LEAM DVT Thermal Test Report

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SUMMARY

The LEAM DVT Thermal tests were conducted 15 March through 23 March 1971 in the NRC 4' x 8' thermal vacuum chamber located in plant 2. Sixteen thermal conditions were imposed on the DVT model encompassing Survival, Night, Sunset, and Noon cases.

Temperature data from these tests was used to update the thermal model which in turn was used to update the design of the LEAM qualification model to include: changing the material of the interface bracketry between the internal aluminum structure and outer fiberglass enclosure from titanium to expoxy fiber-glass; relocating the squibs from the thermal bag flange to the outer structure; relocating the bubble level from an interface bracket to the outer structure; and, covering the thermal bag flanges completely with superinsulation masking.

During lunar night testing the silver coated Parylene front films failed, presumably from thermal expansion and contraction. Subsequent retest using a Parylene film coated with aluminum and silicon oxide was carried out subjecting the film to temperatures below the cold survival level and to simulated Solar intensities above 1.3 suns. No degration occurred*.

As a result of the DVT test the present LEAM thermal design is expected to maintain the experiment electronics between -30°C and 65°C when operational and above -55°C during the survival mode.

* A series of high and low temperature soak tests were run at Union Carbide after the film retest. Results showed that the silver coated films failed at low temperatures while the silicon oxide coated aluminum films survived all conditions.

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1.0 PURPOSE OF TEST

The purpose of this test was to provide design data on the thermal characteristics of the LEAM Experiment. This data in conjunction with a math model was used to generate a LEAM thermal design which will operate satisfactorily in the Lunar environment.*

2.0 SCOPE

Environmental conditions simulated during the test were for the lunar night, lunar sunset, and lunar noon cases. Simulated lunar surface temperatures for the respective conditions were -300°F, -150°F, and +250°F. Carbon arc solar simulation was used during the sunset and noon cases, and the test chamber was evacuated to less than 1×10^{-5} Torr for all cases.

3.0 EQUIPMENT

A detailed list of equipment with appropriate part numbers appears in Appendix A and the step by step test setup appears in the DVT test procedure.*

3.1 TEST ITEM

The test item (fig 3-1) consisted of the LEAM DVT model described by BxA drawing #2347700, revision X_1. Simulated electronic packages (fig 3-2) were used for the central electronics and sensor microphone electronics and consisted of appropriately sized heaters bonded to an aluminum plate (central electronics) and epoxy fiberglass plates (microphone electronics). Sensor forward electronic modules were not simulated since they each dissipate only 0.08 watts and have temperatures within 2°F of the support structures.

Original front film configurations for the UP and EAST sensors were composed of 1800Å (angstroms) of Parylene C overcoated with 1000Å of silver and finally with 200 Å of Parylene C. The film was bonded to a 6 mil beryllium copper mesh (1/8" x 1/8" openings) and the laminate was bonded to a 1" x 4" Lexan frame. The EAST sensor front film was later changed to 1750 Å of Parylene C overcoated with 700 Å of aluminum and 3250 Å of silicon oxide for retest. This front film configuration also used the beryllium copper mesh.

* See Ref 1

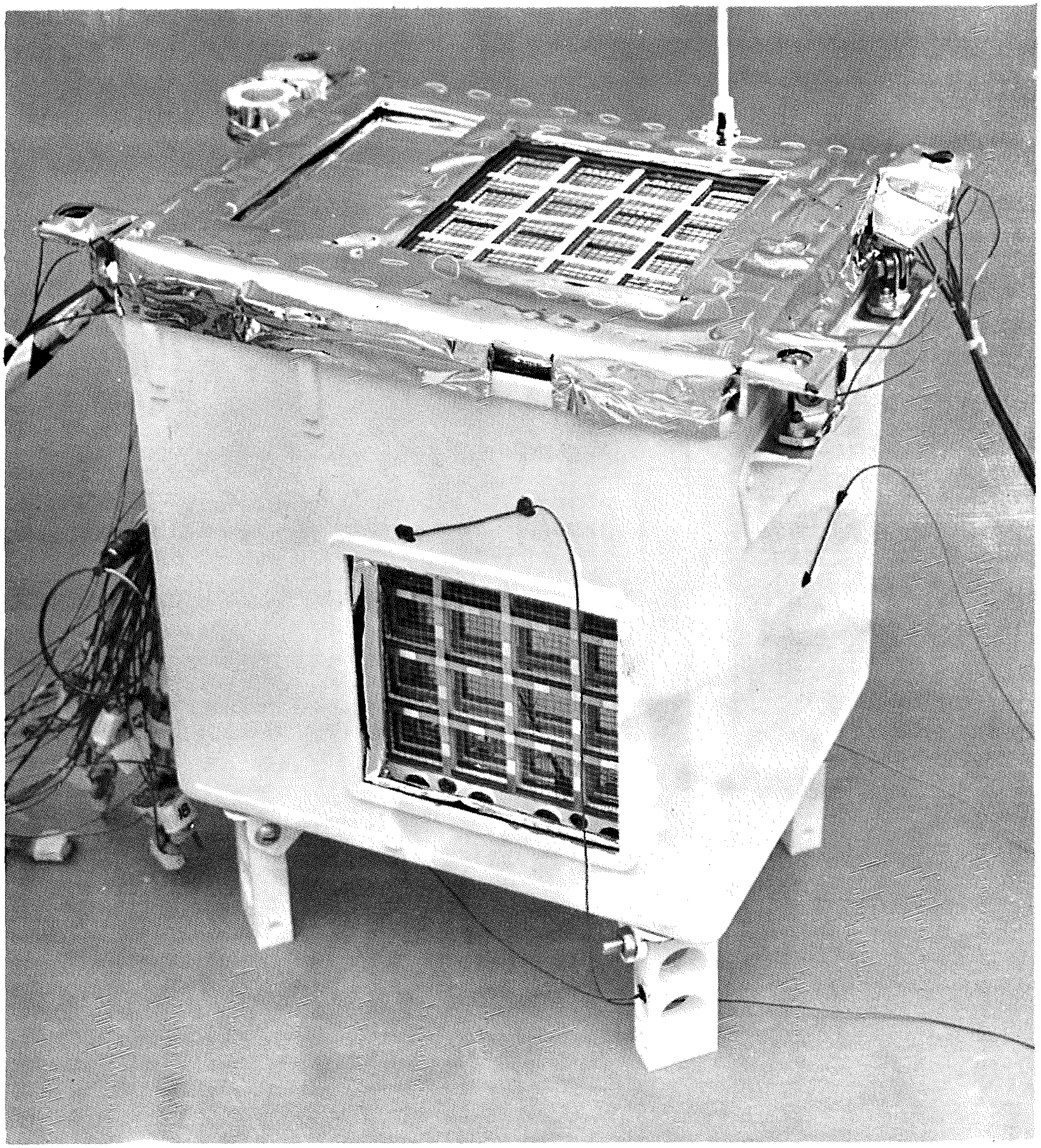

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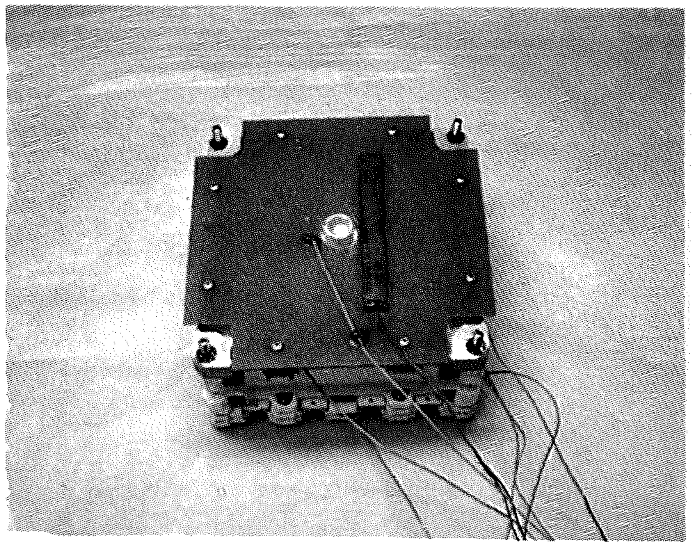
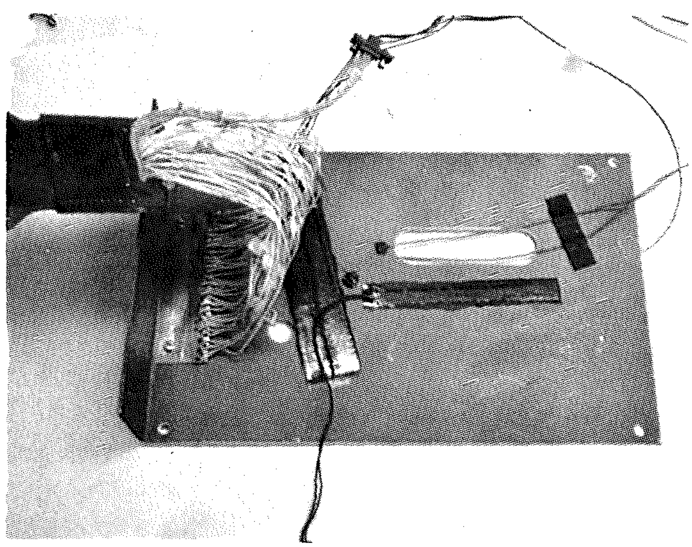
Figure 3-1 LEAM DVT Model



EAST SENSOR MICROPHONE "BOARD"



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CENTRAL ELECTRONICS "BOARD"

Figure 3-2 Simulated Electronics

The LEAM internal structure was constructed from 2024 aluminum and was attached to an outer fiberglass enclosure with 4 titanium clevis joints rivetted to the internal structure with aluminum rivets. A multilayer super insulation bag separated the two structures and was suspended from the top of the experiment with fiberglass flanges. Ten square inches of second surface mirrors mounted on the thermal plate were used to balance the heat load during the Lunar noon condition. Additional thermal isolation between the LEAM model and the environment consisted of S13G paint on the fiberglass enclosure, super-insulation masking around of edges of the radiator and clevis joints and low emittance surfaces between the sensor openings and space. External surfaces facing downward were covered with vacuum deposited aluminum or aluminized tape.

Individually controlled heaters were placed on the internal structure opposite the central electronics near the radiator and behind the Up and East sensor microphone electronics boards. Additional heaters were centered on the West sensor electronics shield outside the sensor cavity, and on the West sensor microphone shields.

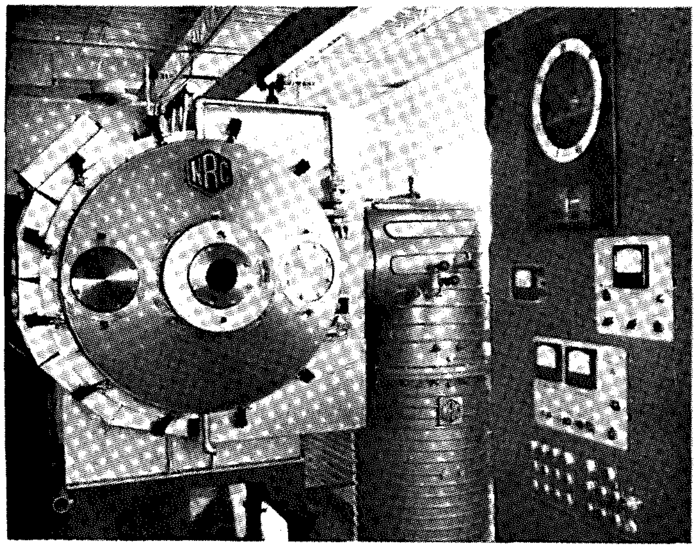
3.2 TEST EQUIPMENT

The DVT test was conducted in the NRC 4' x 8' thermal vacuum chamber (fig 3-3) located in plant 2. The chamber facility has a full liquid nitrogen cryowall and can maintain vacuums below 1×10^{-5} Torr.

Solar simulation for the sunset and noon cases was supplied by a Genarco carbon arc lamp (fig 3-3) located outside the quartz window on the north end of the chamber. Infrared heating (to be used during qualification testing) was supplied by G. E. Quartzline lamps.

A lunar surface simulator (fig 3-4) was built and instrumented by Bendix and consisted of a 34" aluminum dish with a 7" lip and was equipped with liquid nitrogen tubing and electrical heaters sufficient to maintain temperatures from -300°F to +250°F. The size and configuration of the simulator was chosen to allow the largest possible surface in the 4' x 8' chamber and to give view factors of 0.5 between the East and West sensors and the simulated surface. A 9.75" x 3.5" aperture was cut in the lip to allow irradiation of the West sensor during the sunset condition.

Auxiliary test equipment is listed in appendix A.



