Bendix
Aerospace Systems Division

LSPE Qualification and Flight Acceptance T/V Test Summary and Thermal Design Final Report	NO. ATM 1110	REV. NO.
	PAGE ____ OF ____	
	DATE 20 Sept. 1972	

This ATM Summarizes the analytical and test results of the Lunar Seismic Profiling Experiment Thermal Control Systems. The report is divided into three sections. The first section introduces the hardware and develops the mathematical thermal model of the explosive package. The second section summarizes the Qualification and Flight Acceptance thermal vacuum testing programs and the third section presents the lunar surface predictions of the hardware.

Prepared by: D. Toelle

Checked by: G. Psaros

Approved by: E. Granholm

SUMMARY

The LSPE high explosive package maintains thermal control, within the +40 °F to 180 °F operating limits, passively, by means of insulated surfaces and thermal coatings.

A 35 node thermal math model was developed utilizing the Bendix thermal analyzer computer program which accounts for all modes of heat transfer including radiation and conduction. This model was used to optimize the thermal design during the initial design phases by considering selective insulation surfaces and package shape, and determining effects of soil conductivity on lunar surface to package heat leak.

Qualification and Flight Acceptance thermal vacuum tests are summarized including test setups and pertinent results. Detailed correlation studies are summarized and compared with the analytical model demonstrating the validity of the model in predicting thermal response.

Lunar predictions are presented which are based on the test correlated thermal math model. These predictions include both a nominally clean and dust covered model deployed equatorially and at a 20° latitude landing site. Peak temperature of a clean explosive package will be +167°F; whereas, a dust covered package with antenna handle exposed to the sun could attain +177°F.

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1.0 SCOPE

The purpose of this report is to document the development of the Lunar Seismic Profiling Experiment thermal analysis and the results and conclusions resulting from the thermal vacuum testing of the LSPE Qualification and Flight Models in the BxA thermal vacuum test chamber. This report is in three parts; experiment objectives and thermal analysis, Qual and Flight thermal vacuum testing, and lunar predictions.

SECTION I

EXPERIMENT OBJECTIVES AND THERMAL ANALYSES

This section summarizes the objectives of the LSPE experiment and the development of the thermal model and analysis.

2.0 BACKGROUND AND PURPOSE

The Lunar Seismic Profiling Experiment (LSPE) consists of eight packages, each containing an explosive charge and detonation mechanism, and a central electronics package which is housed within the ALSEP Central Station. The explosive charges weight from 1/8 pound to 6 pounds and are approximately equivalent to TNT in energy per pound. They will be deployed from the Lunar Roving Vehicle (LRV) by the astronauts at distances from 160 meters to 2.4 kilometers from an array of four geophones deployed on the lunar surface. The charges will be detonated after the astronauts leave the lunar surface by a r.f. command from the ALSEP Central Station.

The explosive package (EP) temperature range between 40°F and 180°F will be maintained for the EP components over the period from lunar morning to lunar noon during which the package is to be exposed to the lunar environment. Absorbed solar heat at high sun angles will be minimized by means of a 20 layer multilayer insulation bag inside the fiberglass top cover and by a coating of white thermal coating on the exterior of the upper portion of the package. The remaining exterior surfaces of the EP are coated black to permit rapid initial warm-up of the packages which will be deployed at low sun angles when temperatures are near the minimum operating limit.

3.0 DESIGN SPECIFICATION REQUIREMENTS

3.1 Temperature Requirements

3.1.1 High Explosive Package

TABLE 3.1
THERMAL PLATE TEMPERATURE

	Minimum	Maximum
Operational Limits	+40°F	+180°F
Non-Operational Limits	-80°F	+185°F

3.1.2 Central Electronics

TABLE 3.2
THERMAL PLATE TEMPERATURE

Operating and Non-operating Limits	Minimum	Maximum
Qual	-22°F	+158°F
Acceptance	-10°F	+146°F

3.1.3 Geophones and Cables

TABLE 3.3
GEOPHONE TEMPERATURE

	Minimum	Maximum
Operating Limits	-100°F	+261°F
Non-operating Limits	-279°F	+261°F

3.2 Power Requirement

The design limit power required of the experiment shall be 9.0 watts of operating power.

4.0 THERMAL DESIGN AND ANALYSIS GOALS

4.1 Design Goals

4.1.1 Maintain the high explosive package electronics and mechanical components within the specified temperature limits.

- Minimize the effects of solar radiation
- Provide good component heat paths to the temperature controlled baseplate.
- Minimize the effects of heat leaks

4.1.2 Design to a ± 25° off-equator deployment.

4.2 Thermal Analyses Goals

4.2.1 Determine heat leak or gain through

- Experiment cover
- Multilayer bag.
- Baseplate extensions and protrusions
- Receiving antenna
- High explosive

4.2.2 Determination of thermal performance in a lunar environment.

4.2.3 Recommend thermal coatings.

4.2.4 Design and supervise fabrication of thermal simulator

4.2.5 Develop a thermal math model.

4.2.6 Correlate analytical data with test results obtained from thermal Simulator, Prototype, Qual, and Flight model tests.

4.2.7 Utilize data obtained from the performance of DVT to design Qual and Flight models.

4.2.8 Utilize data from the DVT and ALSEP system Qualification and Flight tests to verify the performance of lunar hardware.

5.0 ANALYTICAL THERMAL MODEL

5.1 Nodal Description

The thermal model of LSPE (Figure 5.1) was developed utilizing the Bendix Thermal Analyzer Computer Program. The model consists of 35 nodes representing various components of the LSPE in addition to the lunar surface and space. These nodes and their physical significance are listed in Appendix A.

5.2 Thermal Resistances

There are 101 resistances in the LSPE thermal model. These resistances represent all heat exchange, both through conduction and radiation, between all nodal surface of the experiment and the environment. These resistances, their interconnecting nodes, configuration factors, and surface areas are listed in Appendix A.

5.3 Solar Heating

The absorbed solar flux is produced in model by applying equivalent heat to the surface node of the irradiated surface.

The surfaces receiving solar irradiation are, the electronic's cover, the high explosive cover, the baseplate extensions, and the receiving antenna.

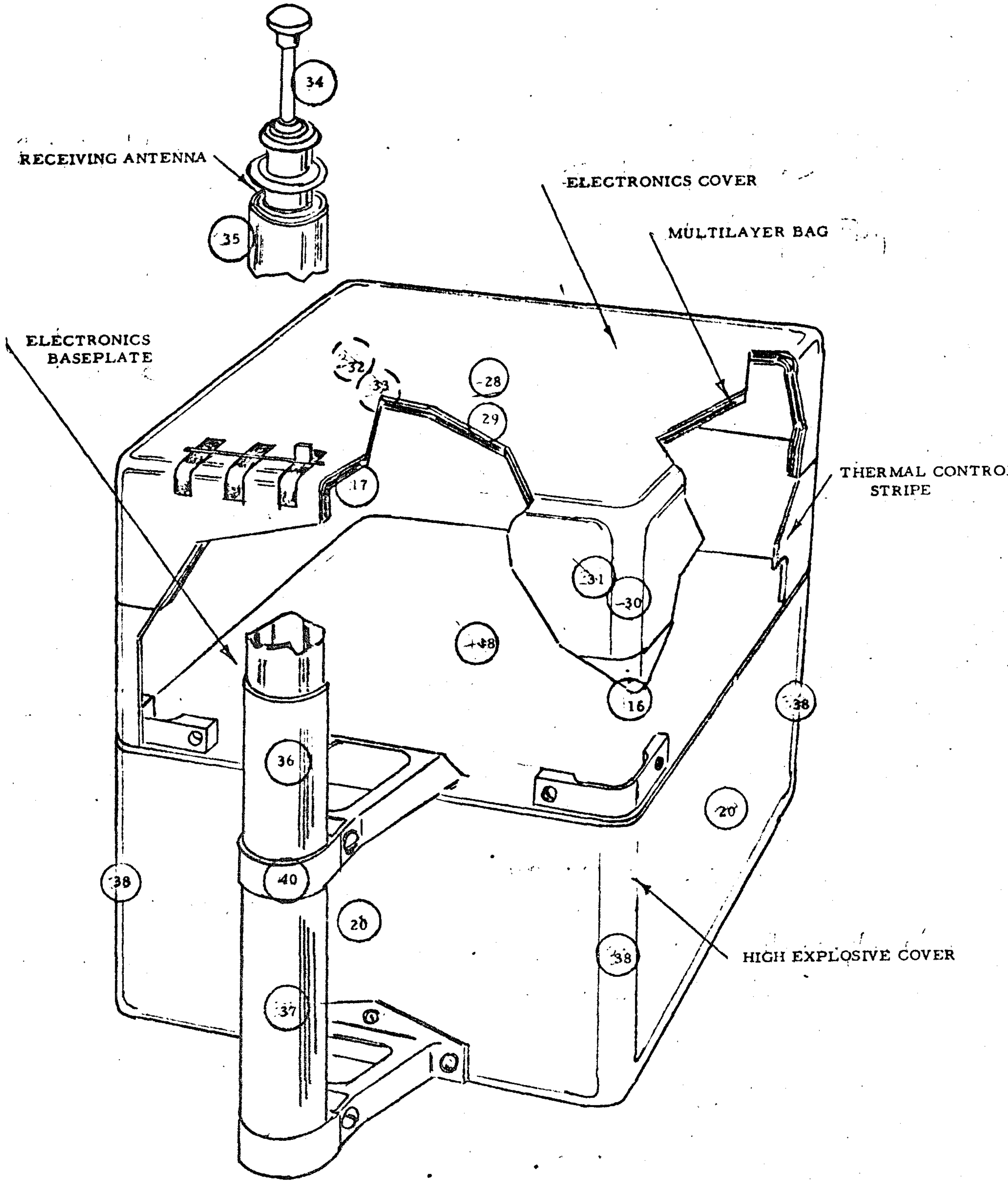
5.4 Lunar Surface Temperature

Variation of the lunar surface temperature as a function of deployment angle and solar angle was considered in the analysis. Temperatures of the surface as a function of these variables are indicated in Figure 5.2. During lunar night the lunar surface was taken as -300°F.

5.5 Baseplate Handle Extension and Edge Protrusions

Mounting of the receiving antenna and fixing of the package to the transport frame during transit require portions of the baseplate to be exposed to solar radiation. Maximum exposure occurs when the sun is

Figure 5.1



LUNAR DEPLOYED MODEL HE PACKAGE

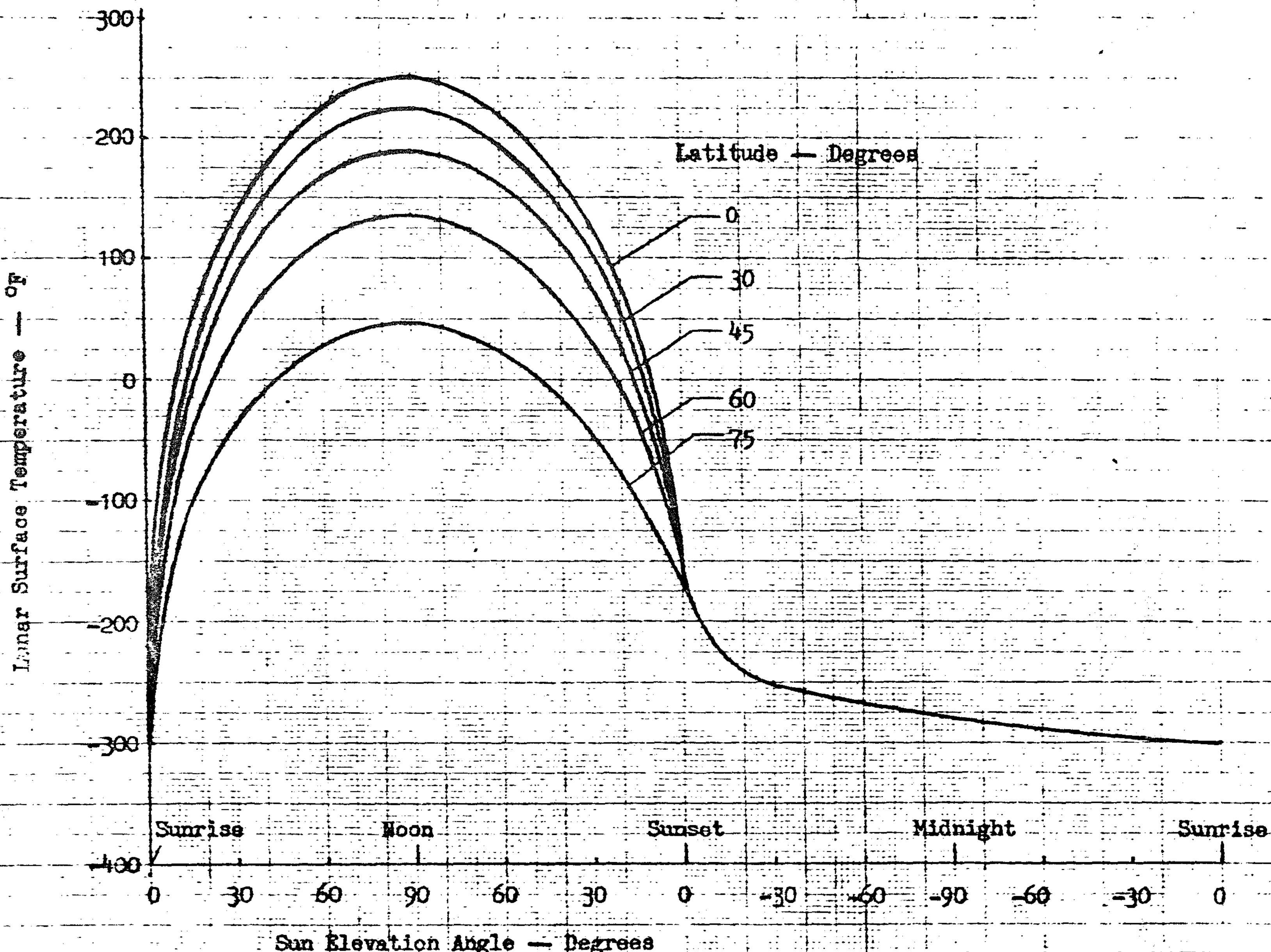


Figure 5.2 Lunar Surface Temperature vs Sun Angle and Latitude

45 degrees to the handle extension eenter-line and dust coverage is 100%. As indicated in a subsequent section the direct solar impingement on the baseplate increases from 0.287 watts to 1.05 watts when covered with dust.

5.6 Multilayer Bag

A multilayer bag was produced from 20 layers of double sided aluminized mylar and spacers. This bag encloses the top and top one half of the electronics cover and is bonded to the inside of the electronics cover. This bag serves to protect baseplate components from high sun angle temperatures and also distributed the electronics temperatures evenly throughout the top of the enclosure. The bag thermal conductivity was taken as K/L = 0.010 Btu/Hr - °F - Ft^2.

5.7 Lunar Surface to High Explosive Conductivity

A study was undertaken to determine the effect of the local lunar soil thermal conductivity on the high explosive baseplate temperature. The six pound explosive was used as the model since the entire explosive (k ≅ 0.20 BTU/°F - HR - Ft) making the lunar surface to baseplate thermal coupling the highest for all packages. Figure 5.3 indicated a sketch of the soil model used.

The model was developed from concentric soil nodes with the outer node forming the boundary of previously determined temperature data.

The boundary node temperatures were obtained in accordance with values presented in reference 7 which gives values of lunar soil temperature gradients with respect to time at depths to the adiabatic soil temperature depth. Figure 5.4 indicates the results of the baseplate temperature analyses for three different soil conductivities, K = 0.60 (lunar rock), K = 0.0011 (Apollo 11) and K = 0.01. Note that LED520 indicates K = 0.00242 BTU/°F - Hr - ft.

It was determined that soil conductivities between K = 0.001 and K = 0.01 remained adiabatic, however, lunar rock would cause substantial heating. This study prompted the requirement that packages must be deployed on lunar soil and not rock or crust.

