LUNAR MASS SPECTROMETER

DESIGN VERIFICATION

THERMAL VACUUM TEST REPORT

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Lunar Mass Spectrometer Design Verification Thermal Vacuum Test	NO. ATM 1097	REV. NO. A
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	DATE 5/17/72	

This revision A is to provide the LMS project group with additional data requested of them during the QTRR 5/17/72. Included are additional thermocouple data on the program sweep high voltage, low voltage power supply, and multiplier tubes high voltage cards obtained during the LMS Design Verification Test of 9/30/71.

D. Toelle

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SUMMARY

The Design Verification Tests of the Prototype model were carried out to verify the design and analysis of the LMS system. Some differences between the LMS test model and the analysis of flight hardware did occur. These differences are a result of hardware changes and factors inherent in the test setup only and can be accounted for analytically. All tests were correlated within $7^{\circ}F$. Those conditions with the greatest discrepancies were those conditions which hadn't established equilibrium.

During the lunar night operating condition 3 watts of heater dissipation was required to stabilize the operating temperature at $-8^{\circ}F$. It was found that operating power dissipation was 7.63 watts instead of 9.21 watts as anticipated.

Subsequent correlation studies indicate 2.58 watts of heat leak between the electronics package and analyzer baseplate. This heat leak will be reduced on Qual and Flight models by lining the analyzer cover with aluminum coated tape. This change coupled with radiator masking change should bring the Qual/Flight operating temperature within the $-10/+125^{\circ}F$ design goal.

1.0 SCOPE

The purpose of this report is to document the results and conclusions resulting from the testing of the LMS Prototype model in the BxA Thermal Vacuum Test Chamber.

2.0 INTRODUCTION

The Lunar Mass Spectrometer-Design Verification Thermal Vacuum Tests were performed during the period of 30 September 1971 to October 1971 at the Bendix Aerospace Systems Division. This report presents the thermal data obtained during those tests together with a correlation of the thermal mathematical model with the experimental data. This report also includes a description of the test installation and testing conditions.

3.0 BACKGROUND AND PURPOSE

The Lunar Mass Spectrometer is basically a magnetic-deflection mass spectrometer designed to identify the constituents of the lunar surface atmosphere. It consists of two major subsystems, the electronics section and the gas analyser section. The subsystems are joined to a common baseplate with each subsystem having its own fiberglass cover. The electronics subsystem is contained in a thermal bag. Thermal control is maintained by means of a second surface mirrored radiator plate and internal power heat dissipation. This control will maintain the electronics heat sink between -10^{o}F (lunar night) and +125^{o}F (lunar day). The gas analyzer subsystem contains no thermal control and is subject to the lunar temperature range of -300^{o}F to +250^{o}F.

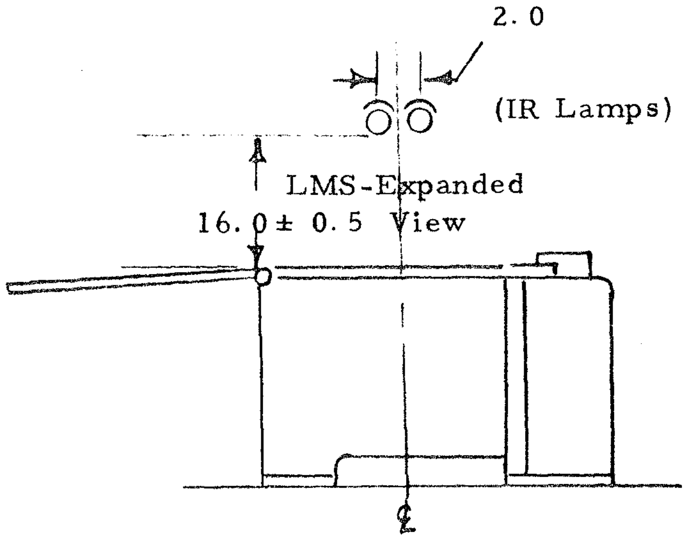
The objectives of the LMS Prototype Thermal Vacuum Design Verification Test are to subject the design to the lunar thermal/vacuum environments verifying the thermal math model and to establish the temperature extremes demonstrating the ability of the LMS design to withstand these extremes without loss of function.

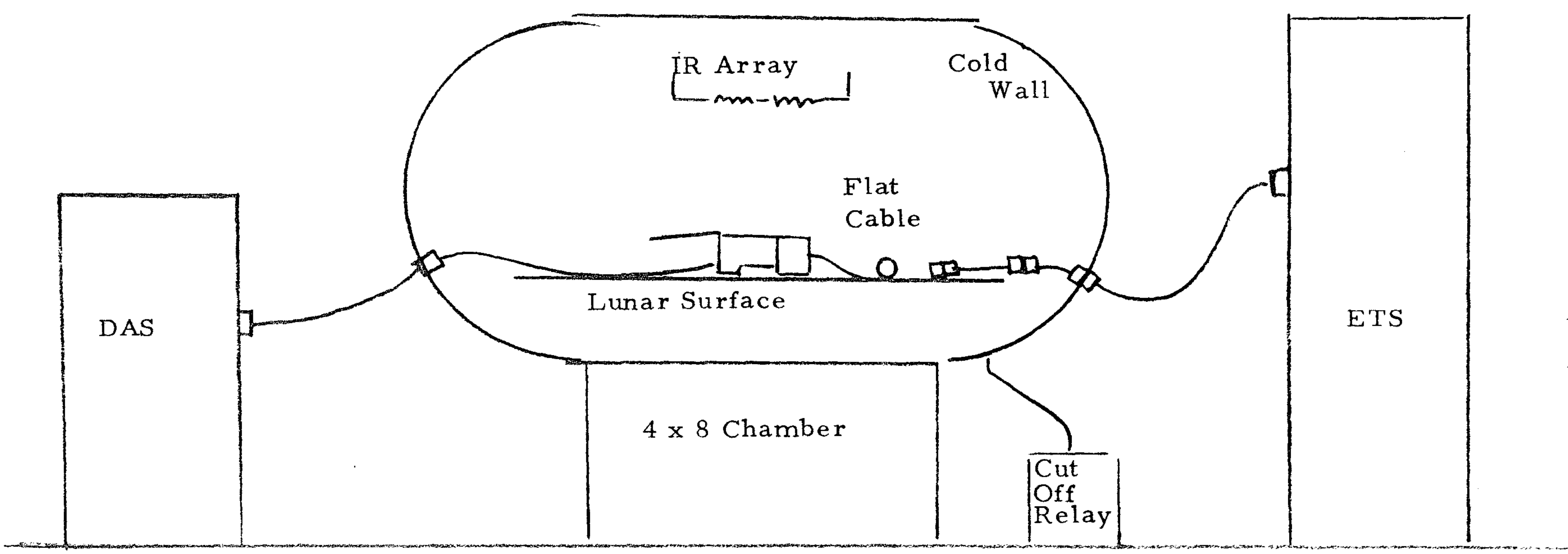
4.0 DESCRIPTION OF TEST CONDITIONS AND TEST INSTALLATION

4.1 Thermal Test Conditions

The LMS Prototype was correlated for twelve thermal test conditions. These conditions simulate various phases of the lunar operating and non-operating mission. (See Table 1).

Figure 1 LMS Test Setup





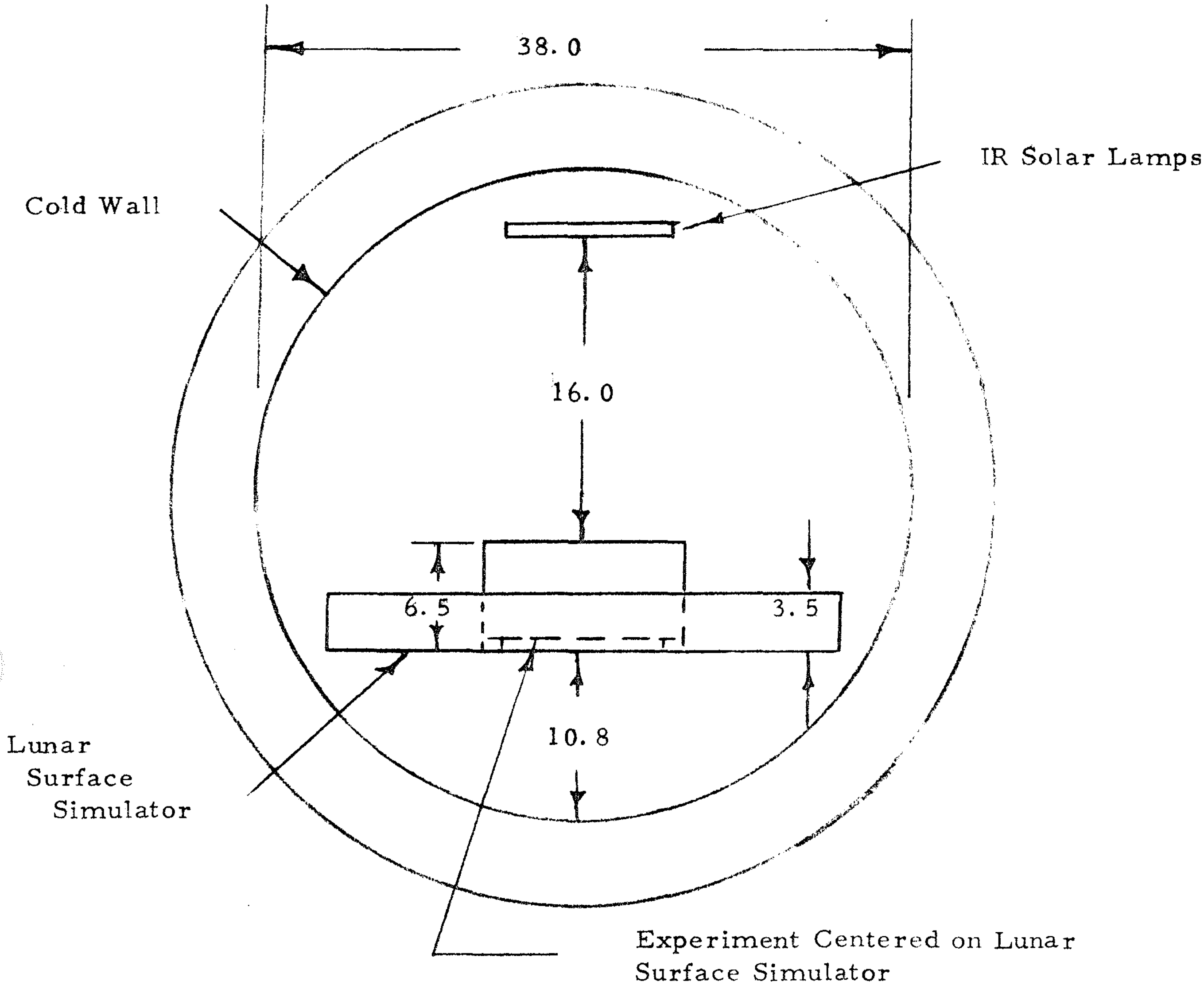
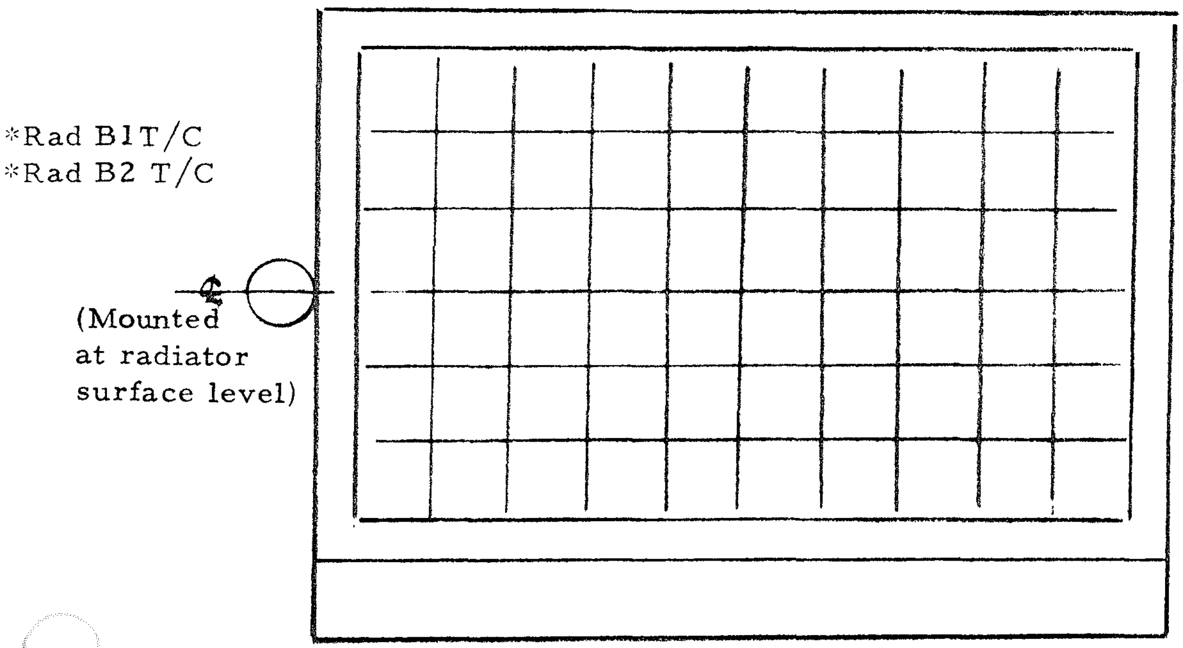