4 FT X 8 FT THERMAL VACUUM CHAMBER

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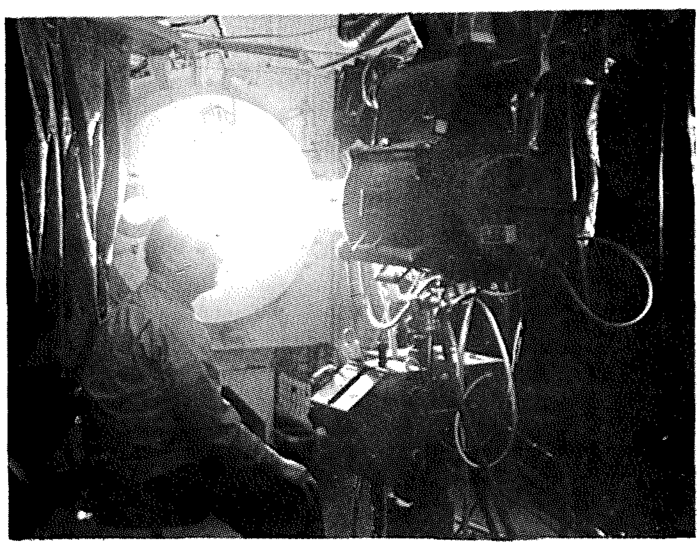

GENARCO CARBON ARC LAMP

Figure 3-3 Test Equipment

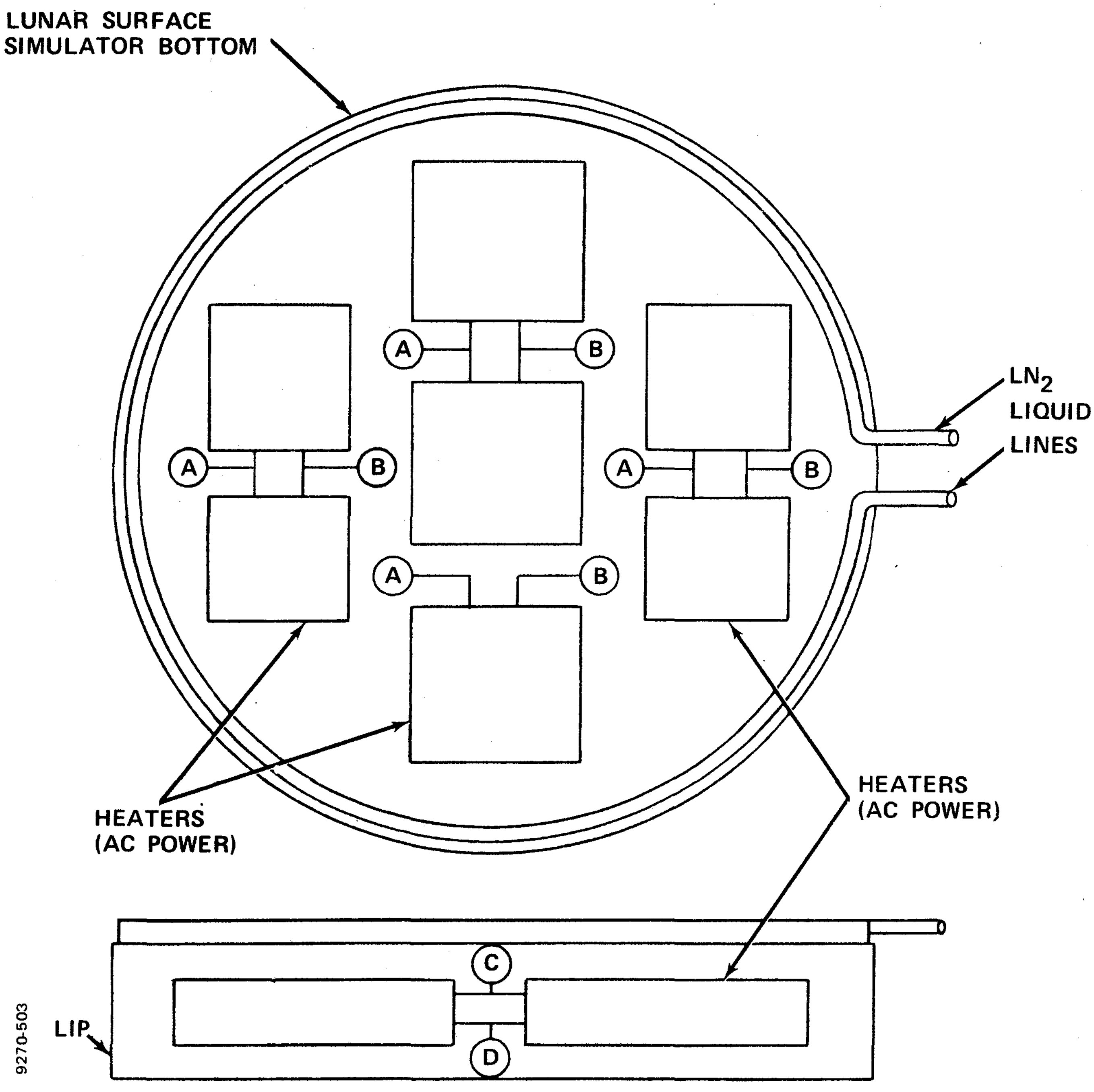

Figure 3-4 Lunar Surface Simulator

3.3 INSTRUMENTATION

Sixty-five, 30-gauge, chromel-constantan, thermocouples were located on the DVT model while the lunar surface and cryowall were instrumented with 31 temperature sensors. Detailed listings and location figures appear in appendix B. The LEAM thermocouple heat leak was minimized by a guard heater located several inches from the external structure. Thermocouple locations on the model were chosen, when possible, to correspond with node locations in the LEAM thermal math model.

Thermocouple reference junctions were provided by 150°F R.I. Controllers and the ice point reference standard was a Jos Kay model.

Solar simulation and IR illumination was monitored by Hy-Cal Pyroheliometers which in turn were maintained at 100°F by a Nes Lab heat exchanger.

All raw data (time, millivolts, milliamps, etc) was tape recorded during the test at ten minute intervals on a Hewlett-Packard Data Acquisition System (fig 3-5). The data was later reduced into engineering units and summarized by a BxA computer program. Real time data, converted by hand during the test, was supplied by a DAS paper tape.

4.0 PROCEDURE

The LEAM DVT test was divided into 7 major conditions with 16 thermal cases. These were as follows:

I. Lunar night

A. 3 watt survival case

B. 4.25 watt survival case

C. 5 watt survival case

D. 5 watt night case

E. 6 watt night case

F. 7 watt night case

G. West microphone night heating case

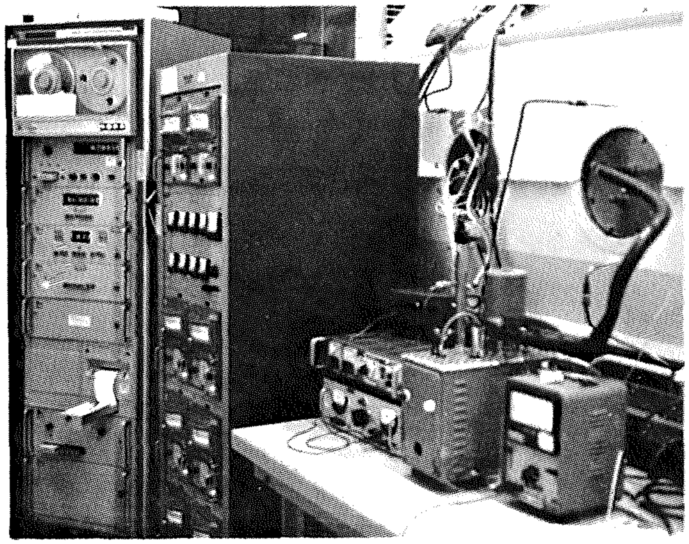

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Figure 3-5 Data Acquisition System
with Support Instrumentation

II. Lunar sunset

III. Lunar noon

A. 2 watt noon case

B. 3 watt noon case

C. 4 watt noon case

IV. Noon dust cover condition

V. Noon IR condition

VI. Increased sun condition

VII. Film retest

A. 3 watt survival case

B. Hot sunrise case

4.1 Condition I test set-up (Lunar Night)

The LEAM DVT test configuration consisted of the LEAM model mounted to the Lunar surface with 4 Teflon legs and oriented with the West sensor facing toward the aperture (fig 4-1). The Lunar surface was then hung vertically in the chamber with the aperture facing the quartz window at the north end. The test equipment, instrumentation and auxiliary equipment was arranged as shown in figure 4-2.

Condition I power settings are listed below in Table 4-1

4.2 Condition I test history

14 March

10:00 Started pumping down chamber

14:00 Flooded cold wall (with LN_2)

14:00 Flooded lunar surface (-300°F environment)

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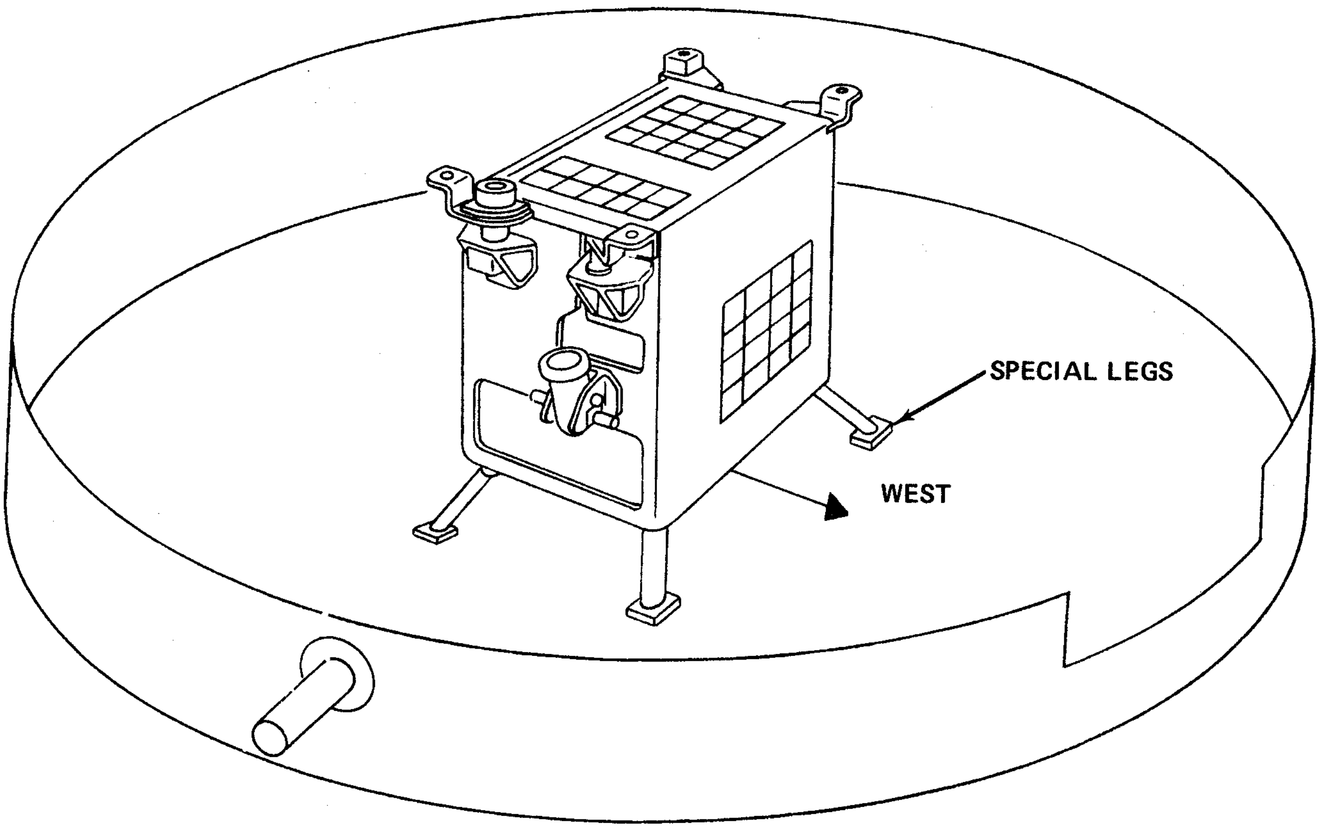