LUNAR SOIL TRANSIENT MODEL NODAL DIAGRAM

Figure 5.3

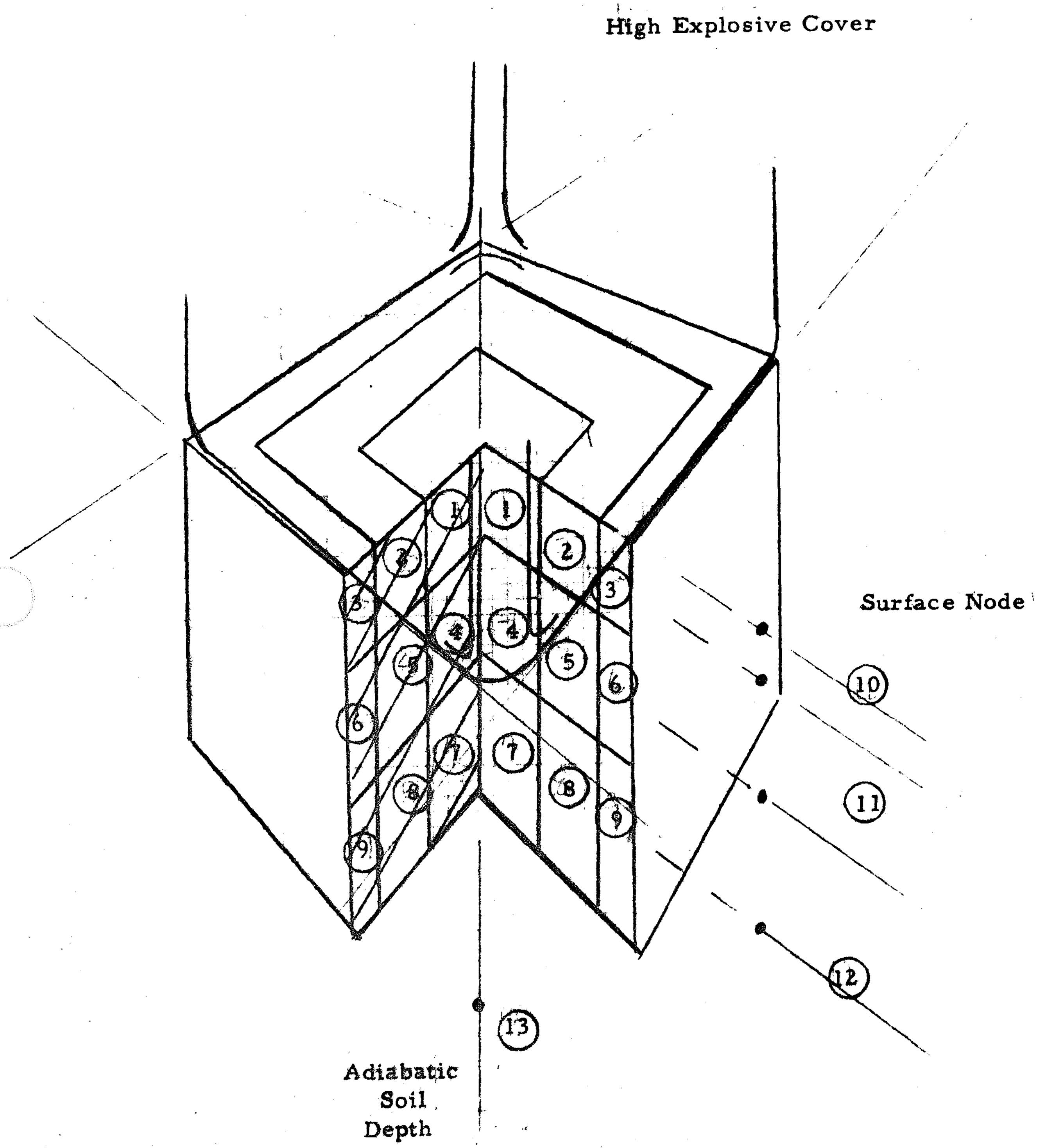
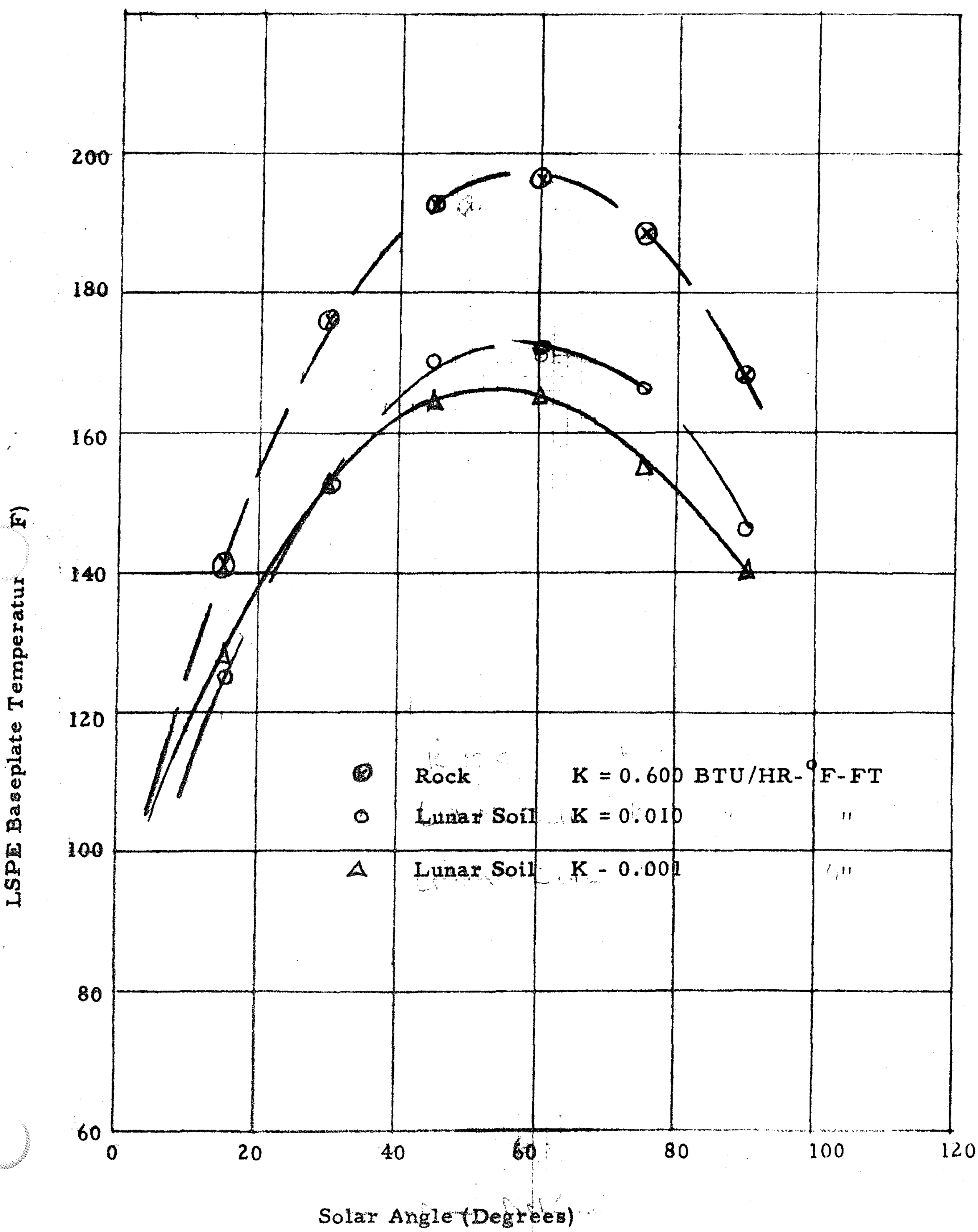


Figure 5.4

EFFECTS OF SOIL CONDUCTIVITIES ON LSPE HIGH EXPLOSIVE BASEPLATE TEMPERATURES



5.8 Antenna Heat Leak

The high explosive package design requires the 6 foot antenna be mounted directly to the aluminum baseplate via an extension which protrudes from the package. Thermal isolation is provided to prevent transmission of the absorbed solar heat to the baseplate components. This isolation is provided by means of the fiberglass sleeve forming the handle, and by means of fiber spacers and washers isolating the antenna clip from the baseplate.

5.9 External Coatings - Optical Properties

Three coatings are significant in the analysis. The high explosive cover is 0.030 inch fiberglass coated with 3M-401-C10 flat black, the electronics cover is also 0.030 inch fiberglass with the bottom half coated with 3M-401-A10 white velvet coat. The receiving antenna is thin walled brass with a bright chrome plate finish. Optical properties of these and other internal coatings are indicated in Table 5.1.

5.10 Heat Leak Summary

Table 5.2 summarizes the significant package to environment heat leaks during the maximum temperature. This table includes heat exchange for the nominal and 100% dust degraded conditions.

TABLE 5.1

LSPE THERMAL COATING PROPERTIES

Component	Coating	Property
Baseplate/Covers	3M-401-C10	$\alpha/\epsilon = 0.96/0.92$
Baseplate/Covers	3M-401-A10	$\alpha/\epsilon = 0.25/.92$
Baseplate	Bright Tin Plate	$\alpha/\epsilon = 0.25/0.05$
Antenna(1)	Bright Chrome Plate	$\alpha/\epsilon = 0.48/0.16$
Fiberglass Covers	Electroless Nickel Plate	$\epsilon = 0.33$

(1) Surface temperature 300° - 400°F.

TABLE 5.2

LSPE HIGH EXPLOSIVE PACKAGE HEAT BALANCE

BASEPLATE HEAT LEAKS (WATTS)		
Path	Nominal	100% Degraded
Thermal Bag	-0.0307	+0.0866
Black Thermal Control Stripe (sun side)	+0.934	+0.684
Black Thermal Control Stripe (shade side)	-0.911	-1.212
Direct Exchange with Space	-1.04	-1.15
Direct Exchange with Lunar Surface	+0.44	+0.375
Direct Solar to Handle Extension	+0.287	+1.05
Antenna to Handle Extension	+0.240	+0.172

SECTION II

QUAL AND FLIGHT THERMAL VACUUM TESTS

This section summarizes the Qual and Flight thermal vacuum test results and correlations.

6.0 BACKGROUND

The Lunar Seismic Profiling Experiment Qualification Thermal Vacuum Tests were performed during the period of 20 May 1972 thru 7 June 1972. The Flight Acceptance Tests were performed during the period 01 July 1972 thru 11 July 1972, both at the Bendix Aerospace Systems Division in Ann Arbor, Michigan. This report presents the thermal data obtained during those tests together with a correlation of the thermal mathematical model with experimental data. Also included is a brief description of the test installation.

7.0 TEST OBJECTIVES

The objectives of the LSPE Qualification and Flight Acceptance Tests were to subject the LSPE and integrated ALSEP to the Lunar thermal/ vacuum environment demonstrating the ability of the LSPE design to withstand these extremes without loss of function.

8.0 DESCRIPTION OF TEST CONDITIONS AND TEST INSTALLATION

8.1 Thermal Test Conditions

8.1.1 Qual Model Conditions

The LSP high explosive package temperatures were correlated for four test conditions. These conditions simulate various phases of the operating and non-operating mission. (See Table 8.1). The first two conditions were designed to simulate the minimum operating temperature and solar simulation at the 60° critical solar angle. Conditions 3 and 4, which occurred subsequent to the battery firing and operation mode, were designed to simulate a non-operating temperature limit soak.

The geophones, located on the 14' x 14' lunar surface with the ALSEP central station, were allowed to follow the local lunar surface temperature through its phases.

8.1.2 Flight Model Conditions

There was no solar simulation of the flight hardware during Flight Acceptance Thermal Vacuum.

Four geophones were placed on the 14' x 14' lunar surface and cycled through lunar morning, noon, and night with the ALSEP hardware.

8.2 Vacuum Chamber

Space was simulated by the Bendix 20' x 27' thermal vacuum chamber. A vacuum was maintained at greater than 1×10^{-5} torr. throughout the test. The chamber walls will be painted black to simulate the emissivity of deep space. Liquid nitrogen at -300°F was circulated throughout the cold wall to simulate the temperature of space.

8.3 Lunar Surface Simulator

The lunar surface was simulated by a 5' x 5' black metal plate with 8 inch vertical lips located in the northeast area of the 20' x 27' chamber. The surface was mounted horizontally in the chamber and separated from other surfaces by means of vertical liquid nitrogen cold

TABLE 8.1

LUNAR SEISMIC PROFILING EXPERIMENT QUALIFICATION THERMAL VACUUM TEST CONDITION - EXPLOSIVE PACKAGE

	Lunar Surface (°F)	Cold Wall (°F)	Solar Intensity (Suns)
1. Minimum Operating Limit Condition	+135	-300	—
2. Critical Solar Angle Condition	+224	-300	1.25[1]
3. Minimum Non-operating Condition	+52	-300	—
4. Maximum Specification Condition	+235	-300	1.25[1]

[1] Lamps are 60 degrees from horizontal

panels. The original surface was heated by means of a heat exchanger, however chamber verification proved this inadequate so an additional cover plate was added including resistance heaters. Figure 8.1 indicated the location of thermocouple on this surface.

This surface was used in the Qual test only since Flight packages were not simulated.

8.4 Solar Simulation (Infrared)

8.4.1 High Explosive Package Solar Simulation

Solar simulation was achieved by using an array of two infrared quartz electric heaters. These heaters directed through the center of the electronics package at an angle of 60° from the lunar surface simulator and approximately 18 inches above it. The lamps were oriented such that two sides of the experiment were equally illuminated. Solar intensity was determined by monitoring the output of a radiometer coated with 3M-401-C10 balck thermal coating. This radiometer was oriented normal to the IR array directed energy. This array existed on Qual test only.

8.4.2 Geophone Infrared Heaters

During Flight Acceptance Test the geophone array was irradiated via an array of infrared heaters to maintain the geophones at +250°F during the lunar noon condition.

8.5 Experiment Location

8.5.1 High Explosive Package (Qual Test)

The high explosive package was placed in the center of the 5' x 5' lunar surface simulator. The package was placed on a 5 inch high aluminum standoff to provide an accurate view factor to the lunar surface simulator. The receiving antenna was extended partially in order that it remain within the high intensity field of the infrared solar array.