Figure 2 LMS Prototype Experiment
Deployed in 4 x 8 Chamber



BLACK Radiometer Location

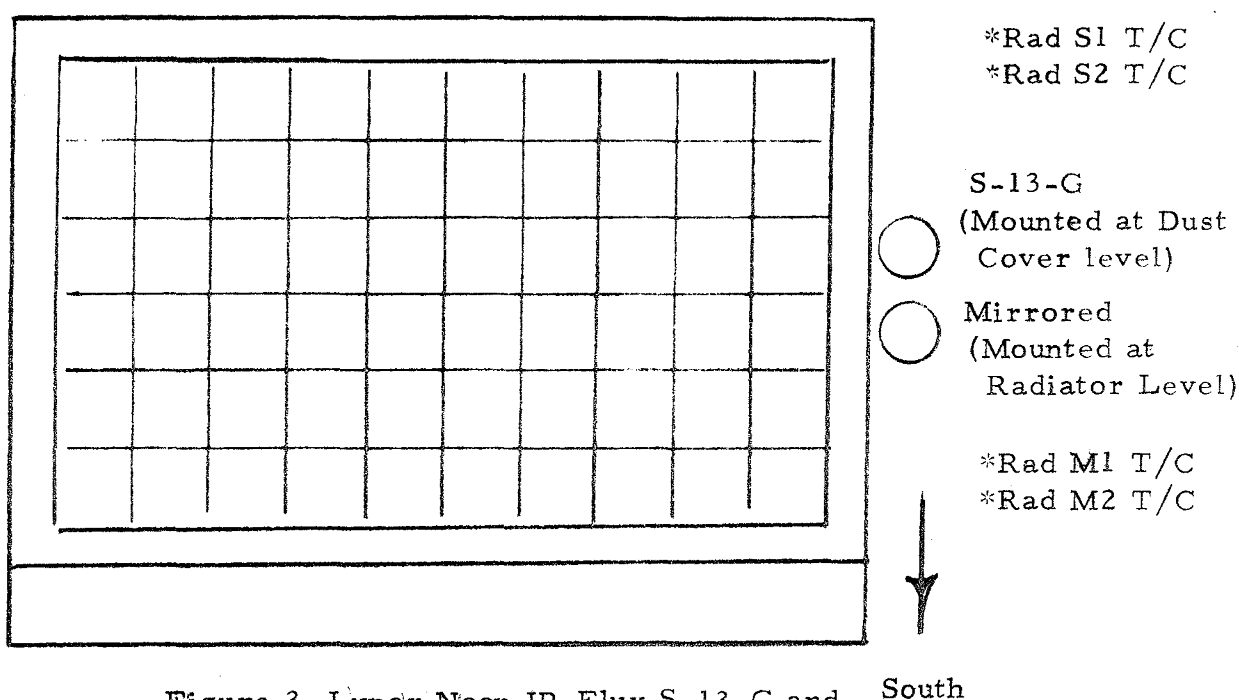


Figure 3 Lunar Noon IR Flux S-13-G and MIRRORED Radiometer Locations

* Thermocouples mounted at intake and output lines.

4.2 Lunar Surface Simulator

The lunar surface was simulated by a metal plate (35 5/8" x 53 3/4") with 3 1/2 inch vertical lips. The surface was mounted horizontally in the vacuum chamber slightly below the center line of the chamber. The surface was coated with black thermal paint to simulate the emissivity of the lunar surface. Surface temperature was controlled by means of resistance heaters beneath the surface and vertical lips, and LN^2 cooling coils beneath the surface.

4.4 Solar Simulation

Solar simulations was achieved by using an array of infrared electric heat lamps. These lamps arranged in pairs were directed through the center line of the experiment at right angles to the horizontal and 16 inches above the experiment surface. The intensity of incident radiation was determined by measuring the intensity of radiation impingement upon three radiometers as indicated in Figure 3. These radiometers were coated with S-13-G white coating, black coating, and a second-surface mirror.

4.5 Experiment Location

The LMS experiment was centered in the chamber with the analyzer section toward the chamber door. Figures 1 and 2 indicate the experiment with respect to the chamber, DAS, ETS, etc.

4.6 Thermocouple Locations

Thirty-eight thermocouples were designated to measure the experiment temperatures. The thermocouple locations are listed in Table 2 and indicated in Figures 4, 5, and 6.

5.0 RESULTS AND DISCUSSION

5.1 Factors Affecting Correlation of the Analytical Model with Test Data

5.1.1 Lunar Surface and Coldwall to Experiment View Factors

The finite dimensions of the lunar surface simulator results in experiment view factors differing from those view factiors experienced on the actual lunar surface. The experiment view factors are improved somewhat by placing the experiment on 1/2 inch blocks. View factors to the lunar surface and coldwall are as follows:

TABLE 3

CHAMBER TO EXPERIMENT VIEW FACTORS

	Lunar Surface Simulator	Actual Lunar Surface	Cold Wall	Space
Electronics Cover	0.50	0.50	0.50	0.50
Analyzer Cover	0.50	0.50	0.50	0.50
Radiator Plate Top	0.0	0.0	1.00	1.00
Radiator Plate Side	0.41	0.50	0.59	0.50
Radiator Plate End	0.42	0.50	0.58	0.50

This model presents a good simulation of the actual deployed configuration. The view factor to the edge of the radiator plate is insignificant in that it is covered by masking and is a small percentage of the total radiation plate area.

5.1.2 Power Dissipations

Power dissipations listed in Table 4 were calculated by the LMS Project Group. Data for these numbers were obtained directly from the TP 2365501 As Run Test Procedure. Adjustments were made to account for testset voltage drops and cable losses. The final experiment power was separated into power dissipated within the thermal bag, to the radiator plate, and to the analyzer base plate.

TABLE 4

POWER DISSIPATION (WATTS)

Conditions	Radiator Plate Heater	Internal Electronics	Analyzer Electronics
1	-	-	-
2	3.68	-	-
3	-	-	-
4	3.68	-	-
5	-	6.59	1.65
6	-	7.04	1.65
7	11.68	-	-
8	11.84	-	-
9	3.05	7.63	1.65
10	7.68	-	-
11	-	6.95	1.61
12	-	6.95	1.61

5.1.3 Solar Simulation

5.1.3.1 Radiometer Error

Accurate Solar Simulation is influenced by both the ability to accurately set and hold good tolerance on the lamp setting, and maintaining an accurate, consistent reference temperature. The effects of these parameters on the incident solar load simulation is indicated in Table 5.

As indicated, during conditions 4 through 6 the radiometer temperature varied from the constant +100°F to as low as +92°F. This is quite significant when measuring the absorptance of highly reflective surface such as second surface mirrors. This drop in reference temperature reduced the absorbed heat by 14.1% of total during these 4 test conditions.

The effects of setting accuracies are also indicated in Table 5. In all conditions the settings produced slightly more solar heat than required.

These effects were incorporated in the correlation studies.

5.1.3.2 Effects of Infrared Solar Simulation on S-13-G Coated Surfaces

During all tests with second surface mirrored surfaces exposed to solar simulation, the infrared lamps were adjusted to simulate the heat absorbed by the second surface mirrors under actual solar radiation. This action results in under simulation of heat absorbed in all S-13-G or 3M 401-A10 coated surfaces. This phenomenon becomes apparent when one considers the solar and infrared absorptances of the mirrors and S-13-G coating. The solar absorptances of S-S mirrors is 0.08, whereas, that of S-13-G is 0.25 or a factor of three. The infrared absorptance, however, is 0.80 for S-S mirrors and 0.90 for S-13-G. Since the Solar simulation is infrared the two coatings are absorbing practically the same percent of radiation, therefore, adjusting the heat source to an effective 8% for the S-S mirrors results in absorption of 9% by the S-13-G coating instead of the 25% under solar radiation. This has been accounted for in the correlation study.

5.2 Graphical Summary of Results

5.2.1 Radiator Plate Temperature (Figure 7a and 7b)

Figures 7a and 7b indicate the temperature at the center of the radiator plate throughout the duration of the test. Figure 7a itemizes each critical condition as described in Table 1.

5.2.2 Electronics Components (Figures 7c through 7h)

Figures 7c through 7h give a comparison for each critical electronic board temperature with the radiator plate temperature. This comparison is summarized in the following paragraphs.

TABLE 5

Radiometer Effects on Solar Load

Effect Factor

Test Condition	Theoretical Absorptance of Controlling Radiometer	Setting Accuracy	Radiometer Temperature	Effective Solar Load
1	0.20	1.130	1.0	1.130*
2	0.20	1.130	1.0	1.130
3	0.08	1.044	0.859	0.897
4	0.08	1.044	0.859	0.897
5	0.08	1.044	0.859	0.897
6	0.08	1.944	0.859	0.897
7	0.08	1.068	1.0	1.068
8	-	-	1.0	-
9	-	-	1.0	-
10	-	-	1.0	-
11	0.08	1.058	1.0	1.0500
12	0.08	1.077	1.0	1.077

*The ideal factor would be 1.0.

5.2.2.7 Program Sweep High Voltage Card

The maximum temperature gradients between the program sweep high voltage card and the radiator plate are, during lunar night 23°F, during lunar noon 21°F.

5.2.2.8 Low Voltage Power Supply Card

The maximum temperature gradients between the low voltage power supply card and the radiator plate are, during lunar night 9°F, during lunar noon 7°F.

5.2.2.9 Multiplier Tubes High Voltage Card

The maximum temperature gradients between the multiplier tubes high voltage card and the radiator plate are, during lunar night 14°F, during lunar noon 12°F.

TABLE 6
CRITICAL TEST TEMPERATURE
Temperature (°F)

Test Condition Number	Elapsed Time Hours	TEST DATA Electronics Radiator Plate	TEST DATA Analyzer Baseplate	ANALYTICAL DATA Electronics Radiator Plate	ANALYTICAL DATA Analyzer Baseplate
1	51.00	107.9	157.8	101.25	154.4
2	62.50	153.7	161.8	151.9	158.4
3	86.00	16.1	136.2	11.5	132.2
4	91.50	44.1	138.0	44.8	135.0
5	104.50	68.6	144.9	68.9	141.7
6	118.5	75.8	147.6	72.2	141.9
7	142.0	111.0	146.9	109.1	141.0
8	163.5	5.9*	-141.3	1.0	-137.5
9	178.0	-8.04*	-125.5	-4.6	-119.0
10	196.0	-46.2*	-164.4	-52.9	-159.0
11	212.2	79.78	149.6	77.2	143.0
12	219.0	89.22	151.2	87.2	145.0

* These temperatures had not stabilized.

6.0 CONCLUSIONS

All discrepancies between calculated temperatures and actual temperatures have been accounted for in the correlation studies. These differences are not anticipated during actual lunar operation.

During the lunar night full power operating condition, number 9 of Table 1, itwas found that the operating temperature was exceeding the -12°F predicted prior to the test. Stabilization at -8°F occurred only after 3 watts of heater power was applied to the radiator plate. Upon analyzing the lunar night power dissipation subsequent to the test, it was determined that 7.63 watts operating power was dissipated instead of 9.21 watts as anticipated.

Correlation studies of test data indicated that considerable heat leak resulted between the experiment electronics and the analyzer baseplate. For example, during lunar night, 1.16 watts leaks out via the titanium support structure and 1.42 watts via the cables bundle. During lunar noon 0.74 watts leaks in via the support structure and 0.88 watt via the cable bundle. In order to reduce this heat leak without major design impact on Qual and Flight models, the analyzer case will be lined with highly reflective aluminum tape. This design change should increase the lunar night operating temperature 7.3°F.

During the operational mode 1.65 watts of power is dissipated within the analyzer components. This dissipation becomes an important consideration in spite of the fact that it is dissipated outside the thermal bag. Addition of this heat to the analyzer baseplate increases the lunar night operating temperature 9.9°F above that of the survival mode in which no analyzer power is dissipated.

These factors coupled with adjustments to the radiator masking area should bring lunar noon/night operating temperatures within the +125/-10°F operating temperature goals.

TABLE 1

SUMMARY OF TEST CONDITIONS

Condition	Description	TP Paragraph	Solar Intensity (Suns)	Lunar Surface Temperature (°F)	Electronics Power Dissipation (Watts)	Heater Power Dissipation (Watts)
1	Lunar noon Cover on Power off	6.8.5	1.0	250	---	---
2	Lunar Noon Cover On Standby Power	6.8.12.1	1.0	250	---	3.68
3	Lunar Noon Cover Off Power Off	6.8.25.2	1.0	250	---	---
4	Lunar Noon Cover Off Standby 1/2 Power	6.8.36.1	1.0	250	---	3.68
5	Lunar Noon Ion Pump On Cover Off Power On	6.8.41.1	1.0	250	6.59	---
6	Lunar Noon Cover Off Full Power	6.8.45.1	1.0	250	7.04	---

TABLE 1

SUMMARY OF TEST CONDITIONS

Condition	Description	TP Paragraph	Solar Intensity (Suns)	Lunar Surface Temperature (°F)	Electronics Power Dissipation (Watts)	Heater Power Dissipation (Watts)
7	Lunar Noon Cover Off Standby + Extra Heater	6.8.51.1	1.0	250	---	11.68
8	Lunar Night Cover Off Standby + Extra Heater	6.9	---	-300	---	11.84
9	Lunar Night Cover Off Full Power + Backup Heater	6.9.14.1	---	-300	7.63	3.05
10	Lunar Night Cover Off Standby Power	6.9.17.1	---	-300	---	7.68

TABLE 1

SUMMARY OF TEST CONDITIONS

Condition	Description	TP Paragraph	Solar Intensity (Suns)	Lunar Surface Temperature (°F)	Electronics Power Dissipation (Watts)	Heater Power Dissipation (Watts)
11	Lunar Noon Dust Cover Off Full Operate Power	6.9.20.10	1.0	250	6.98	---
12	Lunar Noon Dust Cover Off Full Operate Power 1.25 Sun Equiva-lent	9.20.15.5	1.25	250	6.98	---

TABLE 2

THERMOCOUPLE LOCATIONS

DAS Channel	Description	
2	CW 1	Coldwall panel A
4	CW 3	Coldwall panel B
5	CW 4	Coldwall panel C
6	CW 5	Coldwall panel C
7	CW 6	Coldwall panel D
8	CW 7	Coldwall panel E
9	CW 8	Coldwall panel E
10	CW 9	Coldwall door
11	CW 10	Coldwall door
12	CW 11	Coldwall door
13	CW 12	Coldwall rear
15	CW 14	Coldwall rear
20	LS-1	Lunar Surface Simulator
21	LS-2	Lunar Surface Simulator
22	LS-3	Lunar Surface Simulator
23	LS-4	Lunar Surface Simulator
24	LS-5	Lunar Surface Simulator
25	LS-6	Lunar Surface Simulator
26	LSL-1	Lunar Surface Lip
27	LSL-2	Lunar Surface Lip
28	LSL-3	Lunar Surface Lip
29	LSL-4	Lunar Surface Lip
30	LMS-41	Radiator plate
31	LMS-51	Radiator plate
32	LMS-55	Thermal cover
33	LMS-56	Thermal cover
34	LMS-57	Thermal cover
35	LMS-58	Thermal cover
36	LMS-59	Thermal cover
37	LMS-61	Radiator plate
38	LMS-65	Thermal bag-outside
39	LMS-66	Thermal bag-outside
40	LMS-67	Thermal bag-outside
41	LMS-68	Thermal bag-outside

TABLE 2 (CONT.)