Figure 4-1 DVT Model on Lunar Surface Simulator

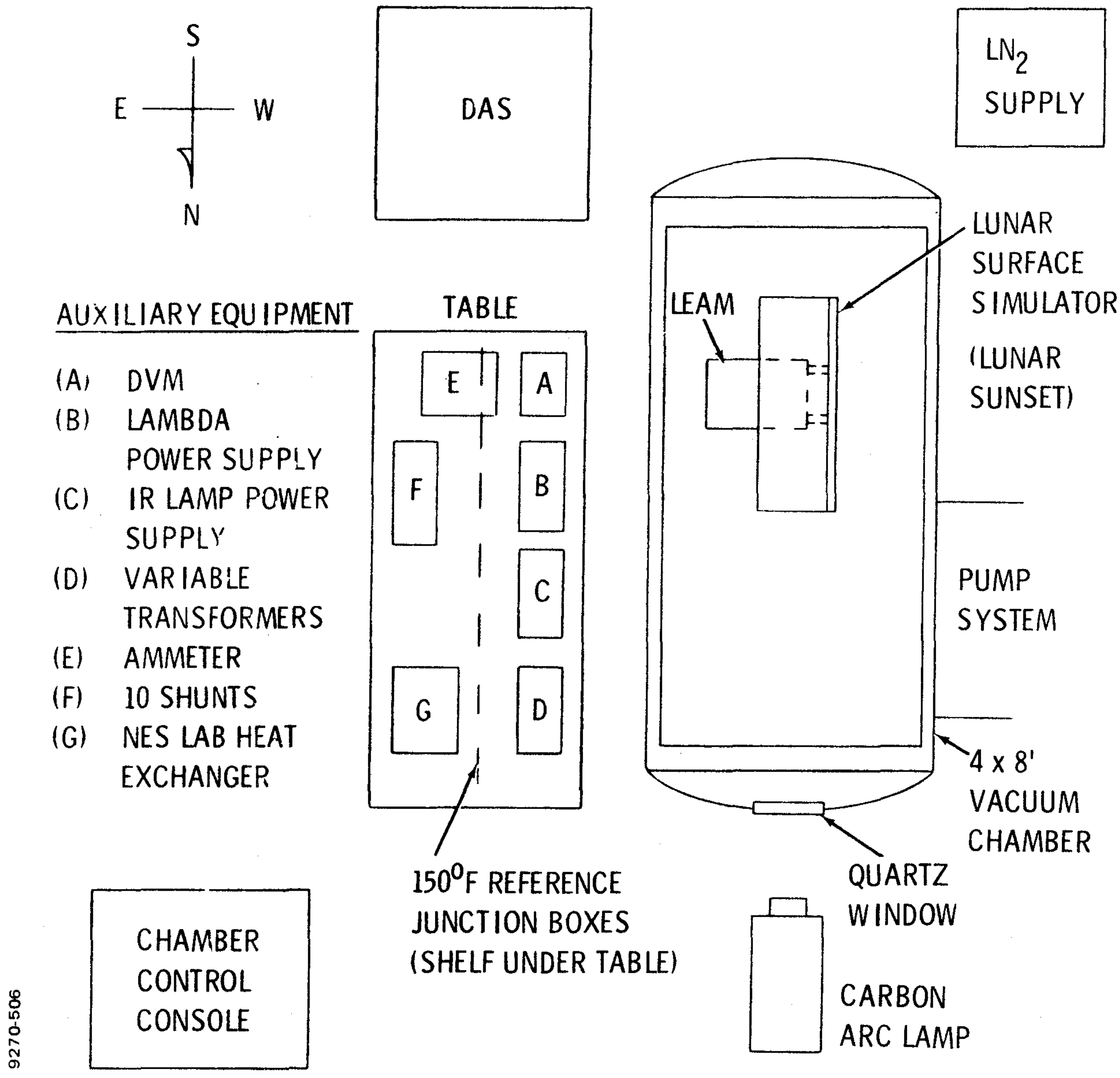

Figure 4-2 Thermal Vacuum Test Configuration

14:00 Turned heaters on for 3 watt survival case (case A)

TABLE 4-1 POWER SETTINGS FOR CONDITION I

	WATTS/CASE						
DESCRIPTION	A	B	C	D	E	F	G
UP ELECTRONICS	0	0	0	.33	.33	.32	.32
EAST ELECTRONICS	0	0	0	.33	.33	.33	.32
GENERAL ELECTRONICS	0	0	0	1.13	2.14	3.13	2.14
UP SENSOR HEATER	.26	.25	.26	.27	.27	.26	.26
EAST SENSOR HEATER	.25	.24	.26	.26	.26	.26	.26
SMALL WEST MIC HEATER	0	0	0	0	0	0	.34
LARGE WEST MIC HEATER	0	0	0	0	0	0	.67
WEST ELECTRONICS	0	0	0	.25	.25	.25	.25
RADIATOR HEATER	.76	1.94	2.06	.76	.75	.77	.72
WEST SENSOR HEATER	1.76	1.72	2.65	1.73	1.73	1.73	.75

15 March

16:00 Reached equilibrium for case A

16:10 Set heaters for 4.25 watt survival case (case B)

23:30 Reached equilibrium for case B

16 March

00:00 Set Heaters for 5 watt survival case (case C)

13:30 Reached equilibrium for case C

13:40 Set heaters for 5 watt night case (case D)

16:00 Reached Equilibrium for case D

16:10 Set heaters for 6 watt night case (case E)

17 March

03:30 Reached equilibrium for case E

03:40 Set heaters for 7 watt night case (case F)

12:30 Reached equilibrium for case F

12:40 Set heaters for West microphone night heating Case (Case G)

12:30 Reached equilibrium for case G. Ended condition I

4.3 Condition II Test Set-Up

For condition II, the sunset case, the carbon arc lamp was positioned such that one sun irradiation was incident on the LEAM west face. Power settings for the test are tabulated below:

TABLE 4-2 POWER SETTINGS FOR CONDITION II

DESCRIPTION	WATTS
UP ELECTRONICS	0.33
EAST ELECTRONICS	0.33
CENTRAL ELECTRONICS	2.14
WEST ELECTRONICS	0.25

.4 Condition II Test History

17 March

21:00 Started to raise lunar surface to -150°F environment

21:30 Turned on carbon arc lamp

18 March

03:30 Stabilized lunar surface at -150°F

12:00 Reached equilibrium for sunset condition

12:30 Started return to ambient conditions

4.5 Condition III Test Set Up

The third environmental condition was designed for the lunar noon condition, ie, the sun irradiating the Up sensor and mirrored radiator and the lunar surface being held at 250°F. For this condition the lunar surface and LEAM were turned 90° in the chamber so that the Up sensor faced the quartz window. The carbon arc lamp was then positioned so that one sun would irradiate the top face of the experiment. Power settings for the cases are listed in table 4-3.

TABLE 4-3 POWER SETTINGS FOR CONDITION III

	WATTS/CASE		
DESCRIPTION	A	B	C
UP SENSOR ELECTRONICS	0.33	0.33	0.32
EAST SENSOR ELECTRONICS	0.32	0.33	0.33
CENTRAL ELECTRONICS	1.14	2.12	3.14
WEST SENSOR ELECTRONICS	0.25	0.25	0.25

4.6 Condition III Test History

19 March

01:00 Started pumping down chamber

02:30 Started heating lunar surface

03:30 Flooded cold wall

04:30 Turned on heaters for 2 watt noon case (case A)

05:30 Stabilized lunar surface at 250°F

09:00 Turned on carbon arc lamp

20:30 Reached equilibrium for case A

20:40 Set heaters for 3 watt noon case (case B)

20 March

10:00 Reached equilibrium for case B

10:10 Set heaters for 4 watt noon case (case C)

14:30 Reached equilibrium for case C

15:00 Started return to ambient conditions.

4.7 Condition IV Test Set Up

The LEAM is to be deployed on the moon with 3 Teflon dust covers, two covering the 3 sensor openings and the third covering the second surface mirror radiator. About half an hour after the departure of the Lunar Module, the mirror cover will come off and the experiment will be checked out for 2 (earth) days before removing the sensor covers. Test condition IV was designed to thermally analyze this check out configuration during the lunar noon condition. The carbon arc lamp was again positioned to irradiate the top of the experiment with one sun. Power levels for the test are tabulated below in table 4-4:

TABLE 4-4 POWER SETTINGS FOR CONDITIONS IV, V, VI

DESCRIPTION	WATTS
UP ELECTRONICS	0.33
EAST ELECTRONICS	0.32
CENTRAL ELECTRONICS	2.12
WEST ELECTRONICS	0.25

4.8 Condition IV Test History

21 March

01:00 Started pumping down chamber

03:00 Started heating lunar surface

03:30 Flooded cold wall

03:30 Turned on heater for dust cover case

04:30 Stabilized lunar surface at 250°F

05:00 Turned on carbon arc lamp

14:30 Reached equilibrium

15:00 Started return to ambient conditions

4.9 Condition V Test Set Up

Test condition V was run as a base line test for qualification testing. The case essentially used IR lamps to heat the LEAM electronics to about the same temperatures as the nominal carbon arc noon case. Test set up consisted of removing the sensor dust covers and erecting a 3 element IR lamp about 3 feet from the top face of LEAM (fig 4-3). Power settings for the test were the same as those shown in table 4-4.

4.10 Condition V Test History

22 March

01:30 Started pumping down chamber

03:00 Started heating lunar surface

03:00 Started flooding cold wall

03:00 Turned on heaters for IR case

04:00 Turned on I. R. lamps

05:00 Stabilized lunar surface at 250 F

14:00 Reached equilibrium

14:30 Started return to ambient conditions

4.11 Condition VI Test Set Up

Condition VI, the increased sun condition, was devised to investigate the thermal behavior of the Up sensor Parylene film irradiated with solar intensities greater than one sun. The test set up envolved removing the IR lamps from the chamber and reconfiguring the carbon arc solar simulator. Increased intensities incident on the Up sensor were generated by moving the arc lamp closer to the chamber. The lunar surface was set to the noon condition and the power settings were again the nominal values listed in table 4-4.

4.12 Condition VI Test History

22 March

22:00 Started pumping down chamber

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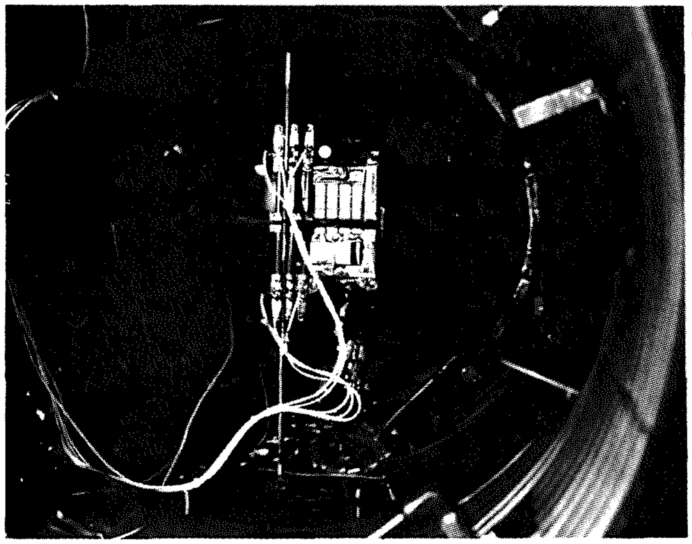

Figure 4-3 Test Setup for IR Case

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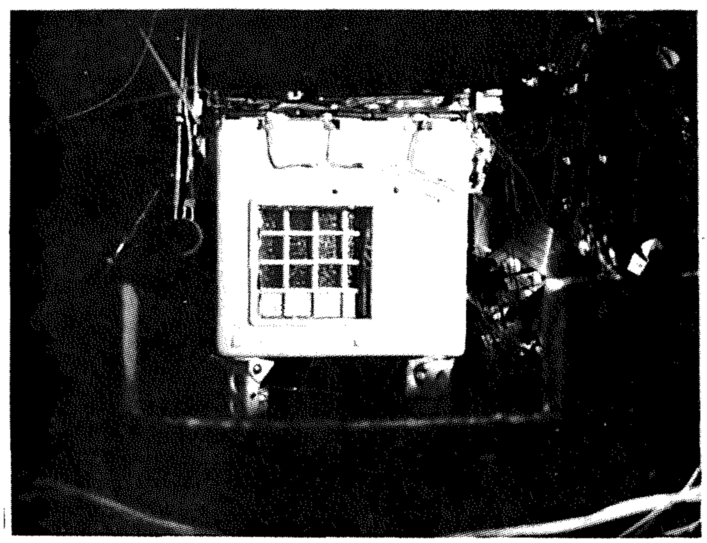


Figure 4-4 LEAM Test Configuration
for the Film Retest

23 March

01:00 Started heating lunar surface

02:00 Started flooding cold wall

03:00 Turned on heaters for increased sun case

03:00 Stabilized lunar surface at 250°F

03:32 Turned on carbon arc lamp; irradiated Up sensor front film with 1 sun

03:41 Increased solar intensity to 1.1 suns

03:46 Increased solar intensity to 1.2 suns

03:51 Increased solar intensity to 1.3 suns

03:58 Increased solar intensity to 1.4 suns

04:00 Started return to ambient conditions

4.13 Condition VII Test Set Up

The film retest, condition VII, was conceived after completion of the original test sequence. While setting up the LEAM configuration for the dust cover case, it was noticed that a series of holes had formed in the Up and East sensor films. These holes were not enlarged during the increased sun case and it was decided to test a new film over the extreme thermal conditions. The LEAM was removed from the Lunar surface and the East sensor was disassembled. The silver coated Parylene film was removed and replaced by a film coated with aluminum and silicon oxide. The LEAM was then reattached to the lunar surface with the East sensor facing the aperture (fig 4-4) and the lunar surface was mounted in the chamber with the aperture facing the quartz window. The test was divided into 2 cases including a survival (case A) and a hot sunrise (case B).

