorded on data sheets by test personnel.

During early test phases, such as Central Station Verification (TP 2333047) and Ambient Integrated System Tests (TP 2333034), the C/S was powered from the RTG Simulator because the Model 14 RTG could not be operated in open air and it was desirable to verify the C/S performance with ambient temperatures and vacuum conditions. The lunar morning start-up was simulated by the following sequence:

1. The chamber was stabilized at lunar morning conditions and the solar array activated simulating lunar morning solar illumination.

2. The C/S was turned off following the sequence which sets the preferred turn-on condition.

3. The relay in the switch box was activated to allow the C/S to be powered with the RTG.

4. The EFCS power input was increased from the 150 watt "hold" condition to 1400 watts in one step.

5. The EFCS and RTG combination required 49 minutes and 39 seconds to warm to the point at which the generator open circuit voltage was slightly over 20 volts, causing the PCU hold-off circuit to fire and allow the system to turn on. At this point the IPU Test Console voltmeter indicated the generator voltage had dropped to the PCU regulated value of 16.3 volts. The hot and cold frame temperatures were 968°F and 295°F, respectively. Thermal steady state for the generator (1078°F and 382°F) was reached about two hours later.

The time required for warm-up in this test was longer than the warm up will be on the moon because of the large thermal capacity of the EFCS. The hot and cold frame temperatures averaged 1105°F and 420°F, respectively, during lunar noon. The power output for the 1400 watt input was about 62.5 watts. The lunar night average operating temperatures of the hot and cold frames were 1065°F and 380°F, respectively and the output power did not change significantly.

Near the end of the lunar night test, the EFCS power was increased to 1500 watts. The output power increased to 68.9 watts and the average hot and cold frame temperatures reached 1109°F and 392°F, respectively. The system was operated with this input power for about two hours and then the C/S was switched back over to the RTG simulator. The generator was then operated with the IPU Test Console load in an attempt to increase the cold frame temperatures to 420° for a comparison check of the IR sensor output with the output during turn-on conditions. This cold frame temperature was reached several hours later with the aid of the RTG lamp array. The highest average temperatures reachdd during this excursion were 1130°F and 420°F. The output power into the test console reached 69.6 watts. These last measurements were of an engineering and calibration nature and did not affect the C/S operation.

The generator was turned off by reducing EFCS power in steps of 200 watts as the chamber was being brought to ambient conditions. The generator and other

SNAP-27 equipment performance was entirely satisfactory and within expected limits throughout the test.

4.5.2 Power Conditioning Unit (PCU). - Throughout the Thermal Vacuum Test, the PCU proved quite adequate in providing all operative loads. Output voltages +29, +15, and +12 VDC stayed within 1% of nominal and +5, -6, and -12 VDC stayed within 3% of nominal output. Reference document Bx-P.O. 1619 (WT) 68-970-1799 describes why these tolerances are compatible with users of the power. Table 4.5.2-1 is a tabulation of selected housekeeping channels and some data acquisition channels. From this table PCU characteristics can be defined for each phase of the test. All PCU temperatures remained within the operating temperature limits throughout the test.

4.5.2.1 Failure to switch on command. - The only major difficulty encountered was the occasional failure of the PCU to switch from side 1 to side 2 or vice versa upon command. Analysis of the data and circumstances surrounding this failure indicate the following factors were responsible.

4.5.2.1.1 The base drive for the relay driving transistors was marginal. The prototype command circuit mode of operation could allow both coils of the relay to be partially energized continuously. During this time, the relay did not center itself because of its magnetic latching feature. Thus, when the command signal appeared on one of the set lines, the current flowing in the commanded coil had to overcome the current flowing in the partially energized coil in order to affect contact transfer.

4.5.2.1.2 The command signal disappeared when the 5 volt-line dropped below approximately 1.66 volts. Thus, the command signal disappeared approximately 100 microseconds after the relay contacts left their original positions. Since both coils were originally energized, the contacts tended to center themselves. The contacts, on occasion, fell back to their original position. This explains the failure to switch from side 1 to side 2. The marginal condition described in the previous paragraph contributed to centering of the contacts since the applied force is proportional to the energy applied to the contacts.

4.5.2.1.3 The undervoltage circuit will transfer the contacts to side 2 or will leave the contacts in side 2 if the +12 V line drops below 11 volts for any reason. Thus, if the contacts stopped in the middle, due to the conditions described in the previous paragraph, the undervoltage circuit transferred the contacts to side 2. This explains the failure to switch from side 2 to side 1. It should be noted that the undervoltage circuit precludes the possibility of the relay contacts remaining in the middle.

TABLE 4.5.2-1

HOUSEKEEPING DATA

TITLE	HK #	AMBIENT TURN-ON					ISOTHERMAL TURN-ON															LUNAR NOON									LUNAR NIGHT							
		DAY 346			347		349	350				351				352				353				354				355					356
		0900	1200	1800	0000	0600	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0630	1200	1800	2230	
CONVERTER INPUT VOLTAGE	1	277	277	277	300	300			300	301	300	300	300	300	300	300	300	300	300	300	301	300	301	301	301	303	302	302	300	274	300	302	
		16.0	16.0	16.0	16.07	16.07			16.07	16.16	16.07	16.07	16.07	16.07	16.07	16.07	16.07	16.07	16.07	16.07	16.16	16.07	16.16	16.16	16.16	16.33	16.24	16.24	16.07	15.90	16.07	16.24	
ADC CAL. 0.25 V	2	015	015	015	015	015			015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	015	
									015 = .24 VOLTS																								
ADC CAL. 4.75 V	3	362	362	362	362	362			362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362	
								OCTAL 362 = 4.76 VOLTS																									
THERMAL PLATE #1	4	111	145	154	132	145	123	212	230	220	044	021	027	025	060	137	166	172	173	173	162	037	016	014	013	015	017	017	077	105	153	015	
		58	78	83	70	78	65	104	114	108	28	-4	+9	+4	39	74	91	93	94	94	88	23	-12	-18	-22	-14	-9	-9	51	55	83	-14	
CONVERTER INPUT CURRENT	5	270	255	264	255	254	262	261	261	261	262	262	262	267	270	271	272	272	272	272	275	272	271	272	272	270	315	263	253	264	255	263	
		3.6	3.51	3.55	3.51	3.50	3.63	3.61	3.61	3.61	3.63	3.63	3.63	3.73	3.77	3.69	3.81	3.81	3.81	3.81	3.89	3.81	3.69	3.81	3.81	3.6	4.3	3.65	3.47	3.57	3.51	3.65	
SHUNT REG. #1 CURRENT	8	001	063	001	126	145	055	074	113	150	166	165	173	153	113	117	121	134	146	152	157	161	222	146	146	267	110	160	155	001	141	210	
		—	1.83	—	1.42	2.24	1.89	1.72	1.53	1.20	1.03	1.04	.97	1.16	1.53	1.48	1.46	1.34	1.22	1.36	1.12	1.09	.971	1.22	1.22	.027	1.57	1.10	1.14	—	1.26	.825	
RCVR. 1 KHz SUBCARRIER PRES	9	071	065	064	066	064			101	100	067	065	067	070	076	076	101	100	076	076	103	072	066	065	065	065	067	065	076	104	104	066	
POWER DIST. EXPTS. 1 & 2	12	300	300	300	277	204	300	300	205	000	000	001	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	277	204	000	
SHUNT REG. #2 CURRENT	13	051	001	070	001	001	001	140	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	001	062	001	000	
		1.93		1.75				1.28																						1.82			
POWER DIST. EXPTS. 3, 4, & 5	14	330	330	241	330	043	330	043	043	241	241	241	241	241	240	240	241	241	330	241	241	241	242	241	242	332	331	332	240	330	241	243	
BOTTOM STRUCTURE #1	15	250	254	254	252	253	254	261	260	246	133	143	224	224	326	342	341	342	341	342	312	147	136	133	131	120	125	154	243	250	254	132	
		71	81	81	77	79	81	94	92	66	-128	-108	+16	+16	+196	228	222	228	222	228	182	-98	-120	-128	-133	-156	-143	-85	+57	70	81	-132	
LOCAL OSC. CRYS. "A"	16	173	000	244	221	000	203		000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	
LOCAL OSC. CRYS. "B"	17	000	234	000	000	236	000		000	000	000	044	056	052	130	227	261	266	267	267	255	073	035	027	025	030	036	036	170	167	245	032	
XMITTER "A" CRYS.	18	000	000	000	000	000	000		000	000	000	044	056	052	130	230	260	264	265	264	255	077	040	031	000	036	040	041	170	176	000	035	
XMITTER "A" HEAT SINK	19	000	000	000	000	000	000	000	000	000	000	037	050	046	121	212	255	262	263	263	251	067	034	025	000	032	034	035	150	171	000	031	
PCU OUTPUT VOLT. #1 (29V)	20	320	320	321	320	320		320	321	320	320	321	321	321	320	320	320	320	320	320	320	320	320	322	322	322	321	323	320	320	320	322	
		2875	2875	2890	2875	2875		2875	2890	2875	2875	28.90	28.90	28.90	28.75	28.75	28.75	28.75	28.75	28.75	28.75	28.75	28.75	29.03	29.03	29.03	28.90	29.17	28.75	28.75	28.75	29.03	
RCVR. PRELIM. LEVEL	21	263	262	256	253	257		254	240	256	272	240	265	262	275	273	266	265	262	260	271	273	352	245	241	252	257	254	277	276	264	252	
XMITTER 'B' DC CURRENT, P. DOUB.	22	237	231	231	227	230	222	226	227	226	177	000	000	000	000	000	000	000	000	000	000	001	001	000	164	000	000	000	000	000	222	000	
#2 CELL VOLTAGE	26	000	000	000	000	000	000	000	000	000	000	040	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	
SUNSHIELD #1	27	251	251	251	251	251	251	251	251	233	101	070	111	112	137	213	234	234	234	232	176	101	067	065	064	064	064	117	240	250	251	065	
		74	74	74	74	74	74	74	74	33	-194	-216	-174	-172	-118	-8	39	39	39	32	-41	-194	-220	-234	-226	-226	-226	-158	49	70	74	-234	
THERMAL PLATE #2	28	123	152	161	145	153	132	216	234	220	043	020	025	025	057	140	166	173	174	173	160	036	016	013	012	015	016	016	102	120	162	014	
		65	82	87	80	83	71	107	117	108	28	-6	+5	+5	38	75	91	94	95	94	86	22	-12	-22	-25	-14	-12	-12	53	63	88	-18	
#2 CELL TEMPERATURE	30	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	
XMITTER 'B' TEMPERATURE	31	000	000	000	000	000	217	304	320	312	107	000	000	000	000	000	000	000	000	000	000	000	000	000	027	000	000	000	000	000	000	000	
XMITTER 'B' HEAT SINK	32	000	000	000	000	000	217	304	320	317	107	000	000	000	000	000	021	050	054	051	004	000	000	000	000	000	000	000	000	000	000	000	

TABLE 4.5.2-1 (CONT.)

TITLE	HK #	AMBIENT TURN-ON					ISOTHERMAL TURN-ON										LUNAR NOON									LUNAR NIGHT							
			DAY 346			347	349		350				351					352			353				354				355				356
		0900	1200	1800	0000	0400	1800	0000	0400	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0430	1200	1800	2230	
ANALOG DATA	33	124	154	164	147	155	130	221	237	224	044	021	027	025	061	143	172	176	177	177	165	040	017	013	011	015	017	017	112	121	165	015	
PROC. BASE		66	83	89	90	85	69	108	118	109	38	-4	+9	+5	39	77	93	96	97	97	90	24	-9	-22	-29	-14	-9	-9	59	64	90	-14	
ANALOG DATA	34	133	166	176	155	166	144	236	254	245	060	027	036	033	074	162	212	217	217	217	210	052	025	020	016	022	025	024	127	127	176	022	
PROC. INTERNAL		72	90	96	85	90	77	118	124	122	39	+9	20	19	39	88	104	107	107	107	103	34	5	-7	-12	0	5	+3	68	68	96	0	
PCU OUTPUT	35	325	325	325	325	325	325	325	326	325	325	325	324	325	324	324	325	325	325	325	325	325	325	326	325	326	325	326	325	325	325	326	
VOLT #2 (15V)		15.00	15.00	[illegible]	[illegible]	15.00	15.00	15.00	15.41	15.0	15.0	15.0	14.94	15.0	14.94	14.75	14.82	14.82	14.82	14.82	14.82	14.82	14.82	14.85	14.82	14.86	14.82	14.86	14.82	14.82	14.82	14.86	
RCVR. LOCAL OSC. LEVEL	36	167	362	174	172	361	200	361	360	360	351	272	317	311	363	362	362	361	361	361	361	344	261	231	214	236	263	260	363	362	361	243	
#3 CELL VOLTAGE	41	000	000	001	000	000	000	202	305	245	000	000	000	000	000	000	017	046	053	050	004	000	000	000	000	000	000	000	000	000	001	000	
SUNSHIELD #2	42	252	252	253	252	252	253	253	253	234	102	017	112	114	140	215	235	235	235	233	177	103	070	066	065	064	065	117	241	251	252	065	
THERMAL PLATE	43	124	153	163	146	154	130	221	237	225	044	021	027	025	062	144	173	177	200	200	164	037	017	013	012	015	017	017	103	121	164	015	
#3		66	83	88	79	72	69	108	118	109	28	-4	+9	+5	39	78	94	97	98	98	91	23	-9	-22	-25	-14	-9	-9	54	64	90	-14	
DIGITAL DATA	46	125	154	164	147	155	131	220	236	224	044	022	027	025	062	143	171	176	176	176	164	037	017	013	012	015	017	020	105	123	164	015	
PROC. BASE		67	83	89	80	85	70	108	119	109	28	-4	+9	+5	39	77	93	96	96	96	90	23	-9	-22	-25	-14	-9	-7	55	65	90	-14	
DIGITAL DATA	47	127	160	170	154	161	134	227	246	242	050	021	027	025	062	150	202	206	207	207	200	044	020	014	013	016	020	017	105	123	170	016	
PROC. INTERNAL		68	87	92	83	87	72	117	122	120	30	-4	+9	+5	39	81	99	102	103	103	97	29	-7	-19	-22	-12	-7	-7	55	65	92	-12	
COMMAND DE-	48	124	150	160	144	152	127	215	233	216	040	020	025	023	056	136	165	171	172	171	155	035	016	012	011	014	016	017	100	121	161	014	
CODER, BASE		66	81	87	78	82	67	104	118	107	27	-6	+5	+2	37	73	91	93	93	93	84	21	-12	-25	-29	-19	-17	-9	52	64	87	-19	
COMMAND DE-	49	127	155	164	151	156	132	222	340	231	045	021	026	024	060	142	172	177	200	177	170	040	017	013	012	015	017	016	102	124	166	015	
CODER, INTERNAL		68	85	89	81	86	70	108	119	117	28	-4	+6	+3	36	76	98	97	98	97	92	24	-9	-22	-25	-14	-9	-12	53	66	91	-14	
PCU OUTPUT	50	313	313	313	313	313	313	313	313	313	312	314	314	314	313	313	313	313	313	313	313	312	314	315	315	313	315	314	313	313	313	314	
VOLT. #3 (12V)		12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.18	12.18	12.18	12.15	12.15	12.15	12.15	12.15	12.15	12.15	12.12	12.18	12.11	12.11	12.15	12.11	12.18	12.15	12.15	12.15	12.18	
XMITTER "A" AGC VOLTAGE	51	000	000	000	000	000	000	000	000	000	000	176	163	164	141	131	132	131	126	126	124	145	123	215	000	377	377	377	131	132	000	377	
#3 CELL TEMPERATURE	56	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	230	377	377	377	377	377	377	377	377	377	377	377	
THERMAL PLATE	58	126	150	157	143	152	130	217	234	222	042	020	026	023	057	140	167	173	174	174	165	036	016	012	012	014	017	017	110	122	157	014	
#4		64	80	83	77	82	69	108	116	109	26	-7	+5	+2	37	75	96	94	95	95	88	22	-12	-25	-25	-12	-9	-9	58	64	86		
VERTICAL STRUC-	59	251	258	253	252	252	253	257	256	241	132	145	214	216	303	313	313	313	312	312	272	144	132	130	127	115	114	156	242	250	253	127	
TURE #1		73	75	78	76	76	78	89	76	52	-132	-102	-05	0	143	165	165	165	163	163	119	-105	-132	-136	-139	-163	-166	-80	55	70	78	-139	
INNER MULTI-	60	252	257	262	256	257	256	273	275	273	234	220	225	223	240	257	265	266	266	266	264	233	216	213	211	213	217	216	244	252	261	214	
LAYER INSUL.		76	89	97	76	89	76	122	130	122	38	+5	+20	+13	+49	89	107	108	108	108	103	34	0	-9	-12	-9	+2	0	60	75	95	-5	
COMMAND DEMOD-	61	130	156	165	151	157	135	225	243	233	046	021	027	025	062	146	176	202	203	202	172	041	017	013	013	016	020	020	105	125	166	015	
ULATOR VCO		69	85	89	81	87	73	110	122	115	30	-2	+6	+5	39	79	96	99	99	99	93	25	-9	-22	-22	-12	-7	-7	55	67	92		
POWER DIST.	62	125	162	171	147	163	133	227	246	234	052	024	033	031	067	153	201	207	210	207	176	045	021	016	014	016	022	021	112	122	172	017	
BASE		68	88	93	79	88	72	113	123	116	34	+4	19	+13	44	82	98	103	103	103	96	29	-7	-12	-19	-12	-6	-7	59	64	93		
POWER DIST.	63	136	205	215	163	206	157	264	301	301	110	043	054	050	115	210	241	245	247	246	242	077	037	030	026	031	040	034	141	132	216	033	
INTERNAL		74	102	107	88	102	86	133	144	144	58	27	35	33	62	103	119	122	123	122	120	40	23	18	6	19	24	21	76	70	107		
PCU POWER	64	130	176	201	157	202	150	250	266	260	066	033	043	041	105	173	224	232	232	232	222	060	030	023	020	022	031	030	130	124	211	025	
OSC. #1		69	96	98	87	99	81	124	136	131	44	17	28	26	55	96	114	116	117	116	112	35	19	3	-7	0	19	19	70	66	105		
PCU OUTPUT VOLT. #4 (5V)	65	332	334	333	332	333	332	333	334	334	331	331	331	331	331	332	333	333	333	333	333	331	332	331	332	333	332	333	331	332	333	333	
XMITTER "B" AGC VOLTAGE	66	246	247	245	242	242	224	216	217	213	244	000	000	000	000	000	000	000	000	000	000	000	000	000	307	000	000	000	000	000	210	000	

TABLE 4.5.2-1 (CONT.)