DAS Channel	Description	
42	LMS-69	Thermal bag-outside
43	LMS-70	Baseplate
44	LMS-73	Baseplate
45	LMS-77	Baseplate
46	LMS-80	Analyzer cover
47	LMS-81	Analyzer cover
48	LMS-85	Electronics cover
49	LMS-86	Electronics cover
50	LMS-87	Electronics cover
51	LMS-88	Dust cover
52	LMS-89	Electronics cover
53	LMS-91	Analyzer cover
54	LMS-101	Counter and data compressor card
55	LMS-102	Counter and data compressor card
56	LMS-103	Signal conditioner card
57	LMS-106	Housekeeping card
58	LMS-107	Pre-amp discriminator card
59	LMS-110	Control and monitor card
60	LMS-111	Emission control card
61	LMS-112	Emission control card
62	LMS-114	Program sweep high voltage card
63	LMS-115	Low voltage power supply card
64	LMS-165	Multiplier tubes high voltage card
66	LMS-76	Baseplate
67	LMS-84	Analyzer cover
68	LMS-150	Baseplate thermister

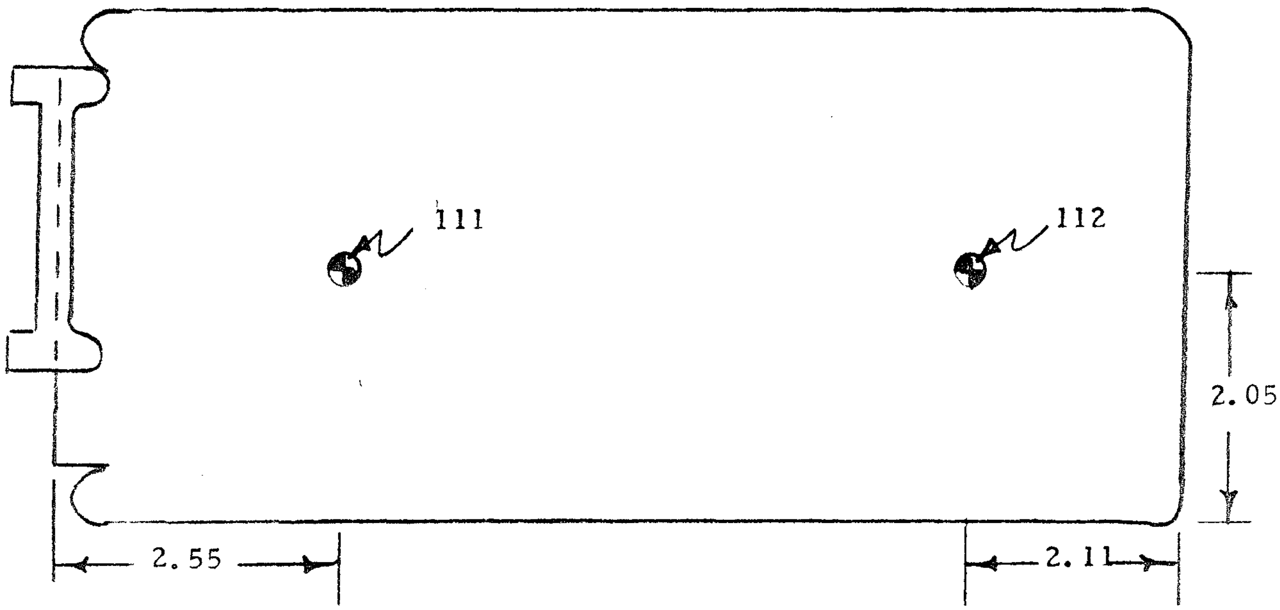


Figure 4a Emission Control Circuit Board Thermocouple Location
(Ref Dwg #UTD 151-600)

T/C Locations

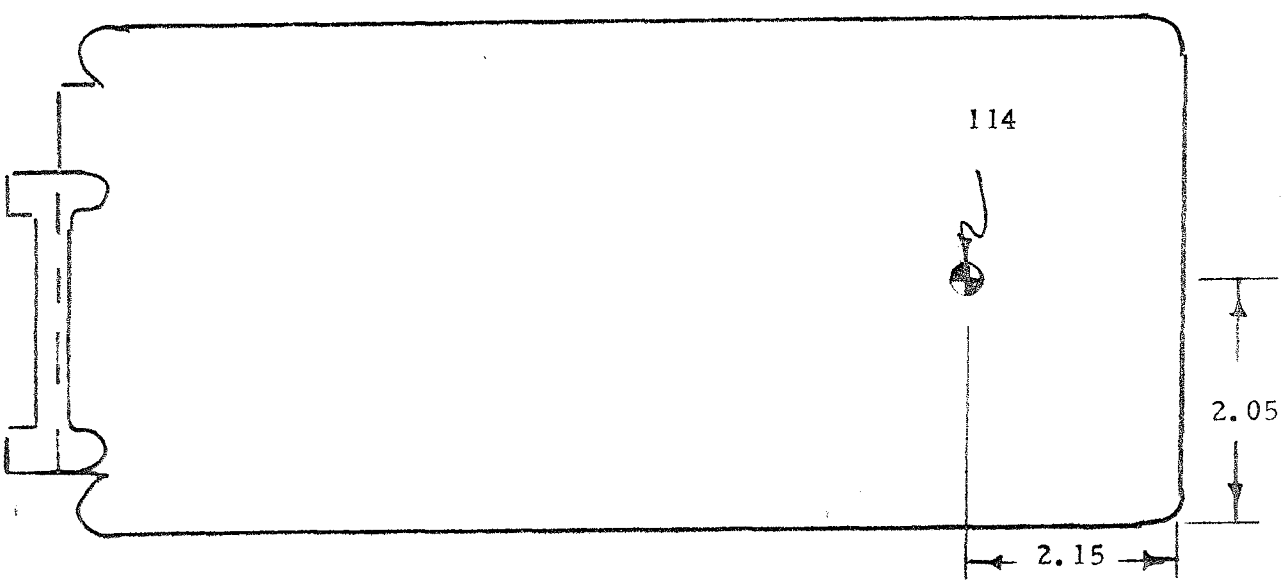


Figure 4b Sweep High Voltage Circuit Board Thermocouple Location
(Ref Dwg # UTD 151-600)

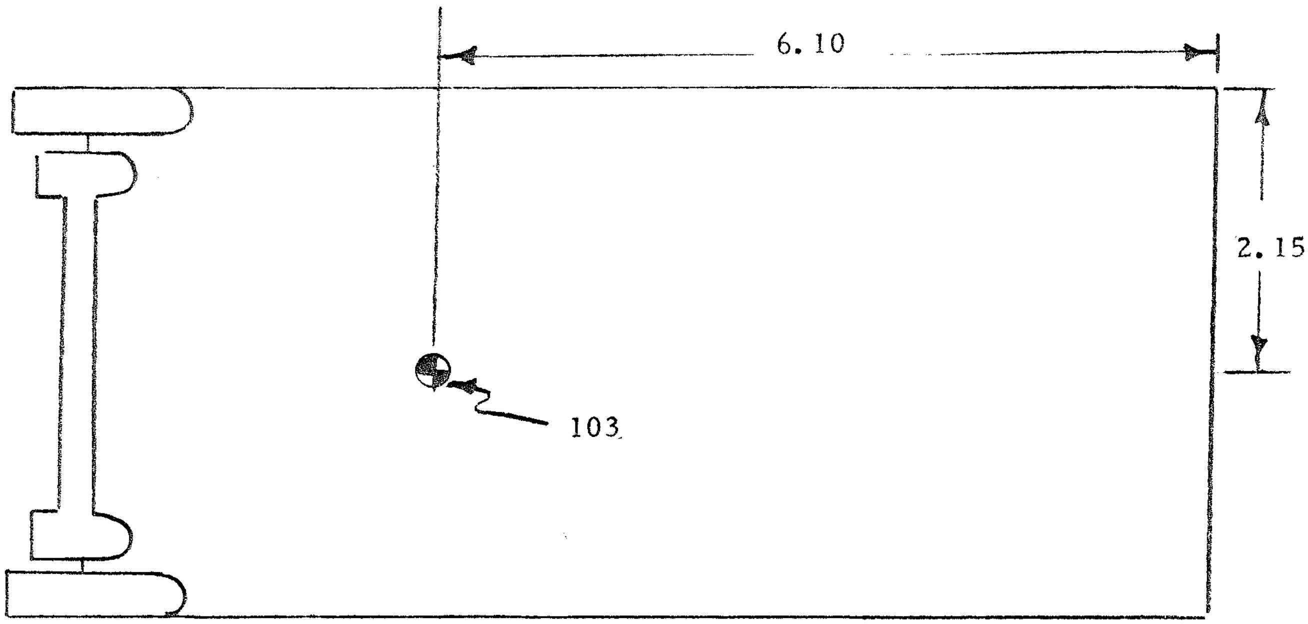


Figure 4c Decoder and Signal Conditioner Circuit Board
Thermocouple Location
(Ref Dwg #2347540)

T/C Location

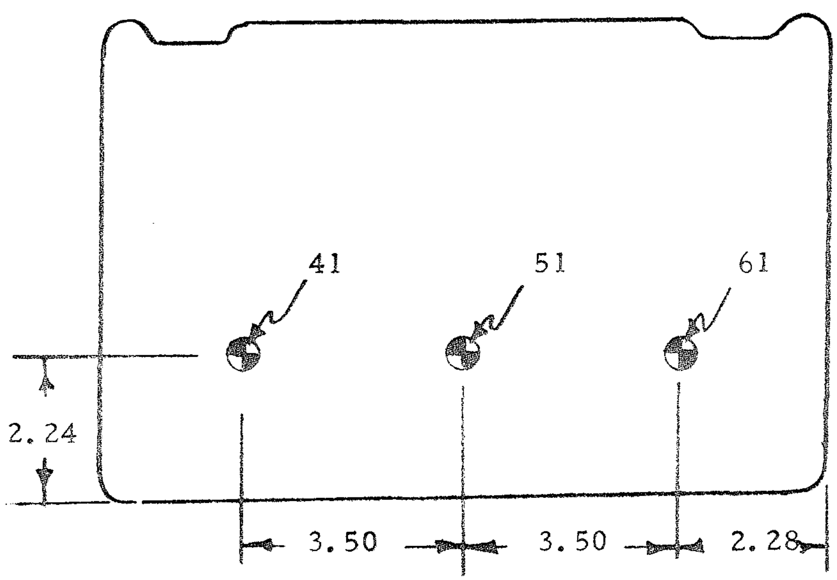


Figure 4d Radiator Plate
Thermocouple Location
(Ref Dwg #2347607)

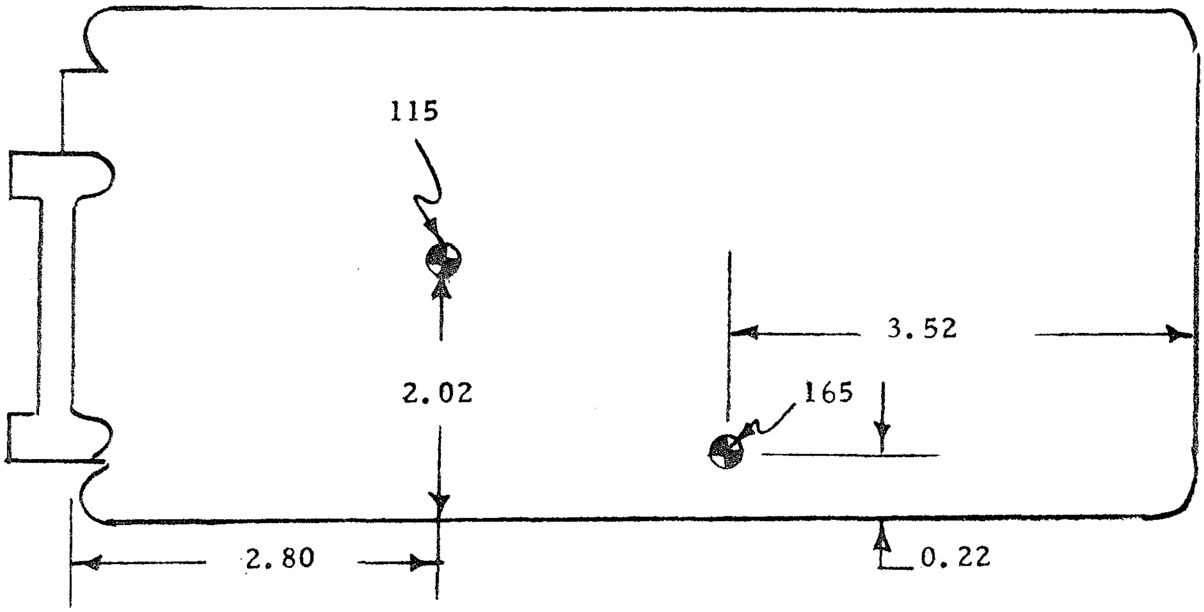


Figure 4e Power Supply Module
Thermocouple Location
(Ref Dwg 2347480)