Power levels for these cases are tabulized below:

TABLE 4-5 POWER SETTINGS FOR CONDITION VII

DESCRIPTION	WATTS/CASE A	WATTS/CASE B
UP SENSOR ELECTRONICS	0	0.33
EAST SENSOR ELECTRONICS	0	0.33
CENTRAL ELECTRONICS	0	3.14
UP SENSOR HEATER	0.25	0
EAST SENSOR HEATER	0.24	0
WEST SENSOR ELECTRONICS	0	0.25
RADIATOR HEATER	0.74	0
WEST SENSOR HEATER	1.72	0

4.14 Condition VII Test History

2 April

11:20 Started pumping down chamber

15:00 Flooded cold wall

15:00 Flooded lunar surface -300°F environment

3 April

05:50 Turned heaters on for survival case

14:30 Reached equilibrium for case A

14:50 Started return to ambient conditions

20:00 Opened chamber door; examined film

5 April

00:00 Started pumping down chamber

02:30 Flooded cold wall

02:30 Started heating lunar surface

02:30 Turned on heaters for hot sunrise case*

* Lunar surface at 120°F.

13:20 Turned carbon arc lamp on

15:20 Reached pseudo equilibrium * for case B

15:21 Increased solar intensity to 1.3 suns

15:50 Started return to ambient conditions

5.0 TEST RESULTS

5.1 GRAPHICAL HISTORY

Figure 5-1 shows a graphical temperature history of the central electronics, the second surface mirrors, and West sensor quartz plate for the first 13 thermal cases. A steady state equilibrium condition was defined as a time-temperature change of less than 1°F per hour for the central electronics. These are listed below with the elapsed times indicated on the graph.

TABLE 5-1 EQUILIBRIUM CONDITION VS ELAPSED TIME

Thermal Case	Elapsed Time (Hrs)	Thermal Case	Elapsed Time (Hrs)
3 Watt Survival	64.0	West Mic Heating	116.5
4.25 Watt Survival	71.5	Nominal Sunset	132.0
5 Watt Survival	85.5	2 Watt Noon	164.5
5 Watt Night	88.0	3 Watt Noon	178.0
6 Watt Night	99.5	4 Watt Noon	182.5
7 Watt Night	108.5	Nominal Dust Cover	206.5
		Nominal IR	230.0

The inflection in the curves at elapsed time 64.0 are due to the 1.25 watt increase in power applied at the end of the 3 watt survival case. As indicated by the curve, a true equilibrium point had not been reached at time 64.0 but 4 more hours of testing would have depressed temperatures by only 2 or 3 more degrees F.

The 3 night case equilibrium points, times 88.0, 99.5 and 108.5, show a central electronics temperature increase of about 22°F per watt of power dissipation. This gives an indication of the strong dependence of internal temperatures as function of small power changes.

*East outer grid frame temperature same temperature as up grid frame during nominal noon case (condition III B)

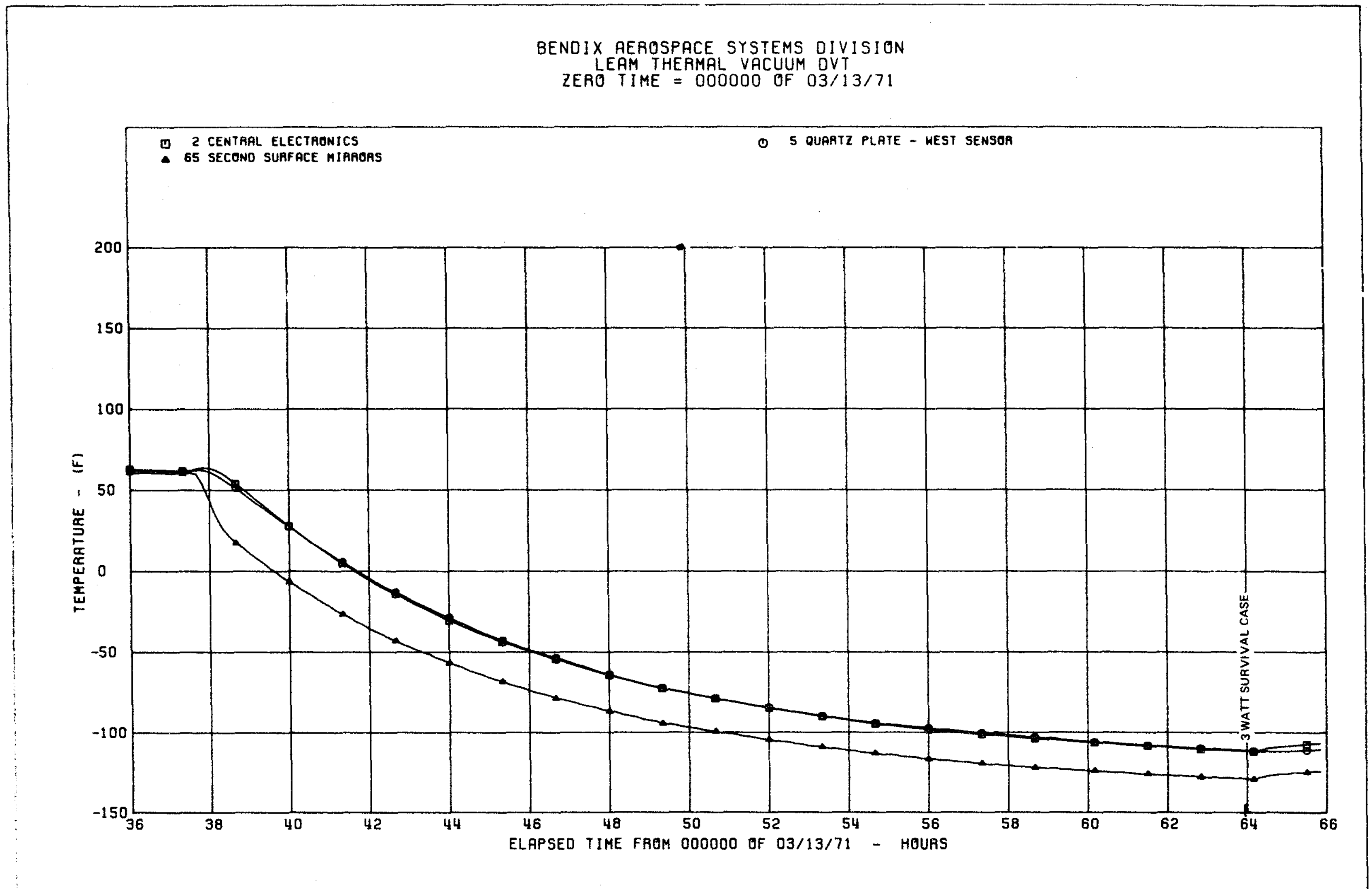


Figure 5-1 Graphical History of Test

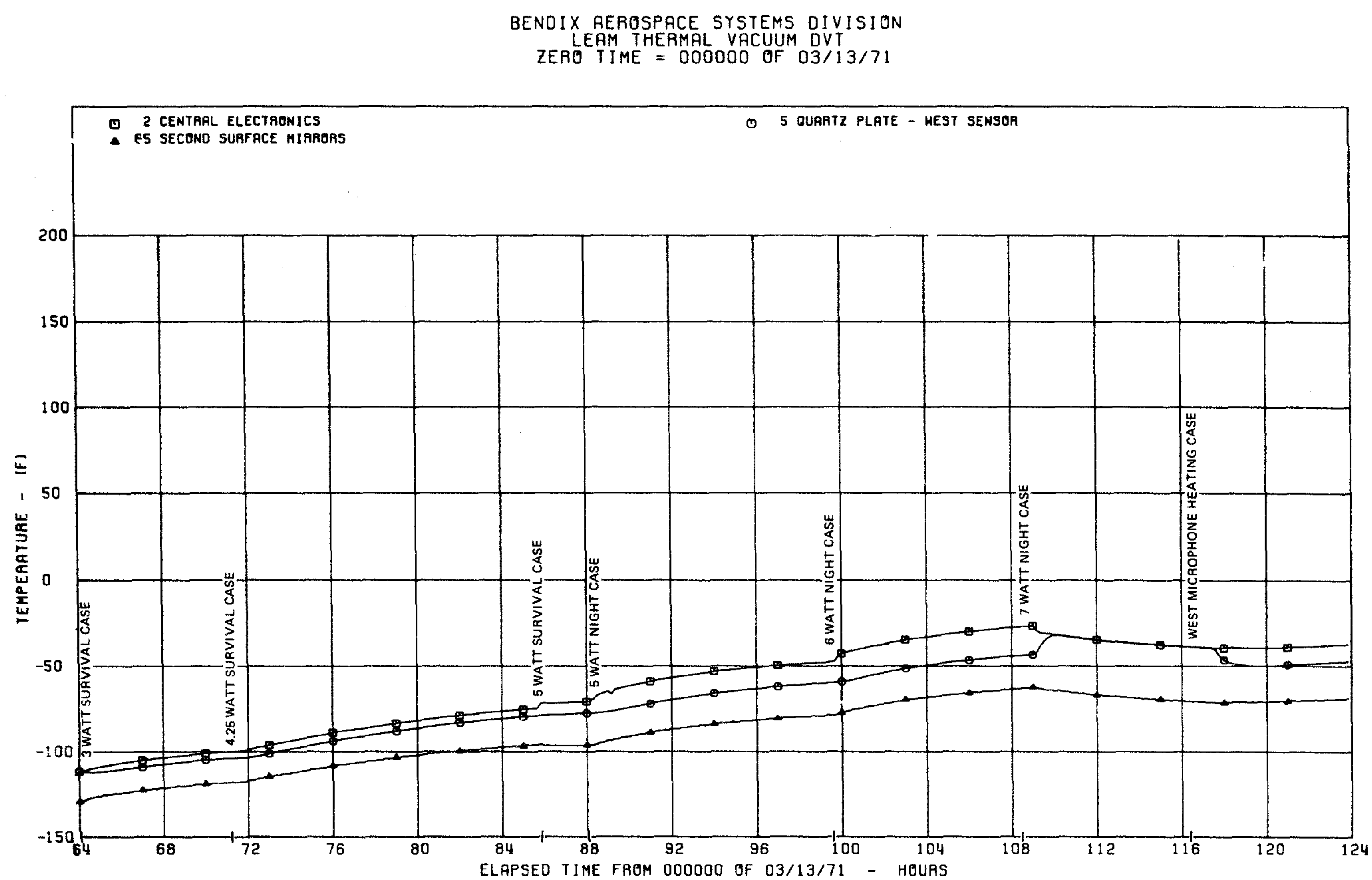


Figure 5-1 Graphical History of Test (Cont.)

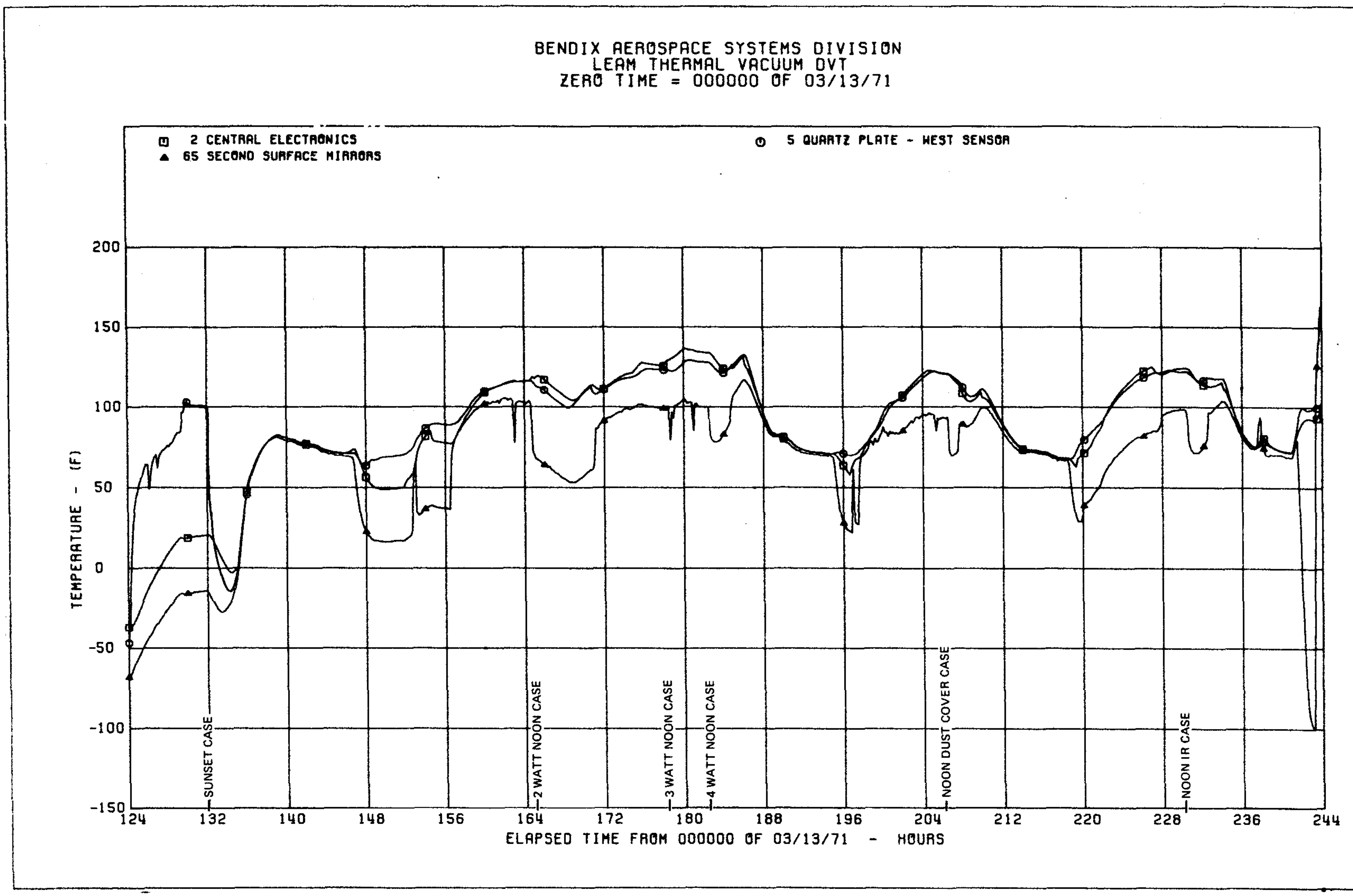


Figure 5-1 Graphical History of Test (Cont.)