TITLE	HK #	AMBIENT TURN-ON					ISOTHERMAL TURN-ON											LUNAR NOON									LUNAR NIGHT						
		DAY																															
		346			347		349	350				351				352				353				354				355				356
		0900	1200	1800	0000	0600	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0430	1200	1800	2230
THERMAL PLATE	71	123	155	163	144	156	131	222	240	227	045	023	030	026	065	147	176	273	204	203	171	041	020	014	013	014	020	020	106	120	164	016
#5		66	85	88	78	85	70	109	111	113	30	0	12	+7	43	78	96	133	100	99	93	25	-7	-19	-22	-19	-7	-7	55	64	90	
OUTER MULTI-	72	252	255	257	255	255	256	264	264	254	164	101	222	222	303	317	320	321	320	320	305	172	156	152	151	145	145	163	243	251	257	151
LAYER INSUL.		76	85	88	85	85	87	103	103	81	-65	-73	+10	+10	143	177	179	181	179	179	154	-52	-80	-93	-94	-103	-103	-68	+58	74	89	-94
PCU POWER	76	136	172	210	152	172	137	237	256	247	037	027	036	034	075	163	213	220	221	220	211	052	025	020	020	020	025	024	120	132	201	022
OSC #2		74	94	103	82	94	74	118	129	124	39	+9	22	19	50	89	104	110	111	110	103	34	5	-7	-7	-7	+5	+4	63	70	98	
PCU REG.	77	136	241	212	234	264	220	315	335	333	145	077	112	111	166	257	303	311	313	312	304	135	062	060	054	032	067	072	220	133	272	057
#1		74	120	104	116	134	108	155	170	168	79	51	59	58	91	127	146	151	152	151	146	73	36	36	35	19	37	38	112	72	132	
PCU REG.	78	177	202	257	160	206	160	253	272	264	073	037	047	045	112	201	231	236	237	237	227	064	033	076	024	223	034	033	136	174	215	030
#2		97	99	129	87	102	87	127	138	134	48	23	32	31	59	98	117	119	119	119	117	37	19	5	4	110	19	19	73	95	104	
PCU OUTPUT	79	213	214	213	214	214	214	215	215	215	214	215	216	214	214	214	214	214	213	214	214	213	215	214	216	213	215	216	214	213	214	215
VOLT. #5 (+12V)		11.68		11.68																												
PCU OUTPUT VOLT. #6 (+6V)	80	101	102	101	102	102	102	101	102	101	102	103	103	102	102	101	101	101	101	101	102	101	103	103	103	104	104	103	102	101	102	104
XMITTER "A" DC CURRENT P. DUB.	81	000	000	000	000	000	000	000	000	000	000	147	147	143	163	205	217	220	213	212	205	146	127	137	000	250	133	250	155	211	000	250
#1 CELL TEMPERATURE	83	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377	377
#1 CELL VOLTAGE	84	000	000	000	000	000	000	000	000	000	000	010	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000
VERT. STRUC-	87	251	256	256	253	254	252	260	257	241	132	136	233	222	304	323	322	333	322	324	300	153	142	135	135	124	131	153	241	250	255	134
TURE #2		72	87	87	80	83	75	93	89	51	-131	-120	34	+9	147	186	184	187	184	192	135	-88	-110	-123	-123	-146	-135	-88	22	71	84	-126
BOTTOM STRUC-	88	252	377	377	377	362	377	256	230	250	141	150	224	226	377	332	256	233	232	200	312	155	143	141	137	120	131	159	244	250	257	134
TURE #2		75	312	312	312	272	312	87	27	71	-113	-96	16	+22	312	206	87	33	32	-37	162	-83	-108	-113	-118	-156	-133	-75	+60	71	89	-126
LSM SURFACE	°F						72	72	73	45	-320	55	75	75	283	275	278	270	270	275	105	-320	-320	-320	-330	-315	-320	70				
PSE SURFACE	°F						70	70	70	45	23	23	25	22	40	47	40	50	57	75	95	58	56	10	10	10	10	65				
CS SURFACE	°F						72	73	75	-305	-320	62	65	61	248	260	255	252	251	260	0	-320	-320	-320	-320	-320	-320	55				
COLDWALL	°F						70	70	70	45	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	-310	+30	+40	+55		
PRESSURE	TORR						3.7	3.5	3.1	7.0	1.7	0.86	0.98	0.78	1.8	1.2	1.2	0.87	0.87	0.90	1.2	1.9	1.6	1.3	1.4	1.1	1.0	340		$(\times 10^{-6})$		

TABLE 4.5.2-1 (CONT.)

TITLE		AMBIENT TURN-ON					ISOTHERMAL TURN-ON											LUNAR NOON							LUNAR NIGHT									
		DAY 346			347		349	350				351				352				353				354				355					356
		0900	1200	1800	0000	0600	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0930	1200	1800	2230	
	SWS																																
DW11 TEMP. SENSOR MOD. 100	1				171	163																											
DW12 TEMP. SENSOR MOD. 200	2				170	164																											
DW13 TEMP. SENSOR MOD. 300	3				171	162																											
DW14 TEMP. SENSOR CUP. ASSY.	4				177	176																											
DW15 SUN ANGLE SENSOR	5				107	110																											
DW16 PROGRAMMER VOLTAGE	6				340	340																											
DW17 STEP GEN. VOLTAGE	7				220	220																											
DW18 MOD. MONITOR	8				253	254																											
	LSM																																
DM #1 TEMP. #1	1									076	015	015		015	015	026	050	056			057	015	015	015			015	015	021			015	
DM #2 TEMP. #2	2									074	012	013		013	013	025	045	052			051	011	012	012			012	013	022			013	
DM #3 TEMP. #3	3									075	011	002		003	003	014	034	042			045	007	007	010			006	012	020			007	
DM #4 TEMP. #4	4									112	065	047		037	052	100	116	125			130	100	053	037			021	021	044			020	
DM #5 TEMP. #5	5									117	076	060		050	063	107	124	132			136	112	067	051			030	030	053			027	
	SIDE																																
DI4 TEMP. #1	1					000				000	000	000		000	000	000	000				000	—	—	—									
DI5 TEMP. #2	2					122				063	134	162		144	114	070	037				041	114	146	160									
DI6 TEMP. #3	3					120				063	147	172		144	116	064	035				040	132	156	167									
DI9 TEMP. #4	4					122				061	124	147		131	110	063	025				030	114	134	146									
DI10 TEMP. #5	5					000				000	000	000		000	000	000	—				—	—	—	—									
DI19 TEMP. #6	6					245				214	317	343		306	253	213	156				163	275	325	336									
DL7 SENSOR UNIT TEMP.	PSE 1									000	000	000		000	000	000	000	000			574	592	353	000			000	000	000				

TABLE 4.5.2-1 (CONT.)

TITLE	HK #	AMBIENT TURN-ON					ISOTHERMAL TURN-ON											LUNAR NOON									LUNAR NIGHT					
		DAY 346			347		349	350				351				352				353				354				355				356
		0900	1200	1800	0000	0600	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0600	1200	1800	0000	0630	1200	1800	2230
					DAS READ-OUTS																											
THERMAL PLATE #1	4						71.4											109								-2.4						
BOTTOM STRUCTURE #1	15						72.0											231								-169						
SUNSHIELD #1	27						72.0											42								-230						
THERMAL PLATE #2	28						71.5											98								-7						
SUNSHIELD #2	42						72.0											42								-230						
THERMAL PLATE #3	43						71.4											103								-5						
THERMAL PLATE #4	58						71.7											100								-6						
VERTICAL STRUCTURE #1	59						72.0											165								-176						
THERMAL PLATE #5	71						71.6											108								-2						
VERTICAL STRUCTURE #2	87						72.5											185								-159						

4.5.2.2 Design improvements for subsequent models. - The mode of operation for the command circuits has been changed. The "no command" signal is now used to turn on an NPN transistor. With this transistor on, the relay driver transistor is biased off. The "command" signal is used to turn off the NPN transistor, causing the relay drive transistor to be driven into saturation. Thus, current flows through only one relay coil at any time and only when a command signal is present. The marginal conditions are now eliminated since both coils are no longer energized at the same time.

4.5.3 Data Subsystem. - This section summarizes the electrical performance of the C/S and provides an evaluation of Discrepancy Reports (DR's). After evaluating all data, the following Data Subsystem hardware and test parameters were defined:

(1) System compatibility

(2) Validity of data

(3) Completeness of DR's

(4) Thoroughness of test

(5) Test procedure inadequacies.

4.5.3.1 Receiver. - The command receiver performed to specification throughout the thermal vacuum test sequence. No excessive temperature rise was indicated at any time during the test. Functional performance of the receiver is indicated by proper execution of commands at typical signal levels. In addition, the following receiver telemetry housekeeping data was obtained:

1. Temperatures
    a. Crystal temperature, Local Oscillator "A" (HK-16)
    b. Crystal temperature, Local Oscillator "B" (HK-19)
2. Pre-limiting Level (HK-21)
3. Local Oscillator Level (HK-36)
4. 1-KC Subcarrier Presence (HK-9)

All telemetry points are tabulated in Table 4.5.2-1 such that a comparison can be made of the measured parameter under four conditions of simulated environment, namely:

1. Room ambient
2. Ambient-vacuum
3. Simulated lunar noon
4. Simulated lunar night.

The only possible receiver anomaly noted was a fluctuation in the Receiver Pre-limiting Level (HK-21) which would indicate either a fluctuation in signal level to the receiver or a change in gain within the receiver. When receiver gain (IF) is at fault, a gain change of 2 db is indicated which could typically reflect into the signal-to-noise ratio as a 5 db degradation. Subsequent testing (S-Band Compatibility Tests) indicated that the anomaly noted actually did exist. No discrepancy report has been written since the deviations did not exceed tolerance limits.

4.5.3.2 Command decoder. - The command decoder operated properly throughout the Thermal Vacuum Tests. Internal temperature telemetry points read out via the RF link indicated proper thermal control. The following telemetry data is peculiar to the command decoder.

1. Command decoder base plate temperature (HK-48)
2. Command decoder internal temperature (HK-49)
3. VCO temperature (HK-61)

The command decoder telemetry points are tabulated in Table 4.5.2-1 which allows comparison of data at simulated lunar conditions.

4.5.3.3 Transmitter. - Each of the two transmitters performed properly within the scope of the Thermal-Vacuum Tests. Telemetry points peculiar to the transmitters indicated that the "AGC voltage measurement" of transmitter "A" was out-of-tolerance when operating at the coldest temperature, but operated normally otherwise.

Transmitter "B" apparently operated properly but telemetry channel HK-32 (transmitter B heat sink) was noisy from 0600 of day 352 to 0600 of day 353. Transmitter A was operating during this time so HK-32 should have been reading 000.

The housekeeping data collected from the transmitters are:

1. AGC voltage, Transmitter "A" (HK-51)
2. AGC voltage, Transmitter "B" (HK-66)
3. Doubler Current, Transmitter "A" (HK-81)
4. Doubler Current, Transmitter "B" (HK-22)
5. Heat Sink, Temperature, Transmitter "A" (HK-19)
6. Heat Sink Temperature, Transmitter "B" (HK-32)
7. Crystal Temperature, Transmitter "A" (HK-18)
8. Crystal Temperature, Transmitter "B" (HK-31)

These parameters are tabulated in Table 4.5.2-1.

4.5.3.4 Data processor. - The data processor, when operating on redundant section Data Processor "Y", performed to specifications throughout the Thermal Vacuum Test sequence. Housekeeping data peculiar to the data processor equipment consists of base plate (heat sink) and electronics temperature measurements for each component of the processing equipment. No out-of tolerance temperature readings were obtained during the test. Analog to digital conversion was performed to specification as evidenced by the correlations of the calibration inputs on data channels HK-2 and HK-3. Additional correlation was obtained via housekeeping channel HK-50 which monitors the most closely regulated output of the Power Conditioning Unit. Calibration data channel outputs and power conditioning unit outputs as well as all component temperature monitor outputs are tabulated in Table 4.5.2-1 for the four environmental conditions of interest. This data is readily compared and establishes confidence in the data processor performance under simulated lunar surface environment conditions.

Data processor section "X" exhibited an apparent anomaly during the test as indicated on DR 6366. It was noted that upon switching to section "X" of the Data Processor that the digital LSM "X" axis input was fluctuating in value. This anomaly was not noted on Section Y of the Data Processor. A probable defect was presumed to exist in the Data Processor "X" section. The Data Processor was given a complete functional checkout (PIA) during Prototype "A" to Prototype "C" retrofit. Cause of failure was not determined.

4.5.3.5 Power distribution unit - The Power Distribution Unit performed properly throughout the Thermal Vacuum Test sequence except for out-of-tolerance RTG temperature readings obtained as housekeeping data. The RTG temperature sensors were simulated with fixed resistors at the end of a long unshielded cable running to the outside of the chamber. A significant amount of noise was exhibited on all RTG temperature channels. Hence, the performance of the signal conditioning for these sensor inputs was not established. All power control circuits, switch status monitors, temperature monitors, voltage dividers, and marginal power Ripple-Off Sequencing circuits operated without discrepancy throughout the test sequence.

4.5.3.6 Data Subsystem signal conditioning - Signal conditioning within the Central Station consists of voltage monitors, thermal plate temperature monitors, heat sink temperature monitors, and power switch position monitors. Thermocouples placed in close proximity to system sensors allow a comparison of normal system telemetry read-outs with independently obtained data from the thermocouples whose outputs were recorded by the DAS (Data Acquisition System).

A tabulation of the housekeeping data and the independently derived DAS data indicated that all temperature monitors with the exception of HK88 were operating properly.

Five thermistor probes, mounted at appropriate points on the thermal plate, monitored temperatures of the thermal radiator such that an indication of thermal continuity between the component heat sinks and the thermal plate was obtained. The thermistors were mounted on the component mounting side of the plate. Independent DAS thermocouples were mounted on the opposite side of the plate and essentially in the same area as the thermistors to yield a direct correlation of thermal plate temperature telemetry with the DAS thermocouples. The correlation between DAS channels and Central Station housekeeping channels was within 10°F. Following is a list of the channels monitored both by the DAS and HK. Values for these channels are shown in Table 4.5.2-1.

TM Channel	DAS Channel	
HK 4	DAS-59	Thermal Plate No. 1
HK 28	DAS 62	Thermal Plate No. 2
HK 43	DAS-60	Thermal Plate No. 3
HK 58	DAS-57	Thermal Plate No. 4
HK 71	DAS-58	Thermal Plate No. 5
HK 27	DAS-52	Sunshield Temp. No. 1

4.5.4 Discrepancy report evaluation - Throughout the Proto "A" Thermal Vacuum Test a total of 22 discrepancy reports were written against the Central Station. The following paragraphs will indicate (1) the discrepancy report identification, (2) a description of the discrepancy, (3) probable cause of discrepancy and (4) corrective action taken.

Discrepancy report 6210 concerns housekeeping out-of-tolerance readings as follows:

Item #	TM Channel	Function
1	HK-5	PCU Input current
2	HK-6	RTG HJ Temp. #1
3	HK-36	Local Osc. Level Receiver
4	HK-37	RTG HJ Temp. #2
5	HK-52	RTG HJ Temp. #3
6	HK-7	RTG CJ Temp. #1
7	HK-67	RTG CJ Temp. #2

The disposition for items 1 and 3 involved a change in allowable limits within the test procedure. In the case of item 1, the input to the RTG simulator was not adjusted properly prior to testing and a change to the test procedure was initiated via DR 5862. Item 3 also involved a change to the test procedure in that the octal 50-350 limits were changed to octal 13-365 to encompass the proper range of the measurement. Items 2, 4, 5, 6 and 7 were RTG temperature telemetry channels and the noise pick-up on the long unshielded cable made it impossible to assess the performance of the sensor networks and therefore, no corrective action was specified. Future RTG cables will be properly shielded.

Discrepancy report 6252 was initiated due to telemetry channel HK-8 indicating that power converter section #2 was operating when section 1 of the PCU was last commanded to "ON". Octal command #60 was reissued and the proper indication was obtained. See paragraph 4. 5. 2. 1 for detailed discussion.

Discrepancy Report 6299 is essentially a reiteration of DR 6210 in that RTG temperature sensing channels were out-of-tolerance as well as unused channels HK-73, HK-74, and HK-75. In this case RTG #3 Cold Junction Temperature #3 (HK-82) was out-of-tolerance. No corrective action was initiated. The cause was listed as being attributed to excessive noise pick up on long test cables.

Discrepancy Report 6305 was written due to the test conductor's choice to deviate from the procedure because of a desire to determine the cause of fluctuations of signal on telemetry channel HK-8 (Shunt Regulator Current #1) even though the fluctuations were caused by variance of load initiated by a thermal control thermostat cycling a heater "ON" and "OFF" as dictated by thermal control requirements. No discrepancy should have been written against the equipment.

Discrepancy Report 6307 reported telemetry channel HK-66 (Transmitter "B" AGC Voltage) out-of-tolerance. The Acceptance Test Data Package confirmed that the test procedure tolerances were not proper and that the transmitter AGC voltage was in tolerance. Corrective action involved changing the test procedure limits on HK-66.

Discrepancy Report 6329 should not have been written against the equipment as it involved changes in the procedure to obtain desired environmental conditions.