Figure 8.1

LSP LUNAR SURFACE
THERMOCOUPLE LOCATIONS

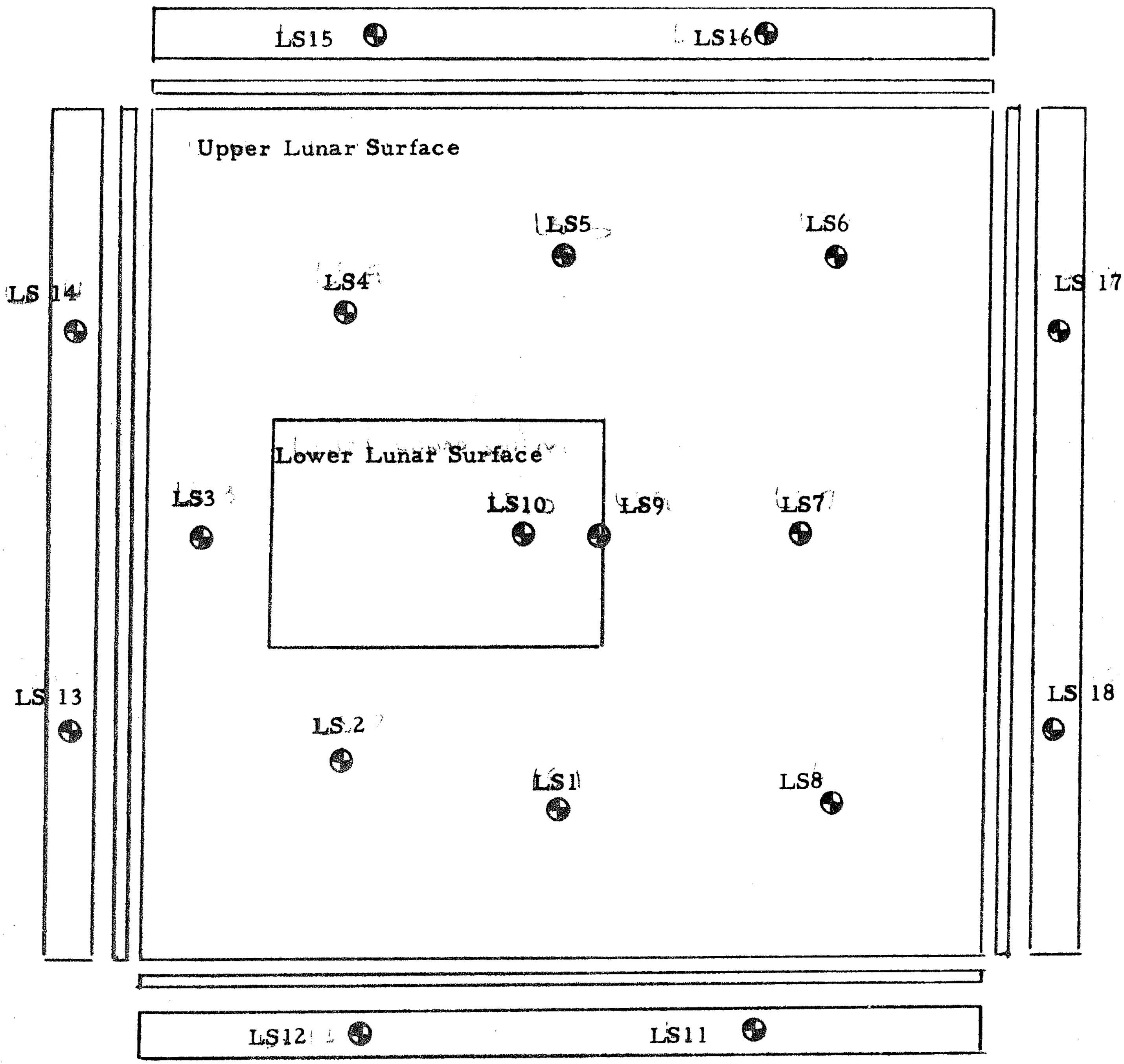


Figure 8.2

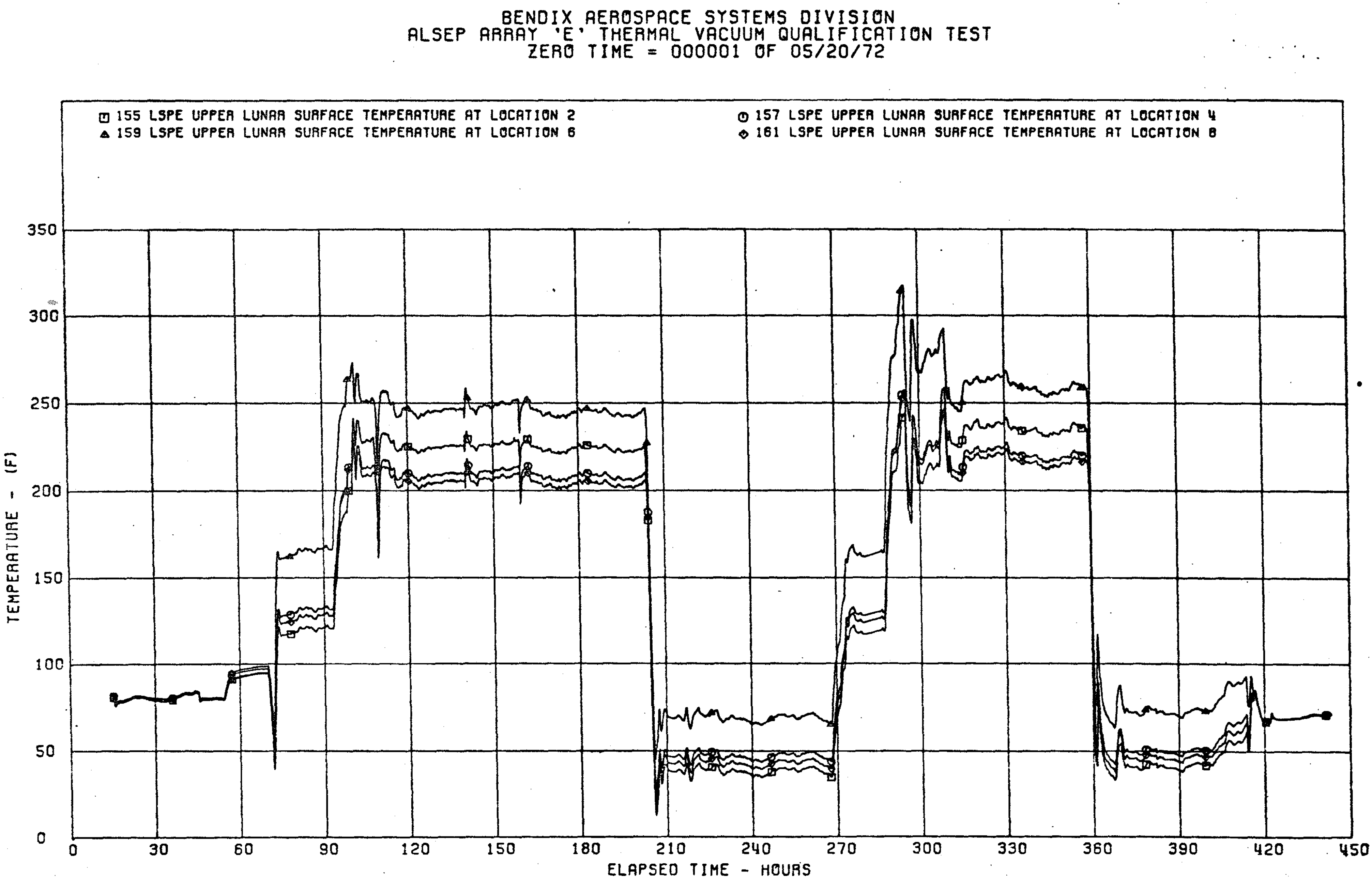
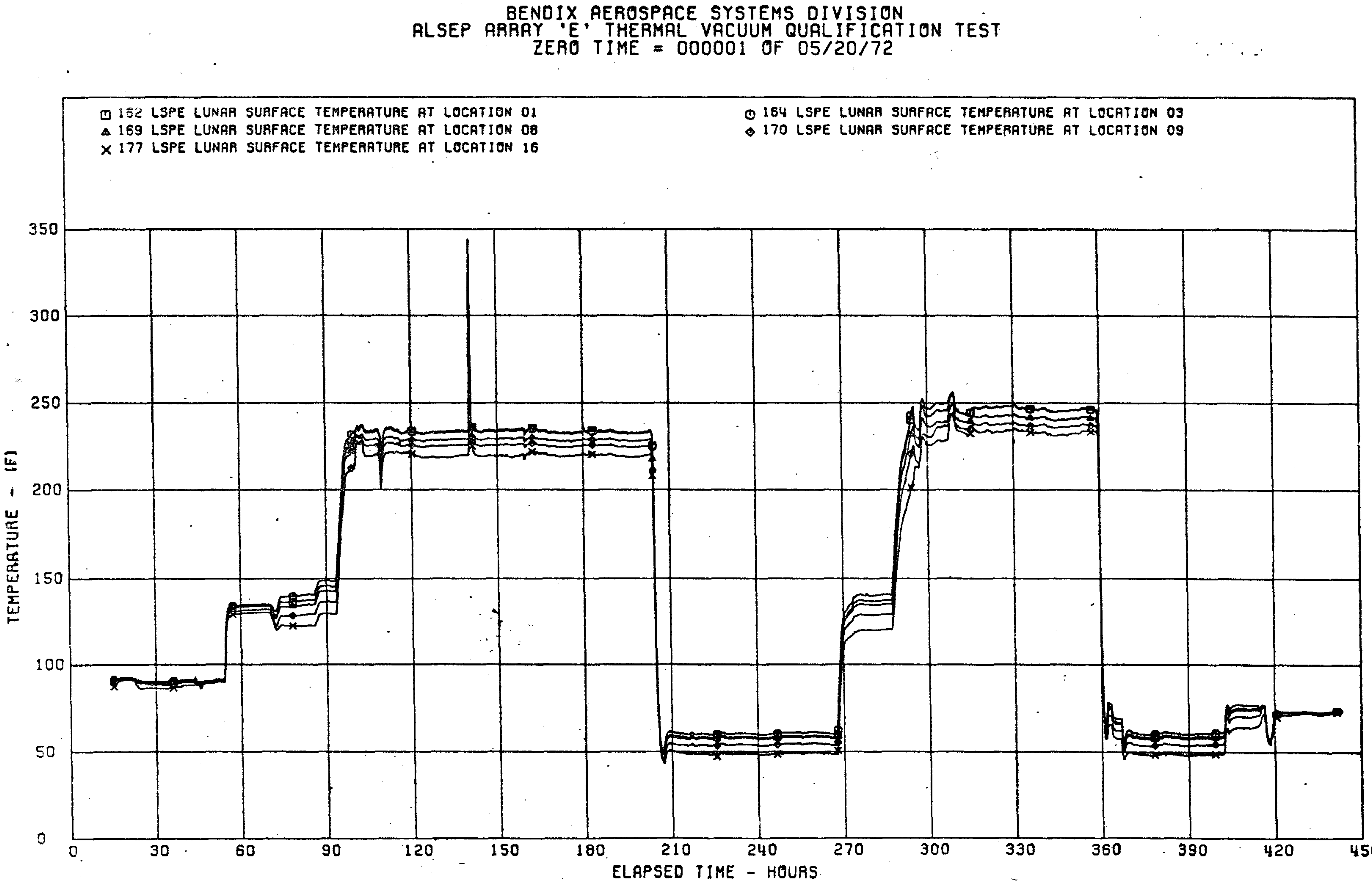

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM QUALIFICATION TEST
ZERO TIME = 000001 OF 05/20/72
155 LSPE UPPER LUNAR SURFACE TEMPERATURE AT LOCATION 2
157 LSPE UPPER LUNAR SURFACE TEMPERATURE AT LOCATION 4
159 LSPE UPPER LUNAR SURFACE TEMPERATURE AT LOCATION 6
161 LSPE UPPER LUNAR SURFACE TEMPERATURE AT LOCATION 8
TEMPERATURE - (F)
0
50
100
150
200
250
300
350
ELAPSED TIME - HOURS
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450

Figure 8.3


BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM QUALIFICATION TEST
ZERO TIME = 000001 OF 05/20/72
162 LSPE LUNAR SURFACE TEMPERATURE AT LOCATION 01
164 LSPE LUNAR SURFACE TEMPERATURE AT LOCATION 03
169 LSPE LUNAR SURFACE TEMPERATURE AT LOCATION 08
170 LSPE LUNAR SURFACE TEMPERATURE AT LOCATION 09
177 LSPE LUNAR SURFACE TEMPERATURE AT LOCATION 16
TEMPERATURE - (F)
0
50
100
150
200
250
300
350
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
ELAPSED TIME - HOURS

8.5.2 Geophone Array (Qual and Flight Tests)

8.5.2.1 Geophones Qual Test

The Qual geophones were each set horizontally in a V groove of a machined finish aluminum block. This block contained an adjusting screw to tilt the geophones simulating lunar gravity. All geophones were located on the 14' x 14' lunar surface simulator on the outer zone in the northeast corner of the surface. This entire array was covered with a multilayer insulation blanket.

8.5.2.2 Geophones Flight Test

Location of the Flight geophones was similar to Qual except that the aluminum blocks were coated with high emissivity paint to provide a more rapid temperature response. The geophones were irradiated by infrared heaters in lieu of the multilayer blanket in order to attain lunar noon temperatures of +250°F.

8.6 Thermocouple Locations

8.6.1 Qualification Model

Six thermocouples were designated to measure the experiment temperatures. Four of these were located within the high explosive package, one was on the transmitting antenna mounting socket, and one was mounted on a geophone outer shield. (See Figures 8.7 and 8.8)

8.6.2 Flight Model

Four thermocouples were located on the outer shields of each of the four geophones.

Figure 8.4

QUAL MODEL T/V TEST SETUP (H.E. PACKAGE
AND TRANSMITTING ANTENNA)

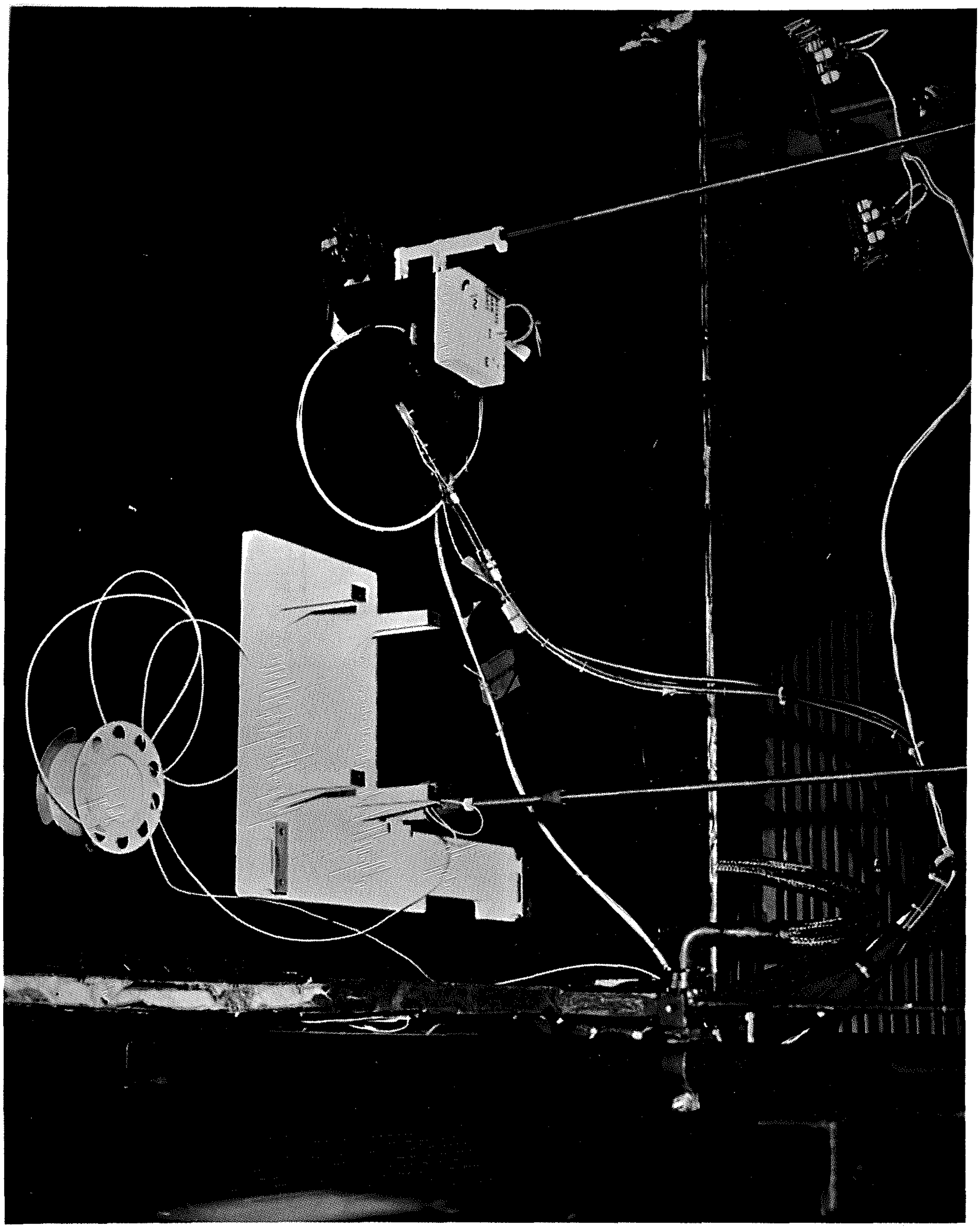


Figure 8.5

QUAL MODEL T/V TEST SETUP
(GEOPHONE ARRAY)