The second temperature comparison of interest exists between the 6 watt night case at time 99.5 and the West microphone heating case at time 116.5 (also a 6 watt case). Here it is seen that a one watt shift from the plate behind the West electronics directly to the West microphone shields changes the West impact plate temperature from -60°F to -39°F. It was discovered later however that microphone shield heaters would be electrically noisey and this design was abandoned.

The sunset case shown at time 132.0 is about 50°F away from correlation and the difference is unexplained at this time. The fiberglass structure facing the sun was recorded to be 140°F while analysis shows that the reading should have been about 75°F. Analysis also shows that the corner clevis joints were recorded 40°F higher than they should have been.

In any event the electronics were all well below spec for the case and the 100°F West microphone impact plate temperature shows* that good conductive coupling exists between the plate and the internal structure. The LEAM flight configuration has an even greater degree of thermal coupling between the impact plate and the adjacent structure.

Lunar noon case temperatures, elapsed times 164.5, 178.0 and 182.5, show central electronics temperatures increasing about 9°F per watt increase of power dissipation. The general temperature levels of the noon dust cover case, time 206.5 are about the same as the previous noon cases. Other specific details will be covered in a subsequent paragraph.

5.2 CASE DISCUSSIONS

A comparison between test results and the corrected analytical model is made for the 3 watt survival case in table 5-1. The average temperature difference, excluding the forward grid frames and West electronics, is 9.9°F. A visual inspection of the grid frame thermocouples and the West electronics thermocouple showed both readings were biased. The grid frame thermocouple areas had no view of space and the West electronics thermocouple was mounted about 0.4" from the simulator heater.

*The Solar absorptivity/hemispherical emittance is 4.0 for the plate.

The 4.25 watt and 5 watt survival cases together with the 3 watt survival case gave the first clues about the heat leaks through the titanium clevis joints. It was discovered that about 46% of the dissipated power was leaving the experiment through these joints. Replacement on the flight model of the titanium sections with fiberglass reduced the leak by 70%.

TABLE 5-1

WATT SURVIVAL CASE COMPARISON TEMPERATURE °F

IDENTIFICATION	TEST	ANALYSIS
CENTRAL ELECTRONICS	-112	-127
UP SENSOR		
FWD GRID FRAME	-142	-173
FWD FILM FRAME	-140	-151
SUPPORT STRUCTURE	-114	-125
REAR GRID FRAME	-114	-124
IMPACT PLATE	-112	-122
REAR ELECTRONICS	-112	-121
EAST SENSOR		
FWD GRID FRAME	-143	-169
FWD FILM FRAME	-136	-146
SUPPORT STRUCTURE	-112	-119
REAR GRID FRAME	-113	-119
IMPACT PLATE	-110	-117
REAR ELECTRONICS	-109	-117
WEST SENSOR		
GRID FRAME	-128	-140
IMPACT PLATE	-111	-128
ELECTRONICS	-102	-129
STRUCTURE	-114	-126
STRUCTURE	-114	-125
STRUCTURE	-112	-123
STRUCTURE	-111	-120

A comparison between the 5 watt survival case (heaters only) and the 5 watt night case (heaters and electronics) gives an indication to the effect of power distribution inside LEAM. These cases are summarized below:

TABLE 5-2

COMPARISON BETWEEN 5 WATT SURVIVAL AND 5 WATT NIGHT CASES

	5 WATT SURVIVAL	5 WATT NIGHT
HEATING COMPONENT	DISSIPATION WATTS	
UP ELECTRONICS	0	0.33
EAST ELECTRONICS	0	0.33
WEST ELECTRONICS	0	0.25
CENTRAL ELECTRONICS	0	1.13
UP ELECTRONICS HEATER	0.26	0.27
EAST ELECTRONICS HEATER	0.26	0.26
WEST ELECTRONICS HEATER	2.65	1.73
RADIATOR HEATER	2.06	0.76
COMPONENT	TEMPERATURE ^0F	
UP ELECTRONICS	-76	-71
EAST ELECTRONICS	-73	-67
WEST ELECTRONICS	-64	-54
CENTRAL ELECTRONICS	-75	-71
UP MICROPHONE	-77	-76
EAST MICROPHONE	-75	-73
WEST MICROPHONE	-79	-78

In general, none of the component temperatures changed a great deal, indicating the existence of satisfactory thermal coupling between the electronic components and the heater locations.

Table 5-3 presents 3 comparisons between the test and analysis for the night cases. Analytical values are for the corrected thermal model which was used as a base line model for the design of the LEAM flight configuration. In addition to the temperature discrepancies between forward grid frames and West electronics, the radiator temperatures have substantial differences. Analysis of the test revealed the radiator thermocouple was measuring mirror surface temperature while the thermal model predicts the average radiator plate temperature.

TABLE 5-3

NIGHT CASE COMPARISONS TEMPERATURE °F

IDENTIFICATION	5 WATTS Test	5 WATTS Anal	6 WATTS Test	6 WATTS Anal	7 WATTS Test	7 WATTS Anal
CENTRAL ELECTRONICS	- 71	- 77	- 48	- 46	- 27	- 19
UP SENSOR						
FWD GRID FRAME	-113	-137	- 98	-117	- 84	-100
FWD FILM FRAME	-111	-111	- 97	- 89	- 83	- 70
SUPPORT STRUCT	- 78	- 81	- 59	- 57	- 43	- 35
REAR GRID FRAME	- 78	- 77	- 59	- 54	- 42	- 34
IMPACT PLATE	- 76	- 70	- 57	- 48	- 40	- 29
REAR ELECTRONICS	- 71	- 69	- 52	- 47	- 36	- 28
EAST SENSOR						
FWD GRID FRAME	-113	-133	- 97	-115	- 83	- 99
FWD FILM FRAME	-104	-107	- 88	- 86	- 74	- 69
SUPPORT STRUCT	- 75	- 77	- 56	- 54	- 39	- 35
REAR GRID FRAME	- 75	- 73	- 55	- 52	- 38	- 33
IMPACT PLATE	- 73	- 67	- 54	- 46	- 37	- 27
REAR ELECTRONICS	- 67	- 66	- 49	- 45	- 32	- 27
WEST SENSOR						
GRID FRAME	- 98	-102	- 82	- 86	- 67	- 73
IMPACT PLATE	- 78	- 82	- 60	- 63	- 44	- 47
ELECTRONICS	- 54	- 81	- 37	- 62	- 21	- 46
STRUCTURE	- 76	- 83	- 56	- 60	- 38	- 39
STRUCTURE	- 77	- 82	- 58	- 58	- 41	- 38
STRUCTURE	- 75	- 82	- 56	- 58	- 39	- 38
STRUCTURE	- 72	- 77	- 53	- 54	- 35	- 34
RADIATOR	- 96	- 88	- 79	- 65	- 63	- 44

The comparisons between the test and analysis for the lunar noon cases are listed in table 5-4. The temperature difference for the Up sensor forward grid frame is again a function of thermocouple placement. This difference is dimished for the East sensor because of the frame view factor of 0.5 to the 250^{o}F lunar surface. The peculiar array of test temperatures for the radiator are due to momentary fluctuations in the carbon arc lamp. No design chages were made to LEAM as a result of the noon cases but the thermal model was verified.

The dust cover case was run to examine the temperature distribution of LEAM when sensor openings were covered. A brief comparison between the nominal noon case and dust cover case is presented in table 5-5.

Condition V, the IR noon case was run only as a base line test for the up coming qualification testing. The test plan very simply increased the IR lamp output until most noon condition electronic temperatures levels were about the same as for the carbon arc case. The intensity level on the black faced radiometer was 250 BTU/HR FT2. Temperature comparisons are listed in table 5-6.

TABLE 5-5

NOON DUST COVER COMPARISON

	TEMPERATURE ^{o}F	
IDENTIFICATION	3 WATTS COVERS OFF	3 WATTS COVERS ON
CENTRAL ELECTRONICS	126	121
UP ELECTRONICS	123	117
EAST ELECTRONICS	125	120
WEST ELECTRONICS	127	124
UP MICROPHONE*	124	116
EAST MICROPHONE	125	120
WEST MICROPHONE	123	121

*Microphone temperatures are approximately the same as impact plate temperatures.

TABLE 5-4

NOON CASE COMPARISONS

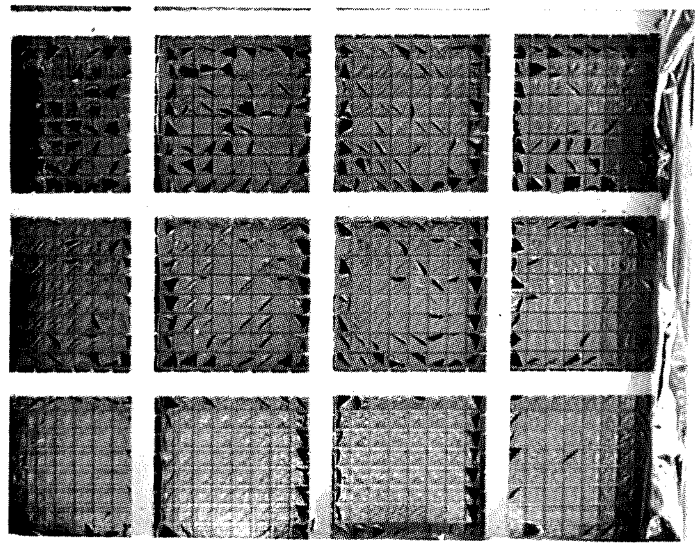
	TEMPERATURE °F					
	2 WATTS		3 WATTS		4 WATTS	
IDENTIFICATION	Test	Anal	Test	Anal	Test	Anal
CENTRAL ELECTRONICS	116	108	126	125	134	144
UP SENSOR						
FWD GRID FRAME	105	58	104	66	103	75
FWD FILM FRAME	115	98	111	106	107	116
SUPPORT STRUCTURE	117	105	122	117	126	131
REAR GRID FRAME	116	107	122	118	125	131
IMPACT PLATE	118	109	124	120	128	133
REAR ELECTRONICS	116	110	123	121	127	134
EAST SENSOR						
FWD GRID FRAME	104	115	111	120	115	127
FWD FILM FRAME	119	113	127	120	131	128
SUPPORT STRUCTURE	116	109	124	119	129	131
REAR GRID FRAME	117	111	124	120	130	132
IMPACT PLATE	117	113	125	123	130	135
REAR ELECTRONICS	118	113	125	123	130	135
WEST SENSOR						
GRID FRAME	113	118	119	122	124	128
IMPACT PLATE	117	116	123	124	128	134
ELECTRONICS	121	117	127	125	132	134
STRUCTURE	112	103	118	115	123	128
STRUCTURE	115	104	121	115	126	129
STRUCTURE	114	104	121	115	125	129
STRUCTURE	115	107	123	118	129	130
RADIATOR	104	90	99	100	99	112

TABLE 5-6
IR NOON CASE COMPARISONS

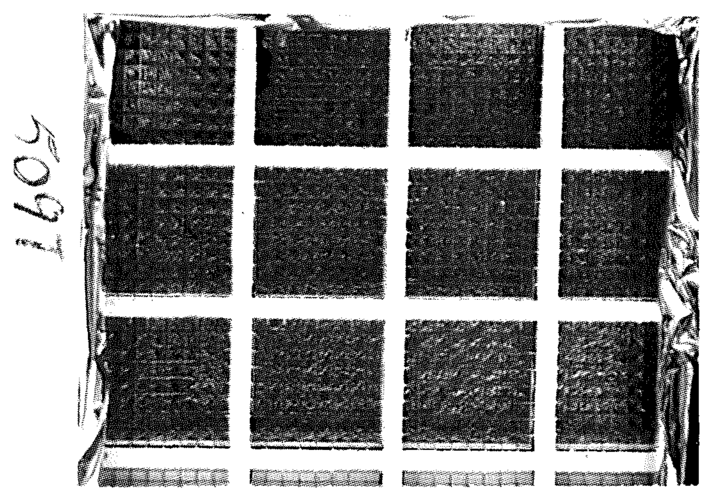
IDENTIFICATION	TEMPERATURE °F 3 WATTS Carbon Arc	3 WATTS IR Lamps
CENTRAL ELECTRONICS	126	124
UP SENSOR		
FWD GRID FRAME	104	100
FWD FLM FRAME	111	90
SUPPORT STRUCTURE	122	118
REAR GRID FRAME	122	117
IMPACT PLATE	124	119
REAR ELECTRONICS	123	120
EAST IMPACT PLATE	125	123
EAST ELECTRONICS	125	123
WEST IMPACT PLATE	123	122
WEST ELECTRONICS	127	126
RADIATOR	99	98

The increased sun case, condition VI, tested the film configuration for melting or softening under the influence of increased solar intensities. Noon lunar surface temperatures were used to give the highest possible temperature background. As was stated earlier, the carbon arc intensity was increased from 1 sun to 1.4 suns at about 5 minute intervals. After each increase, the Up film was visually inspected through the window. No signs of melting or softening were observed. This test verified the fact that high temperature film damage is prevented by conduction of excess incident energy to the beryllium copper mesh bonded to the rear of the film.

