Bendix Aerospace Systems Division

R. Miley (2)

NO.	REV. NO.
ATM-1120	
PAGE ___ OF ___	
DATE 22 March 1973	

LEAM THERMAL ANOMALY INVESTIGATION REPORT

Prepared by: D. Perkins

Approved by: D. Fithian

1.0 Introduction and Anomaly Description

An investigation was conducted to determine why the temperature of the Lunar Ejecta and Meteorites Experiment (LEAM) exceeded the math model predictions when operating on the lunar surface.

The LEAM was deployed on the lunar surface at approximately 0200 hours GMT, on December 12, 1972. The experiment was operated briefly to verify that it had suffered no damage during the translunar flight and landing. The power was then removed until the dust covers could be released, after detonation of the Lunar Seismic Profiling Experiment (LSP) explosive charges. The temperature, as measured on temperature sensor AJ 11, at noon, in this configuration, was 176°F which exceeded the preferred maximum operating temperature of 150°F. (AJ 11, Survival Temperature Monitor, is a temperature sensor located on the experiment internal structure under the radiator plate and which is monitored by the ALSEP at all times.)

When the temperature decreased to 160°F, after lunar noon, the experiment was operated for a short time to allow the mirror cover to be released. A distinct increase in cooling rate was observed after this event. The experiment was finally turned on, on December 23rd. after an attempt, approximately 24 hours earlier, which had to be terminated when the temperature reached 150°F.

The period between December 23 and December 28 was used to gather background science data with the dust covers on. The command to release the sensor covers was transmitted at 19.57.30 GMT on the 28th of December 1972, and verification of squib firing was obtained from the experiment. The temperature profile before and after the command was cyclic, varying between the upper and lower limits of the temperature controller (0°F and 9°F nominal). The period of the temperature cycle did not change after the command, indicating that the covers may not have released, even though the squibs had fired.

The temperature at sunrise on the second lunar day increased at an extreme rate of up to 16°F until the experiment was turned off at 165°F. The profile then exhibited peaks of 192.5°F and 186.5°F at sun angles of approximately 45 and 115 degrees, respectively, with a minimum of 163°F at 85 degrees. The experiment was returned to the operate mode at 130°F.

To satisfy a request from the Principal Investigator, the experiment was turned off for a period of eighty minutes around optical sunset at the site. This was done in support of his dust transport theory. The temperature during the following night was considerably colder than during the previous one, being at -20°F with the heater on continuously.

The off/on technique was repeated at optical sunrise on the third lunar day. The temperature profile was significantly different to that of the second day, being some 45°F cooler at 15 degrees sun angle, allowing the experiment to remain on approximately 24 hours longer. The temperature remained cooler than previously until around 80 degrees sun angle when the second day profile was followed for the remainder of the third lunar day/night cycle.

The investigation described below was conducted to establish the cause of the anomaly and to recommend an operational plan for the experiment based on the requirements of the Principal Investigator and reliability considerations.

2.0 Task Description

The investigation was performed by the LEAM Program Office, the ALSEP Thermal Design Group and ALSEP Reliability Group, with assistance from the ALSEP Systems Group.

The tasks performed are summarized below.

A. Prepare a list of potential causes of the anomaly.
B. Analyze each potential cause, in detail.
C. Review the test history of all LEAM models for details of configuration, environments and results.

D. Review the film development program for results and selection criteria.

E. Correlate thermal math model with lunar temperature profile to give insight into the problem and predictions of temperatures in the continuous mode of operation.

F. Perform reliability analyses to determine advisability of operating up to various temperatures and advantages of turning off at temperature peaks.

G. Prepare a test plan for the Qualification model.

H. Prepare an operational plan for the experiment during future lunations.

3.0 Results of Investigation

The results of the study were presented at a meeting with personnel from MSC, Houston, on 13 March 1973. A copy of the presentation material is enclosed as a part of this document.

4.0 Conclusions

The following conclusions were reached as a result of the study.

A. No single, definite, cause can be associated with the anomaly. The most probable cause is a combination of lunar surface and site effects, including a complicated method of dust transport.