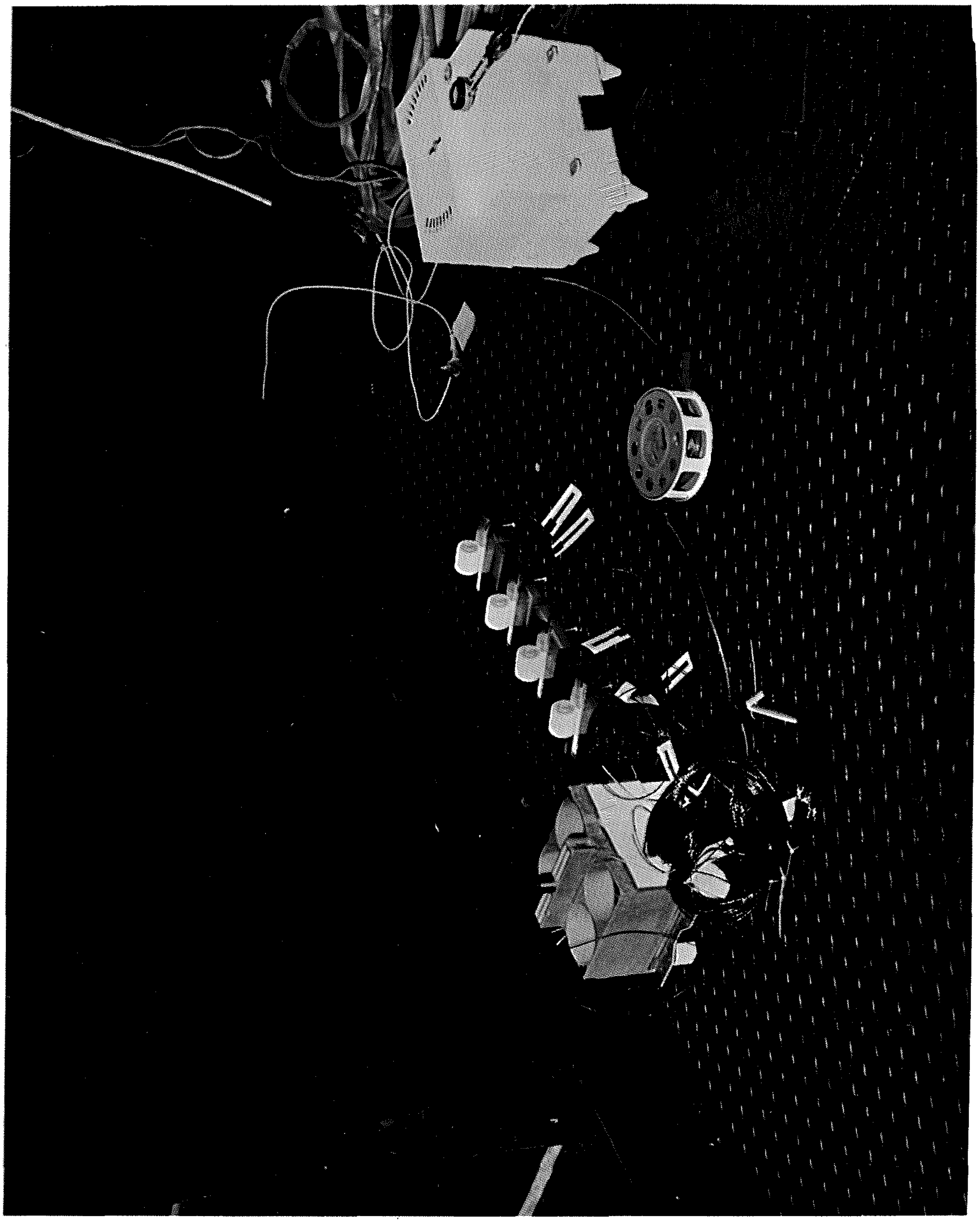


Figure 8.6

FLIGHT MODEL T/V TEST SETUP
(GEOPHONE ARRAY)

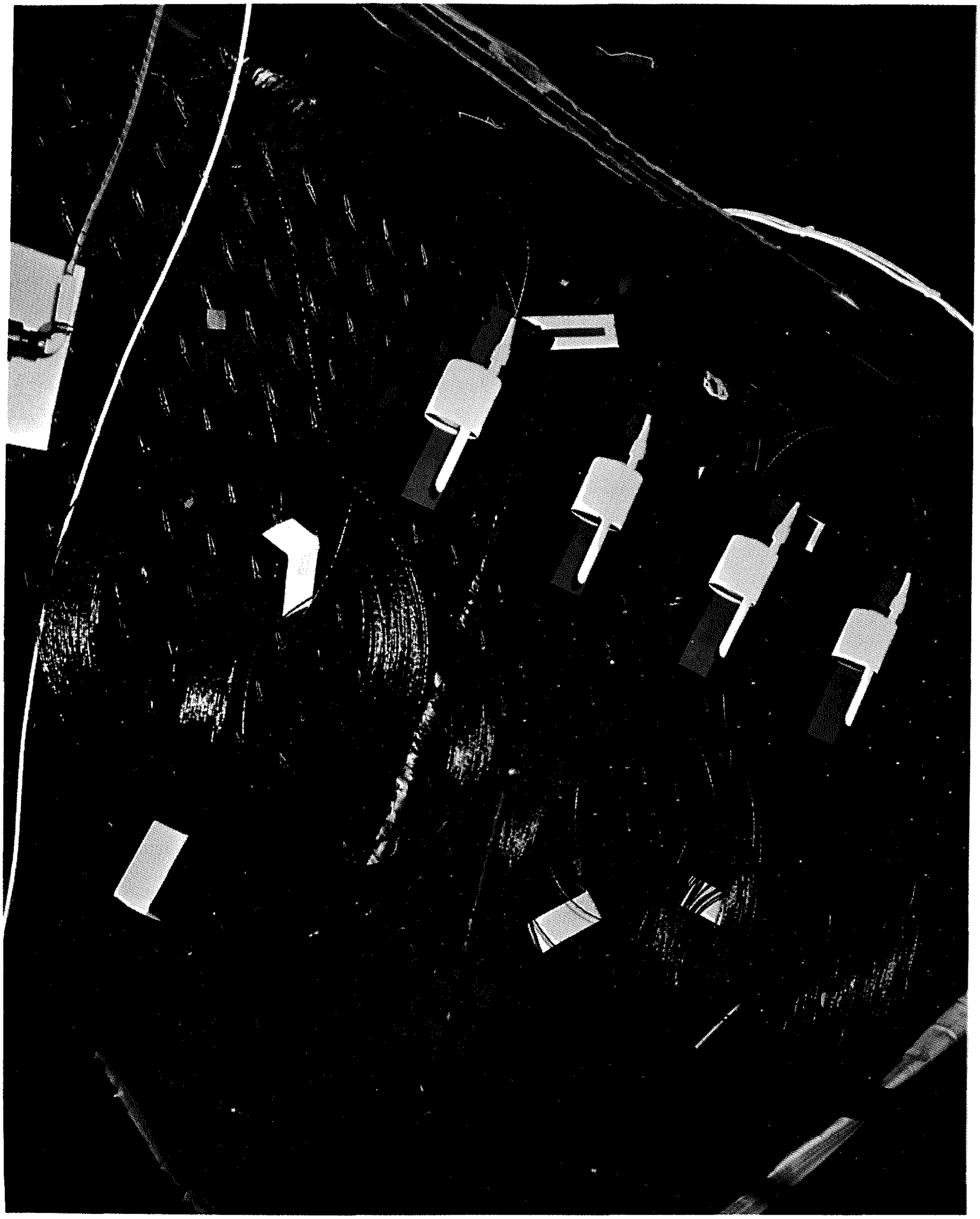
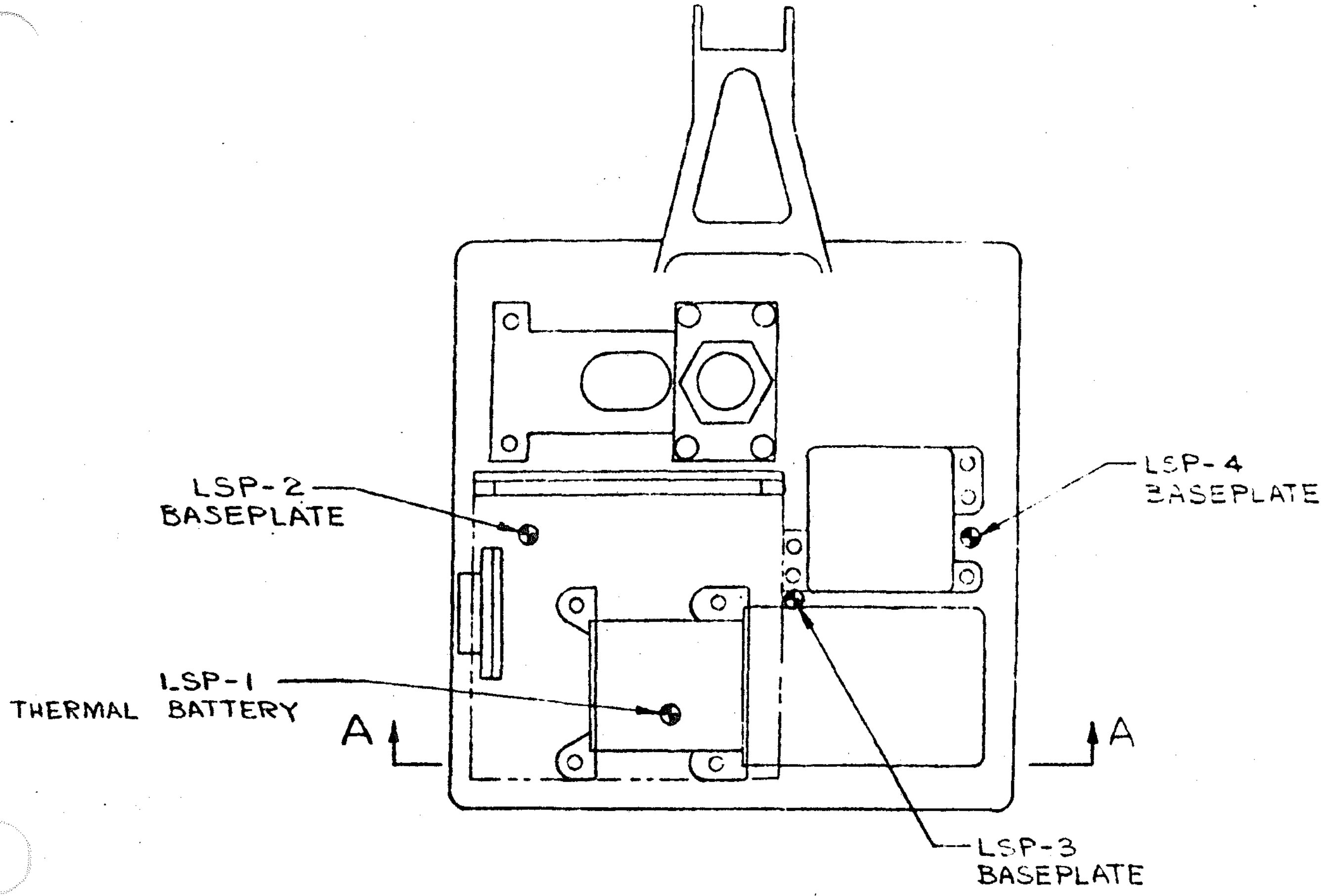
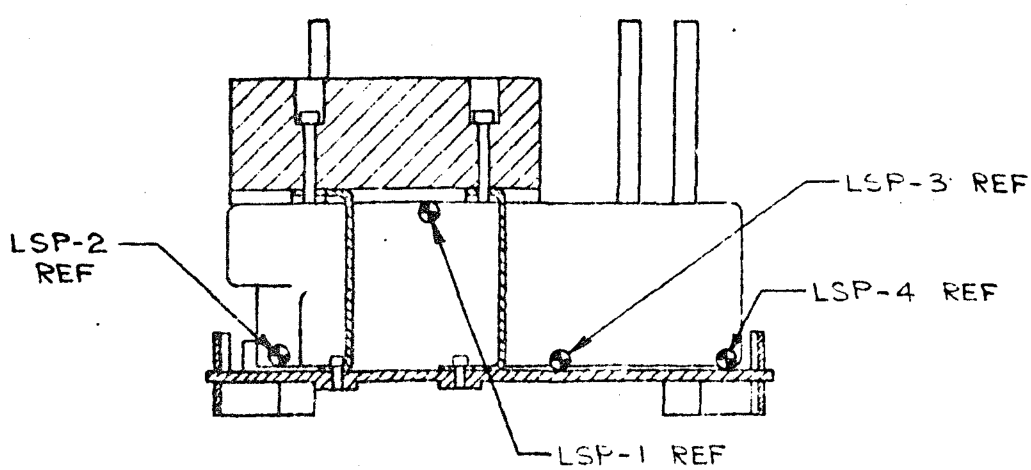


Figure 8.7

LSPE QUAL MODEL THERMOCOUPLE LOCATIONS



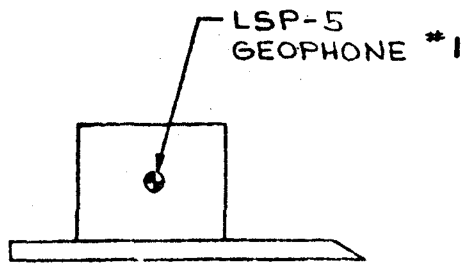
BASE PLATE ASSY (REF DWG 2348552)
HIGH EXPLOSIVE PACKAGE



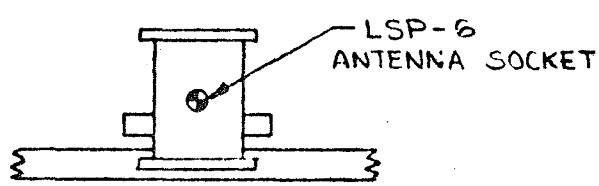
SECTION A-A

Figure 8.8

LSPE QUAL MODEL THERMOCOUPLE LOCATIONS



GEOPHONE



LSP TRANSMITTER ANTENNA
ON HFE SUBPALLET

9.0 RESULTS AND DISCUSSION

9.1 Graphical Summary of Results

9.1.1 Qual Test Results

9.1.1.1 Baseplate and Summary of Events Figure 9.1.

Figure 9.1 indicates a summary of the high explosive baseplate temperatures indicating the thermal test conditions. The high explosive baseplate temperature during the critical solar angle simulation exhibited a uniform distribution. Three baseplate thermocouples indicated 166°, 168° and 169°F.

9.1.1.2 LSPE Thermocouple Summary (Figure 9.2)

Figure 9.2 includes all baseplate thermocouples including the thermal battery T/C LSP 01, the geophone T/C LSP05 and the antenna socket T/C LSP06.

The thermal battery and baseplate T/C's peak sharply at 136 hours of elapsed time. This peak is the result of the thermal battery firing. The baseplate and components all peak at 205 °F some 30 minutes after the firing of the thermal battery. The thermal battery thermocouple T/C LSP 01 was damaged subsequent to the firing and read low for the remainder of the test.

The geophone thermocouple LSP 05 indicated +137°/295°/-202°F for design limit/acceptance noon/lunar night conditions respectively.

The antenna socket thermocouple LSP 06 indicated +157°/145°/-12°F respectively for the three test conditions. Table 9.2 summarizes these temperatures.