Condition VII, the film retest, was run because the silver coated films had failed. During this final test sequence, an aluminum and silicon oxide coated film was cycled between the low temperature survival case and a 1.3 sun case. The chamber door was opened between the two phases to inspect the film. No failures were observed after either test case. Figure 5-2 shows the silver coated film after the original DVT test sequence and the aluminum-silicon oxide coated film after the film retest.



SILVER COATED FILM AFTER FIRST TEST SEQUENCE



ALUMINUM – SILICON OXIDE COATED FILM AFTER FILM RETEST

Figure 5-1 East Sensor Films

After completion of the DVT testing a special series of film tests were run at Union Carbide.* Silver coated Parylene films and aluminum/silicon oxide film were subjected to a group of high as well as low temperatures. The silver film failed when reduced to $-108^{\circ}F$ but the aluminum - silicon oxide film passed the same test.

6.0 CONCLUSIONS

The LEAM Thermal DVT tests were conducted to provide base line data for upgrading the thermal design. The data was analysed and the thermal model was updated yielding several design changes. These included a new fiberglass interface bracket, relocation of the squibs and relocation of the bubble level. In addition, the interface bracket, will be completely covered on the sides and ends by superinsulation masking.

A second result from the testing changed the Up and East sensor front films from Parylene overcoated with silver to Parylene overcoated with aluminum and silicon oxide. The second configuration successfully completed both a low temperature survival test and a 1.3 Sun test.

As a result of the DVT testing the LEAM experiment electronics are expected to be maintained between $-30^{\circ}C$ and $65^{\circ}C$ when operational and above $-55^{\circ}C$ during the survival mode.

*See Ref 2.

REFERENCES

(1) BxA TP 2365510 LEAM Design Verification Model (DVT) Test Procedure, A. Cenci, 8 March 1971

(2) ATM 1010 LEAM Sensor Front Film Development Report, D. Perkins, 11 June 1971.

APPENDIX A

EQUIPMENT REQUIRED FOR DESIGN VERIFICATION MODEL MODEL TESTING OF LEAM

	Item	Manufacturer	Part No. or Model
1.	4 ft x 8 ft Thermal Vacuum Chamber	National Research Corp	N/A*
2.	Control Console (Chamber)	Bendix	N/A
3.	Vacuum Gage Control	National Research Corp	751
4.	Ion Gage (North)	National Research Corp	551AS
5.	Ion Gage (South)	National Research Corp	551AS
6.	Alphatron Vacuum Gage	National Research Corp	520
7.	Thermocouple Controller	Thermo Electro Co.	32411
8.	Pyroheliometer	Hy-Cal Engr. Co.	P 8410
9.	Pyroheliometer	Hy-Cal Engr. Co.	P 8410 (with mirror)

*Not Applicable

APPENDIX A (CONT'D)

	Item	Manufacturer	Part No. or Model
10.	Ice Point Reference Standard	Jos Kay Co.	RCS 4
11.	Arc Lamp (Solar)	Genarco	ME-6
12.	IR Lamp P/S	Research Inc.	(Labac)
13.	Digital Volt-Meter	Hewlett-Packard	3439A
14.	Plug-In	Hewlett-Packard	3443A
15.	Lunar Surface Simulator	Bendix	N/A
16.	Heat Exchanger	Nes Lab	TO 3-10W
17.	D.C. Power Supply (40V)	Sorensen	QR 36-4A
*18.	Current Shunts		
19.	LN_2 Cold Wall (Including ends)	Bendix	N/A
20.	Data Acquisition System	Hewlett-Packard	2010J
21.	Variable Transformer	General Radio Co.	W-10M (1KW)

*See BxA Engineering for shunt types and ratings.

APPENDIX A (CONT'D)

	Item	Manufacturer	Part No. or Model
22.	Variable Transformer	General Radio Co.	W-20M (2KW)
23.	IR Array	Bendix	N/A
24.	Reference "J" Junctions (Voltage and Current Junctions)	R. I. Controls	RJ4801

APPENDIX B

LEAM THERMOCOUPLES LOCATIONS

Number	Location on Model
Flight Locations	
1	Upper Internal Structure - Near Radiator
2	Central Electronics Enclosure
3	Up Sensor Quartz Plate Near the Microphone
4	East Sensor Quartz Plate Near the Microphone
5	West Sensor Main Quartz Plate Near the Main Microphone
Up Sensor	
6	Outer Fwd Grid Frame - West Edge
7	Fwd Film Frame - Center Strut
8	Rear Outer Grid Frame - West Edge
9	Support Structure - Outer West Face
10	Guard Htr. #1
11	Inner Fwd Grid Frame - West Edge
12	Rear Electronics Board - Center of Board
East Sensor	
13	Outer Fwd Grid Frame - Bottom Edge
14	Fwd Film Frame - Center Strut - Middle
15	Rear Outer Grid Frame - Bottom Edge
16	Support Structure - Outer Bottom Face
17	Guard Htr. #2
18	Inner Fwd Grid Frame - Bottom Edge
19	Rear Electronics Board - Center
West Sensor	
20	Grid Frame - Bottom Edge
21	Electronics Board - Center

APPENDIX B (CONT'D)

Number	Location on Model
Outer Envelope	
22	Outside Fiberglass Structure - North
23	Outside Fiberglass Structure - East
24	Outside Fiberglass Structure - South
25 (A)	Outside Fiberglass Structure - West
26	Outside Fiberglass Structure - Bottom
27 (B)	Super Insulation Bag Outside - North
28 (A) (B) (C)	Super Insulation Bag Outside - East
29 (B)	Super Insulation Bag Outside - South
30 (B) (C)	Super Insulation Bag Outside - West
31 (B)	Super Insulation Bag Outside - Bottom
32 (B)	Super Insulation Bag Inside - North
33 (B) (C)	Super Insulation Bag Inside - East
34 (B)	Super Insulation Bag Inside - South
35 (B) (C)	Super Insulation Bag Inside - West
36 (B)	Super Insulation Bag Inside - Bottom
37	Corner Support - Experiment Side - North - East
38	Corner Support - Experiment Side - North - West
39	Corner Support - Experiment Side - South - East
40	Corner Support - Experiment Side - South - West
41	Corner Support - North - East
42	Corner Support - South - West
43	Corner Support - South - East
44	Corner Support - South - West

NOTE A: Bad Thermocouple

NOTE B: Attached T/C to .5 x .5 x .010 aluminum strip. Placed under outer Kapton or Teflon layer near center of given side for thermocouples numbers 27 thru 36.

NOTE C: East and West Reversed.

APPENDIX B (CONT'D)

Number	Location on Model
Misc	
45	Radiator Masking Primary - Bottom
46	Radiator Masking Primary - Top
47	Radiator Masking Secondary - Bottom
48	Radiator Masking Secondary - Top
49	Corner Masking Top - North - East
50	Corner Masking Top - North - West
51	Corner Masking Top - South - East
52	Corner Masking Top - South - West
53	Internal Structure - Top Flange
54	Internal Structure - Center East Wall
55	Internal Structure - Center West Wall
56	Internal Structure - Center Bottom Wall
57	Support Leg - Center North East
58	Support Leg - Center North West
59	Support Leg - Center South East
60	Support Leg - Center South West
61	West Microphone (3 x 4)
62	West Microphone Heat Shield (3 x 4)
63	West Microphone (1 x 4)
64	West Microphone Heat Shield (1 x 4)
65	Center of Second Surface Mirrors

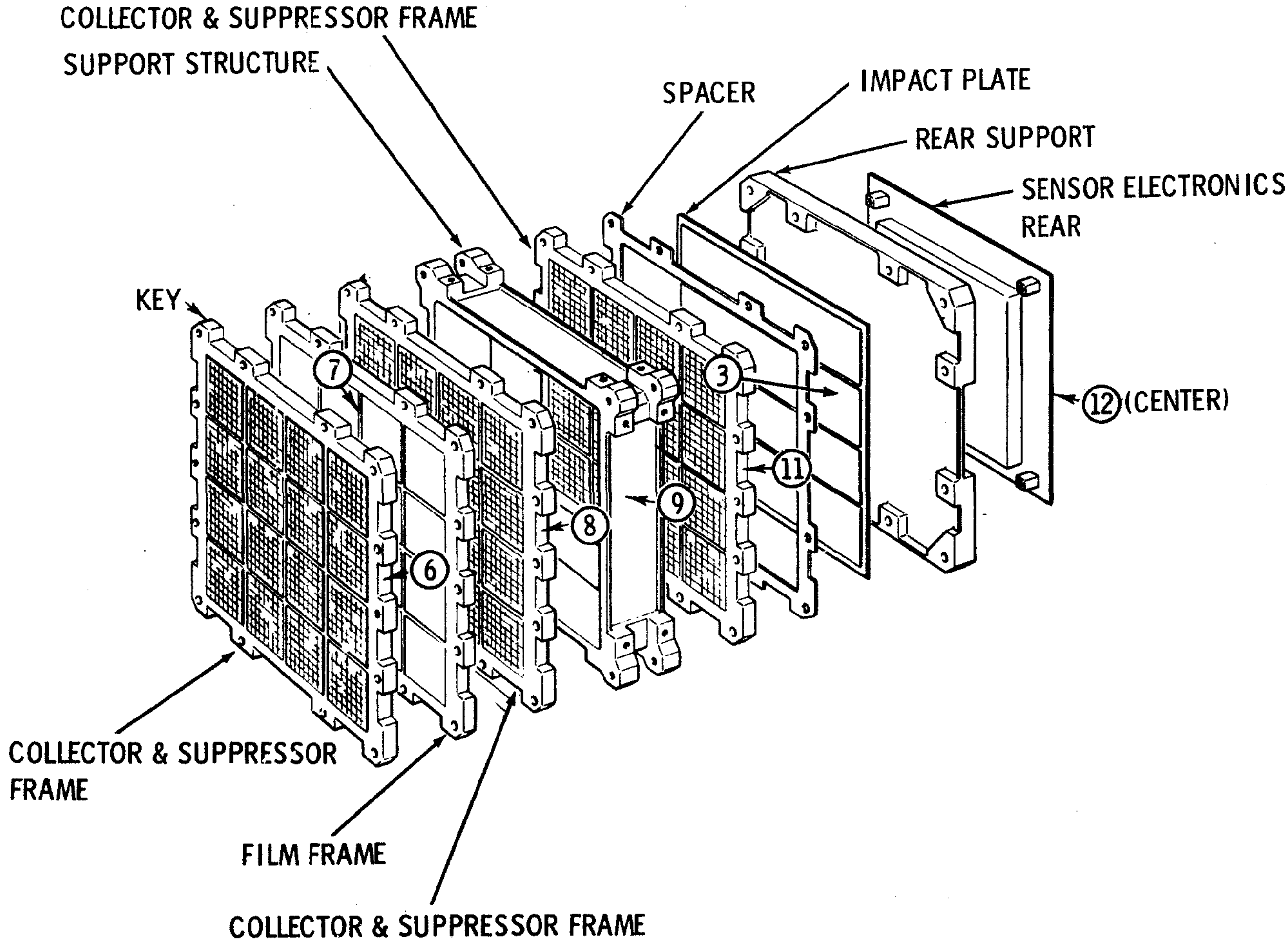


Figure B-1 Exploded View of Dual Sensor (T/C Locations Up Sensor)