T/C Location

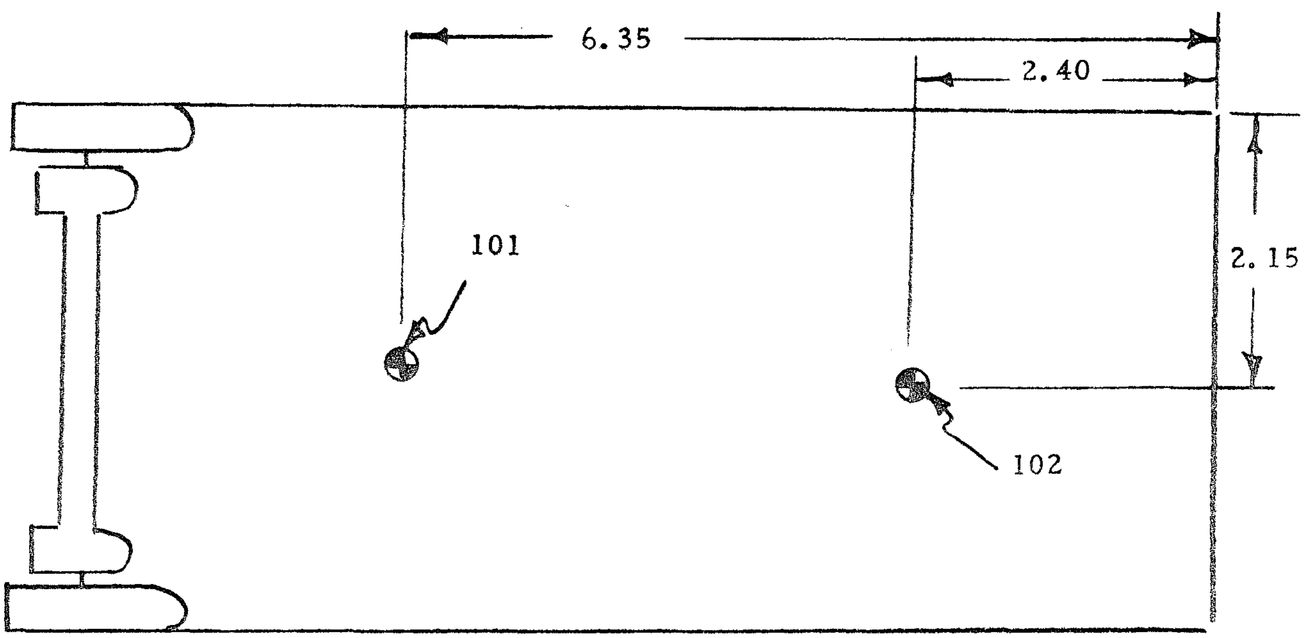


Figure 4f Counter and Data Compressor Circuit Board
Thermocouple Location
(Ref Dwg #2347550)

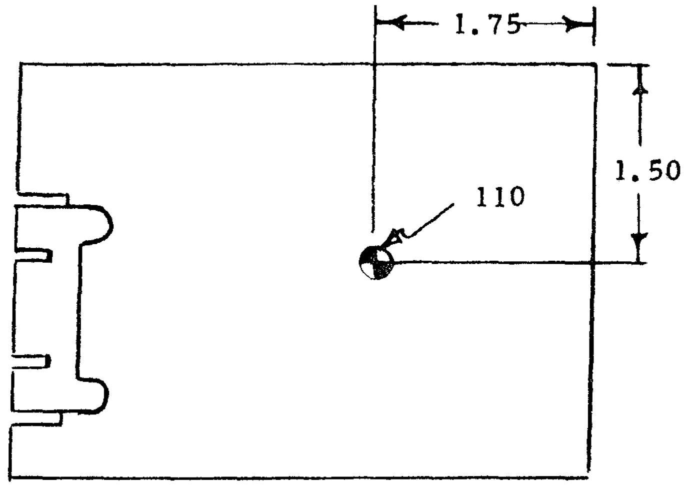


Figure 4g Control and Monitor Circuit Board
Thermocouple Location
(Ref Dwg #2347530)

T/C Location

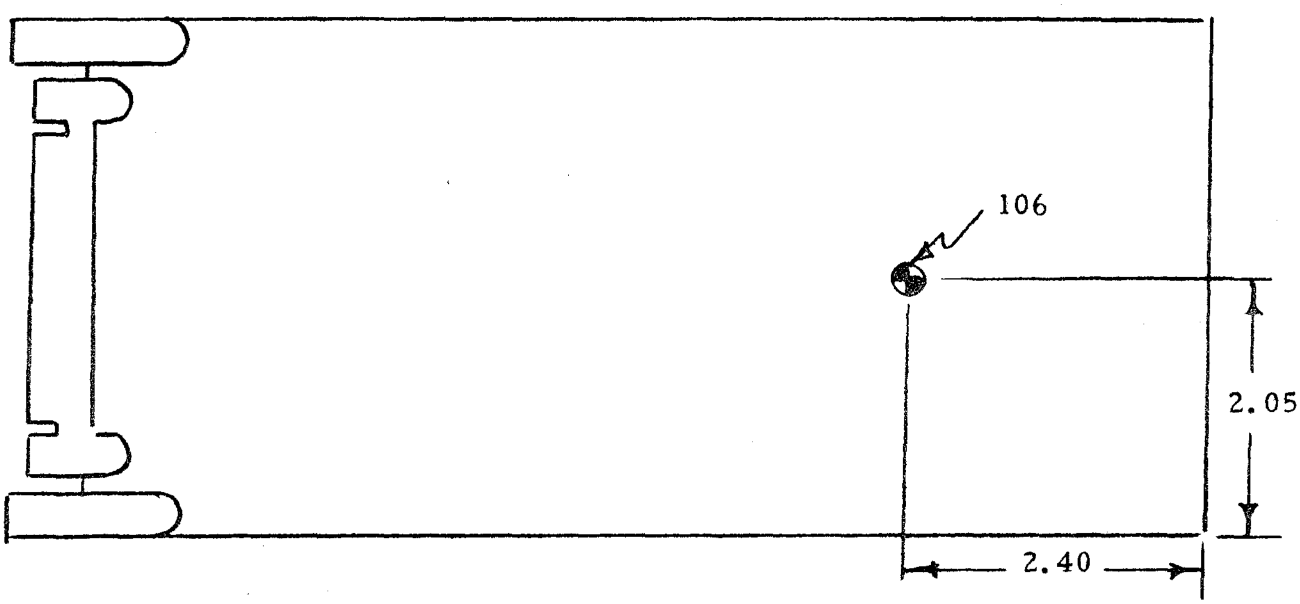
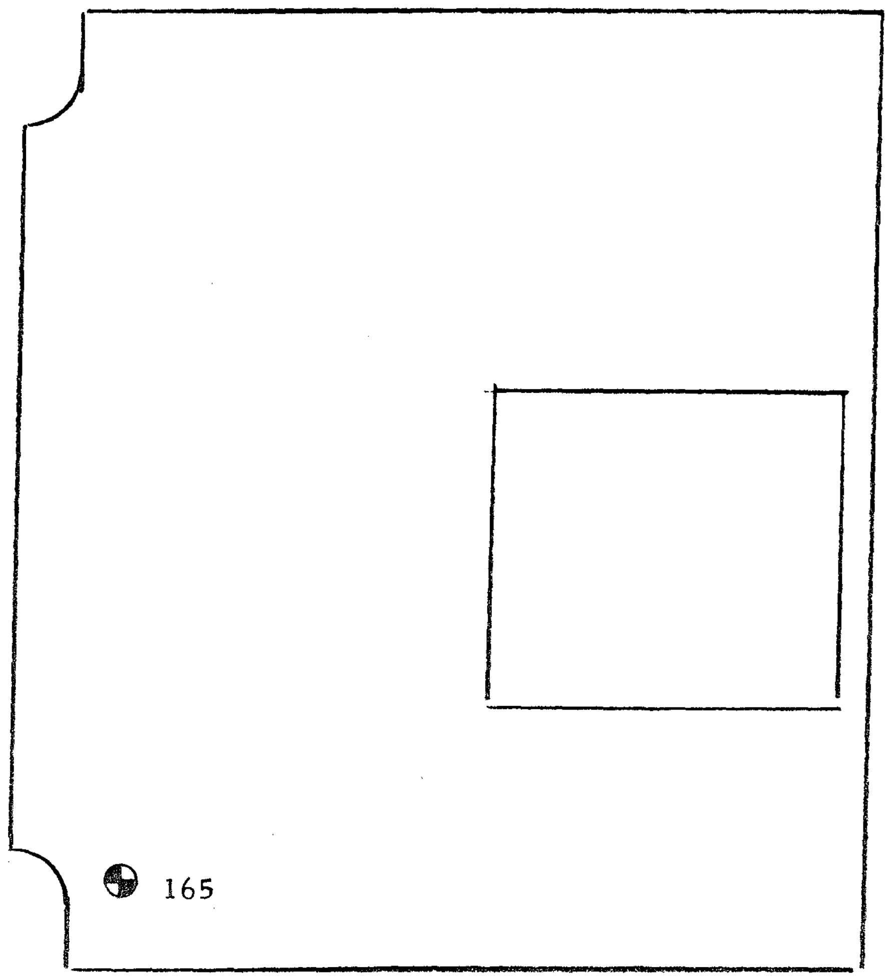


Figure 4h Housekeeping Multiplier Circuit Board
Thermocouple Location
(Ref Dwg #2347555)

Figure 4i Elect. Multiplier HV Power Supply
(Ref Dwg #2347567)



T/C Location

Figure 4j Preamp/Discriminator Housing Thermocouple Location
(Ref Dwg #UTD 151-636)

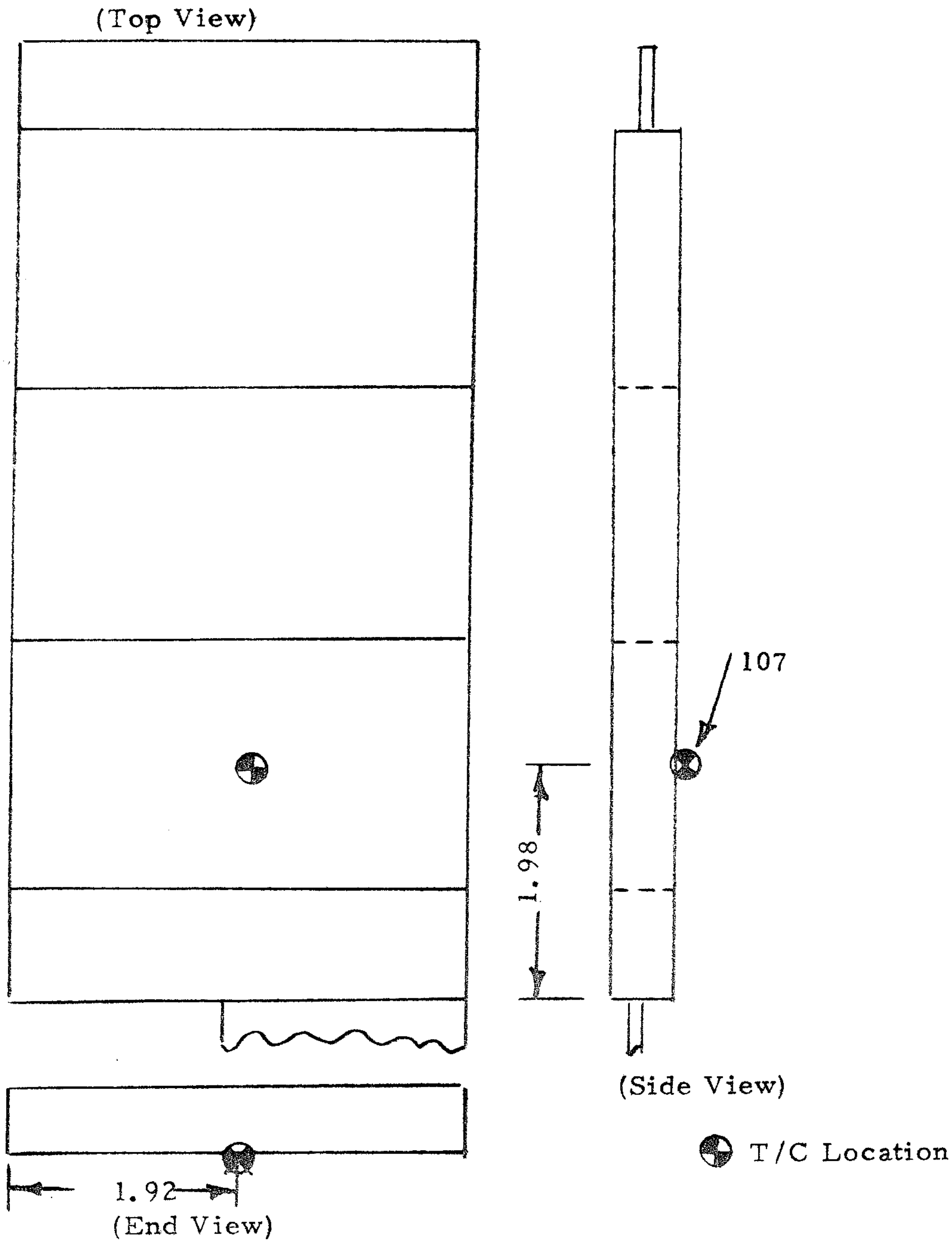
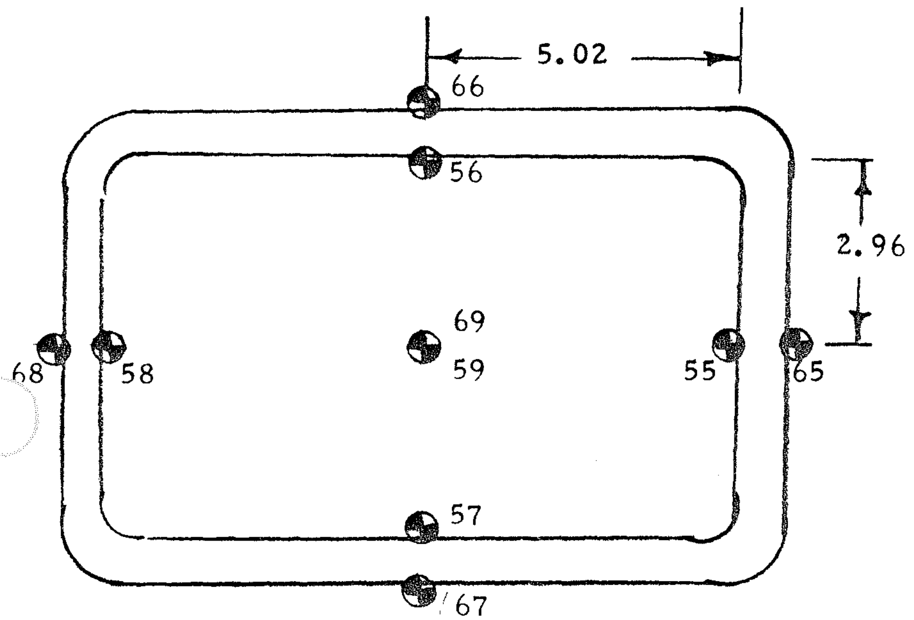
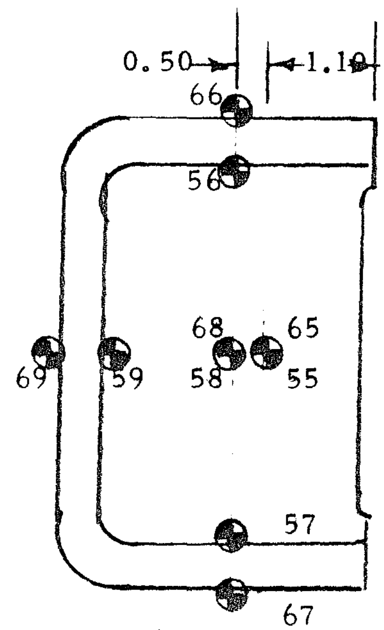