9.1.2 Flight Test Results (Figure 9.3, 9.4, 9.5 and 9.6.)

Each of the four Flight model geophones was thermocoupled. The results are summarized in Figures 9.3 through 9.6 and in Table 9.3. The lunar noon temperature distribution over the geophones was 184°/225°/244°/219°F. The night distribution was -228°/-216°/-216°/-228°F.

Figure 8.9

QUAL MODEL T/V TEST SET UP

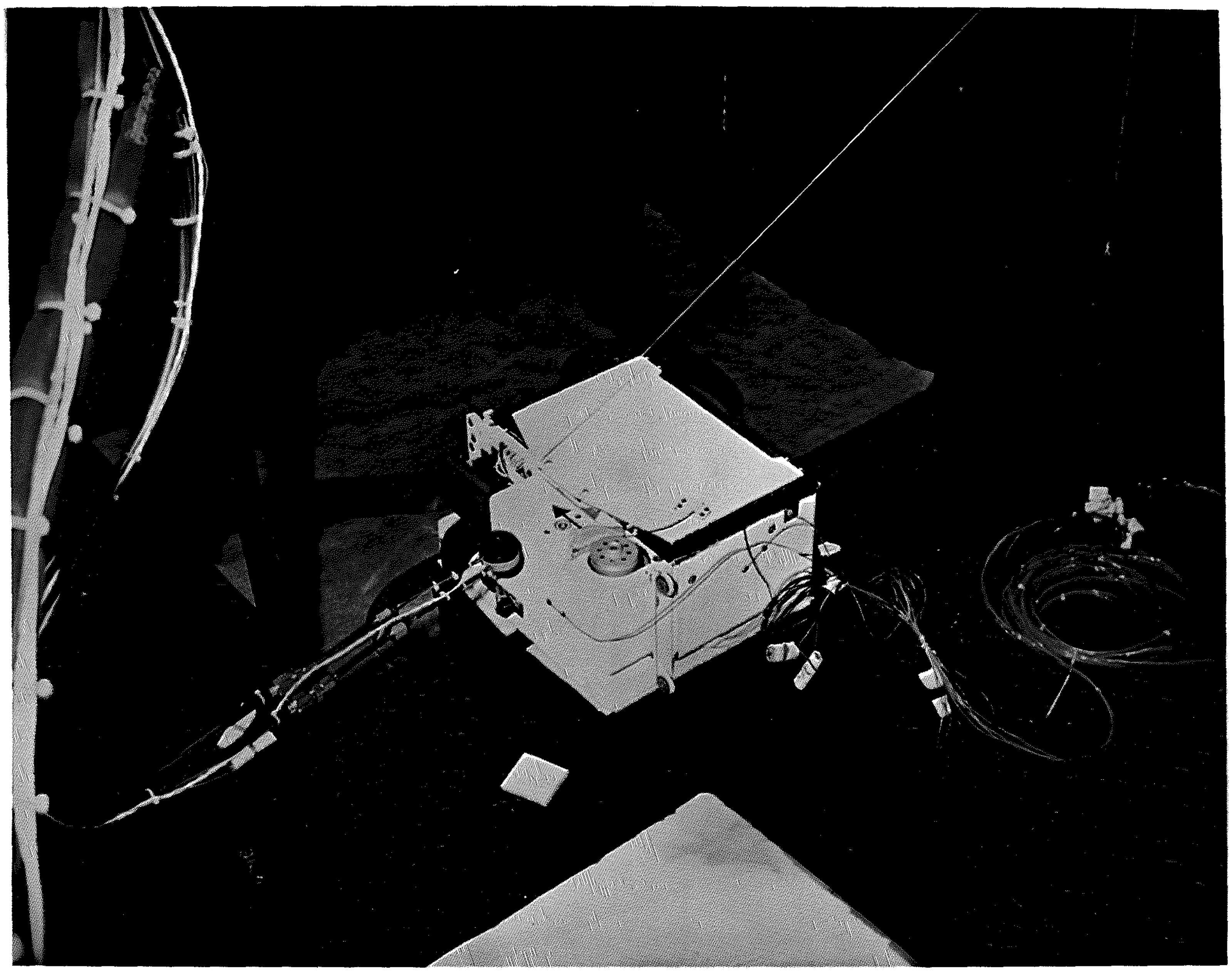


Figure 8.10

FLIGHT MODEL T/V TEST SETUP

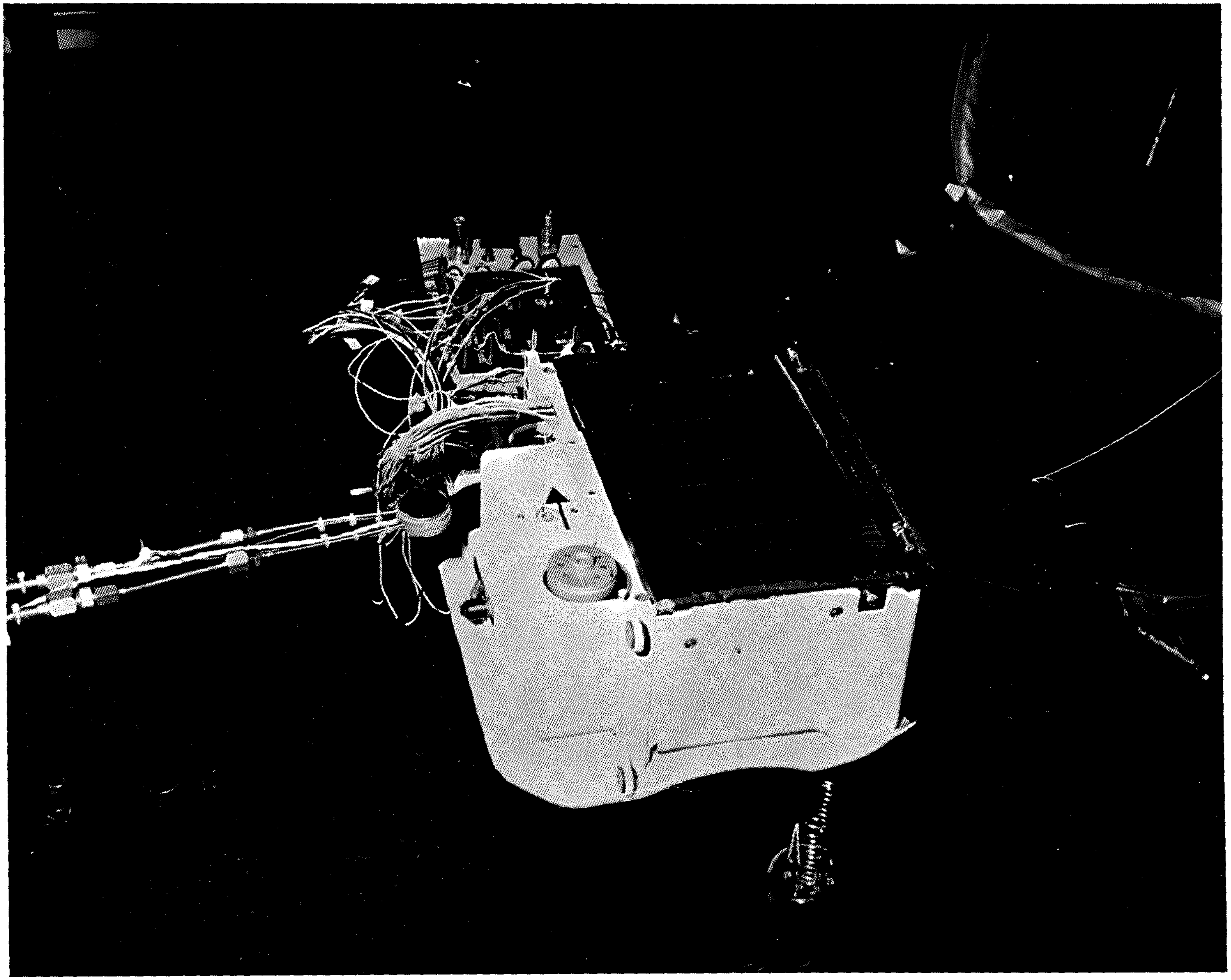


Figure 9.1

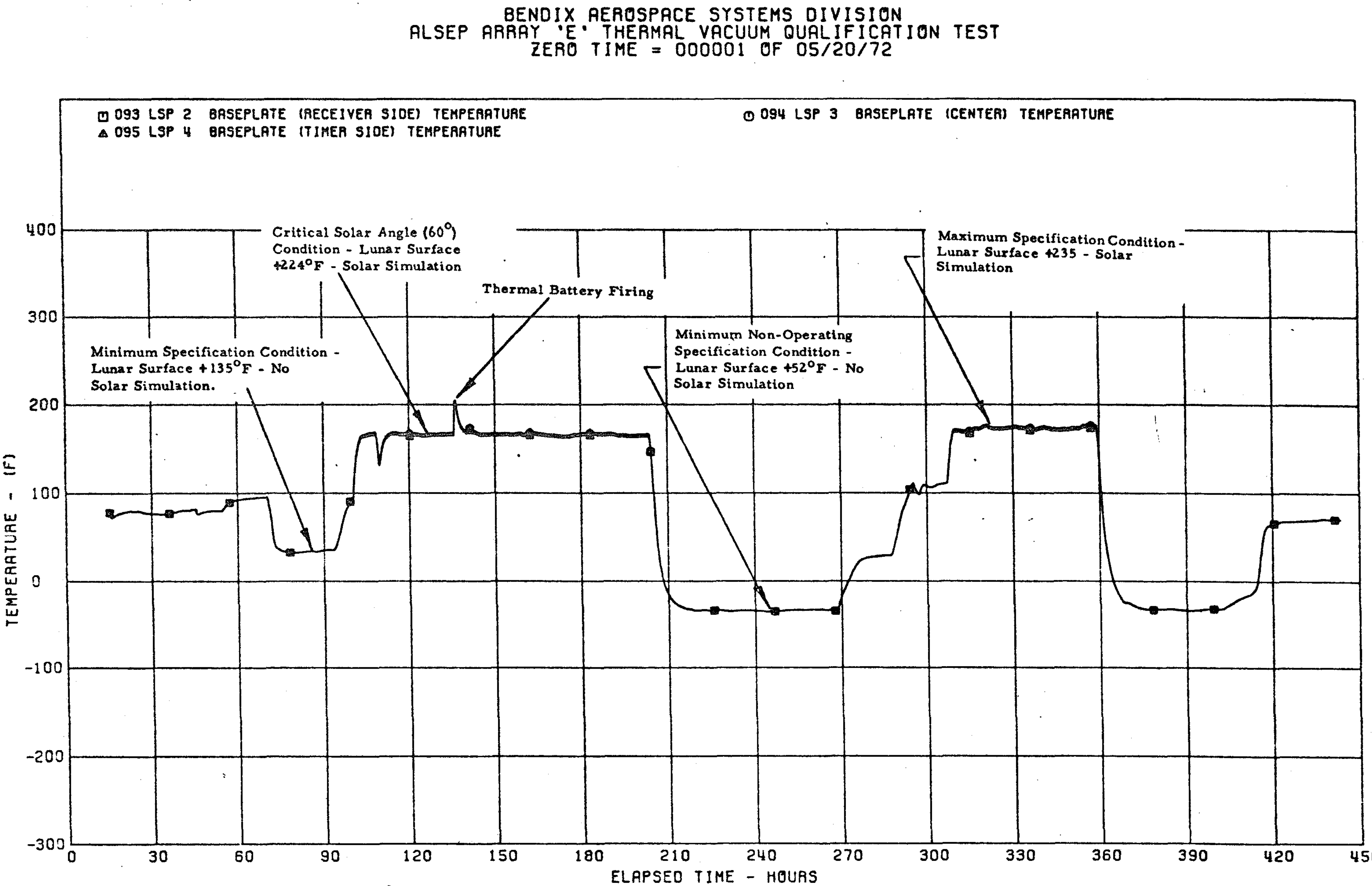

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM QUALIFICATION TEST
ZERO TIME = 000001 OF 05/20/72
093 LSP 2 BASEPLATE (RECEIVER SIDE) TEMPERATURE
095 LSP 4 BASEPLATE (TIMER SIDE) TEMPERATURE
094 LSP 3 BASEPLATE (CENTER) TEMPERATURE
Critical Solar Angle (60°) Condition - Lunar Surface +224°F - Solar Simulation
Thermal Battery Firing
Maximum Specification Condition - Lunar Surface +235 - Solar Simulation
Minimum Specification Condition - Lunar Surface +135°F - No Solar Simulation.
Minimum Non-Operating Specification Condition - Lunar Surface +52°F - No Solar Simulation
TEMPERATURE - (F)
400
300
200
100
0
-100
-200
-300
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
ELAPSED TIME - HOURS

Figure 9.2

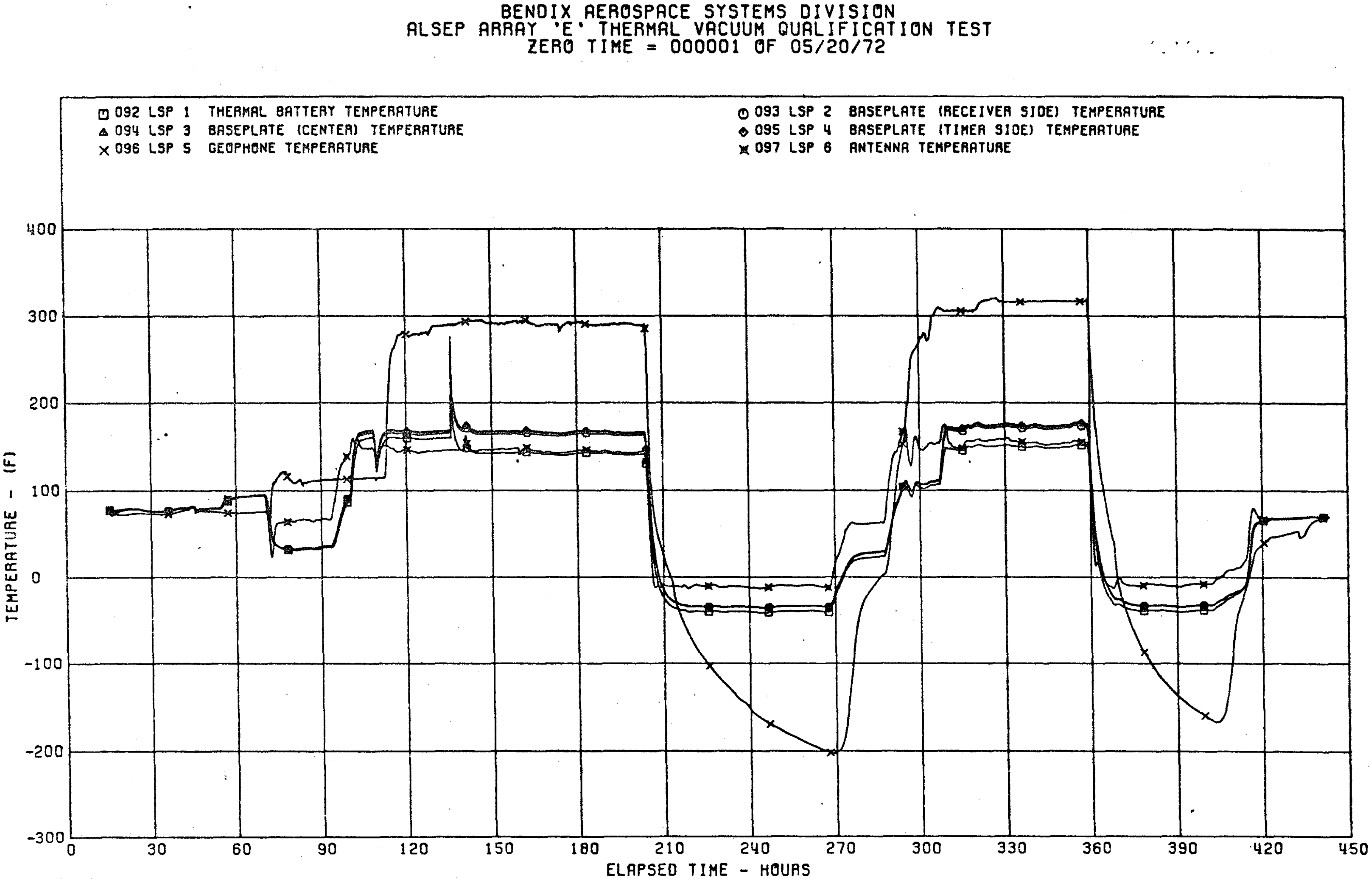

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM QUALIFICATION TEST
ZERO TIME = 000001 OF 05/20/72
092 LSP 1 THERMAL BATTERY TEMPERATURE
094 LSP 3 BASEPLATE (CENTER) TEMPERATURE
096 LSP 5 GEOPHONE TEMPERATURE
093 LSP 2 BASEPLATE (RECEIVER SIDE) TEMPERATURE
095 LSP 4 BASEPLATE (TIMER SIDE) TEMPERATURE
097 LSP 6 ANTENNA TEMPERATURE
400
300
200
100
0
-100
-200
-300
TEMPERATURE - (F)
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
ELAPSED TIME - HOURS