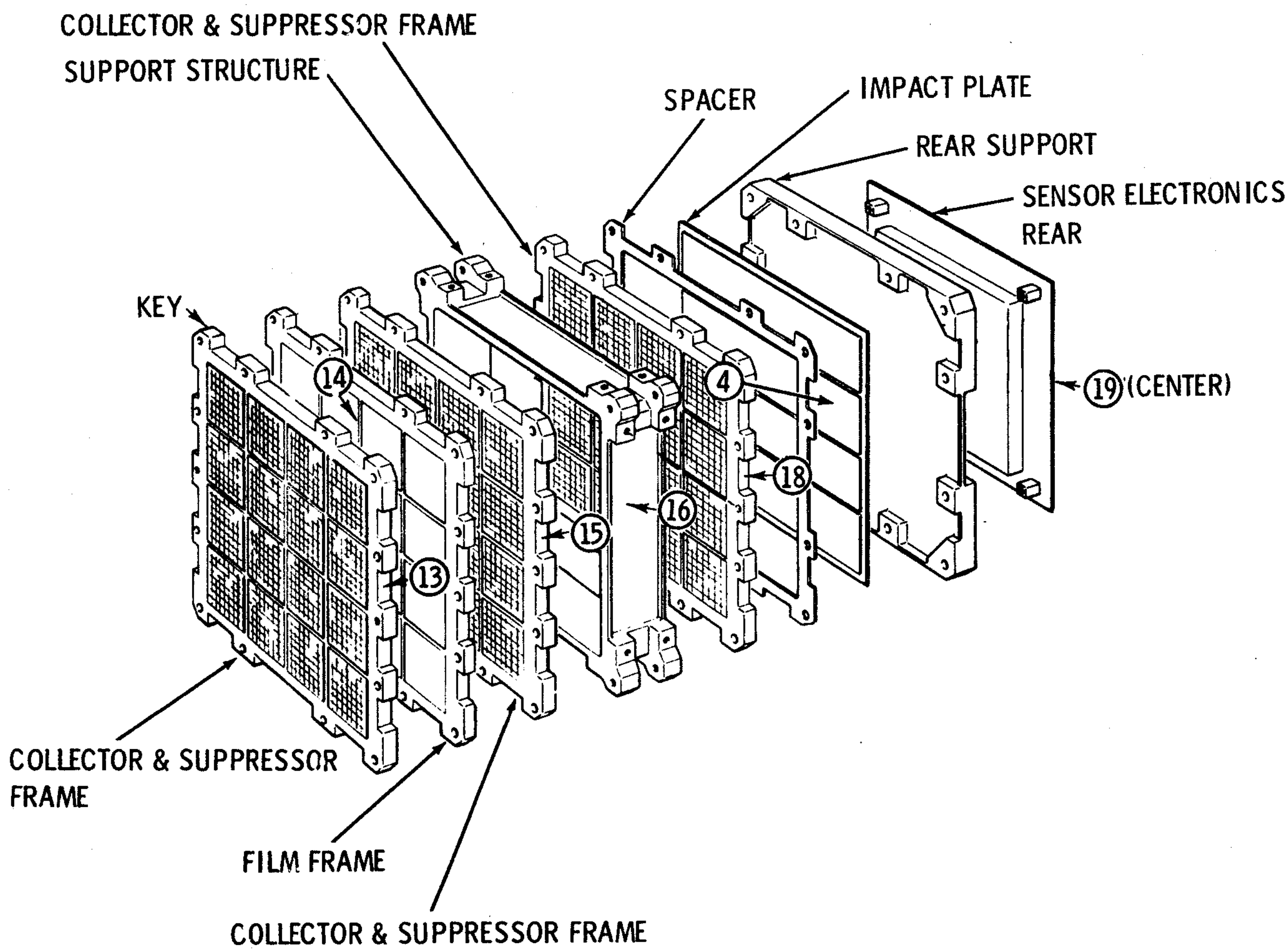


Figure B-2 Exploded View of Dual Sensor
(T/C Locations East Sensor)

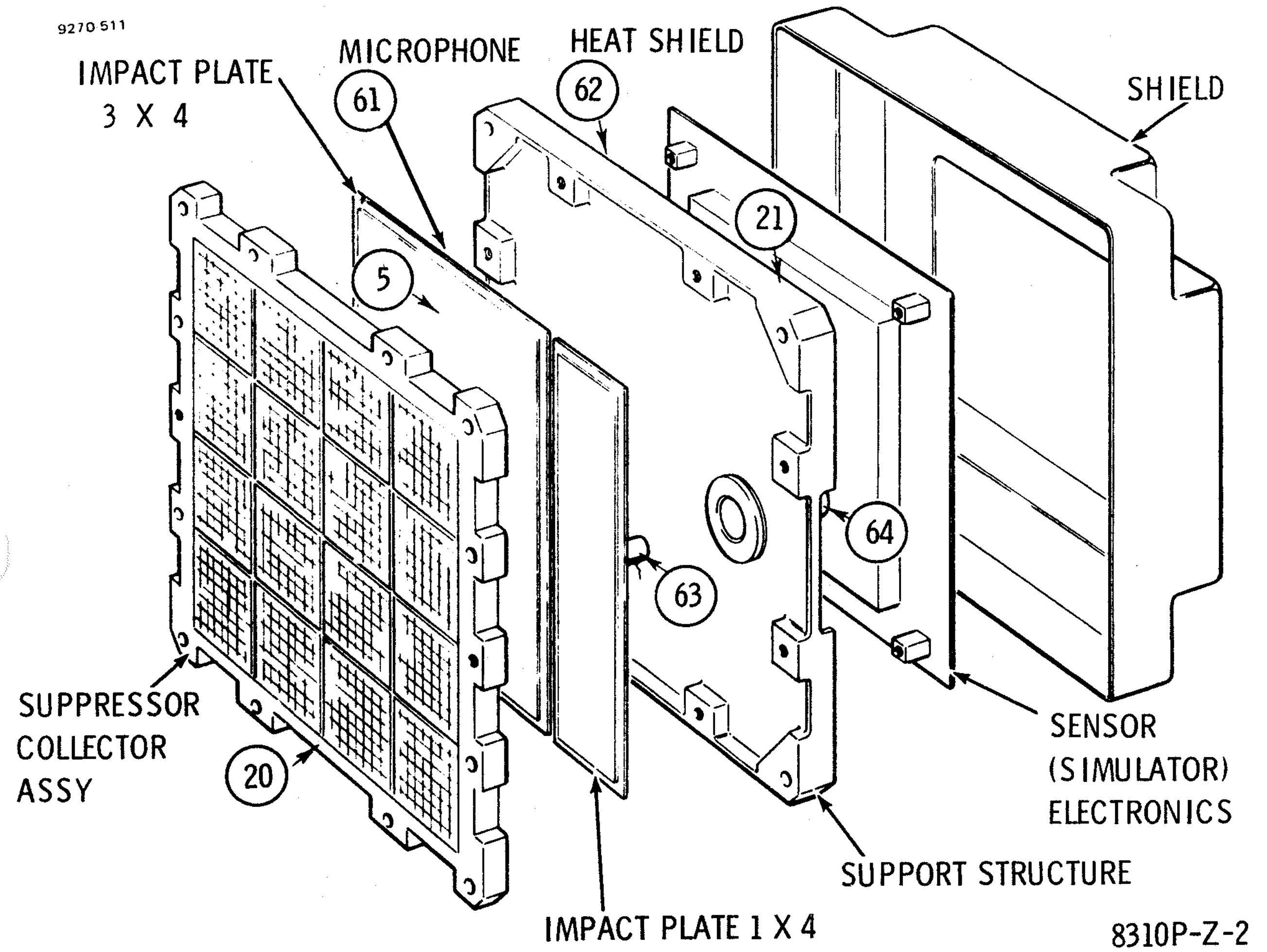


Figure B-3 Exploded View of Single Sensor
(T/C Locations West Sensor)

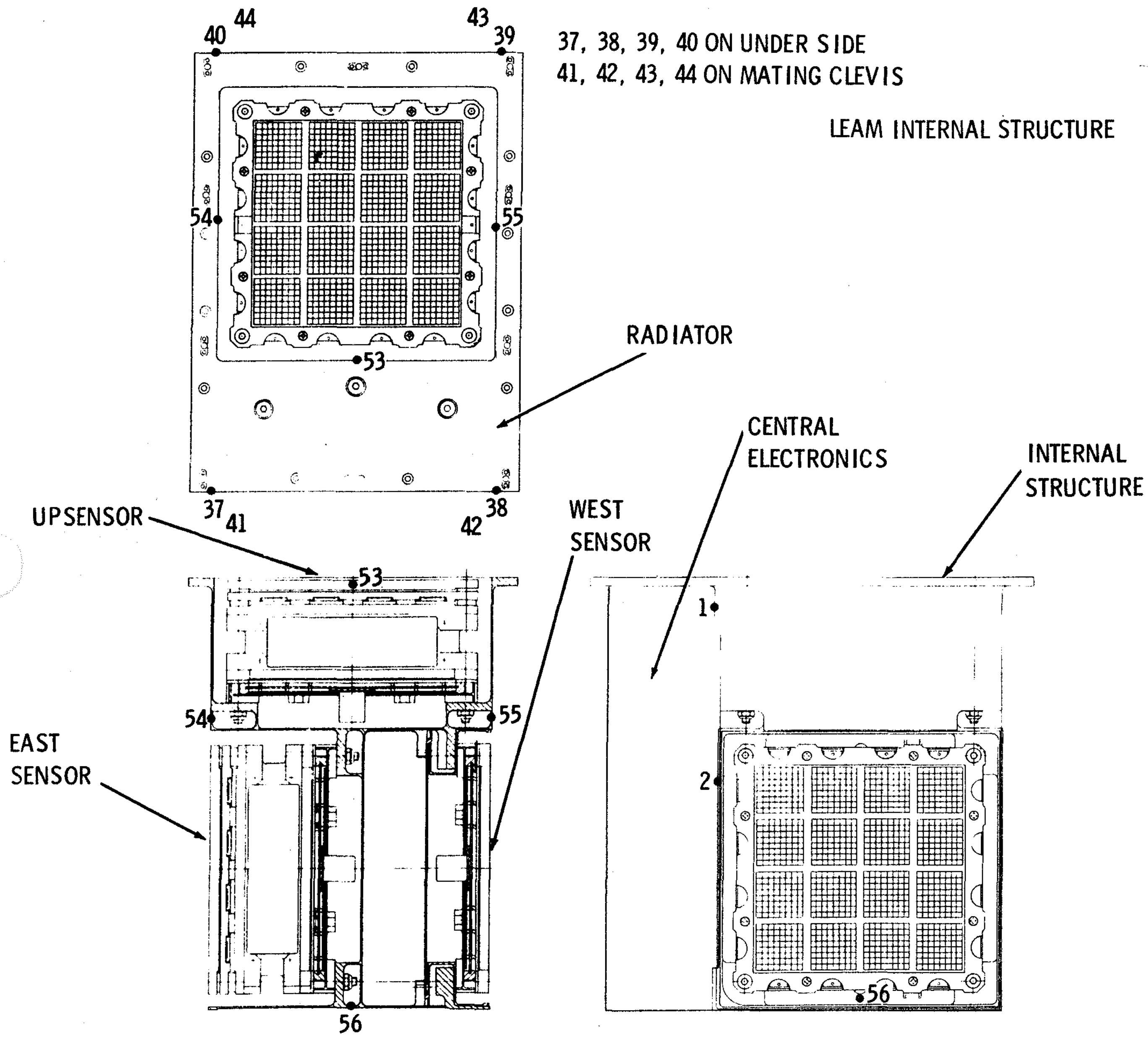


Figure B-4 LEAM Internal Structure
(T/C Locations)