B. The LEAM thermal performance cannot be clearly explained using the detailed math model. A good correlation has been obtained with a simple, 5 node, model which allows good predictions of operating temperatures at the radiator plate. The observed relationship between radiator and electronics temperatures is used to predict their operating profiles.

C. The original thermal analysis and testing performed before flight has not been invalidated by any information found during the study.

D. The LEAM may be operated continuously throughout the lunar cycle. The maximum temperature predicted in this mode is 212°F at the electronics. The reliability is shown to decrease from an original prediction of 80% probability of successful operation for two years to one of 61% if operated in this mode.

E. No action items resulted from the meeting with NASA personnel, therefore, the material presented is considered adequate to satisfy the requirements of the study.

Attachments:
Meeting Minutes
Presentation Material

Bendix Aerospace Systems Division

Minutes of the
LEAM Anomaly Meeting

MINUTES

Date of Meeting 3/13/73

ATTENDANCE - (On separate list)

Agenda (Attached)

"LEAM Anomaly Investigation" - handout documenting results of Bendix study efforts on the LEAM problem issued to each attendee.

In LEAM analysis it was assumed that sensors would not contribute to heat load, therefore, only IR simulation was used in testing. Predicted maximum temperature level of 150°F was re-evaluated for the final Apollo 17 landing site - no changes were made in maximum temperature prediction. It is noted that the actual operating temperatures do not follow the pre-mission predictions in either level or profile.

The instrument thermal/mechanical design was reviewed from sketches in the handout. The electronics assembly is enclosed in a multilayer thermal bag which is enclosed in a fiberglass box - openings for sensor inputs are provided. The AJ-11 sensor is immediately underneath the internal support assembly adjacent to the heater control sensor.

Predicted forward film temperature max is about 275-300°F. Melting temperature for the Parylene-c is 536°F (per Union Carbide) thermal properties for all areas/elements of the experiment were reviewed. Comments concerning S13G paint-material is very stable and does not degrade due to long exposure to solar input.

Thermal performance after mirror cover removal command tends to confirm that mirror cover did retract. Thermal performance after sensor cover removal command indicates that the sensor cover did not retract at that time; however, following warm-up at sunrise of the next day, performance indicates that sensor covers did deploy.

The rapid increase in temperature immediately after sunrise on the second morning indicates a heat load from the environment - probably the east sensor. A similar load exists in the west sensor in the lunar afternoon. There is some thought that the sensor covers are only partially deployed. There is a history of similar problems on a roll-up type device on the Apollo 9 LM window covers. In that case, after exposure to temperature extremes, the role-up device would not deploy. The LEAM cover is essentially the same as the covers used on CPLEE where no problems were encountered.

In summary, the difference in thermal performance may be caused by a delayed (or partial) sensor cover deployment. The variation from one lunar day to another may be caused by accretion of lunar dust on the east, and to a lesser extent on the west, sensor film (and grid) produced by a dust transport from charge differences between the lunar surface and the sensor at sunrise. It is postulated that the surface may be charged to a negative 200 to 500 volts while the sensor/grid are at -3v/-7v when the experiment is ON. Based on this, a tentative operational plan calls for the experiment to be off during sunrise.

Configuration differences between DVT model and Qual/Flight were reviewed. There are no differences between the Qual and Flight models. All changes made from the DVT model test results were verified by test.

A thermal math model (3rd day) has been derived which correlates with lunar performance. Based on this model, electronics temperature is predicted to reach a maximum of 212°F at a solar angle of ~ 120 degrees.

Review of potential causes. (Each of the following was considered during the LEAM study.)

1. Actual thin film thermal/optical properties different from those assumed in model-agreement of four different sources of film optical property measurements tend to rule this out. Melting temperature (536°F) was not reached.

2. Boost failure of films (accoustical/Pressure vibration induced). Review of Pioneer experience and ALSEP test data and experiment venting tend to rule this out.

3. Anomalous deployment. Air-to-ground transcript, crew debriefing and photos confirm good deployment.

4. Experiment misleveling/misalignment caused by cover release. Force is much too small to move experiment to any degree.

5. Failure of covers to release - complete or partial. Temperature plots indicate sensor covers did not retract when squibbs were fired. May have deployed on second lunar day.