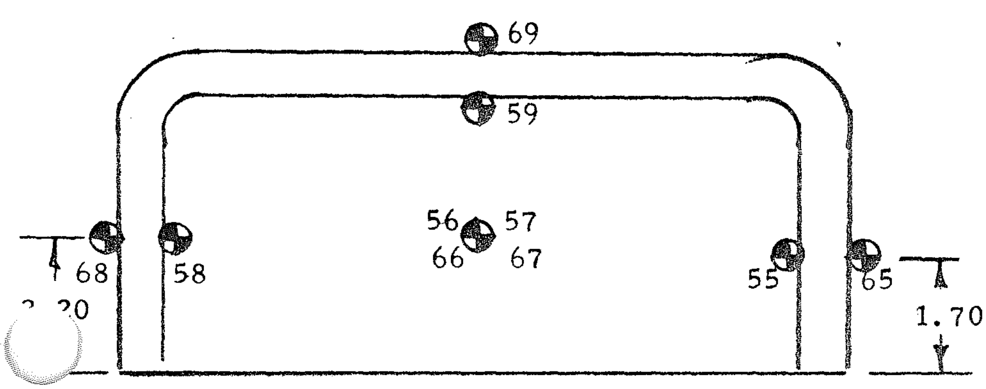
Figure 4k Thermal Cover Assembly
Thermocouple Location
(Ref Dwg #2347510)



(Top View)



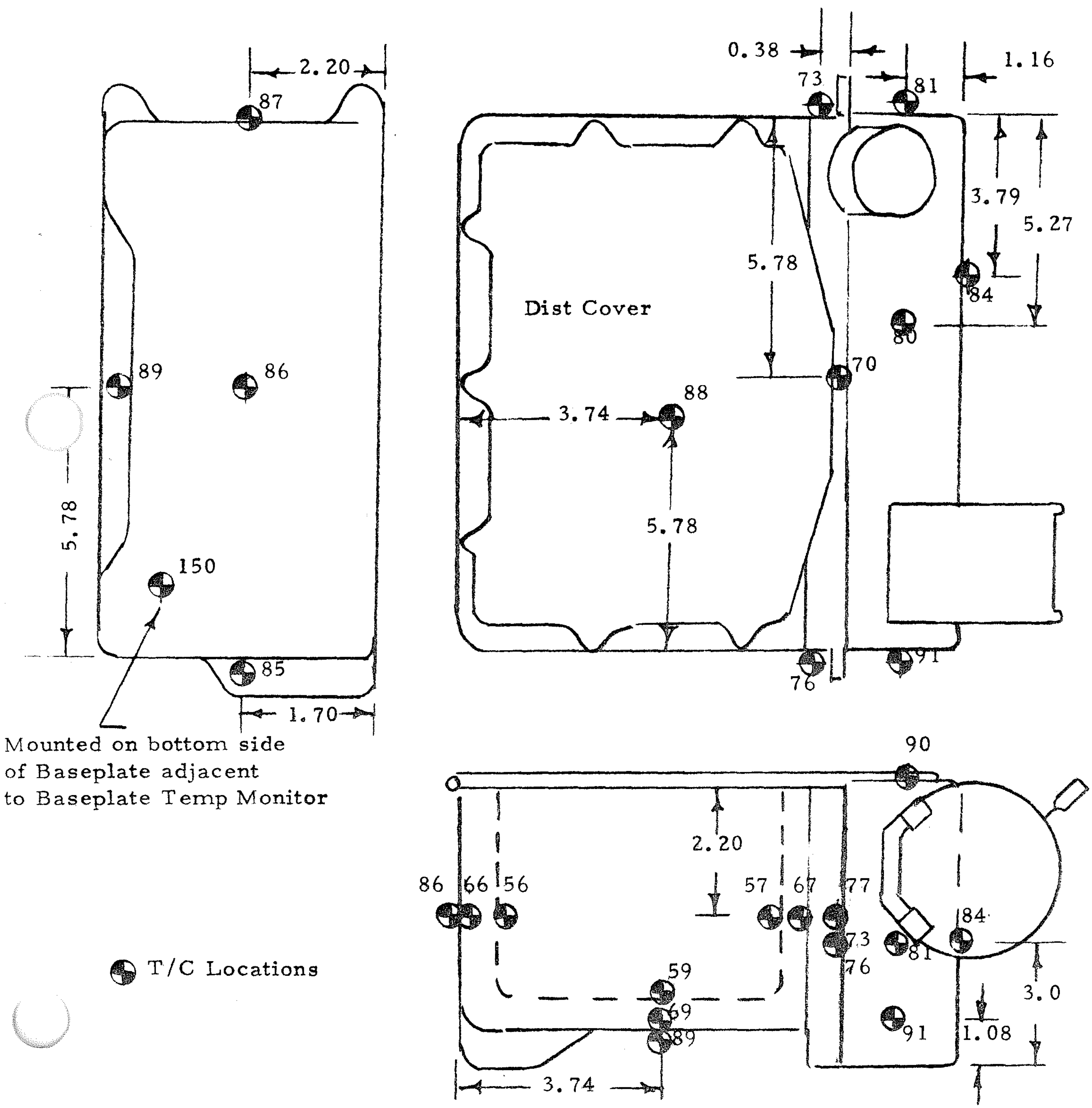
(End View)



(Front View)

T/C Locations

Figure 41 LMS Thermocouple Locations
(Ref Dwg #2347400)