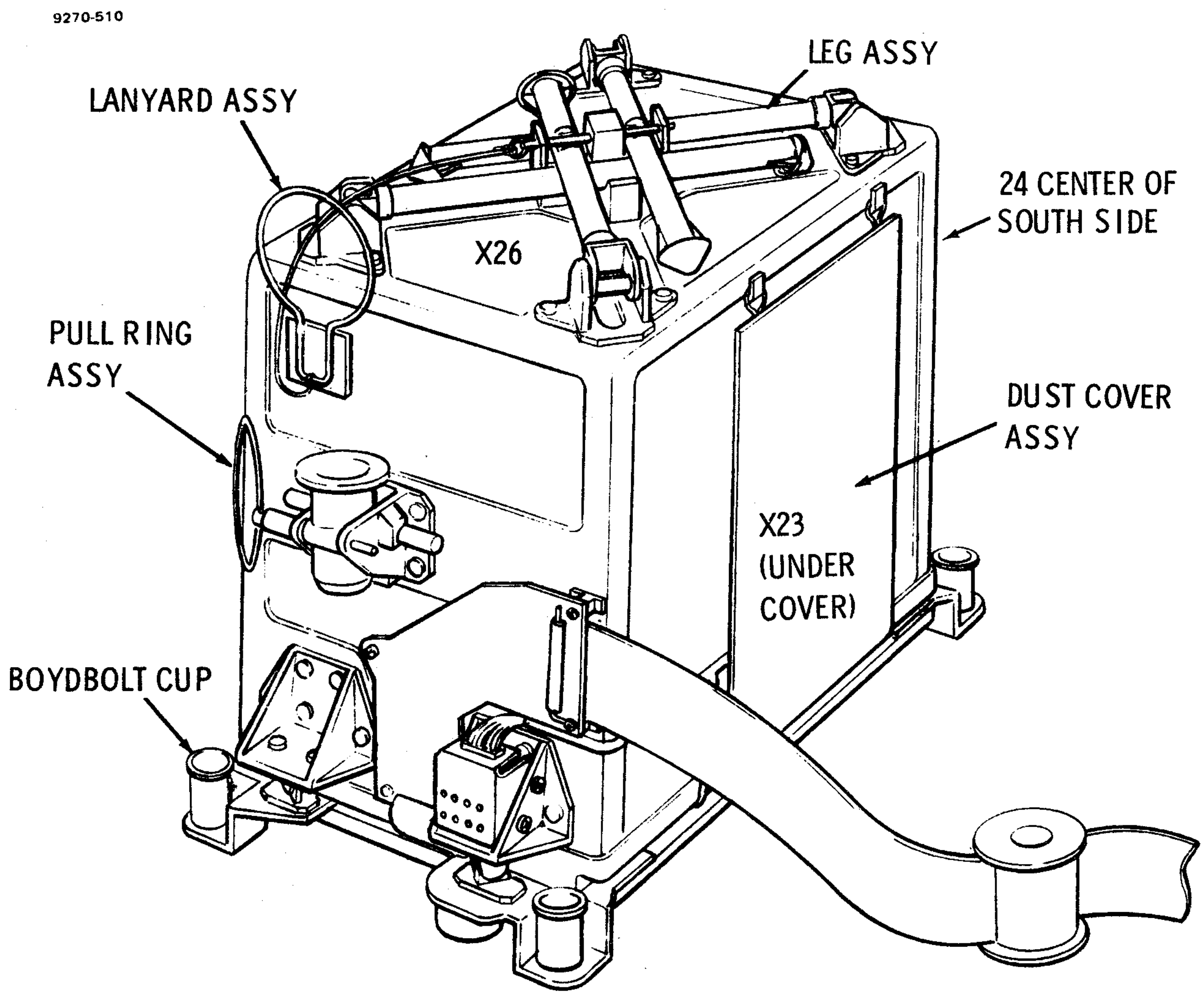


Figure B-5 LEAM External Structure N-E
(T/C Locations)

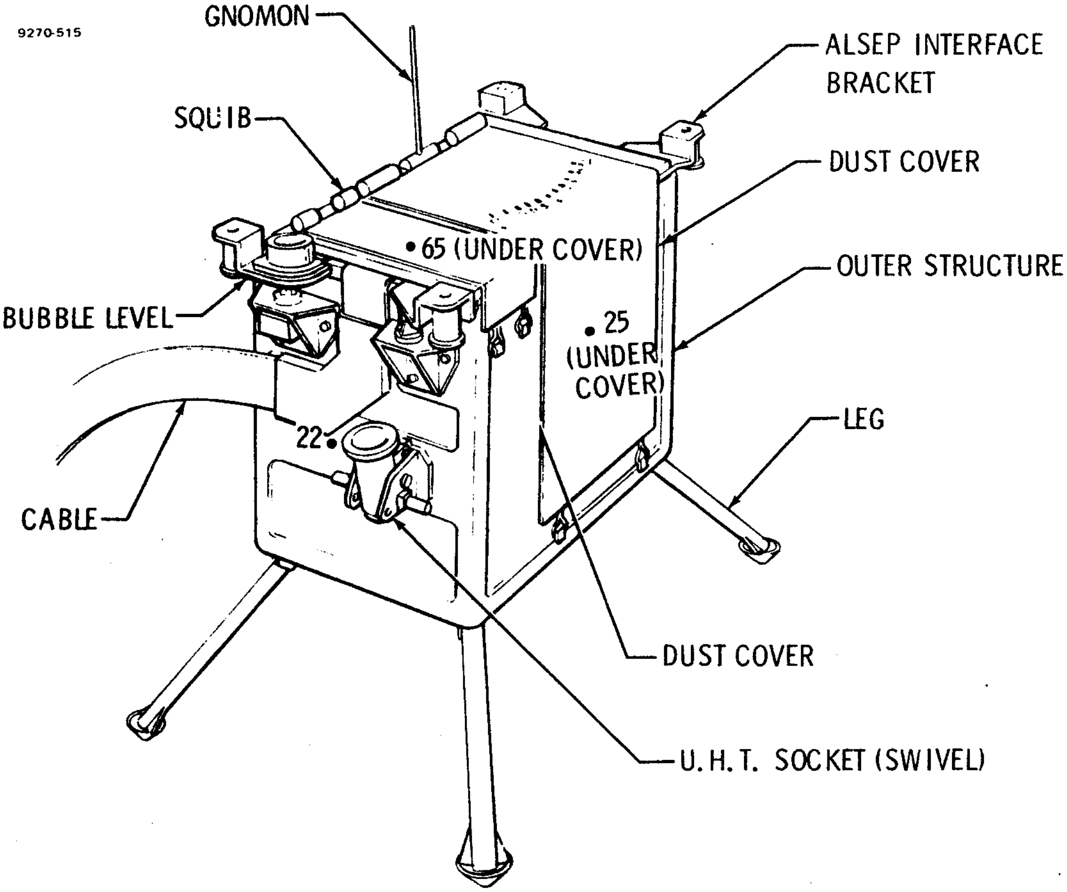


Figure B-6 LEAM External Structure N-W
(T/C Locations)

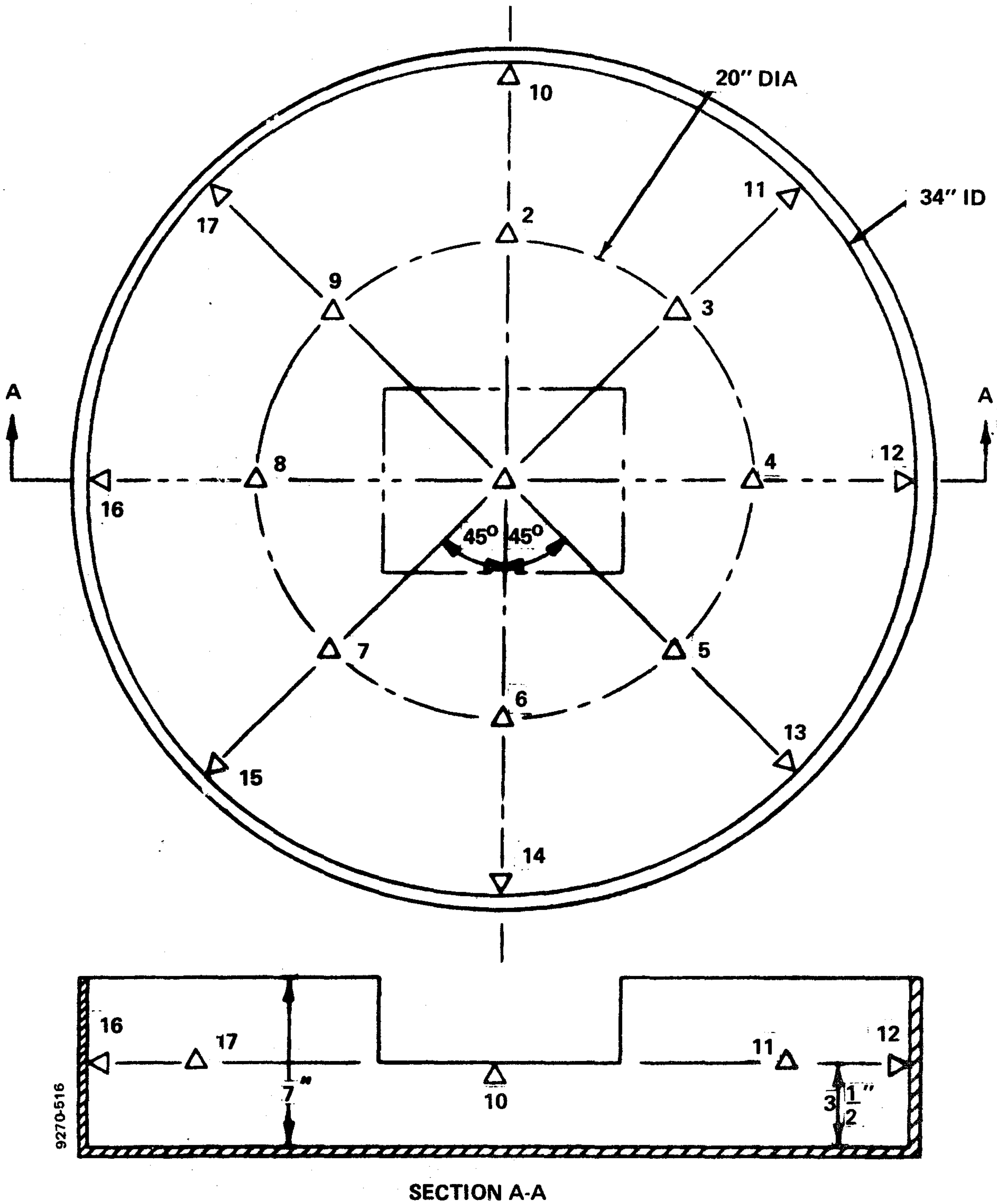


Figure B-7 LEAM DVT Lunar Surface Simulator (T/C Locations)

9270-517

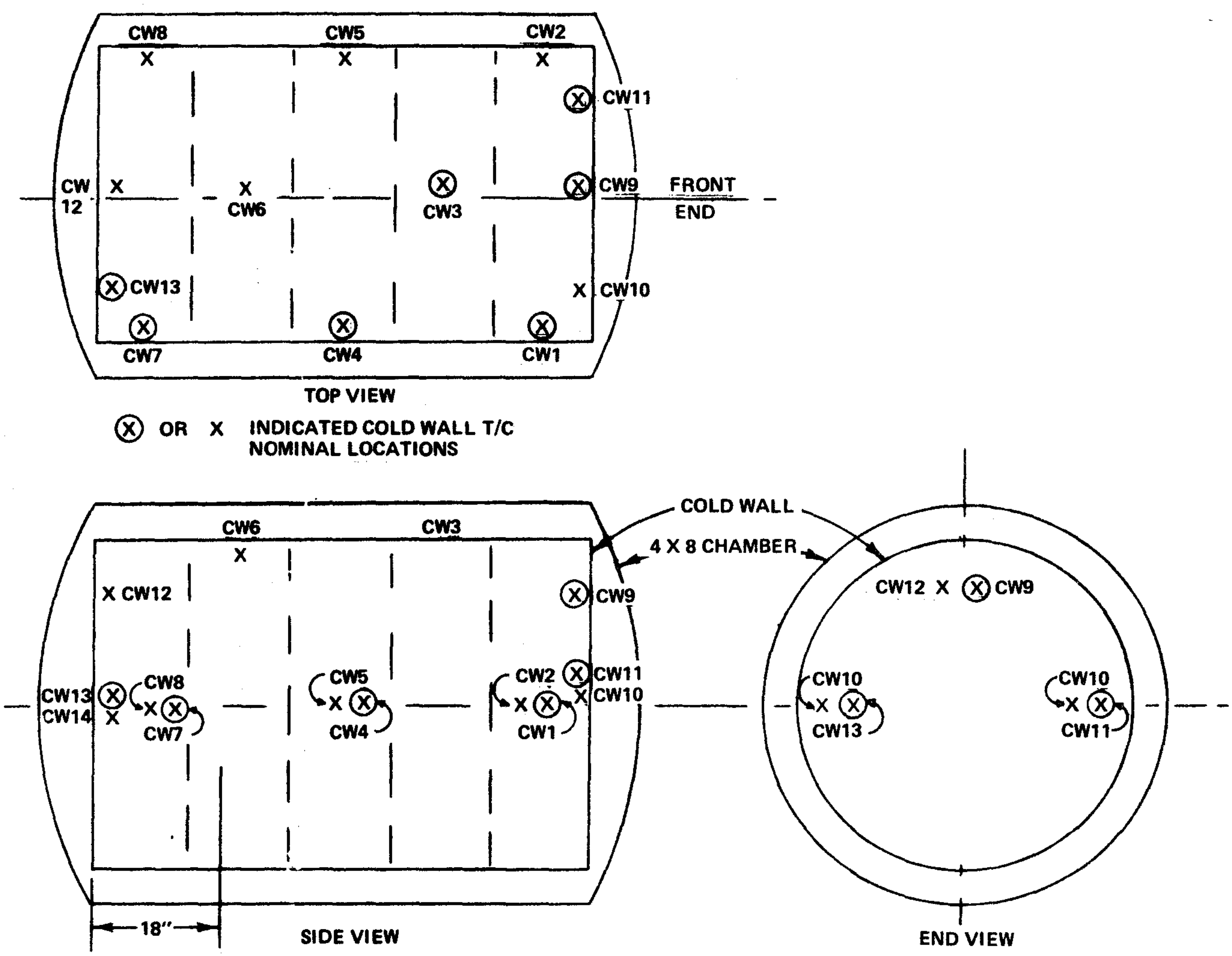


Figure B-8 4Ft x 8Ft Chamber
(T/C Locations)