Discrepancy Report 6335 was initiated when main frame sync was lost at the system test set during the time the infrared heat lamps were cycling. The cause was attributed to EMI radiated or conducted to the System Test Set. No corrective action was initiated nor indicated. This type of problem is a system test configuration problem.

Discrepancy Report 6339 is a reiteration of portions of DR 6210 which involves out-of-tolerance reading on RTG temperature housekeeping telemetry.

Discrepancy Report 6342 reports a situation covered previously on DR 6339 and DR 6210 and should not have been issued.

Discrepancy Report 6359 concerns a deviation from procedure by the test conductor. No equipment discrepancy is indicated.

Discrepancy Report 6365 involves stabilization of temperature in the simulated environment. No equipment malfunction is indicated.

Discrepancy Report 6366 concerns fluctuating X axis data telemetered from the LSM. Section "X" of the data processor was found to be defective. Cause of failure believed to be an open in one of the printed wire boards.

Discrepancy Report 6369 concerns a transient noted on the strip chart recorder which was recording the +12 VDC PCU output, Shunt Regulator Current #1, Shunt Regulator Current #2, and RTG simulator voltage and current. The transient was not caused by the Central Station since the transient appeared on both shunt regulator current monitors, one of which had to be inoperative at that time.

Discrepancy Report 6371 is a test procedure deviation and does not indicate an operational equipment deficiency.

Discrepancy Report 6372 concerns improper data from IR sensors which are not part of the flight hardware. The problem is an environmental chamber problem.

Discrepancy Report 6342 is a reiteration of DR 6210 and concerns RTG Hot Junction Temperature being out-of-tolerance.

Discrepancy Report 6375 indicates a loss of main frame sync which was attributed to EMI influencing the STS and no corrective action is applicable to the Central Station electronic components.

Discrepancy Report 6370 involves out-of-tolerance telemetry readings. Some of the out-of-tolerance readings were reiterations of out-of-tolerances previously dispositioned on other discrepancy reports. All references to housekeeping words 4, 28, 33, 43, 46, 47, 48, 49, 58, 60, 61, 64, 71, 76, 78 are properly accounted for in the disposition written on DR 6370 which states:

> " This is correct operation, the test limits are chosen to force these print-outs when the temperature of the Central Station becomes marginal. The consistency of the read-outs of the various temperature sensors proves that no sensor failure has occurred."

The printout of out-of-tolerance indications were provided to alert the Test Conductor that the danger limits defined in ATM 719 were being approached and therefore appropriate action could be taken before the danger limits were reached. This disposition does not directly apply to the OT indication witnessed on HK 66, HK 51, HK 6, HK 37, HK 52, HK 67, or HK 82. The disposition written on DR 6307 should have precluded HK 66 being listed as a discrepancy on DR 6370, likewise HK 6, HK 37, HK 52, HK 67, and HK 82 were previously dispositioned on DR 6210 and DR 6339. The out-of-tolerance on HK 51 referenced in DR 6370 is definitely out-of-tolerance and indicates that transmitter "A" or perhaps associated cabling is defective. Another indication confirming that a defect exists is the fact that input power to transmitter "B" is between 2 and 4 watts greater than that normally required.

Discrepancy Report 6375 was initiated when main frame sync was lost for approximately 5 to 20 seconds. This occurrence was coincident with a loss of line power caused by lightning. No disposition or corrective action was indicated.

Discrepancy Report 6209 was written against the Central Station (Sub-Package #1) when it was observed that housekeeping channel HK 88 read out-of-tolerance. Upon examination of the data it was observed that the sensing circuit was intermittent. The disposition was use-as-is. Corrective action to be taken was to repair the circuit during Proto A to Proto C configuration retrofit.

4.6 Experiments. - The following section contains detailed discussions of the thermal vacuum test results for the Passive Seismic, Lunar Surface Magnetometer, Solar Wind Spectrometer, and Suprathermal Ion Detector Experiments. Each discussion includes a summary of the electrical and thermal/structural performance, an evaluation of Discrepancy Reports generated during the tests, and design improvements recommended as a result of these tests.

4.6.1 Passive Seismic Experiment (PSE). -

4.6.1.1 Electrical performance. - During those portions of the test when the PSE sensor was maintained within its operating temperature range, the electrical performance of the PSE was normal. Results of IST's for initial ambient reference, ambient temperature vacuum, lunar noon, and post-ambient reference were all consistent.

The PSE sensor caging mechanism became discrepant and had to be mechanically caged prior to the initial reference ambient IST.

A change was made in the IST procedure (2333032) to provide a means of obtaining the X, Y, and Z feedback filter time constants. Some rewording for clarification of the IST procedure regarding this technique will be completed prior to next thermal vacuum test. (DR 6266).

The short period output was thought to be low (9.0 volts instead of 9.4 volts to 10.4 volts) when the attenuator was set to 0 db but normal when set to -10, -20, or -30 db. This characteristic was observed throughout each of the IST's. It was later determined that the output can vary from 8.0 volts to 10.4 volts so the IST procedure (2333032) limits are being changed accordingly. (DR 6253).

Indication of the step voltage response of the TIDAL X output, as viewed on the strip recorder of the STS, was limited to less than the expected 4.2 volts to 7.0 volts when the CAL LP command was executed. The strip recorder maximum reading is +10V and since TIDAL X was reading 6.4 volts before the command, it could only indicate an increase of 3.6 volts before saturating the recorder. Definition of the response indication has been modified accordingly for future test procedures (DR 6265).

During the ambient temperature vacuum IST, the PSE did not respond to the first UNCAGE command but did respond normally to the command on subsequent attempts (DR 6266).

A power interruption to the strip recorder and the PSE sensor exciter caused a spurious UNCAGE command following the lunar noon IST (DR 6360). Throughout the Thermal Vacuum Tests, the PSE sensor exciter status would on occasion, reset. Special engineering tests, conducted after the Prototype Thermal Vacuum Test, indicated the PSE exciter status was being reset by transients from the recorder time marker circuit or switching the recorder chart drive on and off. Additional filtering has been added to eliminate this problem on future tests.

4.6.1.2 Thermal control. - The PSE Central Station Electronics is mounted on the thermal plate of the Central Station and depends on the Central Station for temperature control (see Section 4.4). The PSE sensor relies on its super-insulation blanket to isolate the sensor from the diurnal lunar surface temperature variations. It is estimated that lunar surface temperatures directly below the sensor will vary from +10°F to +40°F for a hard rock lunar surface and +50°F to +70°F for lunar surface composed of loose fragments. Originally, the PSE lunar surface temperatures specified by Teledyne for the Prototype Thermal Vacuum Tests were +50°F for lunar night and +70°F for lunar day. The PSE PI representative was informed, three days prior to the MSC Proto A test review, of the lunar surface simulator temperatures that were stated in the test procedures. The values appeared reasonable to the PI representative at that time. During the MSC test review, the PI representative informed BxA of a need to change the PSE lunar surface temperatures to +10 and +40°F for lunar night and lunar day respectively. These temperatures were discussed and compared with all available data. It was concluded by BxA and the PI representative that these new temperatures would more accurately simulate the lunar surface beneath the sensor. It was also observed by the PI representative that the infinite lunar surface was not included in the simulation. An agreement was arrived at between BxA and the PI representative whereby the infrared energy used to simulate the solar input to the top surface of the shroud would be increased to compensate for this energy input. These two adjustments to the environmental simulation were then formally requested.

At the beginning of the test, it was found that the infrared energy of the solar energy simulators could be increased to only 58.0 percent of the required level due to voltage limitations. To compensate for this deficiency, a calculation was made toshow that the lunar surface should be adjusted to approximately 50 to 60°F. It was then noticed that the sensor was stabilizing below the predicted operating limits and it was felt that this was due to the lamp's output deficiency. As a result, the lunar surface was increased to 50°F. The rate of change of the sensor temperature remained slow (approximately 1°F/hr) and after a few hours it was observed that the sensor temperature would again stabilize below the predicted operation range. The surface temperature was increased to +58°F and the same observations were made.

In order to expedite the test, Test Engineering requested that the lunar surface simulator be adjusted to +70°F and then at a later time to +100°F. Figure 4.6.1-1 shows the PSE sensor temperatures during the test. When the PSE reached approximately 124°F the lunar surface simulator was decreased in temperature to 60°F. The PSE then began to decrease 1°F/hr in temperature until it appeared that eventually the PSE would violate the lower operating limit. At this time it was decided that the manual mode of thermal control would be used instead of the automatic mode. By going to the manual mode the rate of temperature change decreased to approximately 1/2°F per hour. This decrease in the temperature rate of change occurs since 2.5 W ± 10% total power is dissipated in the automatic mode and 3.0 W ± 10% total power is dissipated in the manual mode. As a result, it appeared that the heater circuit was not the cause of the inability of the PSE thermal control system to maintain the design temperature. Rather, it appeared that an excessive heat leak existed. Examination of the test configuration heat leaks showed that the uncompensated heat leak from the sensor exciter cable was responsible for the difficulty in controlling the sensor temperatures. Figure 4.6.1-2 shows that under the design conditions, where the sensor is at 125°F and the lunar surface is at +10°F to +40°F, the heat leak down the sensor exciter cable is on the order of 1.2 to 1.4 watts compared to the combined heat leak of 0.2 watt for the flat cable and thermocouples. The sensor exciter cable is present only during tests and will not be required on the lunar surface. This fault in the test setup will be corrected in future tests by incorporating a guard heater on the sensor exciter cable where it contacts the simulated lunar surface. The guard heater will be maintained at the temperature of the sensor housing, thus eliminating heat flow down the cable. In addition, a radiation barrier has been incorporated on subsequent models which will help maintain the sensor temperatures. (See Figure 4.6.1-3).

4.6.1.3 Discrepancy report evaluation. - During the Prototype "A" Thermal Vacuum Test, the following PSE discrepancies occurred and were recorded.

DR 6251 - The five-bit code within the PSE sensor exciter was reset occasionally throughout the test due to electrical transients from both the thermal and optical analog recorders. Transients were caused by the time marker and also by switching the chart drive on and off. Transient analysis tests were performed following the conclusion of the Thermal Vacuum Tests and filters were added to eliminate this problem during future tests.

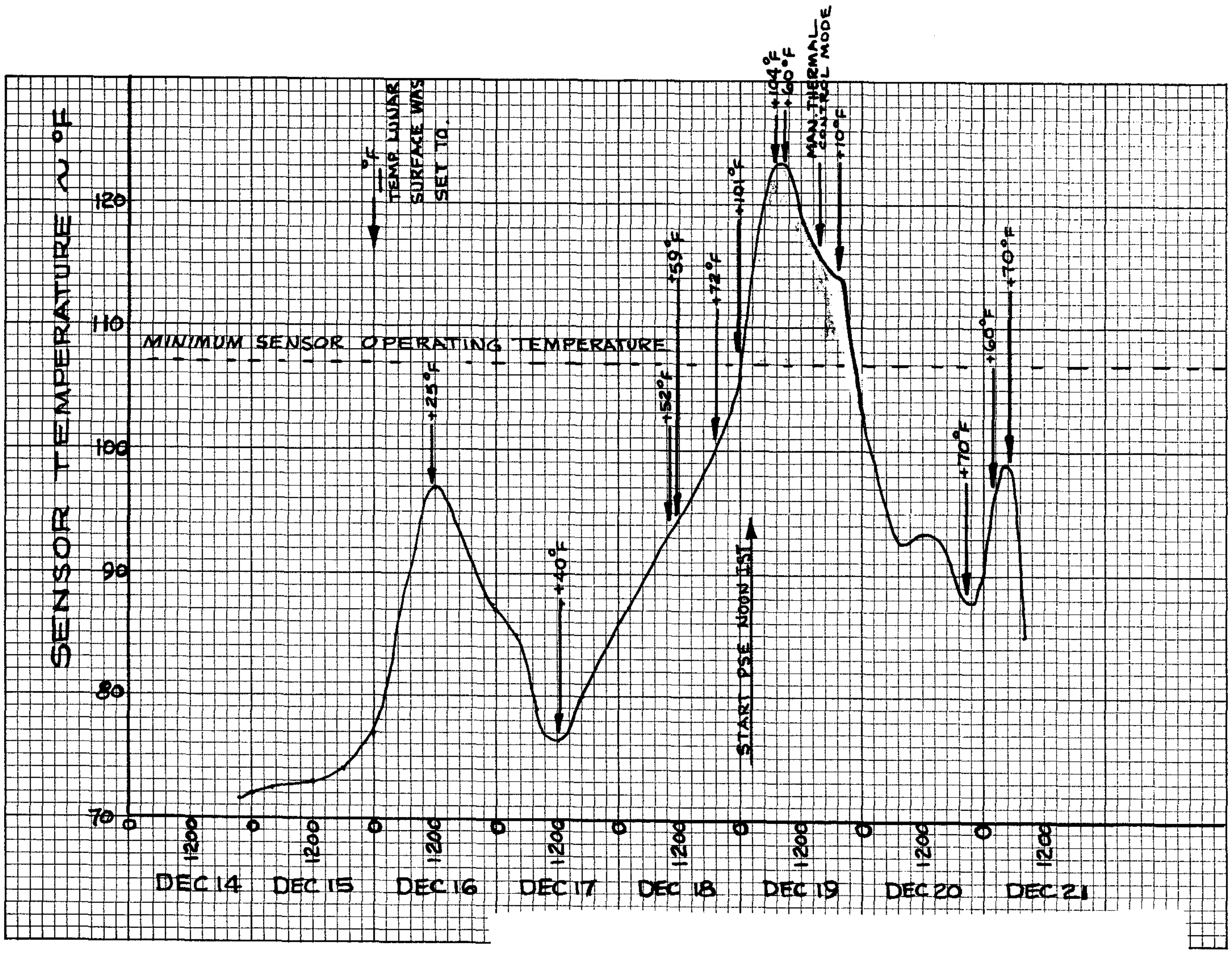


Figure 4.6.1-1 PSE Sensor Temp Profile

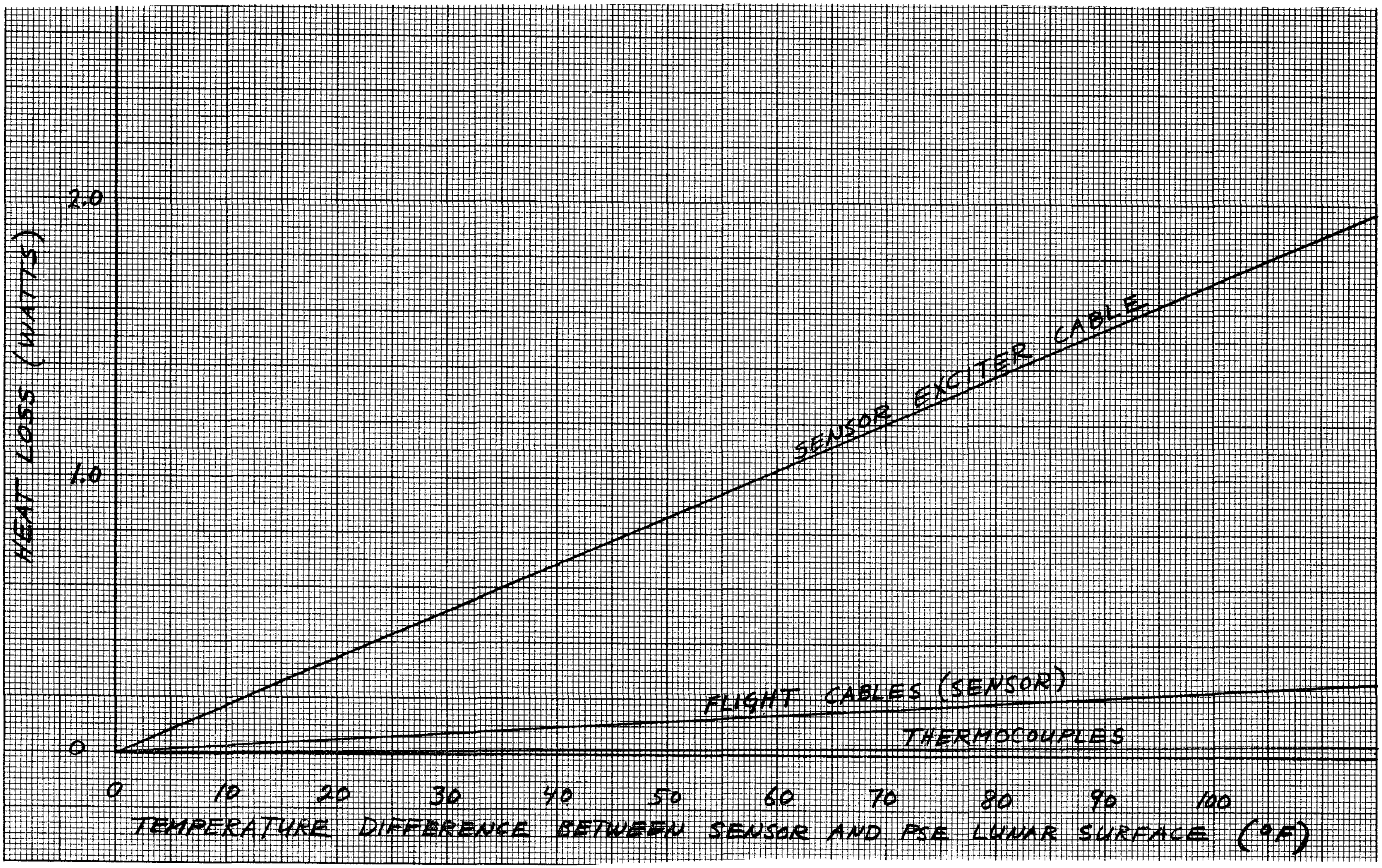
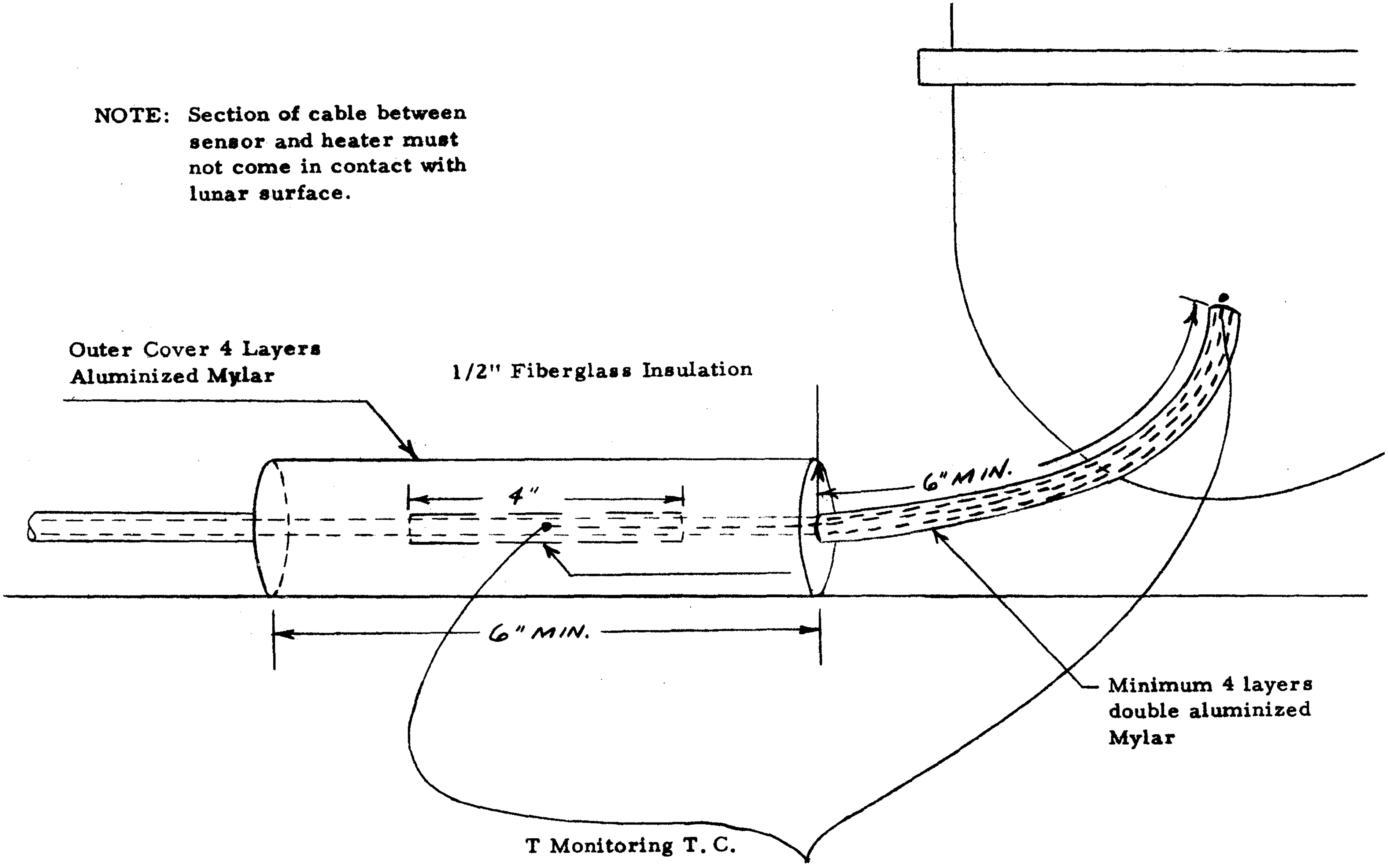