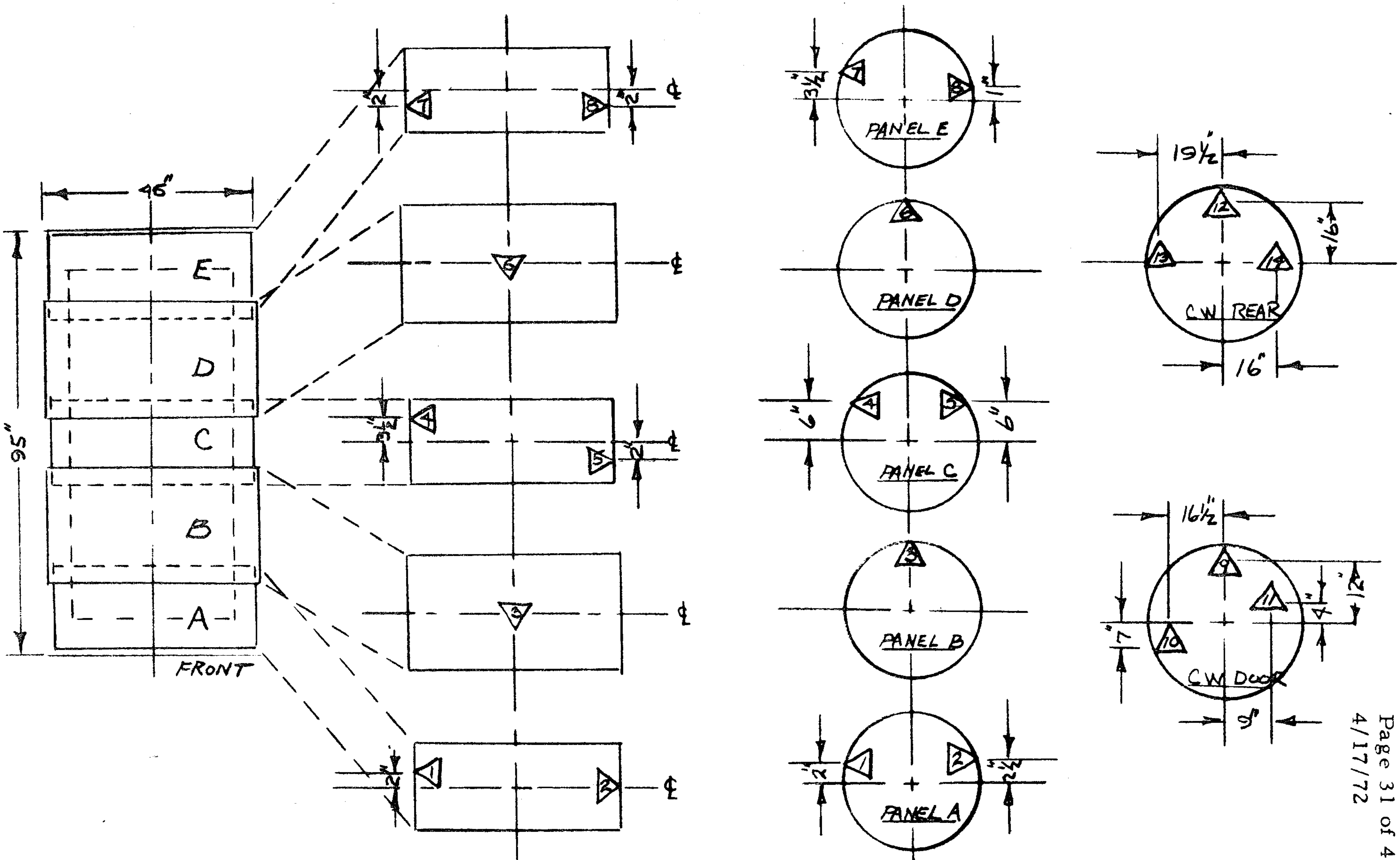


Figure 5
4' x 8' Chamber T/C Locations

Figure 6 Lunar DVT Surface Simulator T/C Locations

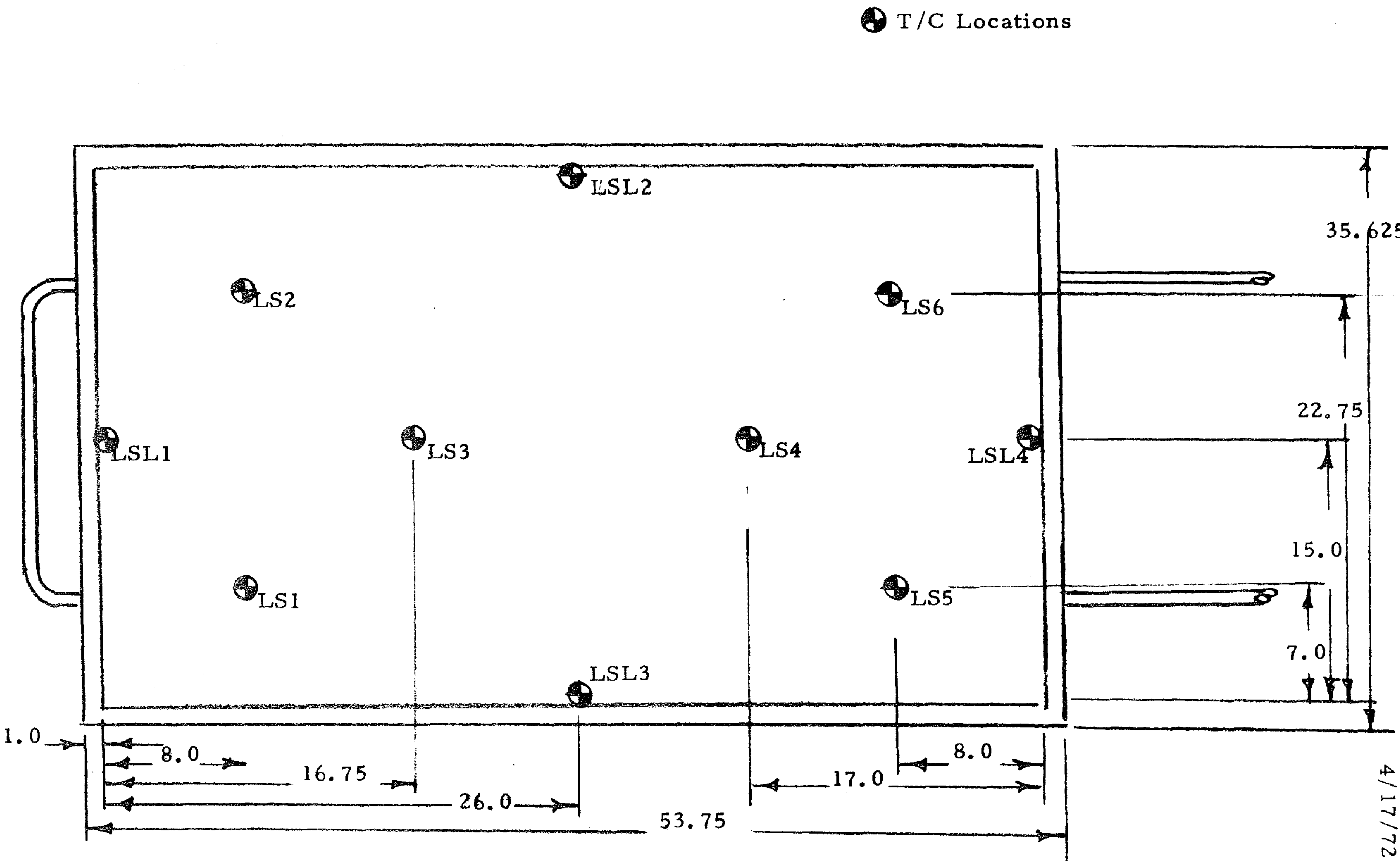


Figure 7a

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71

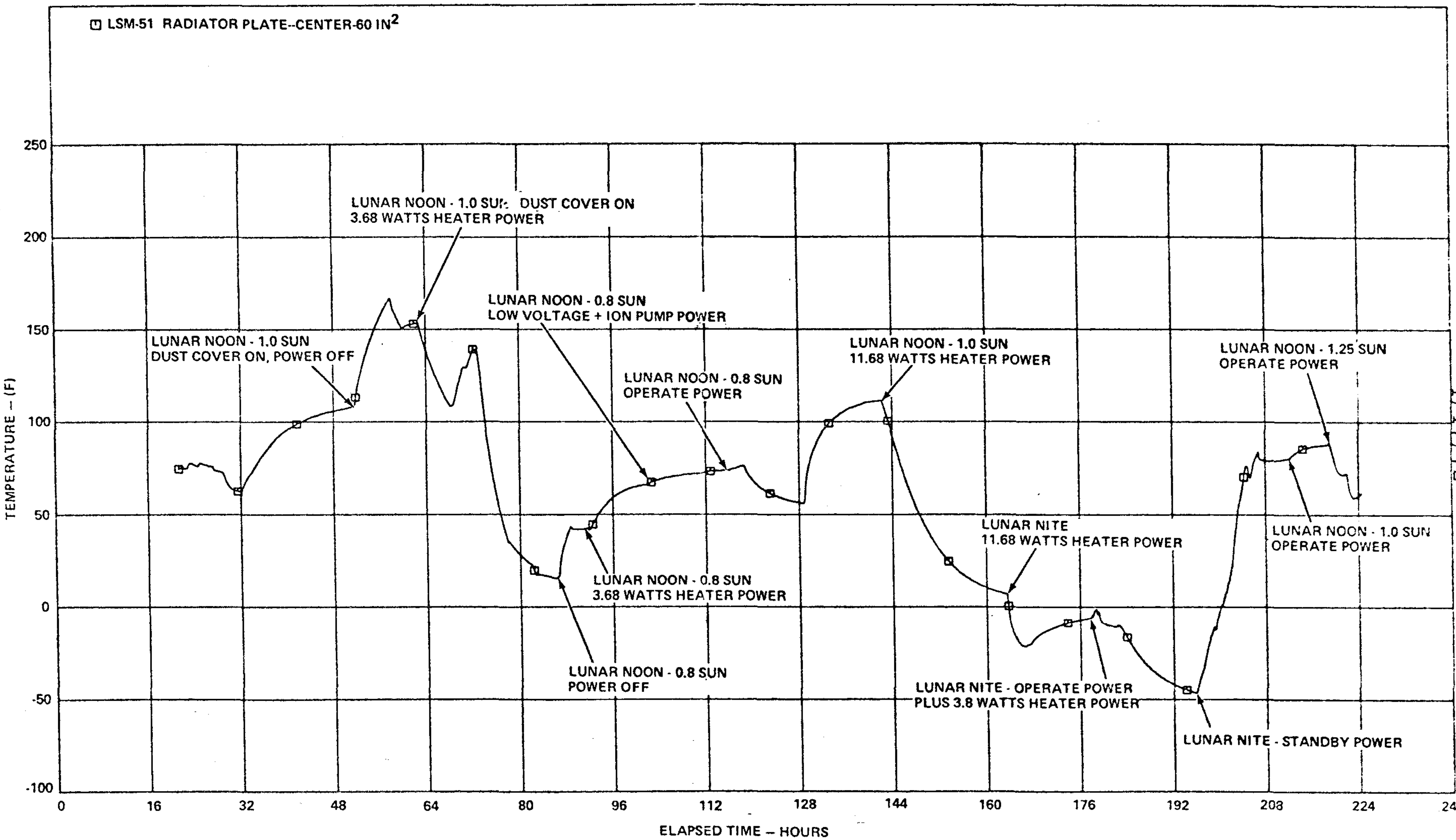
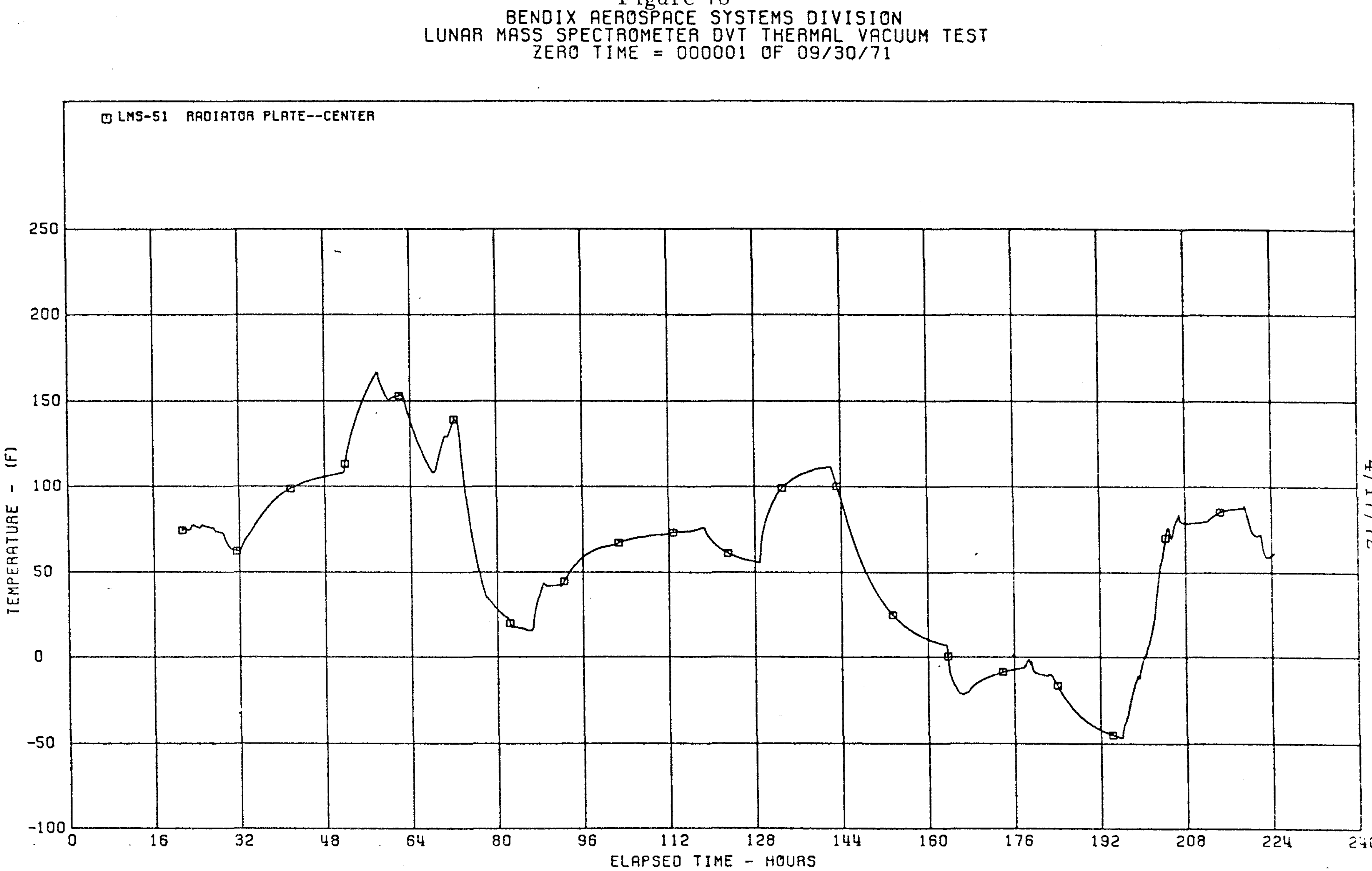
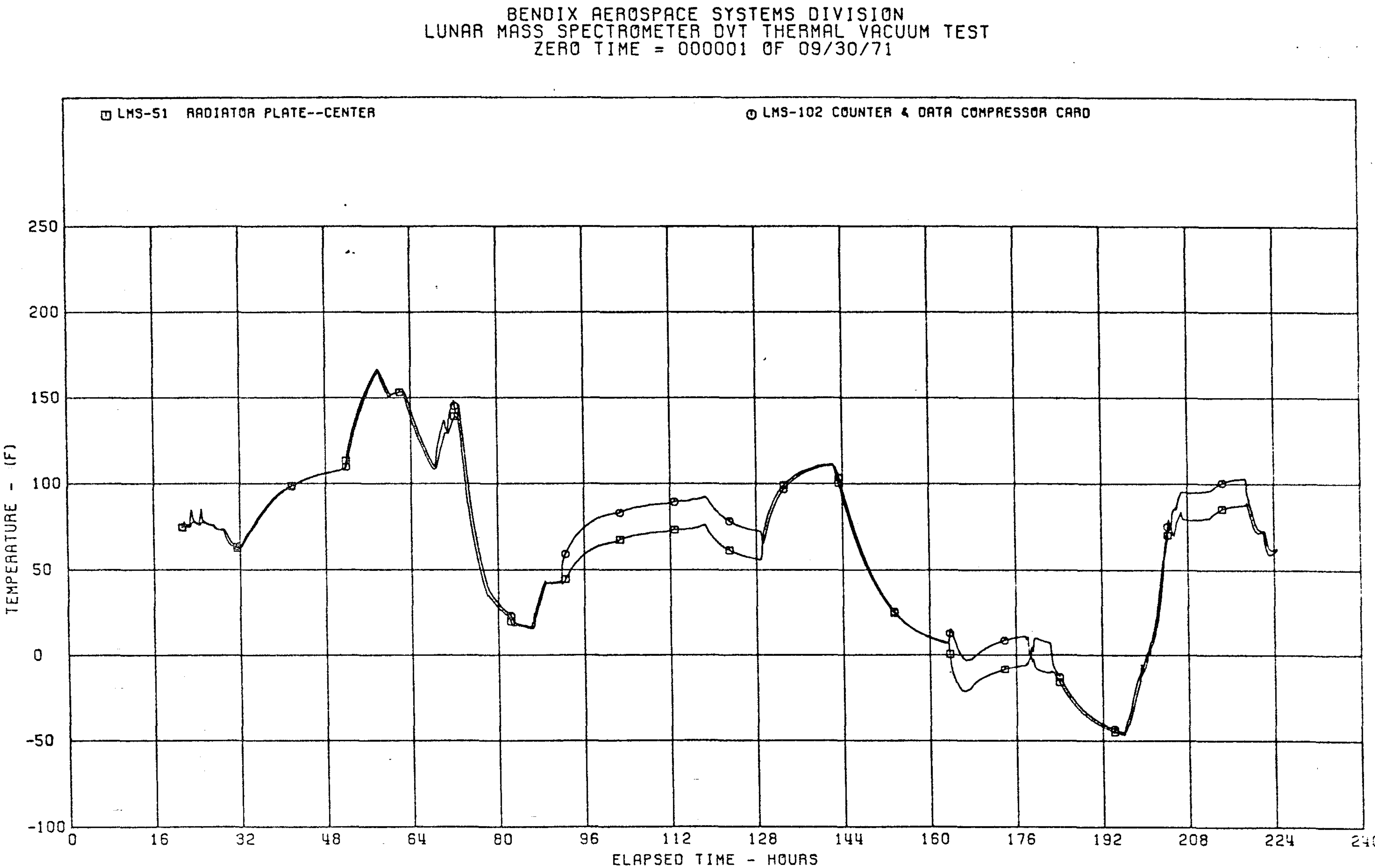


Figure 7b



BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71
LMS-51 RADIATOR PLATE--CENTER
250
200
150
100
50
0
-50
-100
TEMPERATURE - (F)
0
16
32
48
64
80
96
112
128
144
160
176
192
208
224
240
ELAPSED TIME - HOURS

Figure 7c



BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71
LMS-51 RADIATOR PLATE--CENTER
LMS-102 COUNTER & DATA COMPRESSOR CARD
TEMPERATURE - (F)
250
200
150
100
50
0
-50
-100
0
16
32
48
64
80
96
112
128
144
160
176
192
208
224
240
ELAPSED TIME - HOURS