6. Heater on during day - telemetry confirms that this is not the case. Heater status changed as expected. Also, system reserve power confirmed heater on/off change.

7. Taurus Littrow site effects - the surface temperature is somewhat above pre-mission predictions however this cannot explain the LEAM performance.

8. Dust accretion on sensor and/or radiator. Second and third day indicates east sensor optical properties have changed. Dust accretion could explain this change.

9. Errors in telemetered temperature data. Evaluation of telemetry data and calibration confirm correct TM.

Reliability considerations for future experiment operation were presented. A full family of curves were presented which show probability of meeting the 24 month operating life versus a variety of operating temperatures and configurations. It is noted that probability of success (P_s) is reduced with higher operating temperatures, however, (for example) with operation at 100°C the P_s for 24 months is 62%: at 40°C the P_s for 24 months is 80%. These percentages (except for the 40°C curve) are based on a temperature profile which contains 160 hrs. of operation at maximum temperature; 150 hours at a lower temperature and the remainder at 40°C. Based on reliability considerations, the instrument can be operated at a temperature profile which peaks at 100°C.

Bendix presented a test plan including instrumentation requirements for the test. The test is not recommended at this time but may be indicated by future performance data.

Recommendations for future instrument operation:

1. Continue present operating plan for this current lunar cycle. (See SMEAR - Apollo 17 - ALSEP #41)

2. Consideration will be given to leaving the instrument on during sunset on 23 March, pending results of the PI analysis of STDN data.

3. NASA will refine the sunrise/sunset predictions for the Apollo 17 site.

4. No actions are pending from BxA as a result of this meeting.

Original signed by:

Warren Tosh
J. R. Bates
S. J. Ellison
E. Granholm
O. E. Berg
D. Perkins

Distribution:

Attendees
W. Eichelman
B. J. Rusky
D. Fithian
T. Fenske
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LEAM ANOMALY MEETING

3/13/73 ATTENDANCE

John B. Hanley	NASA HQ/SM	(202) 755-1602
John Lowery	ED2/NASA	ext. 3872
Robert Miley	TDX/Bendix	ext. 5067
Erik A. Granholm	BxA	(313) 665-7766 ext. 8111
James R. Bates	TN3/JSC	ext. 2711
John Lobb	PT14/JSC	ext. 2074
Otto E. Berg	GSFC-NASA	(301) 982-5920
R. S. Harris, Jr.	NASA/ES3	ext. 5589
S. J. Ellison	BxA	(313) 665-7766
Edward S. S. Morrison	NASA PD9/GE	ext. 3966
Derek Perkins	BxA	
A. E. Eckermann	NASA/NB5 (Boeing)	488-0910
W. Tosh	BxA	
Earl Smith	NASA/NB5	483-2868

LEAM Anomaly Meeting

Agenda

1. Introduction: Problem definition.

2. Description of experiment, thermal properties, films and coatings.

3. Review of flight temperature profile to date.

4. Description of anomaly investigation and results

   a. Review of test history, including environments and differences between DVT, Qual and Flight models.

   b. Review of film development and selection.

   c. Attempts to correlate thermal math model with lunar temperature profile.

   d. Outline of potential causes.

   e. Discussion of potential causes.

5. Summary of reliability studies.

6. Recommendations for further evaluations on tests.

7. Discussion of future experiment operational plan.

ALSEP ARRAY E

LEAM ANOMALY INVESTIGATION

13 March 1973

LEAM ANOMALY INVESTIGATION

PROBLEM DEFINITION

- LEAM LUNAR DAY TEMPERATURE EXCEEDS MAXIMUM PREDICTED LEVEL OF 150°F.

- LEAM THERMAL DESIGN ADEQUACY HAS BEEN VERIFIED BY THERMAL ANALYSIS AND THERMAL/VACUUM TESTING.

- LEAM ANALYZED AND TESTED CONFIGURATION IS NOT REPRESENTATIVE OF FLIGHT MODEL IN ITS LUNAR SURROUNDINGS.

LUNAR EJECTA AND METEORITE EXPERIMENT DESCRIPTION

The experiment consists of two dual film sensors facing UP and EAST, respectively, and a single film sensor facing WEST. The sensors and electronics are housed in an aluminum internal structure which acts as structural support and electrical shielding.