Figure 4.6.1-2 PSE Heat Loss Paths Proto Thermal Vacuum Test



NOTE: Section of cable between sensor and heater must not come in contact with lunar surface.

Figure 4.6.1-3 PSE Sensor Exciter Cable - Guard Heater - Qual A Test

DR 6253 - During paragraph 6.8.7.7 of the PSE IST, the short period output was thought to be low (9.0 V instead of 9.4 V to 10.4 V) when the attenuator was set to 0 db. This characteristic was observed throughout all the PSE IST's. Further investigation of the short period attenuator and associated circuits showed the expected voltage variation for the short period output to be 8.0 V to 10.4 V when the attenuator is set to 0 db. The limits in the test procedure will be modified accordingly for future tests.

DR 6265 - During paragraph 6.8.8.5 of the PSE IST, indication of the step voltage response of the TIDAL X output (as viewed on the strip recorder of the STS) was limited to less than the expected 4.2 V to 7.0 V when the CAL LP command was executed. The strip recorder maximum reading is +10 V and since TIDAL X was reading 6.4 V before the command, it could only indicate an increase of 3.6 V before saturating the recorder. Definition of the response indication has been modified accordingly for future test procedures.

DR 6266 - Item 1 on the DR concerns the rewrite of the X, Y, and Z feedback filter time constant measurements during paragraph 6.8.11. This portion of the procedure has been rewritten. Item 2 concerns the section of the PSE IST (paragraph 6.8.11.4) which commands the caging circuits. During the Vacuum IST, a command was sent to change the status from CAGED to ARMED but the PSE did not respond, as seen on HK-69. A second command was sent and HK-69 verified a normal response to ARMED as expected. The PSE responded normally each time it was commanded throughout the Thermal Vacuum Test except on this one occasion. No explanation has been found for this "one-time failure".

DR 6341 - Two days prior to the Thermal Vacuum Tests, the solar energy requirement for the PSE during lunar noon was increased by a factor of five. Facilities could not be provided in time to deliver the additional solar energy as required so the radiometer readings were low as expected during the lunar noon PSE IST. The lunar surface temperatures were increased to provide the heat needed for the PSE sensor. Additional fixtures have been constructed in the thermal vacuum chamber to provide the solar energy required for future PSE tests.

DR 6347 - During the lunar noon IST, an incorrect status transfer was noticed between the System Test Set and PSE sensor exciter. The cause was one of the sensor exciter toggle switches which was in the down (zero) position rather than in the center (off) position. This prevented the transfer of a logical ONE to that bit position. Once the switch was placed in the proper position, normal operation was restored.

DR 6358 - During the lunar noon IST, at paragraph 6.8.12, the HK-12 reading was different from that specified in the procedure because the LSM portion of the test was performed before the PSE portion in an effort to allow the sensor to stabilize at the proper temperature. HK-12 monitors the status of experiment 1 (PSE) and experiment 2 (LSM) with regard to operating mode. Had the IST been performed in the proper sequence, LSM would have been in "standby on" during the PSE portion. However, during this test, LSM was in "operating power on" so the corresponding HK-12 readings were correct for this condition.

DR 6360 - Between the lunar noon and lunar night tests a spurious uncage command was received by the PSE causing HK-69 to indicate an "armed" condition. A second uncage command was then transmitted from the System Test Set to return HK-69 to the "caged" condition. The reason for the spurious command was a momentary power interruption to the analog recorder and the sensor exciter.

DR's 6350, 6358, and 6376. - These three DR's are all related to the PSE thermal problem. They are involved with changing the PSE lunar surface temperature, commanding the PSE heater to the manual mode, and aborting the lunar night IST (this was not run since the sensor temperature was below the specified limits). Since the sensor was stabilizing below the predicted operating limits, the lunar surface was raised to 100°F to expedite the lunar noon IST. This enabled the sensor to reach 124°F and the IST was performed. However, when the lunar surface was lowered to 60°F, the sensor temperature began to drop at about 1°F per hour. Commanding the heater to the manual mode reduced the temperature change to 0.5°F per hour (more total heater power is dissipated in the manual mode). Thermal analysis has shown that there is significant heat loss through the sensor exciter cable (which will not be present on the lunar surface). To correct this situation, a guard heater has been designed and will be mounted to the sensor exciter cable in future tests in order to eliminate the heat leak from the PSE sensor to the simulated lunar surface.

4.6.1.4 Test implications for design improvements. - For subsequent thermal vacuum tests, the following modifications are proposed for the PSE lunar environment simulation equipment:

1. A guard heater be mounted to the sensor exciter cable in order to eliminate the heat leak from the sensor to the simulated lunar surface. This heater will not dissipate more than 0.1 W of heat energy.

2. Thermocouples located on the sensor should also be mounted to the guard heater to eliminate any heat leak contribution due to these wires.

3. A temperature differential thermocouple be attached to the sensor and guard heater to ensure that the temperature difference between them is small (less than 0.5°F).

4. A vertical flange be attached to the periphery of the lunar subsurface simulator to simulate the external energy input from the lunar surface to the cannister portion of the shroud. This flange should be maintained at +250 ± 10°F during the lunar day test and -300 ± 20°F during the lunar night tests. The height of this flange should not exceed one half the height of the cannister (1/2 ft.). In addition, the PSE lunar surface simulator should be lowered so that the top edge of the flange is level with the 14' x 14' lunar surface.

4.6.2 Lunar Surface Magnetometer. -

4.6.2.1 Electrical performance. - Throughout the thermal/vacuum test, the offset status bits were in error. This was first witnessed during the Pre-Integration Acceptance Test (PIA) and continued through all operational tests. Table 4.6.2-1 is a summary of the magnetometer tests.

Operation of the Z-axis sensor heater was either intermittent or inoperative through the course of the test. All other aspects of electrical performance of the experiment appeared normal under the various environments. The only true malfunction of the LSM was the incapability to complete the Y-site survey, and this was traced to a mechanical failure of the Z-axis sensor drive during lunar noon conditions. Subsequent flip/cal cycles indicated that the X and Y sensors would respond properly, but the Z-axis sensor remained mechanically erratic. NASA/ARC indicated the cause of the Z-axis malfunction was the severe temperature gradient along the boom.

On the reserve power plot, the ripple amplitude with only the LSM operating was seen to change during the various environments. Normal 130 HZ current ripple is equivalent to about 2.1 watts. The worst case was witnessed during lunar night when a 3.9 watt variation was observed. In addition, LSM word 5 showed that the heater power of the experiment was cycling on for eight seconds and off for twenty seconds.

4.6.2.2 Thermal control. - Overall thermal control of the LSM experiment electronics was adequate for the T/V test; however, undesirable large temperature gradients existed between the electronics and sensors under lunar night conditions. Early in the test sequence it was determined that the Z-axis sensor heater was inoperative. During lunar noon IST conditions, the electronics subsystem attained a temperature of +52°C (Ref. Figure 4.6.2-1). The operative X and Y sensors reached +12 and +8°C, resepectively, while the inoperative heater on the Z sensor allowed it to reach +4°C. During the lunar night IST condition which followed, the electronics temperature was +2°F, and X and Y sensors were -28°C and -34°C, respectively, while the Z sensor was -44°C. Because of this wide temperature variation between sensors and electronics a flip/cal was not attempted under lunar night conditions. A plot of electronics and sensor temperature is shown in Figure 4.6.2-1.

4.6.2.3 Discrepancy report evaluation. - DR 6249 - As part of the initial reference ambient IST, status bits of word 3 did not change and the Z-axis scientific data shifted from -502 to +113, indicating the sensor had partially flipped after the first flip/calibrate command was issued. Investigation showed that the Z-axis sensor drive cable was in contact with an electrical cable near the boom hinge. This was a reoccurrence of DR 5114. Since the chamber door was still open for this initial reference ambient IST, the interference was manually eliminated and verified via STS printout.

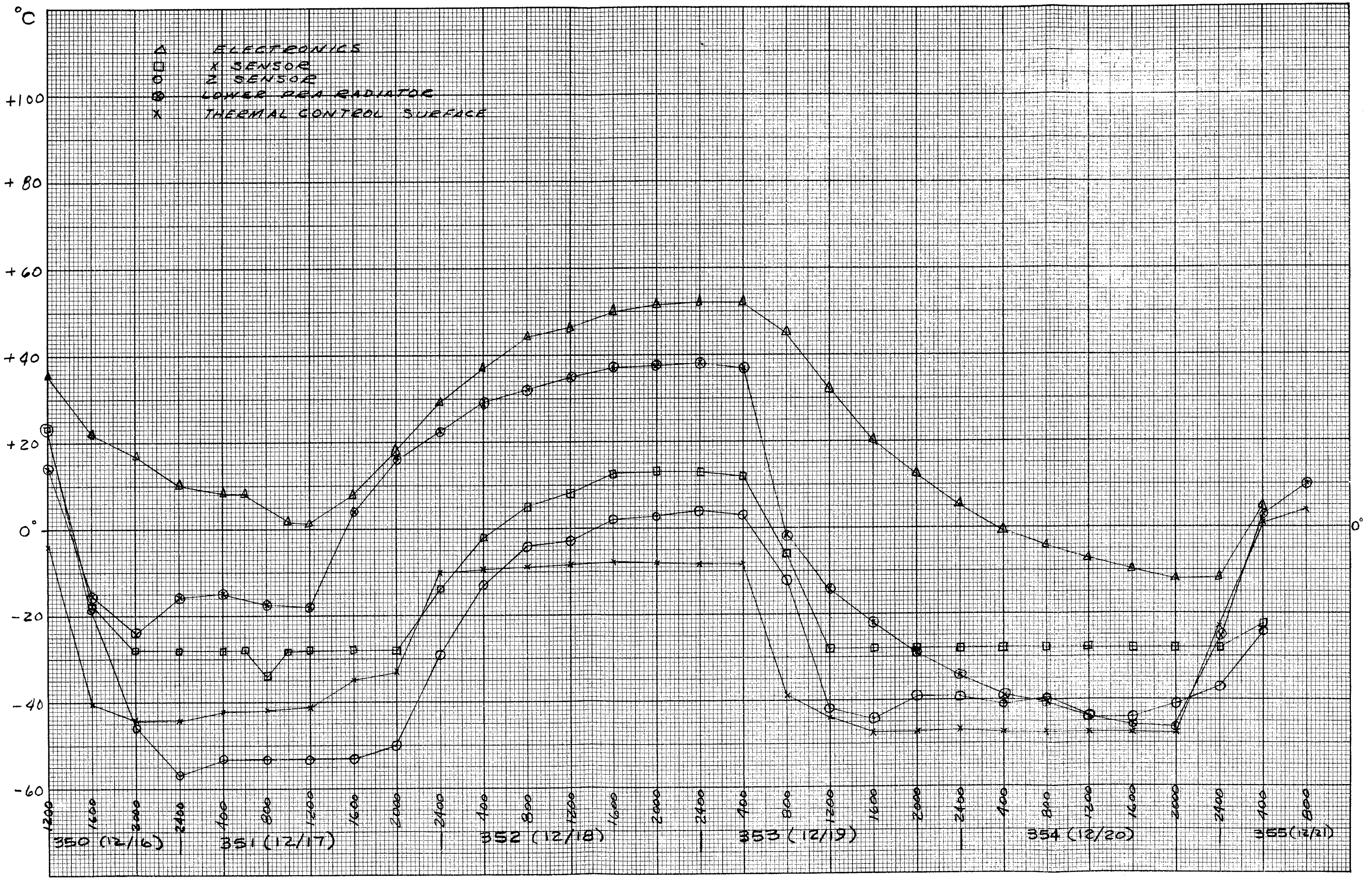


Figure 4.6.2-1 LSM Temperatures

TABLE 4.6.2-1

	SUMMARY: MAGNETOMETER TESTS					
	12/13/67	12/16/67	12/17/67	12/18/67	12/20/67	12/21/67
Start Time (Approx.)	0700 hrs	0700 hrs	0815 hrs	1915 hrs	1000 hrs	2000 hrs
Conditions:						
Temperature	Ambient	Ambient	Morning	Noon	Night	Ambient
Pressure	Ambient	Vacuum	Vacuum	Vacuum	Vacuum	Ambient
Tests Performed	F/C #1	F/C #2 F/C #3	Off/On	F/C #4 X S/S Y S/S F/C	No F/C due to extreme temp. gradient.	2 F/C
Discrepancies Resulting	DR 6249	DR 6306	DR 6332	DR 6346 DR 6349	------	------
Temperature (°C)						
X-Sensor			-27	12	-28	-28
Y-Sensor			-32	8	-34	-32
Z-Sensor			-52	4	-44	-36
EGFU Int.			-4	47	-6	-22
DC Converter			+3	52	+2	-13
X-Hinge		22	-49	29	-100	
Z-Hinge		22	-56	20	-101	
PRA		24	-18	35	-43	
Lunar Surface	21	21	12	113	-185	17

DR 6306 - While proceeding toward the lunar night condition, the X, Y and Z sensor temperatures went out-of tolerance. From the sensor temperature plots, it was apparent that the Z-axis heater was either intermittent or inoperative. The X and Y sensor temperatures fell below the low temperature limits as assigned to the STS computer program, but these were assigned to serve as "flag" items, not critical functions. In the prototype LSM, the sensor heaters are 1/3 W each, whereas subsequent models employ 1 W heaters in each sensor.

DR 6332 - During lunar morning conditions, word 4, bit 2 momentarily read "0", which is post-site survey gimbal position of the Y-axis. The reading corrected itself and did not reoccur.

DR 6346 - Procedural error, corrected immediately so that the test could continue. Additional offset ratchet commands were required to address the Z-axis.

DR 6349

1) In the process of attempting the Y-site survey at lunar noon, the Z-axis sensor did not indicate the flip from 180° to 0° and the site survey sequence was shut down. Scientific data on Z-axis indicated a partial flip. It was decided by NASA/ARC to discontinue the site survey and attempt a flip/cal, taking full status data before and after. During the flip/cal, the Z-axis motor drew power longer than normal, the initial and final status indications showed that X and Y had flipped from 0° to 180°, and Z had remained at 0°. On the basis of the above, NASA/ARC decided not to attempt a flip/cal at lunar night. During ambient post-vacuum IST, a flip/cal was attempted. This time X and Y flipped from 180° to 0°, Z flipped from 180° to 90°, per the status readout. One last flip/cal put all axes to 180°.

   The cause of the Z-axis malfunction, per NASA/ARC, was suspected to be the extreme temperature gradient of approximately 47°C along the Z axis boom end-to-end.

2) This DR again listed the offset status bits as discrepant (Ref. DR 5301). This anomaly was first seen during the Pre-Integration Acceptance (PIA) Test, whereby the sensor offset settings were erroneous and erratic in operation. This same condition was observed in later tests, including the Thermal/Vacuum Test, and was documented again as part of DR 6349.