Figure 9.3

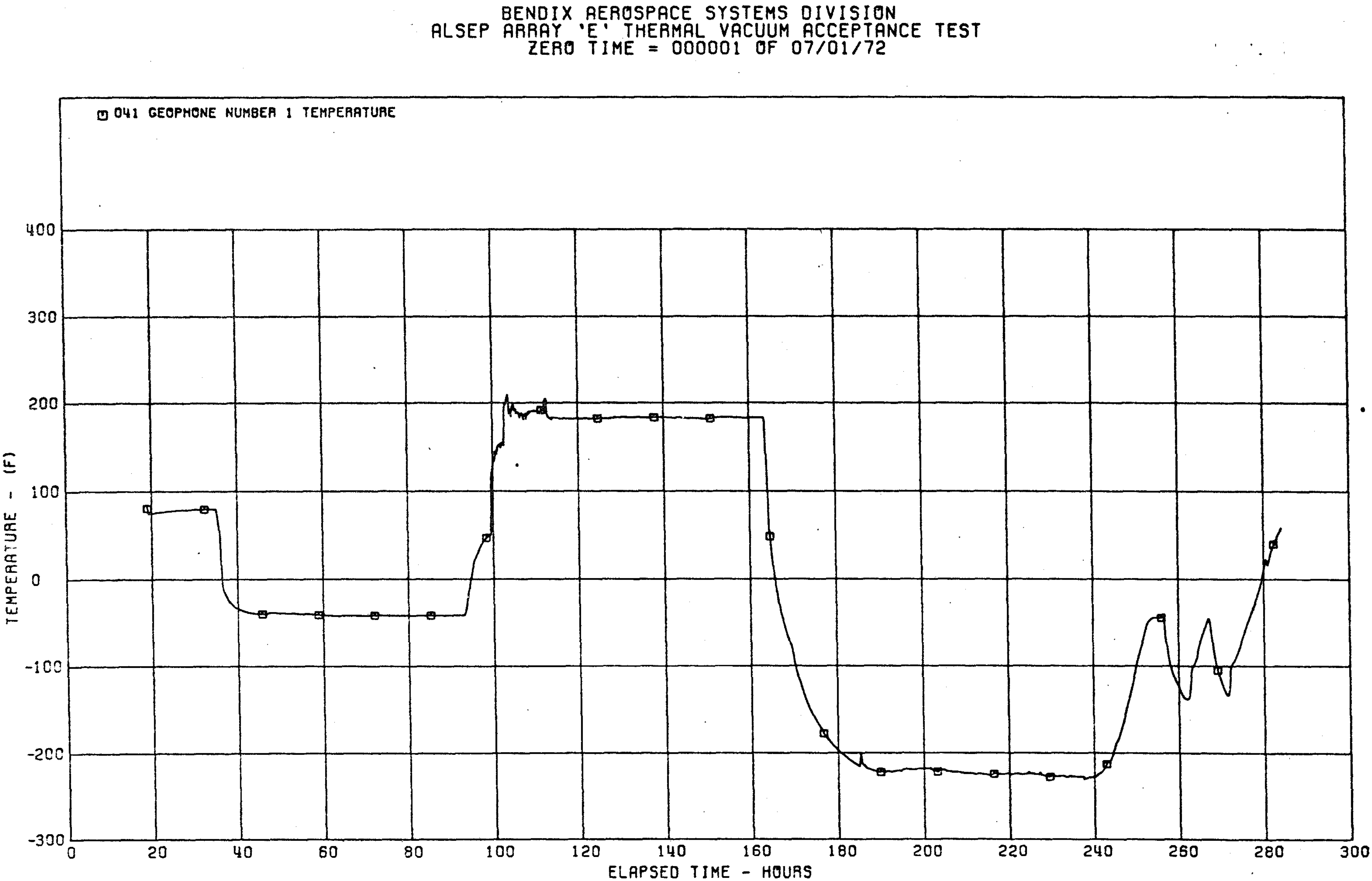

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM ACCEPTANCE TEST
ZERO TIME = 000001 OF 07/01/72
041 GEOPHONE NUMBER 1 TEMPERATURE
400
300
200
100
0
-100
-200
-300
TEMPERATURE - (F)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
ELAPSED TIME - HOURS

Figure 9.4

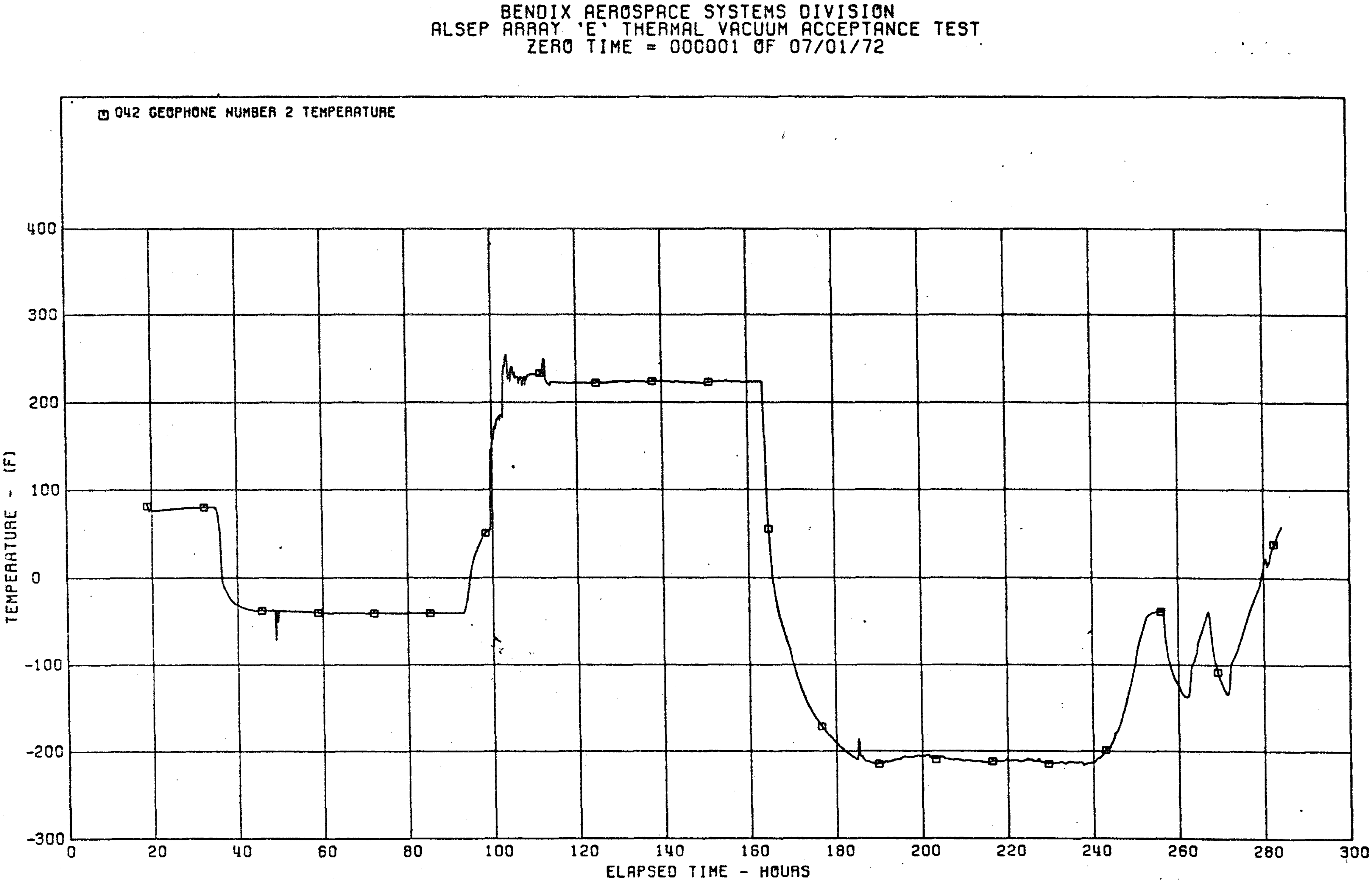

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM ACCEPTANCE TEST
ZERO TIME = 000001 OF 07/01/72
042 GEOPHONE NUMBER 2 TEMPERATURE
400
300
200
100
0
-100
-200
-300
TEMPERATURE - (F)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
ELAPSED TIME - HOURS

Figure 9.5

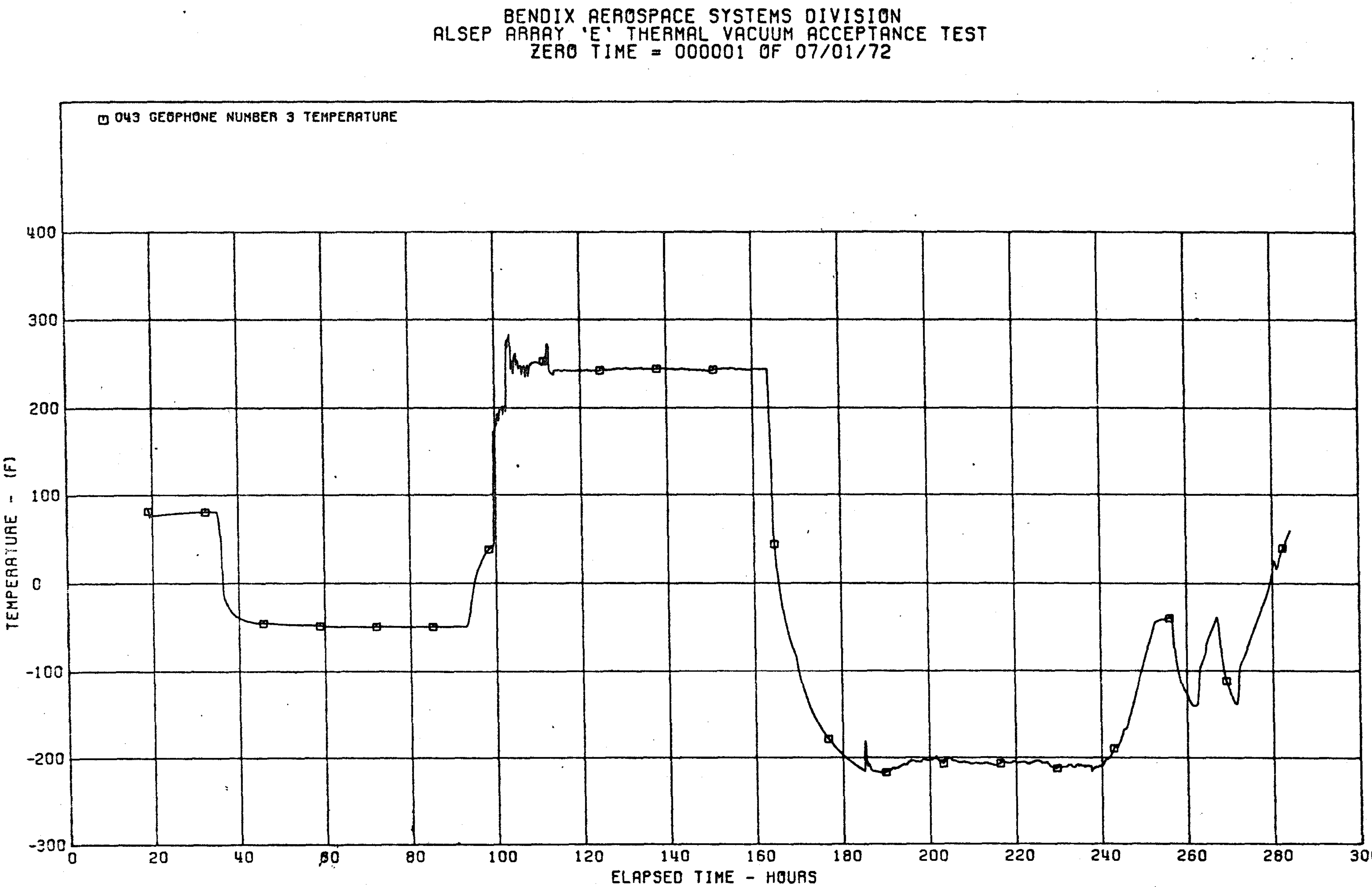
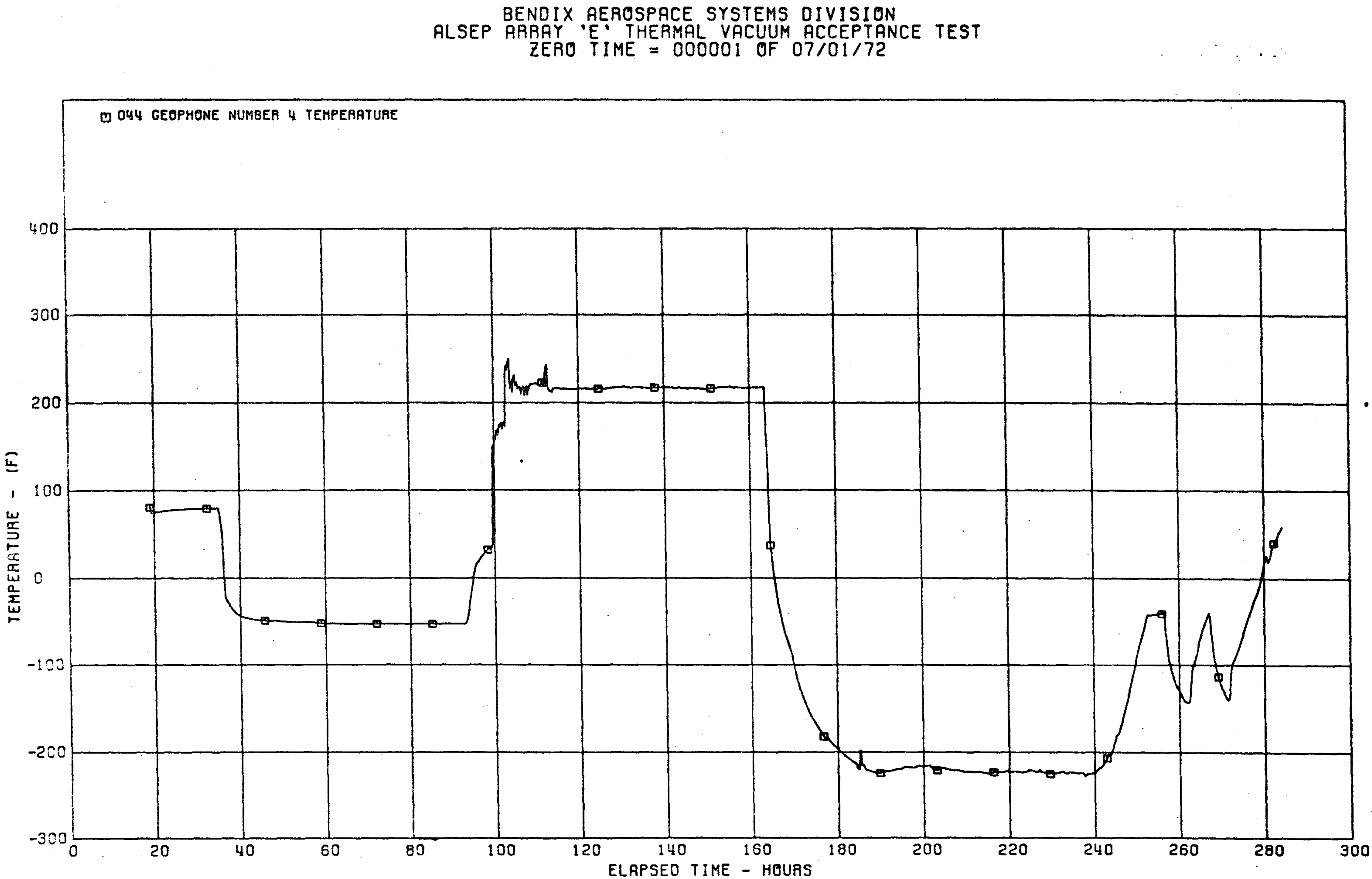

BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM ACCEPTANCE TEST
ZERO TIME = 000001 OF 07/01/72
043 GEOPHONE NUMBER 3 TEMPERATURE
TEMPERATURE - (F)
400
300
200
100
0
-100
-200
-300
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
ELAPSED TIME - HOURS

Figure 9.6


BENDIX AEROSPACE SYSTEMS DIVISION
ALSEP ARRAY 'E' THERMAL VACUUM ACCEPTANCE TEST
ZERO TIME = 000001 OF 07/01/72
044 GEOPHONE NUMBER 4 TEMPERATURE
TEMPERATURE - (F)
400
300
200
100
0
-100
-200
-300
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
ELAPSED TIME - HOURS

9.2 Factors Affecting Correlation of the Analytical Model with Test Data

9.2.1 View Factor

The high explosive package view factor of the lunar surface simulator during the Qualification test was 0.475 instead of 0.50, which is the actual lunar view factor. This reduced view of the lunar surface reduces the baseplate operating temperature by 6°F, during the critical 60° solar angle conditions.

9.2.2 Effects of Solar Simulation

9.2.2.1 Errors in Lamp Adjustments Qualification Test

The incident energy impingement upon the LSP radiometers during the two conditions requiring solar simulation was 1.25 suns or 162.5 watts/sq. ft. Of this 162.5 watts/sq.ft, 11.25 watts was a result of radiation from the lunar surface which was +224°F. This occurs because of the radiator tilt of 60° to the horizontal. The actual contribution of the total heat load attributable to the infrared lamps is 1.16 suns or 151 watts/sq. ft. This factor results in a 4°F decrease in the baseplate temperature during the critical solar angle condition.

9.2.2.2 Absorptance of 3M-401-A10 White Coating - Qualification Test

Heat absorbed on the white coated surfaces including the top of the electronics cover and the baseplate handle extension are higher than under actual solar irradiation. The white coating tend to absorb a greater percent of incident energy in the long wavelength spectrum (infrared). Since the quartz lamps emit both visible and infrared, the effective absorptance tance increases from 0.25 to 0.42.

This phenomonon has little effect on the insulated electronics cover, however, increased absorption on the handle increases the baseplate temperature 1.5°F during the critical solar angle condition.

9.3 Comparison of Data and Correlated Temperatures

Table 9.1 includes the test temperatures of the critical nodes for the Qualification test. The baseplate was correlated to within 3°F for all conditions tested. The only exception was the thermal battery subsequent to firing which ran consistently low after the firing.

Figure 9.7

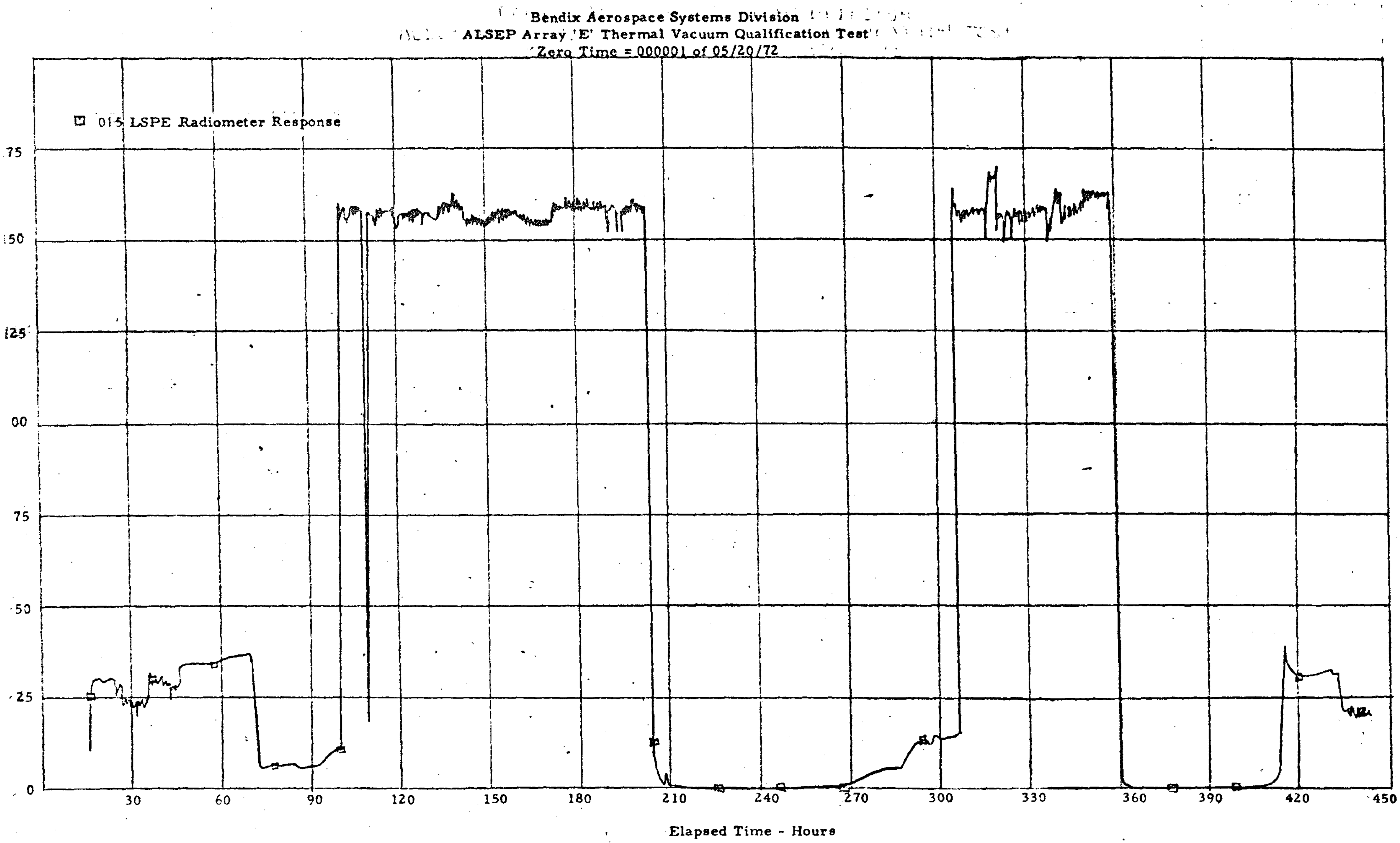

Bendix Aerospace Systems Division
ALSEP Array 'E' Thermal Vacuum Qualification Test
Zero Time = 000001 of 05/20/72
015 LSPE Radiometer Response
175
150
125
100
75
50
25
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
Elapsed Time - Hours

Table 9.1

LUNAR SEISMIC PROFILING EXPERIMENT QUALIFICATION THERMAL VACUUM TEST DATA AND CORRELATION FOR 1/8 # EXPLOSIVE PACKAGE

TEST CONDITIONS

Location	Minimum Specification Condition		Critical Solar Angle Condition		Minimum Non-Operating Specification Condition		Maximum Specification Condition	
	Test Data Data	Analytical Data	Test Data	Analytical Data	Test Data	Analytical Data	Test Data	Analytical Data
Thermal Battery	34°F	33°F	161°F	169°F	-40°F*	-33°F	151°F*	174°F
Baseplate Receiver Side	36°	33°	166°	169°	-34°	-33°	174°	174°
Baseplate Timer Side	35°	33°	168°	169°	-34°	-33°	176°	174°
Baseplate Center	35°	33°	169°	169°	-34°	-33°	176°	174°

* Subsequent to Battery Firing the T/C Indicated a Lower Reading than considered normal

Table 9.2

LUNAR SEISMIC PROFILING EXPERIMENT QUALIFICATION
THERMAL VACUUM TEST DATA

TEST CONDITION

Location

	Acceptance Noon	Design Limit Noon	Qual Night
Geophone	295°F	317°F	-202°F
Transmitting Antenna Socket	145°	157°	-12°

9.4 Geophone Infrared Heater - Flight Test

The four Flight geophones were irradiated via quartz infrared lamps to attain temperatures comparable to lunar surface temperatures. Examining the temperatures of the four geophones, Table 9.3, during lunar noon indicates the center geophones to be warmer than the outer ones. This is attributed to the higher intensity at the center.

Table 9.3

LUNAR SEISMIC PROFILING EXPERIMENT FLIGHT ACCEPTANCE THERMAL VACUUM TEST DATA*

TEST CONDITION

Location	Acceptance Noon	Acceptance Night
Geophone #1	184°F	-228°F
Geophone #2	225°	-216°
Geophone #3	244°	-216°
Geophone #4	219°	-228°

* No High Explosive Package was Tested During Flight Acceptance T/V

SECTION III

LUNAR PREDICTIONS

This section summarizes the lunar surface analysis of the correlated thermal model.

10.0 LUNAR PREDICTIONS

10.1 Nominal Clean Experiment

10.1.1 Nominal Operation of LSPE (Equatorial Deployment)

Figure 10.1 depicts baseplate operating temperatures of a clean high explosive package with maximum projected area exposed to solar radiation. This occurs where two sides of the package are equally irradiated and the antenna is exposed. A maximum temperature of +167°F occurs at a 60° solar angle.

10.1.2 Off-Latitude Operation (20° Latitude)

Figure 10.1 depicts the baseplate operating temperatures of a clean high explosive package baseplate deployed off-latitude at a 20° angle with the equator. Two solar conditions are considered; one with maximum exposed area as above, and one with minimum exposed area or only one surface irradiated.

The package baseplate with two surfaces irradiated will peak at 167°F just as the equatorial deployment, however, it will peak at a higher solar angle, namely 68 degrees.

The package with only one surface irradiated, naturally follows a lower temperature curve. It's equilibrium temperature at the LM touchdown solar angle is +58°F. This package baseplate would peak at 145°F.

10.2 100% Dust Degraded Experiment

10.2.1 Nominal Operation of LSPE (Equatorial Deployment)

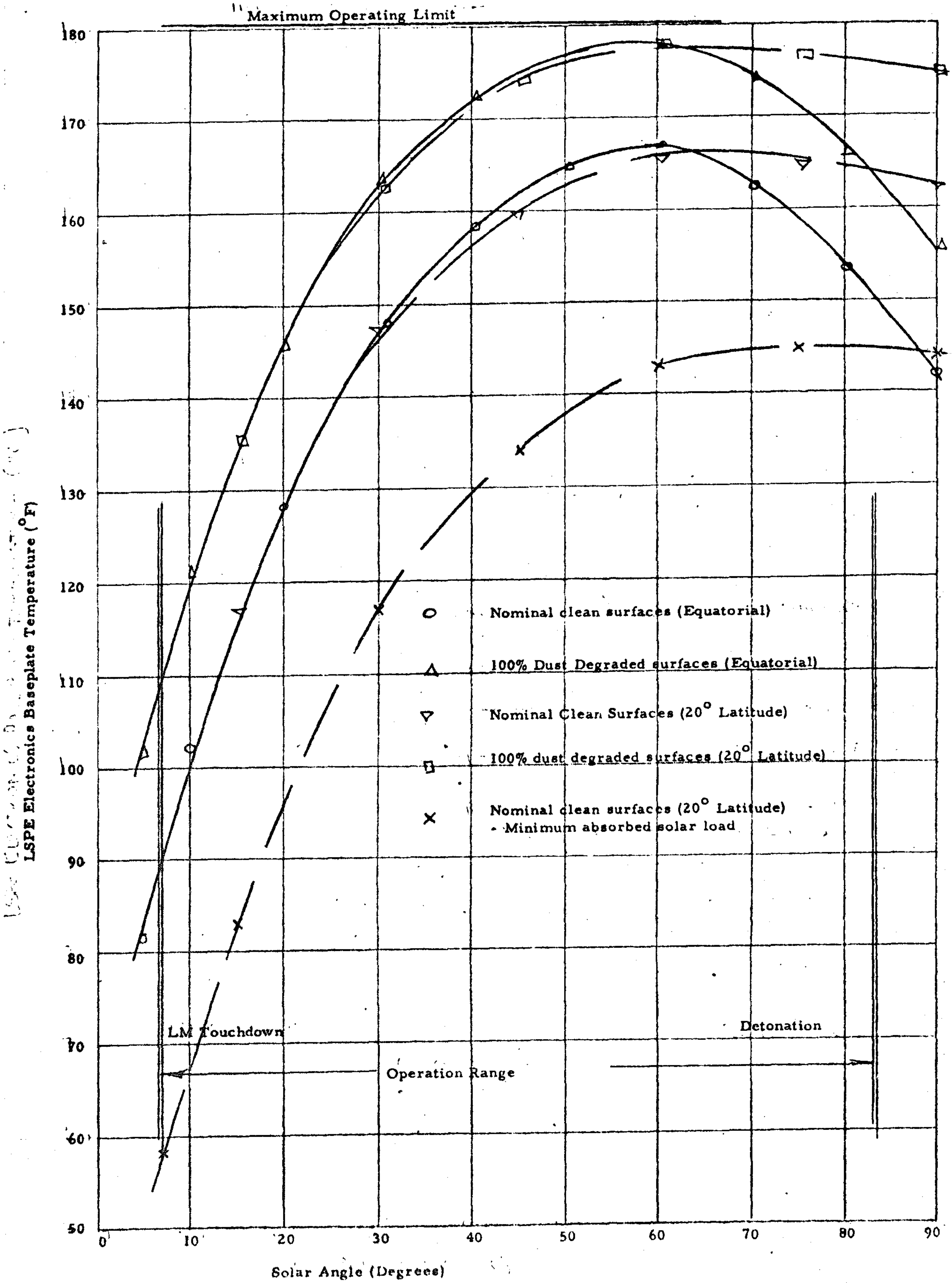
Figure 10.1 depicts the baseplate operating temperature of an explosive package which is 100% degraded with dust ($\gamma = 1.0$). The maximum baseplate temperature of this degraded package would be +177°F at a solar angle of 60 degrees.

10.2.2 Off-Latitude Operation (20° Latitude)

Figure 10.1 depicts the baseplate operating temperature of an explosive package 100% dust degraded which is deployed at the 20 degree latitude. This package baseplate temperature will peak at +177°F at a 68 degree solar angle.

Figure 10.1

Lunar Seismic Profiling Experiment High Explosive Package Operation Temperature Profile



11.0 LUNAR PREDICTIONS SUMMARY

Table 11.1 summarizes the lunar surface predictions.