The sensor and electronic assembly, called the Internal Structure and Sensor Assembly, is housed in a thermal bag which, in turn, is mounted in an outer housing. Legs are attached to the outer housing and are used to support the experiment in the deployed configuration. A radiator plate, with second surface mirrors, is attached to the Internal structure and ALSEP interface bracket. The thermal bag is integral with the ALSEP interface bracket.

The complete Internal structure, thermal bag and radiator assembly is attached to the outer structure via four clevis joints.

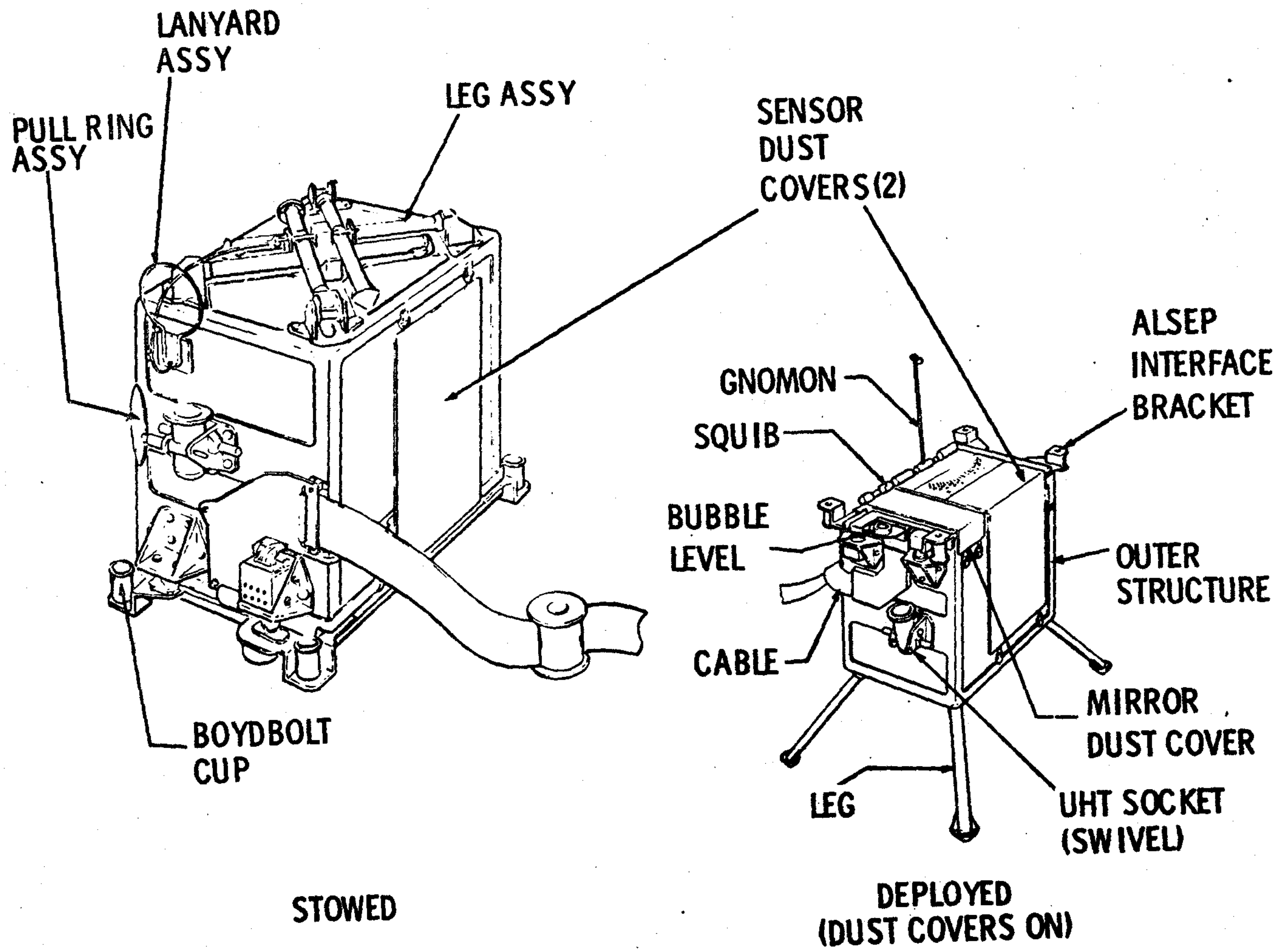
The radiator is covered by a thermal mask which protects all of the top surface except the sensor and required mirror radiator.