3) The fact that the Z-axis sensor had shut down the site survey sequencer, was reflected in erroneous status readings of the flip and gimbal positions.

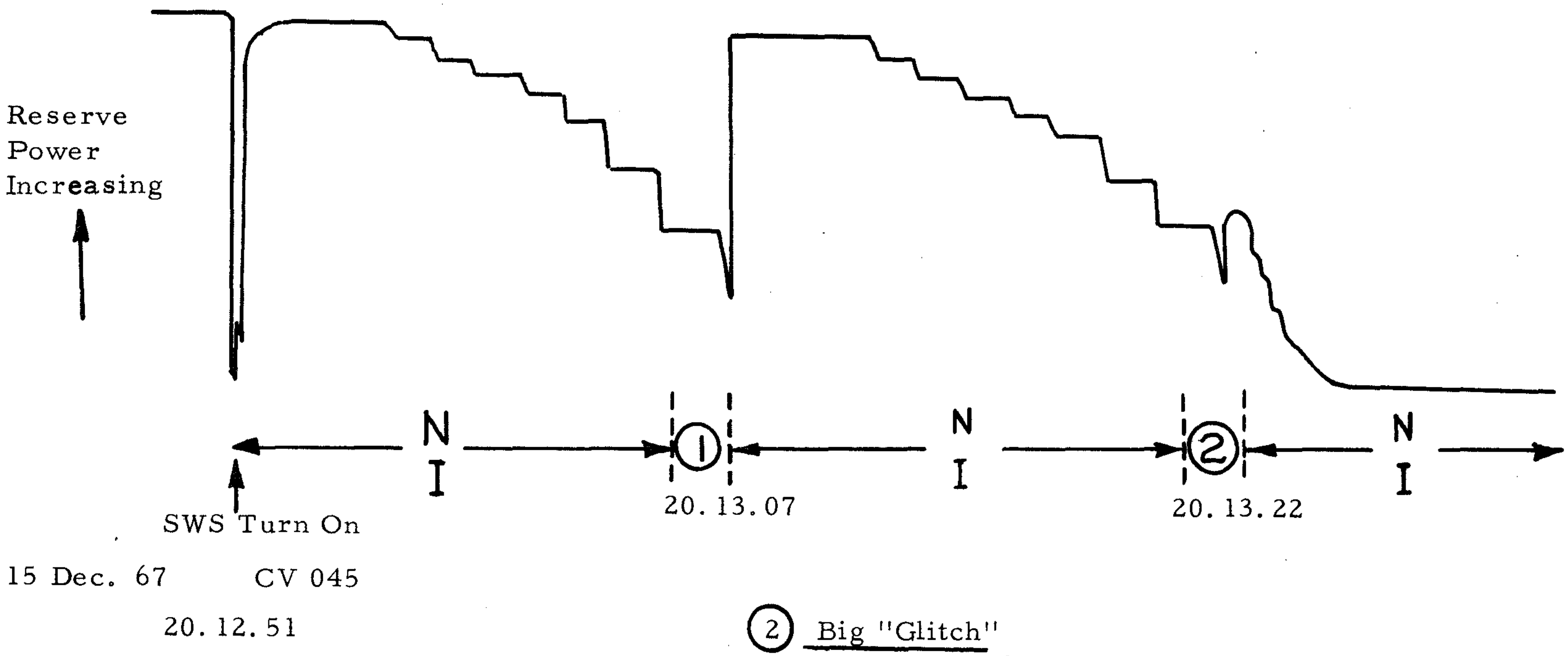
4.6.2.4 Test implications for design improvements. - The results of the Prototype Thermal Vacuum Test have verified the need for additional heater power to the three sensors. The need for this additional power was determined months prior to the test by Philco/Ford and the qual and subsequent experiments have one-watt heaters per sensor, in place of the 1/3-watt heaters used in the proto model. This design change should maintain the sensors at a higher temperature under lunar conditions and also preclude the reoccurrence of the extreme temperature gradient between sensors and electronics.

4.6.3 Solar Wind Experiment. -

4.6.3.1 Electrical performance. - The SWS failed to respond to the turn-on command during the ambient temperature-vacuum IST. The STS processor indicated a loss of main frame sync and also SWS subcommutator lock so the experiment was commanded off. Analysis of the STS printer indicated that the Central Station operation was normal. Several additional turn-ons of the SWS were attempted without success. During earlier room ambient tests the SWS had failed to turn on (DR 5295) but it eventually started and performed satisfactorily after several turn-on attempts.

An analysis of the reserve power profile (see Figure 4.6.3-1) indicated that the SWS turn-on transient was normal and that the SWS switching sequence was normal through the proton voltage levels until reaching the last few steps. At that time, the data indicates an arc occurred within the SWS. No apparent damage resulted at that time since subsequent data appeared nominal. The only apparent effect of the arc was to reset the SWS programmer to the low proton levels again. Once more, the SWS progressed through the proton levels until it reached approximately the same level at which the previous arc occurred. Again, an arc was experienced which resulted in failures, that affected the output data and caused the SWS to draw excessive power which, in turn, caused the programmer to stop. Operating power was removed from the SWS.

SOLAR WIND FAULT
(RESERVE POWER VARIATIONS)



② Big "Glitch"
Loss of Main Frame Sync
Indicators of High Noise Levels
Data Processor Incrementing Sync Pattern Jumped to 100
Multiplexer Jumped to 40

① First "Glitch"
False SWS Turn On CV 045
Multiplexer Skipped Channel 59

Figure 4. 6. 3-1 Reserve Power Variations During SWS Fault

Repeated attempts to reactivate the SWS showed that the high-power drain was permanent and that the SWS programmer would not cycle. The SWS was operated during the remainder of the thermal-vacuum test under standby (survival) power.

4.6.3.2 Thermal control. - The temperature profile of the SWS as measured by the Data Acquisition System during the complete thermal vacuum test is shown in Figure 4.6.3-2. This data indicates that thermal stabilization was approximately 1°F per hour during lunar nighttime and lunar daytime. The maximum internal SWS temperature during lunar daytime simulation was 112°F (44°C). The minimum internal SWS temperature during lunar nighttime simulation was -28°F (-33°C). During the entire thermal vacuum test, the SWS was not functional, and was operating on standby or survival power, dissipating approximately three watts. In normal operation the SWS Experiment dissipates an average of approximately six watts during the lunar nighttime excursion and 4.5 watts during the lunar daytime excursion. The temperature encountered under survival power conditions appear nominal and would be somewhat higher under normal operating conditions.

4.6.3.3 DR evaluation. - During retest at JPL, the problems experienced at Bendix were verified. Upon disassembly of the SWS, it was found that component failures were present in (1) the proton high voltage modulator drives, (2) the electron high voltage 2 KC driver, (3) the high voltage calibrate amplifiers, (4) the data and troubleshooting commutators and (5) the conversion counter. Completed failure analysis is awaiting action from the JPL parts evaluation group. Most of the failures encountered were typical of those found in other models of the Solar Wind Experiment which had experienced a high-voltage arc. Corrective measures are being taken to prevent high-voltage arcs from occurring during normal operation, and to reduce the incidence of component failures should a high voltage arc occur.

4.6.3.4 Test implications for design improvements. - The high voltage arcs encountered during the thermal vacuum test necessitated a thorough investigation into the cause and source of high voltage arcs, their elimination, and circuit protection required in the event an arc occurs.

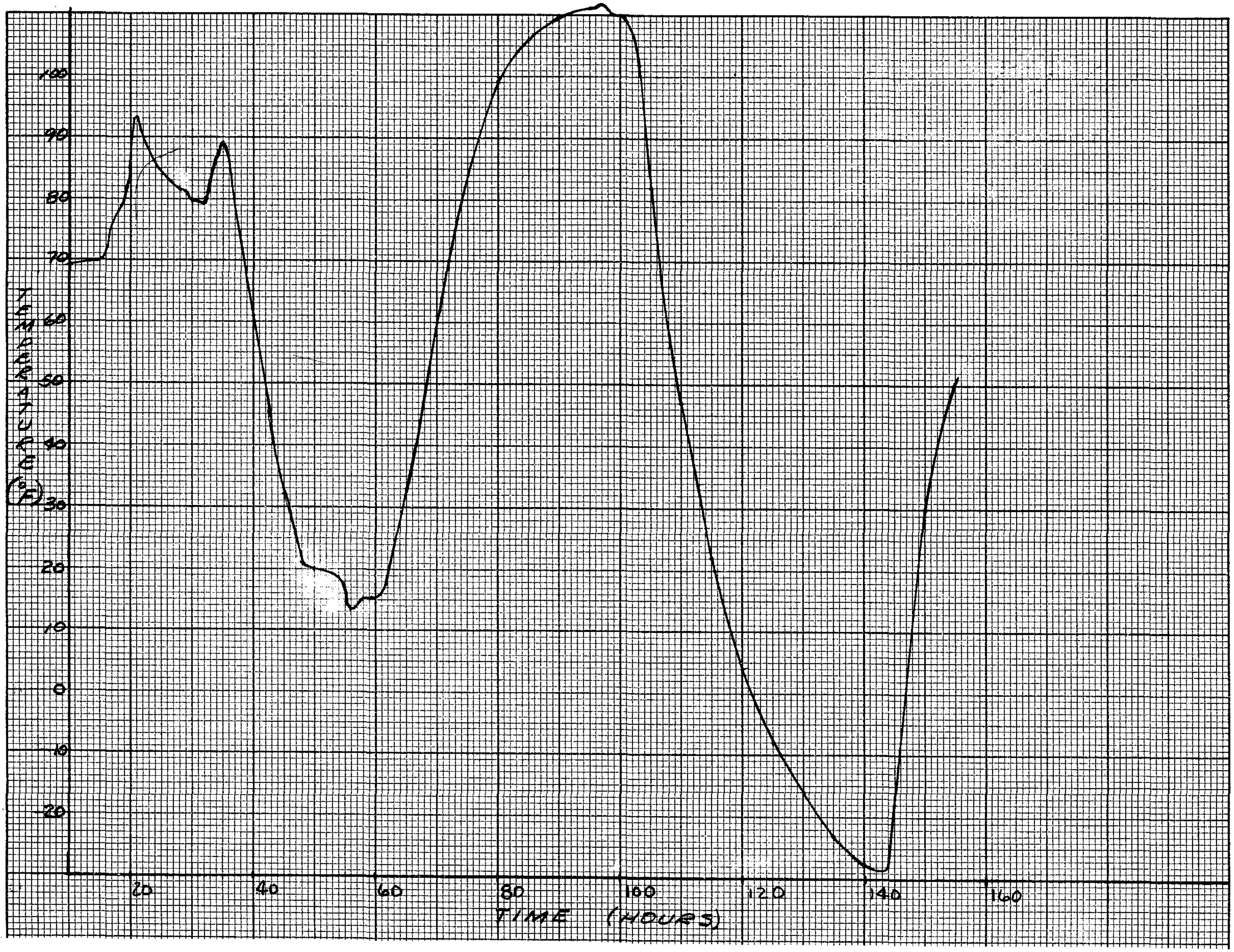


Figure 4.6.3-2 SWS Temperature Profile Proto "A" Thermal Vacuum Test

4.6.4 Suprathermal Ion Detector/Cold Cathode Ion Gauge Experiment. -

4.6.4.1 Electrical performance. - The overall electrical performance of the SIDE was successful since there were no major failures. However, functional problems inhibited test of the high voltage commands during lunar night. The following discussion details the performance at the experiment subsystem level.

4.6.4.1.1 Steppers and counters. - The DPS-2000 of the STS lost sync with the experiment data causing errors to be flagged at times during all phases of the thermal vacuum test. One of the prime causes of sync loss was the effect of the SIDE frame counter resetting to zero after certain commands. The time of reset was dependent on whether the command was executed in an odd or even frame and in the latter case the computer was unable to track the experiment correctly. Insufficient detail of the intricate SIDE logic functions resulted in the inadequate software program for the STS. Defect Report 6248 is an example of this effect, which is not an experiment malfunction. When the experiment is put into the "times ten accumulation" mode, the step at which the SIDE frame counter starts (in the series of ten steps executed for each SIDE frame number) is not predetermined. The computer therefore loses sync, after the command is executed, the first time the SIDE frame number changes (i.e., from 121.9 to 122.0). The experiment data also takes several steps before fully acquiring the desired mode, which causes error flags against the stepper voltage values and the science data calibration values during frames 120 to 127. The high energy curved plate analyzer stepper voltages are often out-of-sync with the SIDE frame counter during the first sequence after turn-on or directly after a command execution which resets the counter to zero. This phenomena causes the majority of the values in word three to be flagged. The foregoing effects are peculiarities of the experiment operation and do not constitute errors. The STS executive program is being modified to prevent this tracking problem and thereby eliminate one source of sync loss. The other areas remain as known sources of deviations. The SIDE frame counter and velocity filter stepper did exhibit malfunctions which are not attributable to experiment/program incompatibility. The SIDE frame counter, and all the steppers, missed steps at various times during the lunar noon systems test. These errors are believed to be due to high voltage arcing associated with the -3.5 kV Channeltron supply and are discussed later in this section.

When the experiment was cooling for the lunar night reference test, the SIDE frame counter apparently stopped for over three minutes. The high-voltage supplies were off at this time, which rules out the possibility of arcing.

The effect on the other words of the SIDE frame was as follows. Word 2 was normal for frame 29, the SIDE frame at which the counter stopped. Words 3 and 8 read 507, while word 3 value was obtained in the word 4 position; words 4 and 5 in the 5 and 6 positions, and words 7 and 8 in the 9 and 10 positions. Word 6 which includes a parity bit and two odd frame identification bits, was printed in word 7 position. A complete SIDE frame of data was printed every two ALSEP frames during the period but the only changes were in the parity bit of word 6, printed in word 7, and in the high energy curved plate analyzer stepper which continued with its correct program throughout. At the end of the three-minute interval the experiment started to operate normally from its stationary position with only the high energy curved plate analyzer out-of-sync. The internal temperatures at the time this occurred ranged between 0°C and 30°C. There cannot be found, at this time, any reasonable cause for this defect other than a combination of three or four faults of singular occurrence. The velocity filter voltage was observed to go off without command on several occasions, at least two of which occurred at SIDE frame 95. The voltage could be commanded on again. This action did not appear to be temperature sensitive since it occurred during all test phases and had been seen during tests at Rice and Bendix before the thermal-vacuum sequence.

4.6.4.1.2 High-voltage supplies. - The high-voltage supplies were a center of major concern throughout the test sequence. The two considerations were that the chamber pressure must be below 5×10^{-6} torr for at least 17 hours after initial chamber pump-down. The latter requirement was to allow sufficient time for out-gassing. The chamber pressure measurements were those recorded on the normal chamber instrumentation. The test procedures required that the experiment was left on with the high voltages commanded off at the end of each test phase. This approach ensured that there would be no harm done to the experiment if the pressure increased temporarily, during changes from lunar noon to lunar night conditions for example. Furthermore, if for an unforeseen reason the chamber pressure was above 5×10^{-6} torr during any phase, the experiment could still be operated without aborting the whole test.

A detailed analysis of the data since the tests indicate that high-voltage arcing probably occurred at the lunar noon phase. A possible cause of arcing is local out-gassing in the experiment, which apparently takes a considerably longer time than originally expected. The pressure was below 1×10^{-4} torr for at least 24 hours before SIDE was turned on for the first time, including 12 hours below 5×10^{-6} torr. The experiment turn-on at the lunar noon phase occurred after 76 hours below 5×10^{-6} torr, including 40 hours below 2×10^{-6}

torr. These latter times include two periods of one and two hours respectively when the pressure rose to a maximum of 2×10^{-5} torr. The pressure at lunar noon turn-on was recorded as 8.6×10^{-7} torr.

The lunar surface temperatures at lunar noon had been stable for three and one-half hours at the start of the SIDE portion of the systems test. The experiment had been turned off earlier because the internal temperatures approached 80°C. The internal temperatures were above 70°C for approximately four hours at this time but fell slightly after turn off, reaching 60°C to 65°C at the start of the test.

4.6.4.1.2.1 Cold Cathode Ion Gauge Supply, 4.5 kilovolt. - The 4.5 kilovolt supply operated satisfactorily during the ambient temperature vacuum IST. When the ALSEP system was turned on during the simulated lunar morning, the SIDE internal temperatures were still below the heater operating temperature of 20°C. The sum of the heater power and power required to release the dust cover was above the 13 watts needed to operate the circuit breaker, making it impossible to send either of the high-voltage commands. The one-time command required to release the cover was included in the combinations of commands encoded to turn-off the high voltages. This troublesome feature has been eliminated in future units. The voltage was commanded on successfully at the beginning of the lunar noon test, but later on in the test sequence the experiment circuit breaker operated every time the "on" command was sent. The high voltage is initially on when the experiment is turned on. Once the high voltage was commanded off, it could not be commanded on without activating the circuit breaker. The results were described in DR 6344. The experiment was turned on with the following readings being obtained:

Word 2, SIDE Frame 56 190 (CCGE range)

Word 6, SIDE Frame 67 3 (electrometer range)

Word 2, SIDE Frame 72 225 (high-voltage on).

After high-voltage off command was sent, there were no error printouts. After the on command, which was received at ALSEP frame 28, SIDE frame 88, the following events occurred:

Word 2, SIDE Frame 104 read 095 (high-voltage off)

Word 6, SIDE Frame 105 read 0 (range one)

The experiment went to Standby at ALSEP frame 73, SIDE frame 110. This indicates that the voltage was still off approximately 19 seconds after the command and the experiment did not go to Standby until approximately eight seconds later. The breaker did not operate at command execution as originally supposed. When further attempts were made to operate this command there were no convenient readouts to indicate voltage status. On one occasion there was an 11 second lapse between the command and the experiment switching to Standby. This defect persisted during the ambient temperature test performed at the end of the thermal vacuum sequence, prior to shutting down ALSEP for the rise back to ambient pressure. The experiment was turned off during a special test prior to the lunar night systems test and the consequent initialization of "one time" commands prevented the operation of the high voltage commands.