Figure 7d

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71

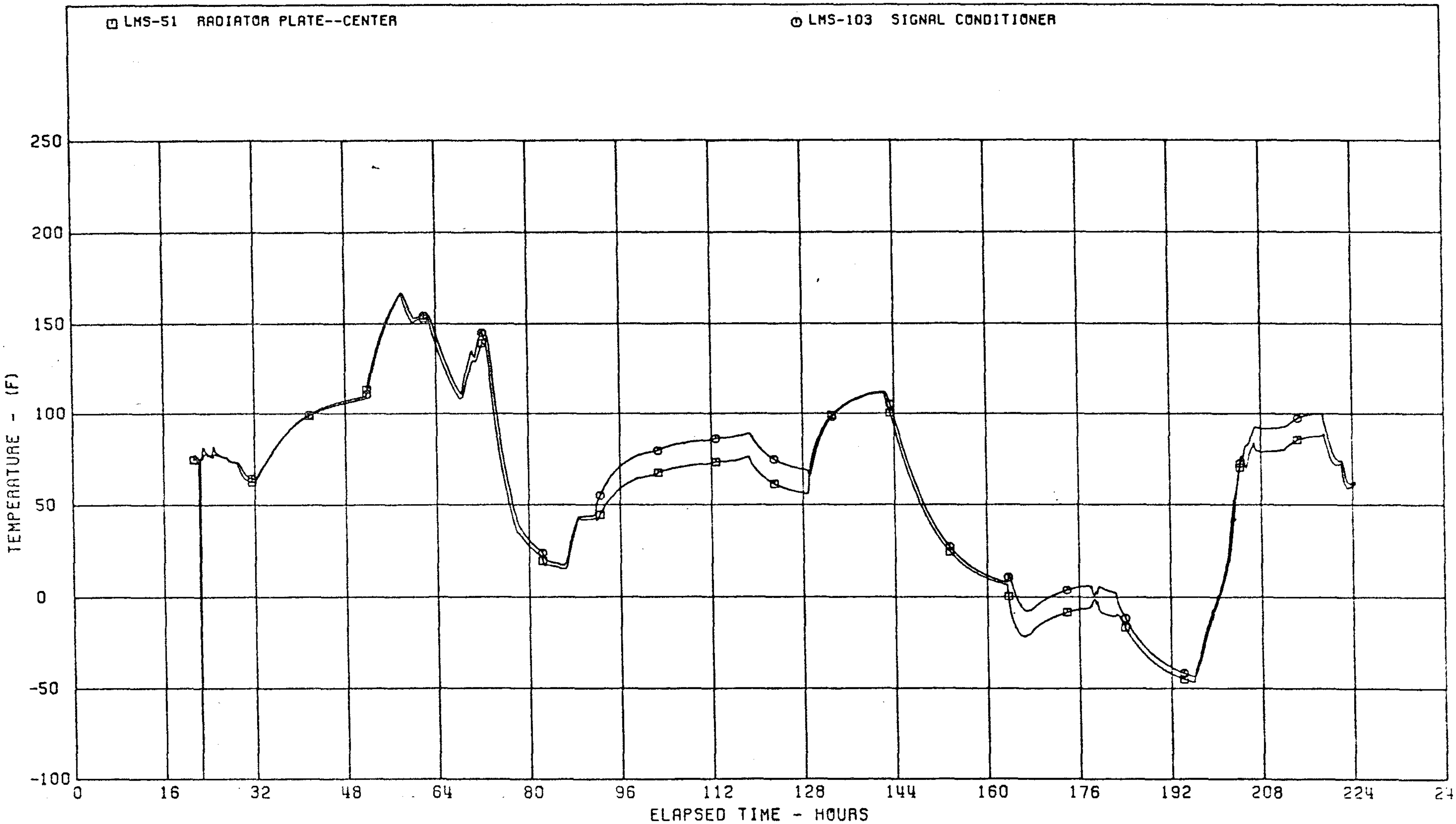


Figure 7e

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71

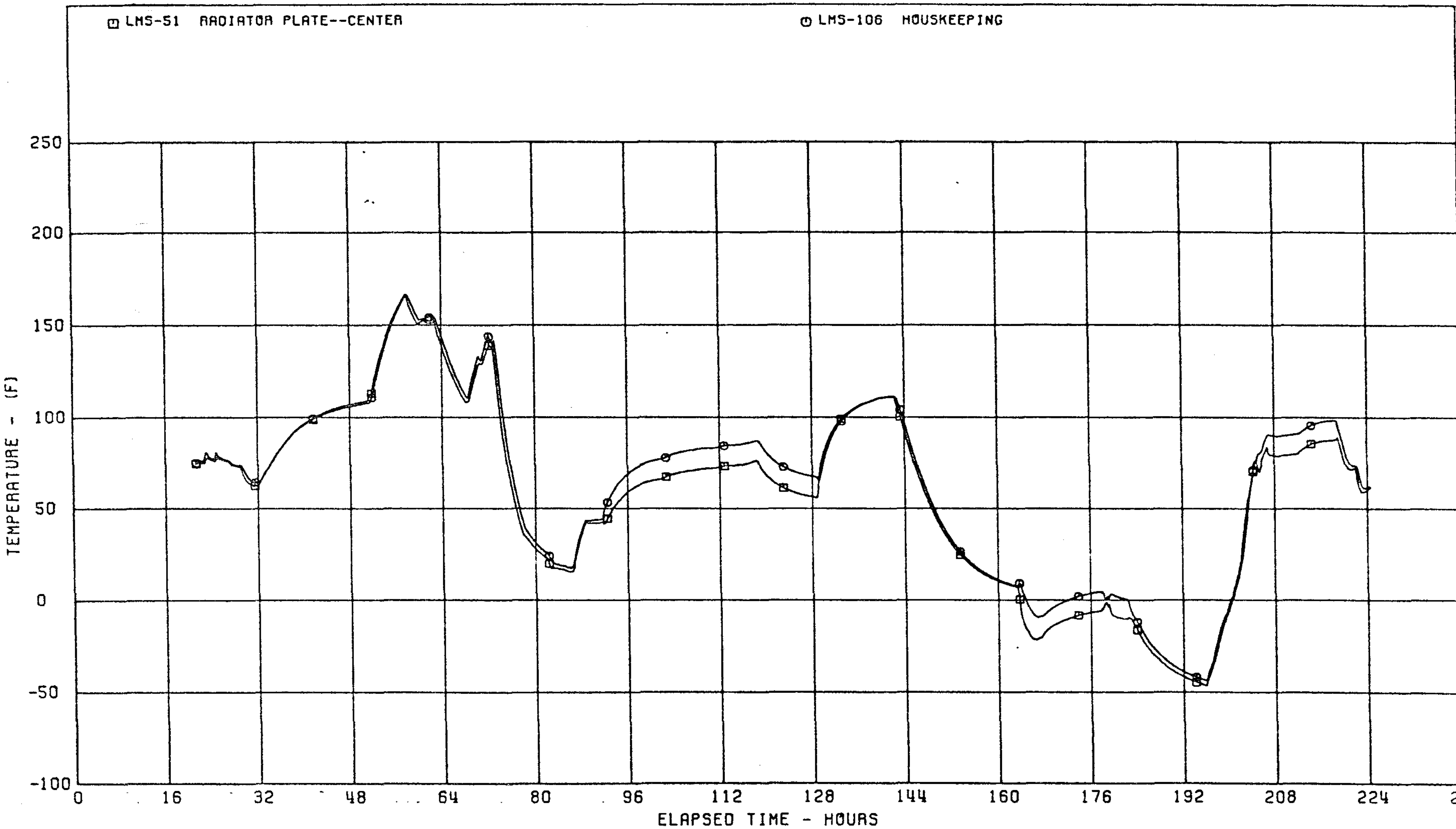


Figure 7f

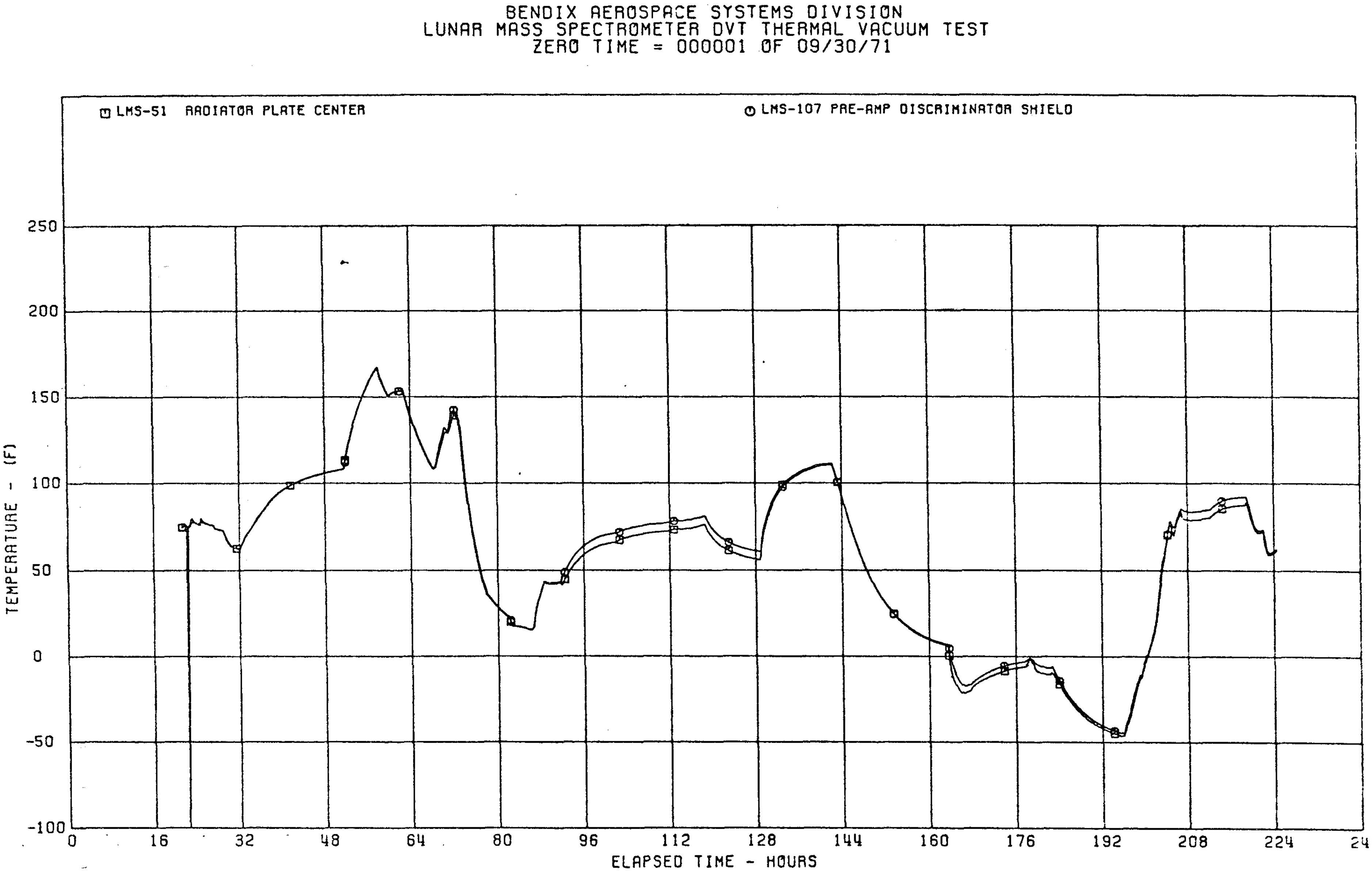

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71
LMS-51 RADIATOR PLATE CENTER
LMS-107 PRE-AMP DISCRIMINATOR SHIELD
TEMPERATURE - (F)
250
200
150
100
50
0
-50
-100
0
16
32
48
64
80
96
112
128
144
160
176
192
208
224
240
ELAPSED TIME - HOURS