Electrical connection is made between the experiment and ALSEP using a flat cable via a short manganin wire assembly.

The sensors are protected by dust covers which are released by earth commands. The mirror cover is released by a pair of squibs, independently of the sensor covers (2) which are released by a separate pair of squibs. One, only, of each pair of squibs is required to release the respective covers.

The experiment and its thermal properties are detailed in the attached Figures and Tables.

LEAM EQUIPMENT



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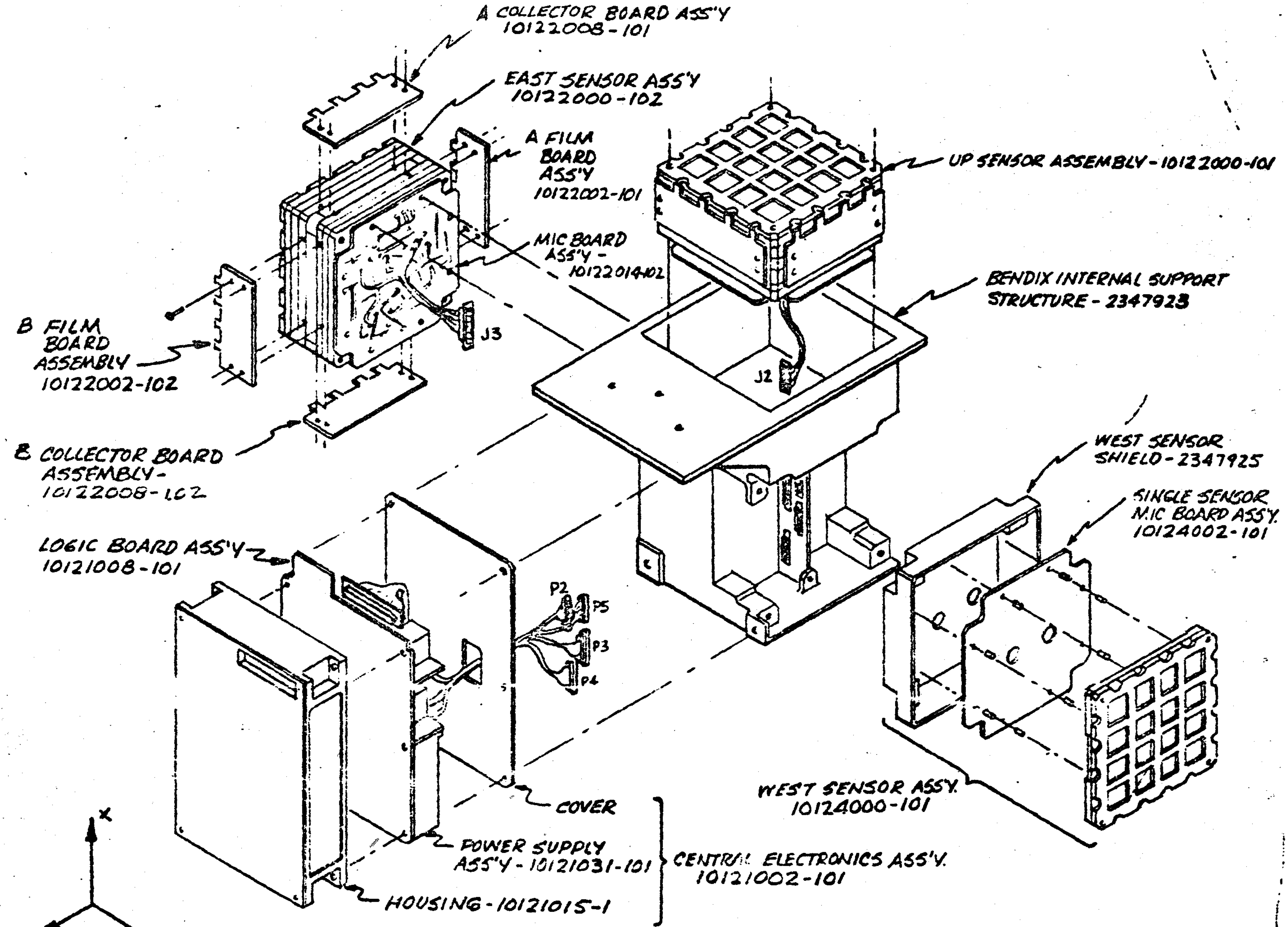