4.6.4.1.2.2 Channeltron supply, -3.5 kilovolt. - The Channeltron supply had an apparent problem in the ambient temperature vacuum IST. When commanded off the supply appeared to remain on. This was determined to be a monitoring error within the experiment because the science count dropped to zero after command execution (confirming absence of voltage) and the voltage monitor read zero when the 4.5 kv supply was also turned off. Marshall Laboratories confirmed an interaction between the high-voltage supply monitor points. This defect remained through all test phases.

The supply repeatedly turned off without command during the simulated noon test. A command would return the supply to the on condition but it would soon go off again. When the voltage went off, the counters (including the SIDE frame counter) jumped counts. The most likely reason for these effects was high-voltage arcing. The supply did not exhibit the effect at lunar night or at the return to ambient temperature.

4.6.4.1.3 Science data. - The science data is read as two groups of two, ten-bit words. The high-energy data is read in SIDE words 4 and 5 combined and the low energy in words 9 and 10 combined. The data is normally zero when the Channeltron power is off, except during calibration when fixed frequencies are applied to check the system from the Channeltron output onwards. When the -3.5 kv supply was on, the following representative counts were read in the science data words during the various test phases. Calibration data is not included.

Ambient-vacuum IST	SIDE FRAME 005	H.E. 1024	L.E. 8155
	SIDE FRAME 119	H.E. 994	L.E. 7978

Lunar night IST	SIDE FRAME 000	H.E. 000005	L.E. 000000
	SIDE FRAME 119	H.E. 000000	L.E. 000000
Return to ambient after lunar night	SIDE FRAME 001	H.E. 000086	L.E. 002943
	SIDE FRAME 119	H.E. 000066	L.E. 002606
Lunar noon turn-on	SIDE FRAME 000	H.E. 001795	L.E. 052773
	SIDE FRAME 119	H.E. 008849	L.E. 066157
	SIDE FRAME 114	H.E. 008849	L.E. 081264
Lunar noon when -3.5 kv went off	SIDE FRAME 010	H.E. 021084	L.E. 090019
	SIDE FRAME 011	H.E. 025971	L.E. 036095
	SIDE FRAME 012	H.E. 000000	L.E. 000000

A representative set of calibration data is given for the conditions when the high voltage was off and on. The low-energy channel was known to have a defect at low temperature which caused no data to be presented.

Frame	SIDE Vacuum IST L.E. Counts	H.E. Counts	Ambient L.E. Counts	IST H.E. Counts
120	8604	1304	000000	000000
121	8449	1260	154	19772
122	26406	1374	19773	632747
123	8455	21121	632743	000000
124	7538	633368	000000	155
125	8370	1314	154	19772
126	28849	1403	19773	632747
127	9034	21012	632728	000000
000	8804	633447	000000	155

Non-calibration frames were approximately 8000 ± 800 and 1100 ± 100 for L.E. and H.E. respectively with the high voltage on. The ambient IST data depicts a mode of operation common to the condition when the high energy curved plate analyzer has slipped with respect to the SIDE frame counter. This condition is corrected in the next sequence after the slip occurs and no out-of-tolerance values are then obtained.

The science data is fed in parallel to two analog channels to give "backup" information should the digital channel fail. The analog data is in the form of a voltage proportional to the logarithm of the count rate. The following figures are representative of the data obtained during the various phases compared with the digital counts read at a corresponding time. The data is quoted from printed records taken during X10, continuous calibration mode. The high voltage to the Channeltrons was on during the ambient-vacuum IST so the readings include noise counts. The low energy channel had a known problem which is apparent from the readings.

Ambient Reference IST

SIDE Frame	Analog Channel	Log Count Expect	Log Count Obtain	Science Count	Approximate Count Rate
120	High (85)	<12	001		
126	Low (70)	159-180	175		
127	High (85)	205-246	223		

Ambient-Vacuum IST

SIDE Frame	Analog Channel	Log Count Expect	Log Count Obtain	Science Count	Approximate Count Rate
120	High (85)	<12	088	3573	1200/step
121	Low (70)	62-83	139	25000 approx.	8500/step
121	High (85)	62-83	87	10407	
122	High (85)	159-180	174	62974	20,000/step
123	Low (70)	205-246	127	14367	6,000/step
123	High (85)	205-246	225		
124	Low (70)	<12	137	16284	8000/step
124	High (85)	<12	88	9431	1100/step
125	Low (70)	62-83	139	60596	

Ambient-Vacuum IST (Cont.)

SIDE		Log Count			Approximate
Frame	Channel	Expect	Obtain	Science Count	Count Rate
125	High (85)	62-83	95	10910	1300/step
126	Low (70)	159-180	178	55438	27,000/step
126	High (85)	159-180	174	62762	
127	Low (70)	205-246	137	65565	9800/step
Lunar Noon-Vacuum IST					
121	Low (70)	62-83	68		
121	High (85)	62-83	68		
122	Low (70)	159-180	172		
122	High (85)	159-180	173		
123	Low (70)	205-247	001		
123	High (85)	205-247	229		
124	High (85)	< 12	002		
126	Low (70)	159-180	172		
127	Low (70)	205-246	002	000000	
127	High (85)	205-246	229		

A reading is not available for each SIDE frame on both high- and low-energy channels.

4.6.4.1.4 Cold Cathode Ion Gauge Experiment data. - The cold cathode gauge gave a full scale output reading throughout the thermal vacuum test, whenever the 4.5 kV supply was on. The pressure in the chamber was not low enough to be within the measuring range of the gauge, which for this unit starts at 2 x 10^{-7} torr. The lowest pressure recorded in the chamber was 7.8 x 10^{-7} torr. The electrometer amplifier ranged correctly between the two extreme ranges when the high voltage was switched on or off. The electrometer amplifier is checked at two current levels and zero on each range, the calibration range being set by the operating range at any particular time. The readings obtained were out-of-tolerance during some phases of test in the normal mode. In the X10 mode of operation the data appeared to slip ten SIDE frames. This was not a known mode of operation. The electrometer amplifier in this unit had a larger time constant than future units will have. In the normal and continuous calibration modes the data is often incorrect because of the long stabilizing time of the amplifier. The X10 mode of operation was correct with the high voltage to the gauge both on and off, if the slip of data in this mode is taken into account.

4.6.4.1.5 Response to commands. -

4.6.4.1.5.1 Mode commands. - There were no serious errors attributable to the experiment during tests involving mode commands. Two defect reports were written against tests involving mode changes but neither were serious. The first DR (6268) occurred when the "Velocity Filter Reset at 9" command would not operate during the initial ambient reference IST. The cause of this was determined to be an incorrectly mated or dirty connector at the Central Station interface. The second DR (6374) occurred during the lunar night IST when the experiment went to Standby on receipt of the "Master Reset" command. This action was caused by the combination of heater current and dust cover release current operating the circuit breaker in the Central Station. The "Master Reset" command also operates the dust cover release command, if the one-time command has not been previously operated since the experiment was turned on. This was the first operation of this command during this test phase. The effect was anticipated and the experiment design has been modified to inhibit the heater during this command on subsequent models.

4.6.4.1.5.2 Toggle on/off commands. - There was one defect which occurred during the lunar day test phase and which remained throughout the thermal vacuum test cycle. This defect was in 4.5 kV CCIG high voltage on command, which sent the experiment to Standby whenever it was sent. The same command combination was used to turn the voltage off (after the supply was turned on with experiment turn on) and no problems were experienced in this area. The cause of this problem has not been determined.

The -3.5 kV, Channeltron high-voltage supply on/off command operated satisfactorily but the supply also went off without command during the lunar noon test. When this occurred, the supply could be commanded on. The probable cause of this effect is high voltage arcing, which almost certainly occurred during the lunar noon test as indicated by high science counts and erratic counter indications.

The Velocity filter on/off command operated satisfactorily. The voltage intermittently went off without command during all phases of testing, including times when the -3.5 kV and 4.5 kV supplies were off. The voltage could be commanded on correctly at these times.

There were no problems with the high and low energy curved plate analyzer commands.

The X10 accumulation command operated satisfactorily. The STS program lost sync with the experiment data when this command was executed because the STS program was unable to predict at which step, of the 10 per SIDE frame, the experiment would start. The sync was soon reacquired and no further problems encountered.

The STS program also lost sync when on/off commands were sent after certain mode commands. This is a predictable event but was not known soon enough before the tests to incorporate into the program. The on/off commands were not operated during the lunar night phase because they all contain the command to operate the dust cover release. This command in combination with the heater caused the circuit breaker to operate.

There were no problems at any phase of the thermal vacuum cycle with commanding experiment turn on, Standby On, or Standby Off.

4.6.4.1.6 Power. - There were no direct measurements of power made during the thermal vacuum test sequence. The SIDE power drain was extrapolated from the reserve power measurements. When SIDE was turned on there was, on nearly every occasion, a computer main frame sync loss. This may have been caused by a fast pulse at the beginning of the turn-on transient.

There were two engineering evaluation tests performed, one at lunar noon and one just prior to the lunar night test, to obtain values of experiment power under various operation conditions. The first at lunar noon gave figures of 7.0 watts for operating and 2.0 watts for Standby power. The second gave 9.5 watts operating and 5.45 watts Standby power. The heater was on in the second case giving higher standby and operating values. The values obtained in these measurements are influenced by the operating conditions of other experiments on line at the time the measurement is made.

When the experiment went to Standby after execution of the 4.5 kV on command, (DR 6344) the reserve power recorder showed a drop to 7.4 watts of reserve power rising to 20.6 watts when the experiment went to Standby. The power before the transient stood at 16.5 watts of reserve power. The

The transient had a peak value of 13.2 watts plus the power of the fixed survival heater (nominally two watts) which was sufficient to operate the circuit breaker.

4.6.4.2 Thermal control. - The operation of the thermal control system could not be completely evaluated since the experiment lay on its side on the simulated lunar surface for the majority of the thermal vacuum cycle. The infrared lamp array was not used after the experiment fell over.

The experiment had six internal temperature sensors whose data was read out via the Central Station digital data output when the experiment was operating. The sensors in the cold cathode gauge and in the 300 blivet were inoperative. When the experiment was in the Standby On and Standby Off condition, four supplementary thermocouples were used to monitor temperatures inside the unit. These four thermocouples were recorded throughout the test and gave information supplementary to that given by the experiment's own monitors when it was operating. Two of the four thermocouples were placed on the underside of the thermal spacer and the other two were placed on the top and bottom of the wrap-around, surrounding the electronics. Temperatures 2, 3, 4, and 6, measured during the ambient vacuum IST which lasted approximately 3-1/4 hours, were 30°, 37°, 33°, and 33°C respectively at the IST start. The lunar reference test lasted 20 hours from start of cool down to lunar morning stabilization. The experiment did not stabilize during the low temperature phase but reached its lowest temperatures around 23.30 hours on day 350. The warm-up to lunar noon started around 22.00 hours on day 350. Temperatures 2, 3, 4, and 6 reached lows of +10°, +5°, +17°, and -7°C respectively. The lunar night test was discontinued because certain commands could not be sent while the heater was on. The experiment had stabilized under its operating conditions, so it was decided to use the rest of the phase to obtain temperature data in the Standby condition. The internal electronics temperatures did not completely stabilize in this mode, but reached a point where they were changing at approximately 3°C in two hours. The sensor recording, the lowest temperature, could have stabilized but it had been off scale for five hours. The lowest temperatures reached during operation and standby for both internal sensors and supplementary thermocouples are listed below:

	Temp. Sensors °C				Thermocouples °C			
	2	3	4	6	1	2	3	4
Operating	+8	+4	+14	-7	-40	-19	-59	-27
Standby	-20	-25	-9	-30*	-55	-36	-86	-43

*Sensor off scale.

The experiment temperatures at lunar noon were due entirely to internal dissipation and proximity of the lunar surface, since no infrared lamps were used. When the experiment fell over it was allowed to operate until its internal temperatures approached 70°C, at which time it was turned to Standby. The unit was finally turned off when the temperatures approached 80°C. The temperatures fell slightly (after approximately seven hours), allowing a complete system test to be performed. The following is a tabulation of relevant temperatures.

	Electronics Temp. °C				Thermocouples °C (DAS)			
	2	3	4	6	1	2	3	4
Leg collapse D351 22/50	43.5	44	45.5	37	39.5	33.9	11.8	42.9
Max. reached D352 07/46	75.0	79	76	70	62.3	61	32.6	73
Start IST D352 15/30	65	61	64	58	54.6	51.7	29.0	60.9
Finish IST D352 18/30	71	74	72	66	59.6	58.4	31.1	72.3

The following graphs, Figures 4.6.4-1 through 4.6.4-6, are included to show temperature variation rates at critical times. The graph of internal temperatures during Standby gives only a rough indication of the temperature trends during the period, since few readings were available.

Figure 4.6.4-1 SIDE Internal Electronics Temperatures
Prior to Lunar Noon IST - 17, 18 December 1967

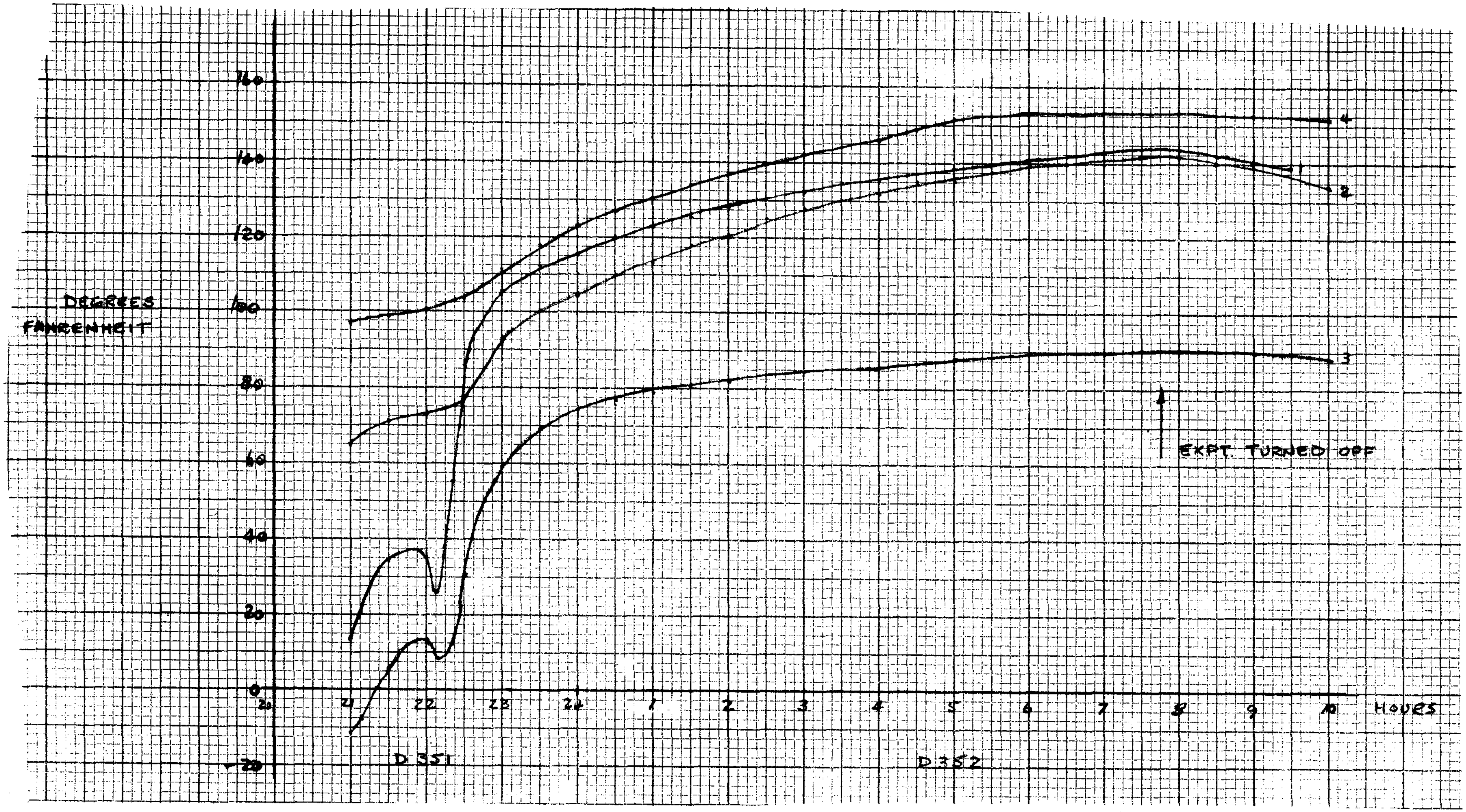


Figure 4.6.4-2 SIDE Internal Thermocouple Temperatures Prior to Lunar Noon IST - 17, 18 December 1967