TABLE 11.1

LUNAR DEPLOYED HIGH EXPLOSIVE BASEPLATE OPERATING TEMPERATURES

Maximum (Clean)	+167°F
Maximum (100% Degraded)	+177°F
Minimum (Clean)	+ 58°F

12.0 REFERENCES

1) AL 900131 "Lunar Seismic Profiling Experiment Specifications", Bendix Aerospace Systems Division.

2) AL 900431 "Specification for Seismic Detection System for Lunar Seismic Profiling Experiment", Bendix Aerospace Systems Division.

3) TP 2365582 "ALSEP Array E Deployed System Design Limit Thermal Vacuum Test Procedure", Bendix Aerospace Systems Division.

4) TP 2365575 "ALSEP Array E Flight System Deployed Thermal Vacuum Test Procedure", Bendix Aerospace Systems Division.

5) Internal Memo 9712-551 "LSPE Structural/Mechanical/Thermal/ Simulator T/V Test", Bendix Aerospace Systems Division.

6) ATM-1109 "Lunar Seismic Profiling Experiment Design Verification Thermal Vacuum Test," Bendix Aerospace Systems Division.

7) Internal Memo 70-210-143 "PSE, One-dimensional Thermal Analysis of Various Lunar Soils at Off Equatorial Latitudes", Bendix Aerospace Systems Division.

8) LED-520-1F "Design Criteria and Environments for the LM", Grumman Aircraft Engineering Corp.

APPENDIX A

THERMAL MATH MODEL NODES

10	Lunar Surface
14	High Explosive
15	High Explosive
16	Electronics Cover Black Stripe
17	Electronics Cover Black Stripe
18	Baseplate
19	Space
20	High Explosive Cover
21	High Explosive Cover
22	High Explosive Cover
23	High Explosive Cover
24	High Explosive Cover
28	Electronics Cover White Top
29	Multilayer Blanket
30	Electronics Cover White Stripe
31	Multilayer Blanket
32	Electronics Cover White Stripe
33	Multilayer Blanket
34	Antenna
35	Antenna
36	Antenna
37	Antenna Handle
38	Silicone Rubber Corner
39	Silicone Rubber Corner
40	Antenna Handle
41	High Explosive
42	High Explosive
43	High Explosive
44	High Explosive
45	Antenna
46	Antenna
47	Antenna
48	Antenna
49	Antenna
50	Antenna

Appendix B

Node			Thermal Capacitance	Initial Temperature	Table Number (Heat Input)		Product of (Absorptance & Absorbing Area)
0	1		-0 -0 -0	NODE DATA			
10	0	0	-.1000E+01	.4000E+02	1	-0	-0.
14	1	0	.1000E-01	.4000E+02	0	0	0.
15	1	0	.1000E-01	.4000E+02	0	0	0.
16	1	0	.1000E-01	.4000E+02	3	-0	.6000E-01
17	1	0	.1000E-01	.4000E+02	0	0	0.
18	1	0	.2540E+00	.4000E+02	4	-0	-0.
19	1	0	-.1000E+01	-.4590E+03	0	0	0.
20	1	0	.2000E-01	.4000E+02	3	-0	.9600E-01
21	1	0	.2000E-01	.4000E+02	0	0	0.
22	1	0	.1000E-01	.4000E+02	0	0	0.
23	1	0	.1000E-01	.4000E+02	0	0	0.
24	1	0	.1000E-01	.4000E+02	0	0	0.
28	0	0	.1200E-01	.4000E+02	2	-0	.4500E-01
29	0	0	.1000E-01	.4000E+02	0	0	0.
30	0	0	.1000E-01	.4000E+02	3	-0	.1720E-01
31	0	0	.1000E-01	.4000E+02	0	0	0.
32	0	0	.1000E-01	.4000E+02	0	0	0.
33	0	0	.1000E-01	.4000E+02	0	0	0.
34	0	0	.1190E-01	.4000E+02	3	-0	.1980E-01
35	0	0	.2380E-01	.4000E+02	3	-0	.3960E-01
36	0	0	.3300E-01	.4000E+02	3	-0	.5200E-01
37	0	0	.1000E-01	.4000E+02	3	-0	.1950E-01
38	0	0	.2540E+00	.4000E+02	3	-0	.3180E-01
39	0	0	.2540E+00	.4000E+02	0	0	0.
40	0	0	.1000E-01	.4000E+02	0	0	0.
41	0	0	.5520E+00	.4000E+02	0	0	0.
42	0	0	.1050E+00	.4000E+02	0	0	0.
43	0	0	.1240E-01	.4000E+02	0	0	0.
44	0	0	.3500E-01	.4000E+02	0	0	0.
45	0	0	.1000E-01	.4000E+02	3	-0	.6000E-03
46	0	0	.1000E-01	.4000E+02	3	-0	.6000E-03
47	0	0	.1000E-01	.4000E+02	3	-0	.1200E-02
48	0	0	.1000E-01	.4000E+02	3	-0	.2400E-02
49	0	0	.1000E-01	.4000E+02	3	-0	.4900E-02
50	0	0	.1000E-01	.4000E+02	3	-0	.9900E-02

Resistor Number	Connecting Nodes		Radiation Area		Configuration Factor				
0	0		-0 -0 -0	RESISTOR DATA					
22	14	15	.1800E+03	0.	0.	0.	0	0	0.
23	15	18	.6250E-01	.6424E-11	.6000E-01	0.	0	0	0.
24	16	18	.9600E-01	.1332E-09	.8100E+00	0.	0	0	0.

25	17	18	.9600E-01	.1332E-09	.8100E+00	0.	0	0	0.
26	14	20	.7100E-01	.3649E-10	.3000E+00	0.	0	0	0.
27	14	21	.7100E-01	.3649E-10	.3000E+00	0.	0	0	0.
28	15	20	.7100E-01	.3649E-10	.3000E+00	0.	0	0	0.
29	15	21	.7100E-01	.3649E-10	.3000E+00	0.	0	0	0.
30	17	10	.9560E-01	.7369E-10	.4500E+00	0.	0	0	0.
31	16	10	.9560E-01	.7369E-10	.4500E+00	0.	0	0	0.
32	17	19	.9560E-01	.7369E-10	.4500E+00	0.	0	0	0.
33	16	19	.9560E-01	.7369E-10	.4500E+00	0.	0	0	0.
34	20	10	.1430E+00	.1102E-09	.4500E+00	0.	0	0	0.
35	21	10	.1430E+00	.1102E-09	.4500E+00	0.	0	0	0.
36	20	19	.1430E+00	.1102E-09	.4500E+00	0.	0	0	0.
37	21	19	.1430E+00	.1102E-09	.4500E+00	0.	0	0	0.
46	22	23	.6700E+03	0.	0.	0.	0	0	0.
47	23	24	.1110E+03	0.	0.	0.	0	0	0.
48	22	42	.2500E+03	0.	0.	0.	0	0	0.
49	23	41	.1110E+00	.5134E-10	.2700E+00	0.	0	0	0.
50	24	14	.9000E+02	0.	0.	0.	0	0	0.
51	15	18	.9000E+02	0.	0.	0.	0	0	0.
52	39	14	.2469E+02	0.	0.	0.	0	0	0.
53	38	14	.2469E+02	0.	0.	0.	0	0	0.
54	39	15	.2469E+02	0.	0.	0.	0	0	0.
55	38	15	.2469E+02	0.	0.	0.	0	0	0.
56	34	35	.5070E+03	0.	0.	0.	0	0	0.
57	35	36	.2700E+03	0.	0.	0.	0	0	0.
60	40	18	.3920E+02	0.	0.	0.	0	0	0.
61	37	20	.3920E+02	0.	0.	0.	0	0	0.
64	39	20	.1230E+04	0.	0.	0.	0	0	0.
65	38	21	.1230E+04	0.	0.	0.	0	0	0.
66	34	19	.1050E+00	.1529E-10	.8500E-01	0.	0	0	0.
67	34	10	.1050E+00	.1529E-10	.8500E-01	0.	0	0	0.
68	35	19	.2090E+00	.3043E-10	.8500E-01	0.	0	0	0.
69	35	10	.2090E+00	.3043E-10	.8500E-01	0.	0	0	0.
70	36	19	.2730E+00	.3975E-10	.8500E-01	0.	0	0	0.
71	36	10	.2730E+00	.3975E-10	.8500E-01	0.	0	0	0.
72	37	19	.6800E-01	.3564E-10	.3060E+00	0.	0	0	0.
73	37	10	.6800E-01	.3564E-10	.3060E+00	0.	0	0	0.
74	37	20	.6800E-01	.3355E-10	.2880E+00	0.	0	0	0.
75	28	29	.5400E+03	0.	0.	0.	0	0	0.
76	29	18	.1560E+00	.1336E-10	.5000E-01	0.	0	0	0.
77	30	31	.8660E+03	0.	0.	0.	0	0	0.
78	31	18	.9600E-01	.8222E-11	.5000E-01	0.	0	0	0.
79	32	33	.8660E+03	0.	0.	0.	0	0	0.
80	33	18	.9600E-01	.8222E-11	.5000E-01	0.	0	0	0.
81	28	19	.1740E+00	.2683E-09	.9000E+00	0.	0	0	0.
82	30	19	.9600E-01	.7400E-10	.4500E+00	0.	0	0	0.
83	30	10	.9600E-01	.7400E-10	.4500E+00	0.	0	0	0.
84	32	19	.9600E-01	.7400E-10	.4500E+00	0.	0	0	0.
85	32	10	.9600E-01	.7400E-10	.4500E+00	0.	0	0	0.
89	37	40	.1500E+02	0.	0.	0.	0	0	0.
91	41	43	.1270E+03	0.	0.	0.	0	0	0.

92	42	44	.2500E+03	0.	0.	0.	0	0	0.
93	14	41	.6235E+02	0.	0.	0.	0	0	0.
94	41	42	.2720E+03	0.	0.	0.	0	0	0.
95	38	10	.2000E-01	.1542E-10	.4500E+00	0.	0	0	0.
96	39	10	.2000E-01	.1542E-10	.4500E+00	0.	0	0	0.
97	38	19	.2000E-01	.1542E-10	.4500E+00	0.	0	0	0.
98	39	19	.2000E-01	.1542E-10	.4500E+00	0.	0	0	0.
99	15	43	.6235E+02	0.	0.	0.	0	0	0.
100	43	44	.6480E+02	0.	0.	0.	0	0	0.
101	43	18	.1110E+00	.1141E-10	.6000E-01	0.	0	0	0.
102	18	44	.1660E+02	0.	0.	0.	0	0	0.
103	18	30	.6550E-02	.6283E-12	.5600E-01	0.	0	0	0.
104	18	16	.6550E-02	.2087E-11	.1860E+00	0.	0	0	0.
105	18	20	.6550E-02	.2726E-11	.2430E+00	0.	0	0	0.
106	18	10	.6550E-02	.6362E-11	.5670E+00	0.	0	0	0.
107	18	19	.6550E-02	.7069E-11	.6300E+00	0.	0	0	0.
108	18	20	.1780E-01	.4330E-11	.1420E+00	0.	0	0	0.
109	18	16	.1780E-01	.4330E-11	.1420E+00	0.	0	0	0.
110	18	19	.1780E-01	.8903E-11	.2920E+00	0.	0	0	0.
111	18	10	.1780E-01	.8019E-11	.2630E+00	0.	0	0	0.
112	18	19	.9700E-02	.7477E-11	.4500E+00	0.	0	0	0.
113	18	10	.9700E-02	.6730E-11	.4050E+00	0.	0	0	0.
114	18	20	.6900E-03	.4787E-12	.4050E+00	0.	0	0	0.
115	18	16	.6900E-03	.4787E-12	.4050E+00	0.	0	0	0.
116	18	17	.2340E-02	.1623E-11	.4050E+00	0.	0	0	0.
117	18	21	.2340E-02	.1623E-11	.4050E+00	0.	0	0	0.
118	18	19	.3030E-02	.2336E-11	.4500E+00	0.	0	0	0.
119	18	10	.3030E-02	.2102E-11	.4050E+00	0.	0	0	0.
120	40	45	.2880E+01	0.	0.	0.	0	0	0.
121	45	46	.2880E+01	0.	0.	0.	0	0	0.
122	45	19	.3230E-02	.4703E-12	.8500E-01	0.	0	0	0.
123	45	10	.3230E-02	.4703E-12	.8500E-01	0.	0	0	0.
124	46	47	.4320E+01	0.	0.	0.	0	0	0.
125	47	10	.6470E-02	.9421E-12	.8500E-01	0.	0	0	0.
126	47	19	.6470E-02	.9421E-12	.8500E-01	0.	0	0	0.
127	47	48	.8640E+01	0.	0.	0.	0	0	0.
128	48	10	.1290E-01	.1878E-11	.8500E-01	0.	0	0	0.
129	48	19	.1290E-01	.1878E-11	.8500E-01	0.	0	0	0.
130	48	49	.1728E+02	0.	0.	0.	0	0	0.
131	49	10	.2590E-01	.3771E-11	.8500E-01	0.	0	0	0.
132	49	19	.2590E-01	.3771E-11	.8500E-01	0.	0	0	0.
133	46	10	.3230E-02	.4703E-12	.8500E-01	0.	0	0	0.
134	46	19	.3230E-02	.4703E-12	.8500E-01	0.	0	0	0.
135	49	50	.3310E+02	0.	0.	0.	0	0	0.
136	50	10	.5180E-01	.7542E-11	.8500E-01	0.	0	0	0.
137	50	19	.5180E-01	.7542E-11	.8500E-01	0.	0	0	0.
138	50	36	.9980E+02	0.	0.	0.	0	0	0.

```
    0     0          -0   -0   -0

    9     0     1   -0.            FUNCTION  9 DATA
                    -0.         .2000E+01  .1000E+01  .2990E+03-0.         -0.
   -1    -0    -0   -0.
   -1    -0    -0   -0.
```

```
0     0          102  -0  -0  -0  -0

1     0    2   -0.          -0.
                0.          -.3000E+03  .1200E+02 -.6000E+02  .2400E+02  .2500E+02  .4800E+02  .1100E+03
                 .7200E+02   .1620E+03  .9600E+02  .2000E+03  .1200E+03  .2270E+03  .1440E+03  .2420E+03
                 .1680E+03   .2500E+03  .1920E+03  .2490E+03  .2160E+03  .2410E+03  .2400E+03  .2230E+03
                 .2640E+03   .1960E+03  .2880E+03  .1560E+03  .3120E+03  .9800E+02  .3360E+03  .3800E+01
                 .3600E+03 -.1900E+03   .3840E+03 -.2320E+03
-1   -0   -0    0.

2     0    4   -0.          -0.
                0.           0.         .2950E+02  .1140E+03  .5900E+02  .2210E+03  .8850E+02  .3120E+03
                 .1180E+03   .3830E+03  .1475E+03  .4270E+03  .1770E+03  .4420E+03  .2060E+03  .4270E+03
                 .2360E+03   .3830E+03  .2650E+03  .3120E+03  .2950E+03  .2210E+03  .3240E+03  .1140E+03
                 .3530E+03 0.           .3531E+03 0.          .3840E+03 0.
-1   -0   -0    0.

3     0    4   -0.          -0.
                0.           .4420E+03  .2950E+02  .4270E+03  .5900E+02  .3830E+03  .8850E+02  .3120E+03
                 .1180E+03   .2210E+03  .1475E+03  .1140E+03  .1770E+03 0.          .2060E+03  .1140E+03
                 .2360E+03   .2210E+03  .2650E+03  .3120E+03  .2950E+03  .3830E+03  .3240E+03  .4270E+03
                 .3530E+03   .4420E+03  .3531E+03 0.          .3840E+03 0.
-1   -0   -0    0.

4     0    4   -0.          -0.
                0.           .9000E-01  .5900E+02  .1170E+01  .1180E+03  .9800E+00  .1770E+03  .1060E+01
                 .2360E+03   .9800E+00  .2960E+03  .1180E+01  .3540E+03  .8950E+00
-1   -0   -0    0.

-1   -0   -0   -0.
```