Figure 7g

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71

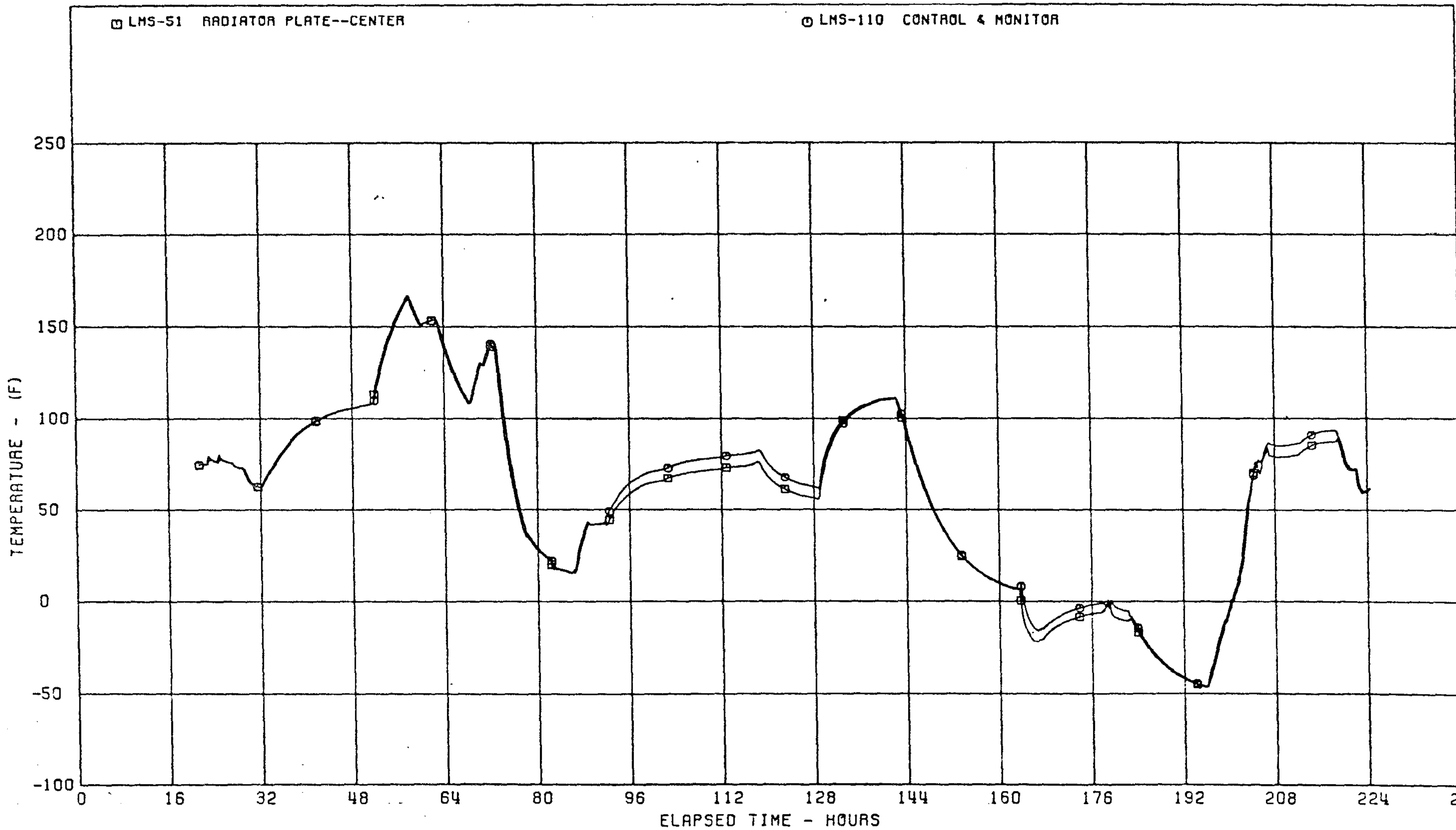
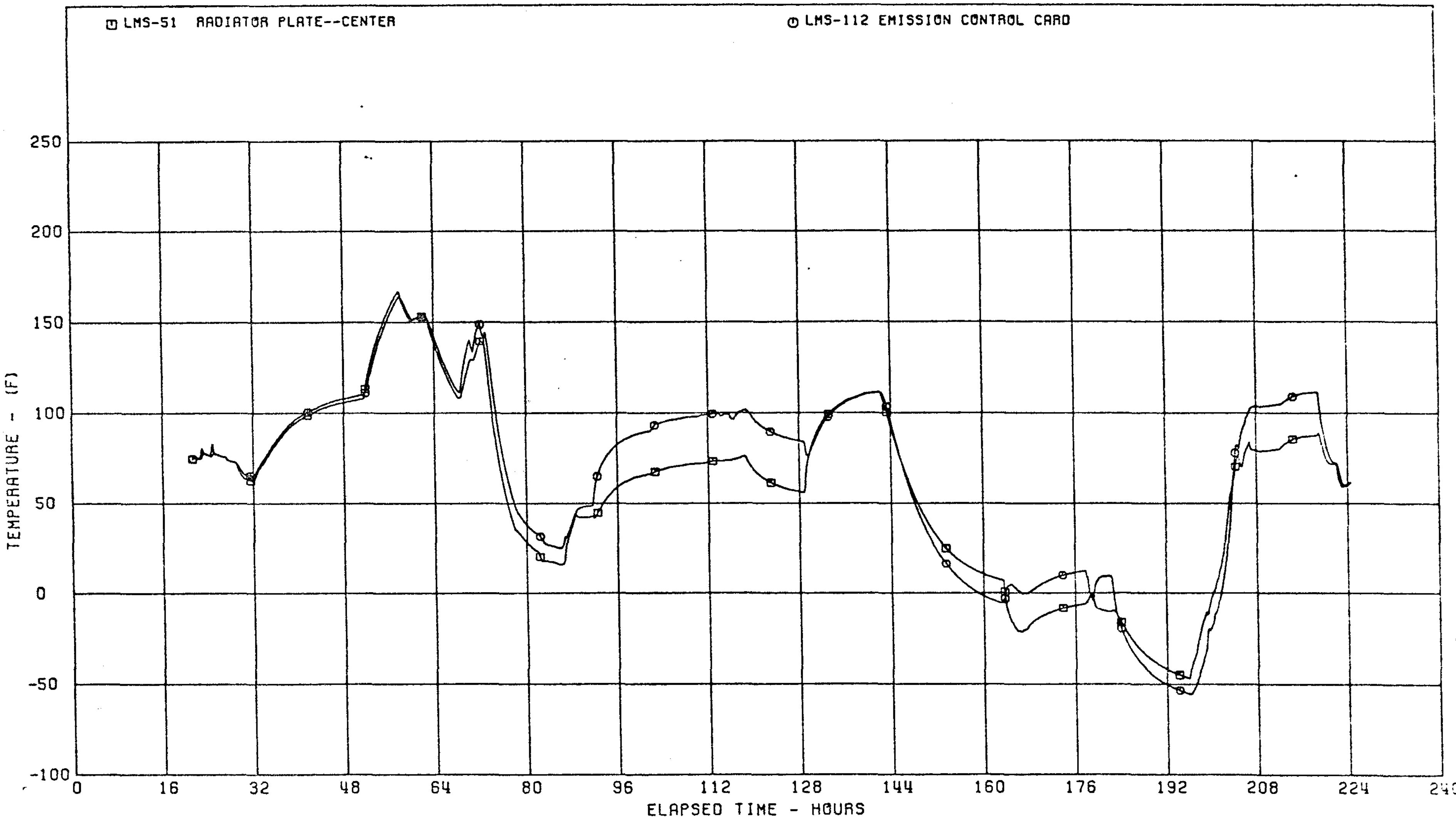


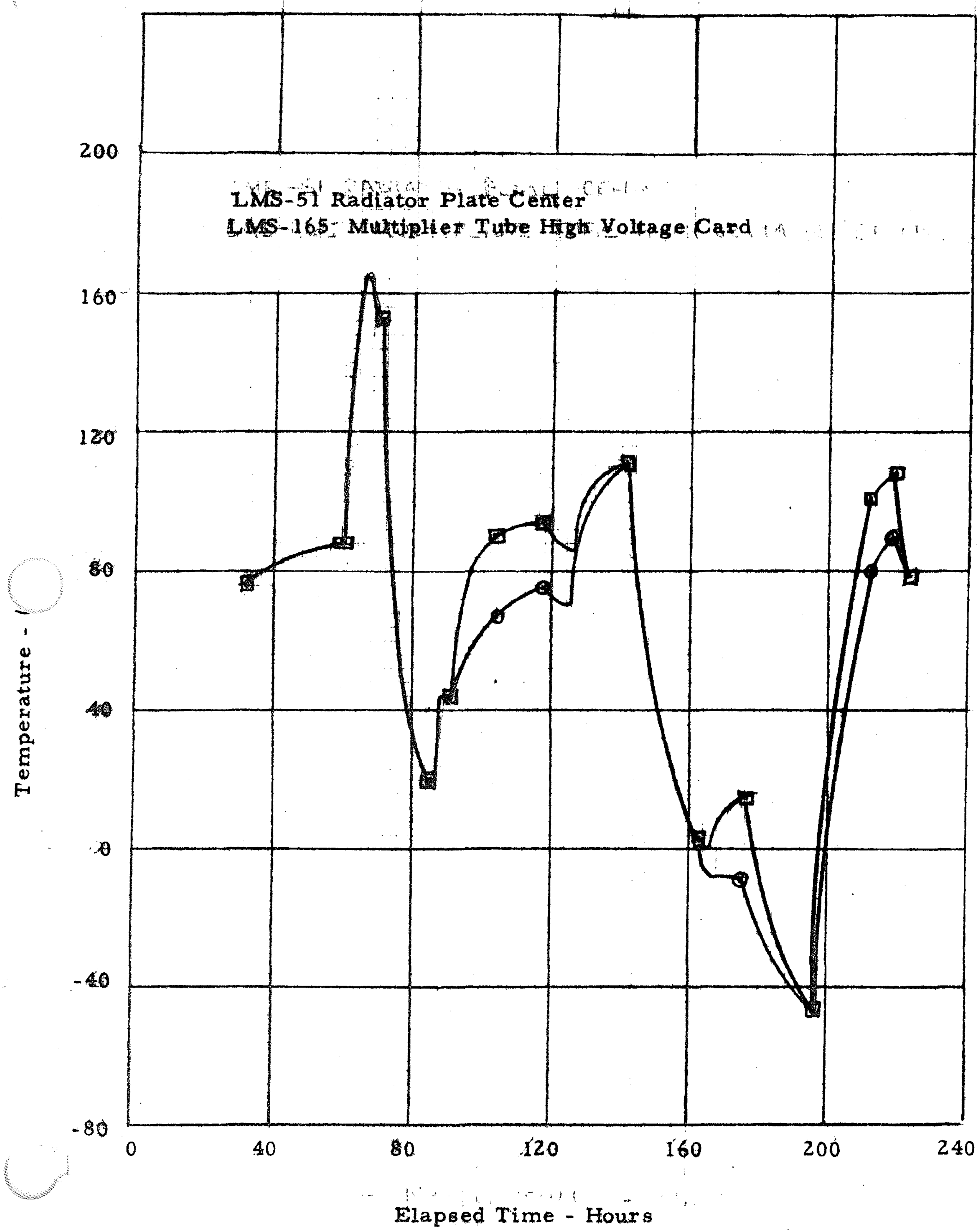
Figure 7h

BENDIX AEROSPACE SYSTEMS DIVISION
LUNAR MASS SPECTROMETER DVT THERMAL VACUUM TEST
ZERO TIME = 000001 OF 09/30/71



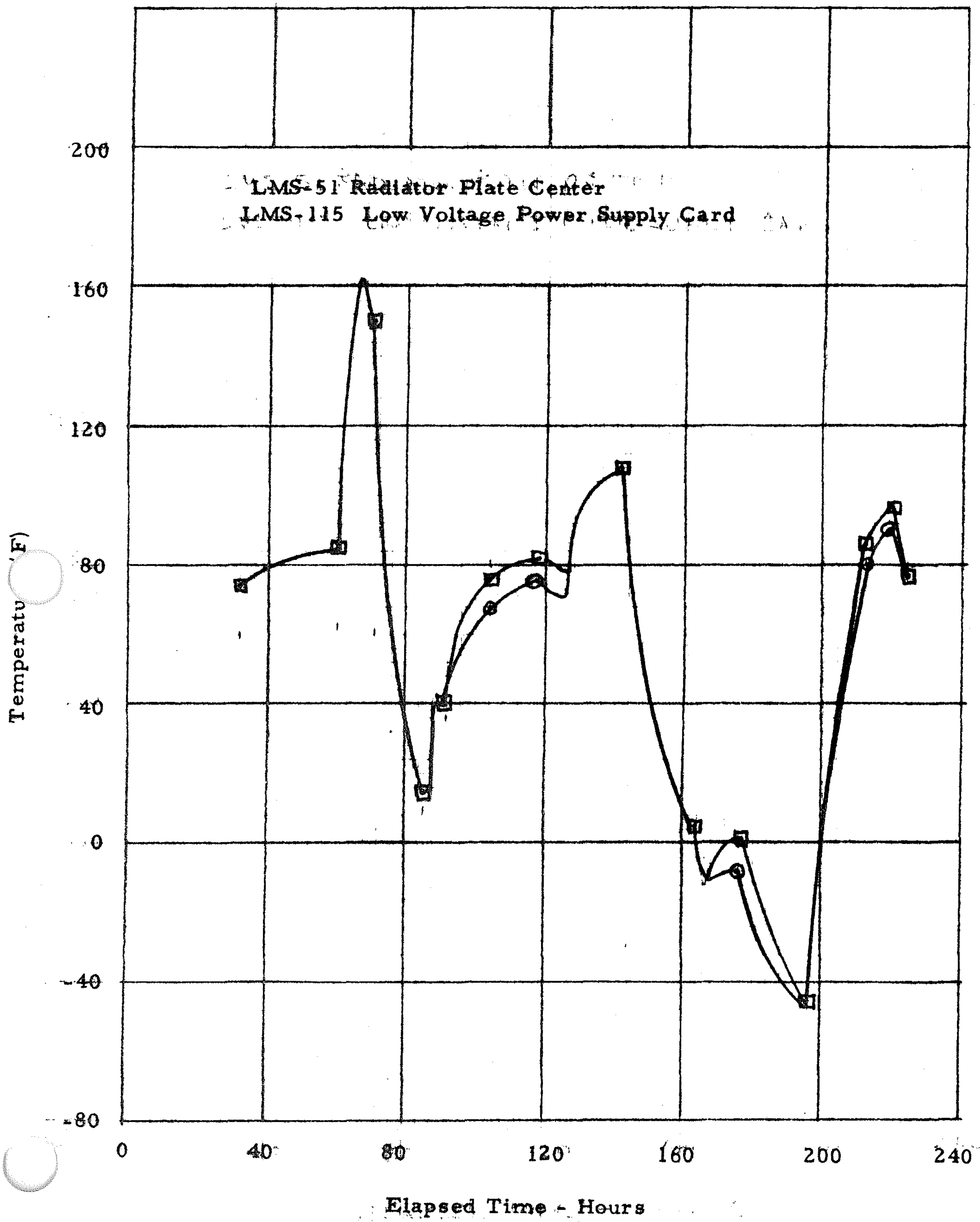
Bendix Aerospace Systems Division
Lunar Mass Spectrometer DVT Thermal Vacuum Test
Zero Time = 000001 of 09/30/71.

Figure 7i



Bendix Aerospace Systems Division
Lunar Mass Spectrometer DVT Thermal Vacuum Test
Zero Time = 000001 of 09/30/71.

Figure 7j



Bendix Aerospace Systems Division
Lunar Mass Spectrometer DVT Thermal Vacuum Test
Zero Time = 000001 of 09/30/71.

Figure 7k