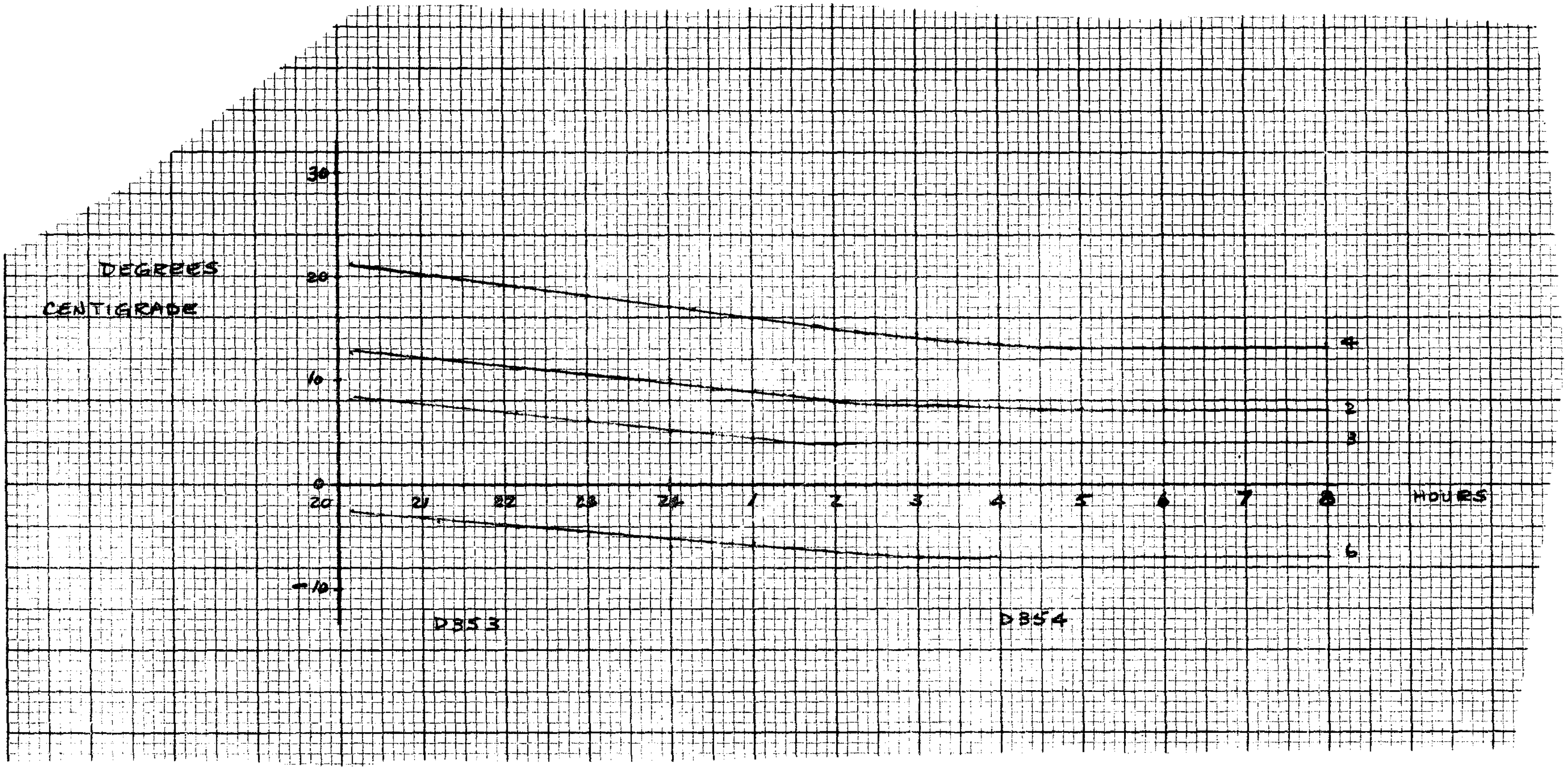


Figure 4.6.4-3 SIDE Internal Electronics Temperatures
Lunar Night Stabilization and IST - 19, 20 December 1967

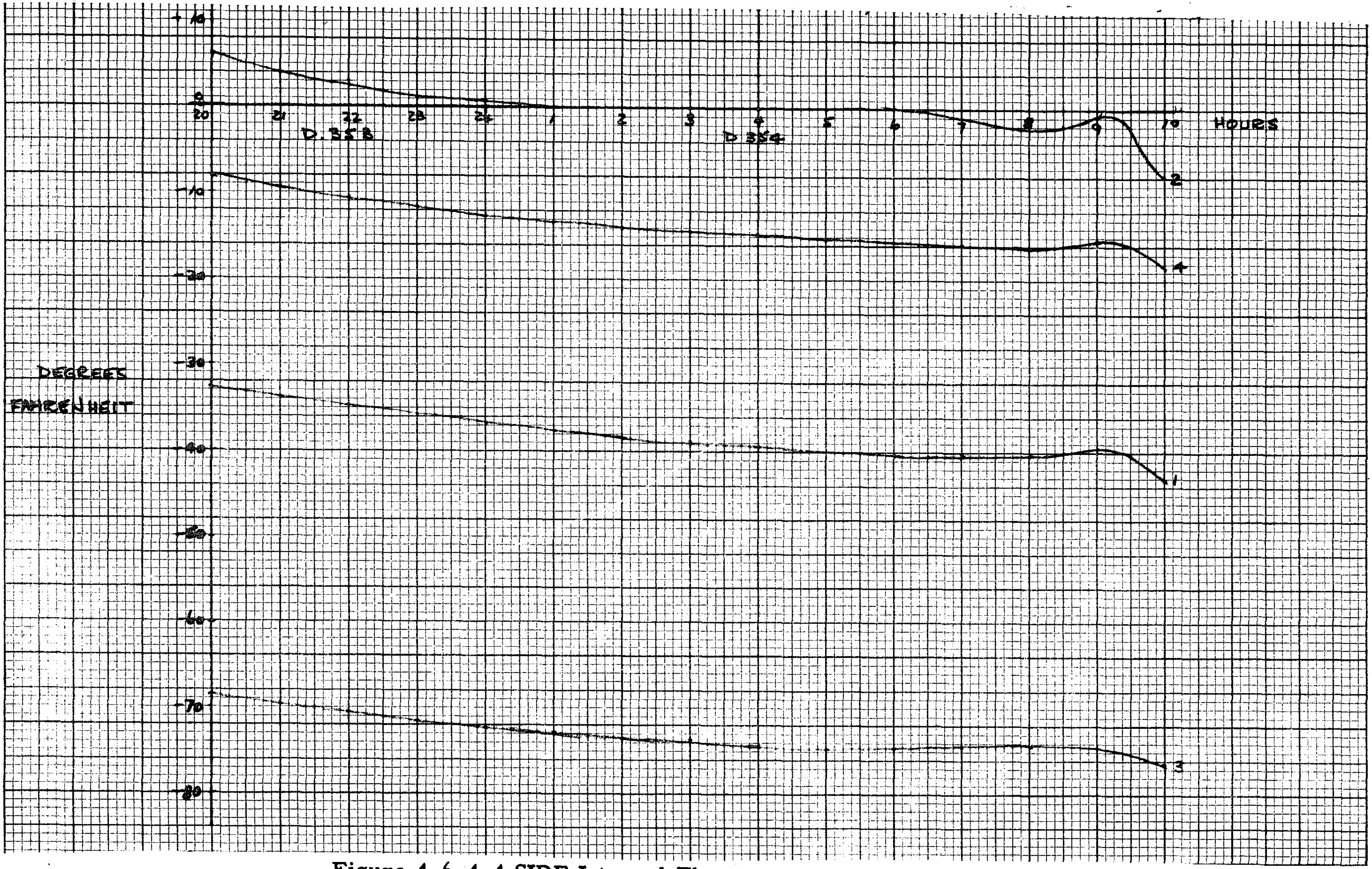


Figure 4.6.4-4 SIDE Internal Thermocouple Temperatures
Lunar Night Stabilization and IST - 19, 20 December 1967

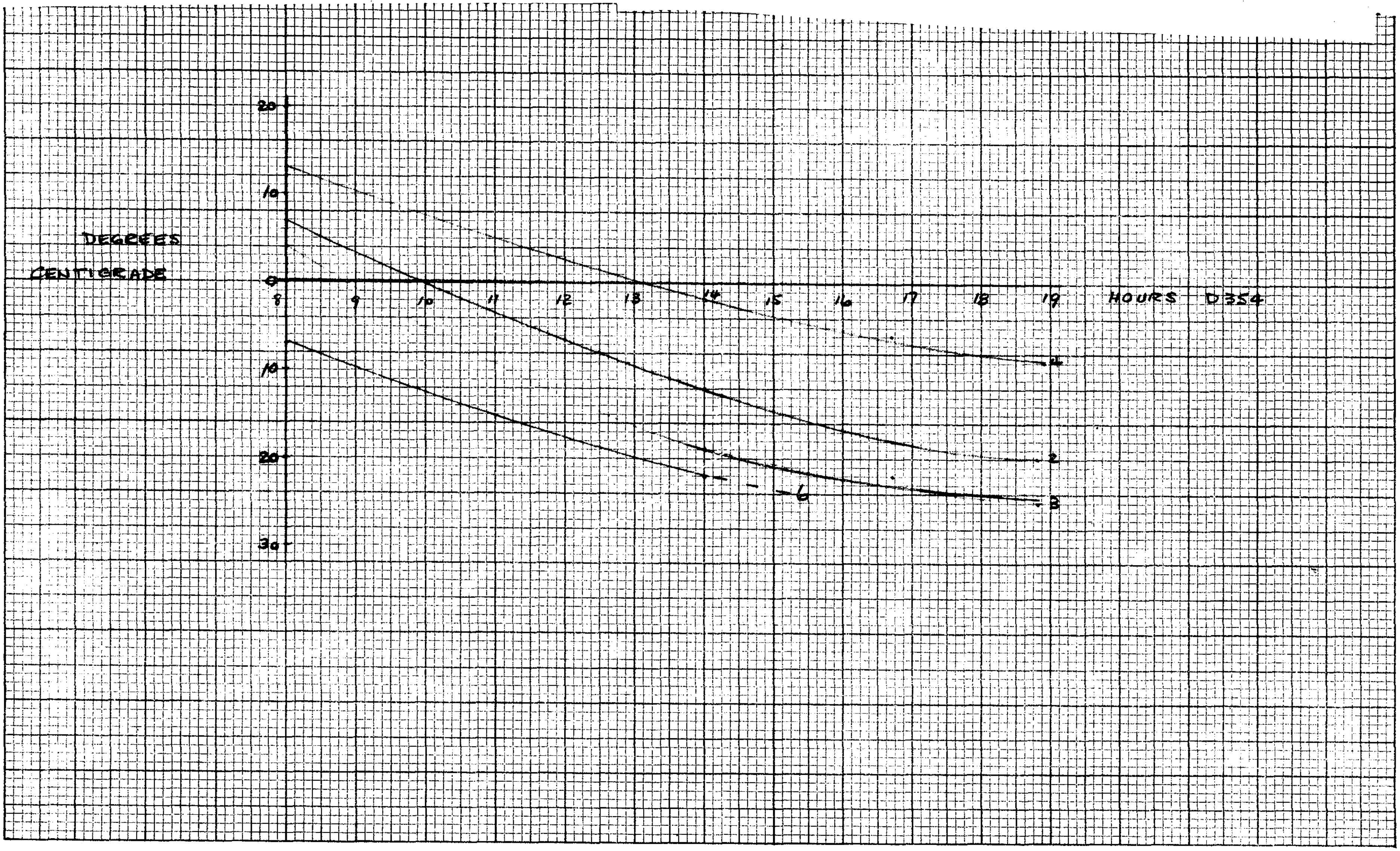


Figure 4.6.4-5 SIDE Internal Electronics Temperatures
Lunar Night Standby 20 December 1967

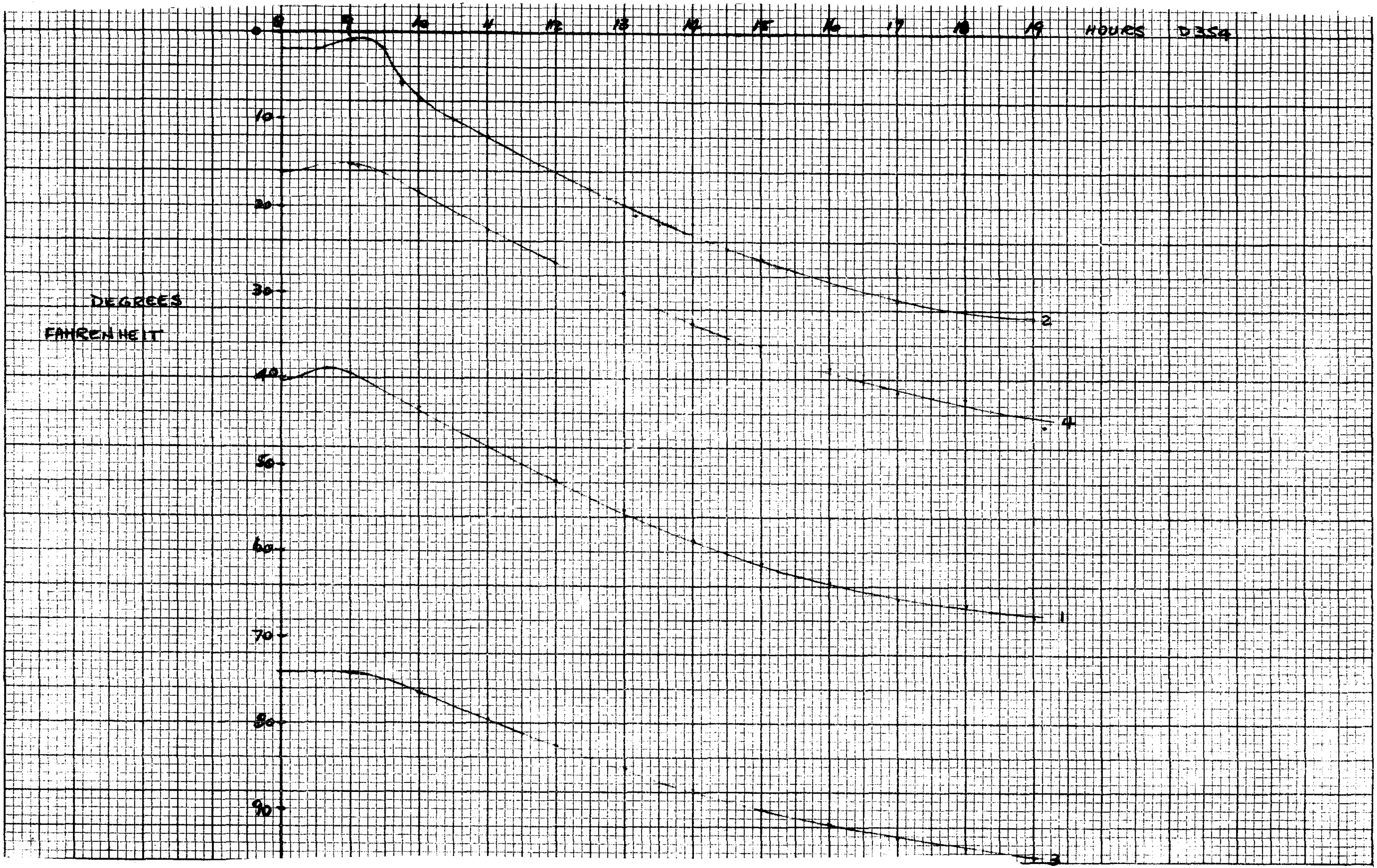


Figure 4.6.4-6 SIDE Internal Thermocouple Temperatures
Lunar Night Standby 20 December 1967

4.6.4.3 Discrepancy report evaluation. - A total of 20 discrepancy reports were written during the Suprathermal Ion Detector portions of the Thermal Vacuum Tests. The following list provides details of the discrepancies with assumed causes and, where known, the remedies.

DR No.	Description	Cause	Remedy
6125 6304 6301	The experiment data indicated that the -3.5 kV Channeltron supply did not turn off as commanded (ambient temperature vacuum and post lunar night vacuum ambient test).	The supply did turn off as confirmed by the science data. The 3.5 kV monitor had a crosstalk problem with the 4.5 kV monitor, caused by an improper short between the high voltage supply ground returns.	The accidental short will be eliminated. A permanent interconnection will be made, for other reasons, in a preferred physical position. An acceptable level of crosstalk remains.
6248	When the ground plane stepper on/off command was executed a SIDE sync loss occurred in the system test set.	This was a previously known function of the STS program's inability to track certain unpredictable experiment command functions.	A modification will be made to the STS executive program to overcome the present incompatibility.
6255 6268	The experiment/Central Station connector was mated incorrectly causing the experiment to be inoperative. When remated correctly, one command could not be transmitted to the experiment.	The Central Station connector was mounted upside down, but to print. The experiment mating half was not marked in a way which easily identified its correct mating orientation. The contacts were found to be dirty and possibly slightly marked by incorrect alignment with their mating parts.	The Central Station drawings have been changed. The experiment cable connectors have all been marked. The contacts on the defective part were cleaned and the connector carefully and securely mated.
6267	The CCGE calibration data in word 2, SIDE frames 122, 125 and 127 was out-of-tolerance.	Electrometer time constant.	Time constant shortened in future units.

DR. No.	Description	Cause	Remedy
6302	Data requested in procedure could not be obtained.	The procedure and the experiment were not compatible.	The procedure will be updated.
6303	The calibration of the high- and low-energy science channels was out-of-tolerance in words 4, 5, 9 and 10 for frames 120 through 127.	This is normal operation when the -3.5 kV is on. The Channeltron noise adds to the calibration counts.	Only the lower limit will be used for the calibration data when the high voltage is on. The present limits will apply when the high voltage is off.
6330 pg. 1	The velocity filter stepper voltage turned off without a command. Later analysis showed that this occurred on several occasions at SIDE frame 95.	Unknown.	
pgs. 2 & 3	When attempting to turn the high voltages off after lunar morning turn on, the experiment tripped its circuit breaker in the Central Station.	The experiment was still cold enough to need its heater on after the lunar night reference test. The combination of required power for the heater and blowing the dust cover, caused the circuit breaker to operate. The high-voltage commands execute the one time dust cover blow command if it has not previously been operated.	The experiment logic has been modified to turn off the heater power for the duration of the dust cover blow command. (2.5 seconds duration).

DR No.	Description	Cause	Remedy
6333	The high-voltage monitors in word 2 were out-of-tolerance. When the high voltage turn off commands were sent the experiment circuit breakers operated, putting the experiment to Standby.	The monitor voltage is discussed in DR 6125. High-voltage command problem covered in DR 6330.	
6336 & 6416	The experiment was seen to be on its side during the lunar noon test. Post-test inspection showed a detached leg and damaged dust cover.	One leg collapsed because a nylon screw, attaching the leg to the experiment melted.	The leg assembly has been redesigned in the attachment area.
6343	The -3.5 kV supply turned off without a command. Simultaneously, the SIDE frame counter and other steppers jumped counts.	High voltage arcing is the possible cause of this defect.	The criteria for high voltage turn on are to be re-evaluated.
6344	The experiment went to standby power when the 4.5 kV on command was executed.	Unknown.	
6362	Word 3 SIDE frame 121-0 read 253 should read less than 80.	Unknown	
6373	Calibration data words 4, 5, and 9, 10 SIDE frames 121 reading out-of-tolerance.	The discrepancies are caused by two effects 1) words 4, 5 reading high due to Channeltron noise. 2) words 9, 10	

DR No.	Description	Cause	Remedy
		reading zero. This fault was seen, in previous tests at low temperature by Rice University.	
6374	SIDE circuit breaker operated when command C-13 was executed. This was a lunar night test.	This command also executes dust cover blow. See DR-6330.	See DR 6330.