LEAM ASSEMBLY- 10120003-101

FIG. 3.2-1

Experiment Thermal Properties

1. External Structure: - Painted on outside with S13G thermal paint (α_s/ϵ_H = 0.2/0.9). Inside surfaces covered with aluminized tape.

2. Internal Structure: - Sensor cavities painted with 3M Velvet Coat (ϵ_H = 0.9). Surfaces facing superinsulation bag covered with aluminized tape.

3. Radiator: - Five square inches of second surface mirrors exposed to space (α_s[1]$/\epsilon_H$ = .07/.80) and mounted to a 60 mil aluminum plate.

4. Radiator Masking: Twenty-one layers of 1/4 mil aluminized Mylar separated by 20 layers of silk separators. Blanket enclosed by single layers of 2 mil aluminized Teflon. Outer layer has Teflon side out (α_s/ϵ_H = .20/.69) and inner layer has aluminized side facing experiment (ϵ_H = .05).

5. Corner Support Masking: Same construction as above.

6. Thermal Bag: Forty-one layers of 1/4 mil aluminized (both sides) Mylar separated by 40 layers of silk separators. Outside layer is 5 mil aluminized Kapton with aluminized side out. Inside layer is 2 mil aluminized Kapton with aluminized surface facing internal structure. (ϵ_H = .05)

7. Up and East Sensor Forward Films: A laminate consisting of 3050 angstroms of Parylene coated with 700 angstroms of aluminum covered by 3250 angstroms of silicon oxide (α_s/ϵ_H = .25/.1).

8. Up and East Sensor Rear Films: Three mil molybdenum foil sand blasted (ϵ_H = .06).

9. West Sensor Film: Three mil molybdenum foil coated with vacuum deposited aluminum (α_s/ϵ_H = .10/.03).

10. Up and East Sensor Outboard Suppressor Grids: Outside face covered with aluminized tape.

11. East Sensor Film Shields: Faced with aluminized tape (76%) and S13G paint (24%) (average α_s/ϵ_H = .124/.254).

12. West Sensor Suppressor Grid: Outside face covered with aluminum tape (76%) and S13G paint (24%).

13. Up and East Sensor Frames with Visibility of Sun: Painted with S13G.

14. West Sensor Frames: Covered with aluminum tape (76%) and S13G paint (24%).

15. Grid and Film Frames with NO Visibility of Sun: Painted with 3M velvet coat.

16. External Hardware Including the Bubble Level, UHT Socket, and Legs: Painted with S13G.

17. Dust Covers:

    Mirrors: Two, 2 mil aluminized Teflon layers bonded with aluminum surfaces together. Two negator springs placed between layers.

    East Sensor: Identical to mirror cover.

    Up and West Sensor: Identical to mirror cover except that outer layer is 1 mil aluminized Kapton. A white plastic adhesive strip is used for the alignment marking area.

Heater distribution for the qualification model is as follows:

1. East Sensor Nominal

   A 0.60 watt heater located on the internal structure behind the East sensor rear electronics.

2. West Sensor Nominal: A 1.90 watt heater located on the rear of the West Sensor electronics shield.

3. West Sensor Survival: A 1.15 watt heater located next to 2 (above).

4. Radiator Nominal: A 0.60 watt heater located on the internal structure near the radiator and south of the central electronics.