4.6.4.4 Test implications for design improvements. - The major problem area, pin pointed by the thermal vacuum test, was that of the leg design. The legs were held by a nylon screw and adhesive. A redesign has been made using metal in both halves of the leg hinge and the experiment half is attached using metal screws. A metal, leg support, pan has been added to further strengthen the base in the leg attachment area. Extensive tests have been performed using an overweight experiment at elevated temperatures to prove the new design.

To overcome the problem of not being able to release the dust cover when the heater circuit is energized and the associated problems with high voltage commands in this condition, a modification has been made. A spare pair of contacts on a relay which drives the dust cover release solenoid have been utilized to break the heater circuit during dust cover operation. This break in the heater circuit is only effective in the operate mode and cannot cause a single point failure in the standby mode.

The dust cover did fail to release in early phases of testing prior to closing the chamber door. The dust cover was manually opened prior to closing the door for the vacuum tests. A redesign of the covers has been performed to alleviate the problems.

4.6.5 Dust Detector. - The Dust Detector was commanded on for approximately two minutes during each Integrated System Test (IST). An octal printout of the three solar-cell voltages and the three cell temperature voltages was made both before and after the Dust Detector was commanded on.

Housekeeping Channel	Dust Detector Function	Printout	Voltage Output
HK-84	Cell #1 Voltage	0000	0.0 V
HK-26	Cell #2 Voltage	0000	0.0 V
HK-41	Cell #3 Voltage	0062	0.8102 V
HK-83	Thermistor #1 Voltage	0377	5.0 V
HK-30	Thermistor #2 Voltage	0377	5.0 V
HK-56	Thermistor #3 Voltage	0377	5.0V

Prior to dust detector turn-on, all cell voltages should have read 0V. It was noted that Cell #3 read 0.8102 V both before and after turn-on. This indicated a malfunction on that channel.

Cell #1 and #2 voltages increased slightly when the electronics was commanded to the on condition. Voltages of typically 80 mV appeared to be of the order of the amplifier offset voltages with no input voltage. This was due to the spectral content of the I-R lamps which was outside the range of cell response.

The thermistor voltages all remained greater than +5.0 V which indicated a temperature less than 90°F which agrees with data of Section 4.4.

The above anomalies shall be investigated at the earliest opportunity.

4.6.5.1 Recommendations for changes to the Test for Qual Model Dust Detector. - In view of the above anomalies it is essential that a complete checkout of the dust detector cell voltages and thermistor voltages be made during all integrated system testing on the ALSEP.

A 150 watt reflector spot lamp may be used at a distance of 14 ± 1 inches from the face of each cell and the cell output voltages measured with the lamp on and off.

During thermal vacuum, this test must be repeated at ambient, early lunar morning, at lunar noon and at an intermediate point during lunar afternoon/evening.

Thermocouples should be attached to the Kovar base of each solar cell to allow correlation of temperature with the voltages from the solar cell thermistors.

SECTION 5.0

RECOMMENDATIONS FOR CHANGE TO TESTS FOR QUALIFICATION MODEL

As a result of knowledge gained during Prototype A Thermal Vacuum Test, the following recommendations for the qualification Model Tests are given:

1. Longer vacuum soak for SIDE and SWE prior to high voltage turn on.
2. Modification of PSE exciter cable so as to not cause heat leak problem to PSE sensor.
3. Establish realistic limits on data received from ALSEP to eliminate erroneous out of tolerance conditions and resulting discrepancy reports.
4. Provide baffles for cold wall and IR lamp arrays to simulate more realistic lunar conditions.
5. Mount pressure sensor on simulated lunar surface in proximity of experiments for more accurate pressure readings.
6. Install commandable heaters in Central Station for more thermal control.
7. Provide solar energy in spectrum of dust detector for thorough operational test.
8. Place Data Acquisition System sensors closer to housekeeping sensors for a better check on ALSEP sensing and downlink data.
9. Off-line computer support for tedious data reduction and plotting.
10. Maintain chronological log for better data correlation.

SECTION 6.0

LUNAR OPERATIONS EVALUATION

The Prototype A Thermal Vacuum Test provided a valuable opportunity for monitoring the ALSEP under simulated lunar operating conditions. The experience proved the adequacy of ALSEP telemetry for reconstruction of the electrical and thermal environment and also suggested the need for operator aids to ensure ready availability of critical parameters for decision making. Observations described in this section pertain to simulated lunar night operations on day 354 (December 20) between the hours of 09:45 and 14:00.

6.1 Electro/Thermal Considerations. - Two capabilities are required for realistic reconstruction of the electro/thermal relationships by the ground controllers:

(a) An accurate measurement of input power
(b) An accurate estimate of the distribution of power dissipation between experiments and Central Station.

ALSEP Telemetry provides an evaluation of power input by sampling both input voltage and input current (housekeeping channels 1 and 5, respectively). Accuracy of the telemetry sensors and readout was confirmed by checking against external measurements during prototype thermal vacuum (PTU) tests.

During the period of observation, telemetry voltage samples indicated a stable input of 16.3 volts (octal 303). Input current to PTU #1 during the same period remained constant at 3.78 amperes (octal 270). Multiplying input voltage by input current gives input power of 61.6 watts.

The set of curves shown as Figure 6.1 was prepared for the prototype PCU with an input of 62 watts and requires only minor interpolation to be valid for analysis of the test case.

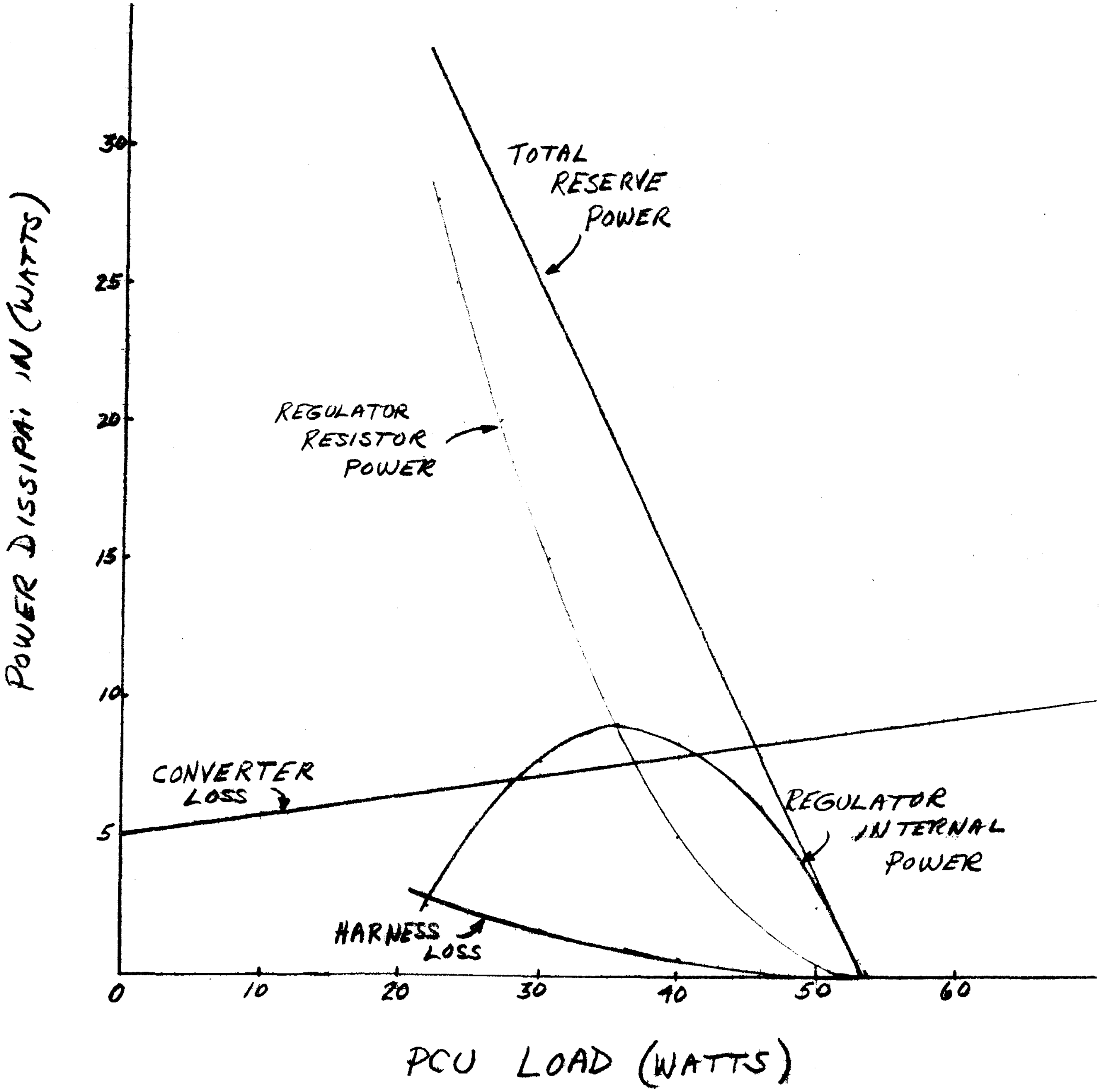


Figure 6.1 Proto Power Balance 62 Watt Input

The parameter shown as "total reserve power" in Figure 6.1 includes all PCU regulator dissipation and is the sum of the three curves, "regulator internal power", "regulator resistor power" and "harness loss". For any value of reserve power, by using these curves, the distribution of reserve power dissipation can be determined.

The balance of the ALSEP power dissipation distribution must be obtained by one of two methods:

(a) From component performance history, e.g., in PIA testing and assuming no major degradation (Telemetry will disclose significant changes in performance).

(b) From observation of discrete changes in reserve power level as the pertinent components are switched in and out by ground command, allowing for power conversion losses in the computation of actual load.

An example, illustrating use of both techniques, is the estimation of power consumption by the two transmitters. Transmitter B, during its PIA test under similar conditions, consumed 6.78 watts. The diplexer switch associated with transmitter B requires an additional 0.15 watts, for a total consumption in this mode of 6.93 watts.

When power was switched to Transmitter A at 09:54, a drop of 1.1 volts was noted in the on-line monitor of reserve power. As the conversion factor of voltage to reserve power is 2.44, this represents a reserve power decrease of 2.68 watts. Allowing 7% for converter losses, results in a computed load increase of 2.51 watts. Comparing this against the Transmitter B baseline of 6.93 watts gives an estimate of Transmitter A power consumption of 9.4 watts. This increased dissipation was found to be caused by AGC action in Transmitter A, a condition confirmed by telemetry.

As a further check on the reserve power method of estimating loads, a check was run on the central station heater. When the heater was switched ON at 09:45, the decrease in "reserve voltage" was observed to be 4.6 volts as measured by the on-line DVM. Applying the 2.44 conversion factor gives 11.2 watts of reserve power lost. Allowing 7% for converter loss results in a computed load increase of 10.5 watts (nominal heater dissipation is 9.9 watts).

With this background, a power distribution and central station thermal dissipation tabulation has been derived for the period 09:54 to 14:00 and is presented as Tables 6.1 and 6.2 Comparable distribution data for the period just preceding 09:54 are shown in Table 6.3 and typical equivalent data for the lunar day are shown in Table 6.4.

Operator aids which will prove useful to the ground controller are the following:

(a) Display of input power. - As this parameter is not expected to vary greatly, an alternative, after initial determination, is the imposition of close limits on this parameter, with alarm and printout if limited are violated. This parameter must be obtained by multiplying input voltage by input current, best done by an on-line real-time computer.

(b) PCU characteristic curves applicable to the RTG in use. - These curves can readily be adapted to slides for projection on a cathode ray tube. Call-up of the appropriate slide can be accomplished after input power is determined.

TABLE 6-1

POWER DISTRIBUTION
(DAY 354, 09:54 TO 14:00)

Parameter	Value	Source of Data
Input Power	61.6 watts	Telemetry
External Experiment Load		
a. PSE	3.2	Exp. Documentation
b. LSM	5.8	PTV ON/OFF Test
c. SWE (STANDBY)	3.0	PTV ON/OFF Test
d. SIDE (STANDBY)	6.0	Exp. Documentation
Total Ext. Exp. Load	18.0 watts	

Central Station Loads

a.	Heater	10.5 Watts	PTV ON/OFF Test
b.	Transmitter A	9.4	PIA and PTV Tests
c.	PSE Electronics	4.4	Exp. Documentation
d.	PDU	1.8	Component Tests
e.	A/D Conv./Multiplexer	1.4	PIA Tests
f.	Command Decoder	1.3	Component Tests
g.	Receiver	0.7	PIA Tests
h.	Data Processor	0.5	PIA Tests
i.	Harness Loss	0.4	Estimated from Residual
j.	Dust Detector	0.2	Component Tests
	Total CS Load	30.6 Watts	
Total Electrical Load		48.6	
	Converter Loss	8.4	PCU Curves (Figure 6.1)
	Reserve Power	4.6	PTV on-line Instrumentation
	Total Dissipation	61.6 Watts	

TABLE 6-2

CENTRAL STATION THERMAL DISSIPATION (DAY 354, 09:54 TO 14:00)

Parameter	Value	Source of Data
Central Station Elec. Load	30.6 watts	Table 6-1
Converter Loss	8.4	PCU Curves
Internal Regulator Dissipation	4.0	PCU Curves
Total Elec. Power Dissipation	43.0 Watts	
Less RF Power Dissipated	-1.0	Component Tests
Total CS Thermal Dissipation	42.0 watts	

TABLE 6-3

POWER DISTRIBUTION
(DAY 354, PERIOD JUST PRIOR TO 09:54)

Input Power			61.6 Watts
External Experiment Load		18.0 Watts	
Central Station Load			
Transmitter B (incl. switch)	6.9 Watts		
PSE Electronics	4.4		
Power Dist. Unit	1.8		
A/D Conv. Multiplexer	1.4		
Command Decoder	1.3		
Receiver	0.7		
Data Processor	0.5		
Harness Loss	0.4		
Dust Detector	0.2		
Total CS Load		17.6 Watts	
Total Electrical Load		35.6	
Converter Loss		7.5	
Reserve Power		18.5	
Total Dissipation			61.6 Watts

TABLE 6-4

TYPICAL POWER DISTRIBUTION, LUNAR DAY

External Experiment Load			
PSE	0.7 Watts		
LSM	5.8		
SIDE (SBY)	2.0		
Solar Wind (SBY)	3.0		
Total		11.5 Watts	
Central Station Load			
Transmitter B (Incl. Switch)	7.9		
PSE Electronics	4.4		
Power Diss. Unit	1.8		
A/D Conv. Multiplexer	1.4		
Command Dec.	1.3		
Receiver	0.7		
Data Processor	0.5		
Harness Loss	0.3		
Dust Detector	0.6		
Total		18.9	
Total Electrical Load		30.4	
Converter Loss		7.2	
Reserve Power		24.0	
Total Dissipation			61.6

(c) A table of electrical loads. - This should include the "fixed" load of the central station plus the nominal "deltas" for each available ground command. The delta can be updated, as necessary, by the operator, each time its respective command is executed.

(d) Display of reserve power. - This requirement is described more fully in the next section. Knowledge of reserve power and its incremental change with the execution of commands will enable the ground controller to update his load tables.

6.2 Reserve power monitoring. - During the Prototype A Thermal Vacuum Test, an on-line digital voltmeter and an analog recorder were directly connected to the external regulator resistors of the PCU. Measurement of resistor voltage provided an indication of "reserve" current which is proportional to reserve power. In the case of the PTV set-up, a conversion factor of 2.44, applied to the voltage reading, gave the value of reserve power in watts.

The same information can be obtained from ALSEP telemetry by checking shunt regulator current (Housekeeping channel 8 or 13 for PCU #1 or #2, respectively). This current is, again, proportional to reserve power and must be multiplied by the input voltage (channel 1) to provide the value of reserve power in watts.

A continuous monitoring of reserve power is highly desirable to permit the ground controller to make sound decisions regarding changes in operating mode of ALSEP. Consideration of ALSEP's operating point with respect to regulator range and thermal control should be a prelude to any command resulting in a change of power consumption.

It should also be noted that the PCU regulator acts as a filter on the power converter, absorbing load variations induced by the experiments, to maintain a constant supply voltage. The reserve power parameters, as monitored by telemetry, are sampled once every 90 frames. The samples are, thus, taken at intervals of about 54 seconds and could include considerable variation. Any reserve power display device provided for the ground controller should include an integrating feature to filter out these variations. (The PTV digital voltmeter, for example, exhibited instantaneous variations of about 0.4 volt (1 watt) peak to-peak, resulting in a probable error in reading for average of about 0.1 volt (0.2 watt). An optional by-pass for the filter would permit the controller to observe maximum and minimum values.

An on-line computer could drive displays of average, maximum, and minimum of the last several (e.g., five) samples. Or a strip chart recorder could provide a complete recent history of reserve power.

In any case, the reserve power display should be calibrated directly in watts, or any required conversion factor should be easily applied by means of a graph or table.

During the PTV tests, in addition to providing an indicating of power status of the system, the analog recording of reserve power provided a valuable trouble-shooting aid. It was the sole real time means of gathering diagnostic information on the Solar Wind Experiment malfunction. The reserve power recording showed that SWE came on and went through several steps in its sequence before the malfunction occurred. Its use for real-time troubleshooting in lunar operations is valuable, but somewhat limited by the 54-second repetition rate of measurements.