5. Radiator Survival: A 0.3 watt heater located next to 4 (above).

6. Structure Survival: A resistor dissipating 0.35 watts located on terminal board.

Parylene Film Vacuum Deposited with Aluminum

SOLAR ABSORPTANCE

Angle of Incidence (degrees)	Solar Absorptance (α_s)
20	$.27_8$
45	$.29_3$
60	$.30_6$
75	$.33_4$

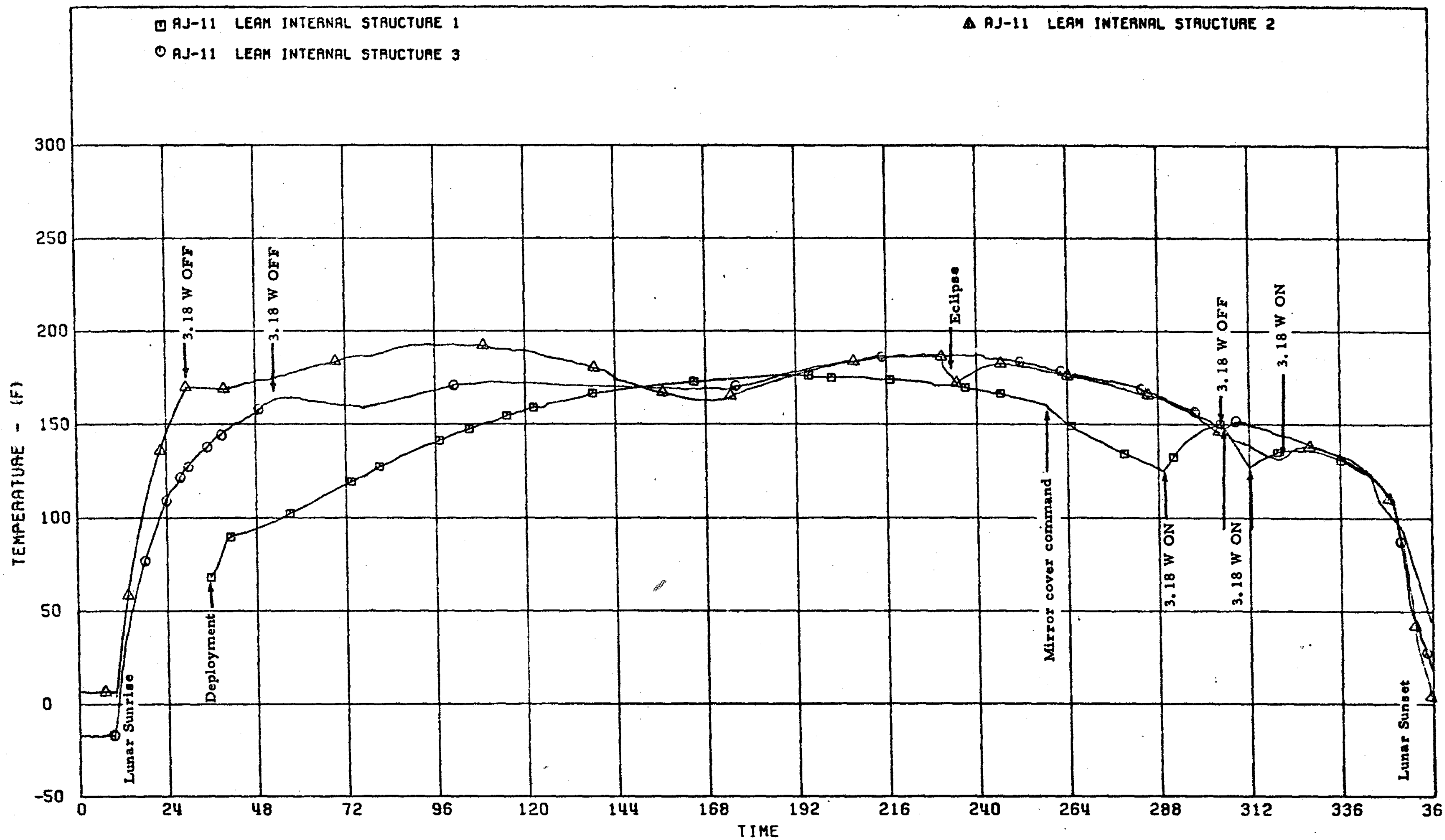
EMITTANCE

Directional Emittance				Hemispherical Emittance (ϵ_H)
A = 20°	A = 45°	A = 60°	A = 68°	
0.08_8	0.11_0	0.15_6	0.19_4	0.13_3

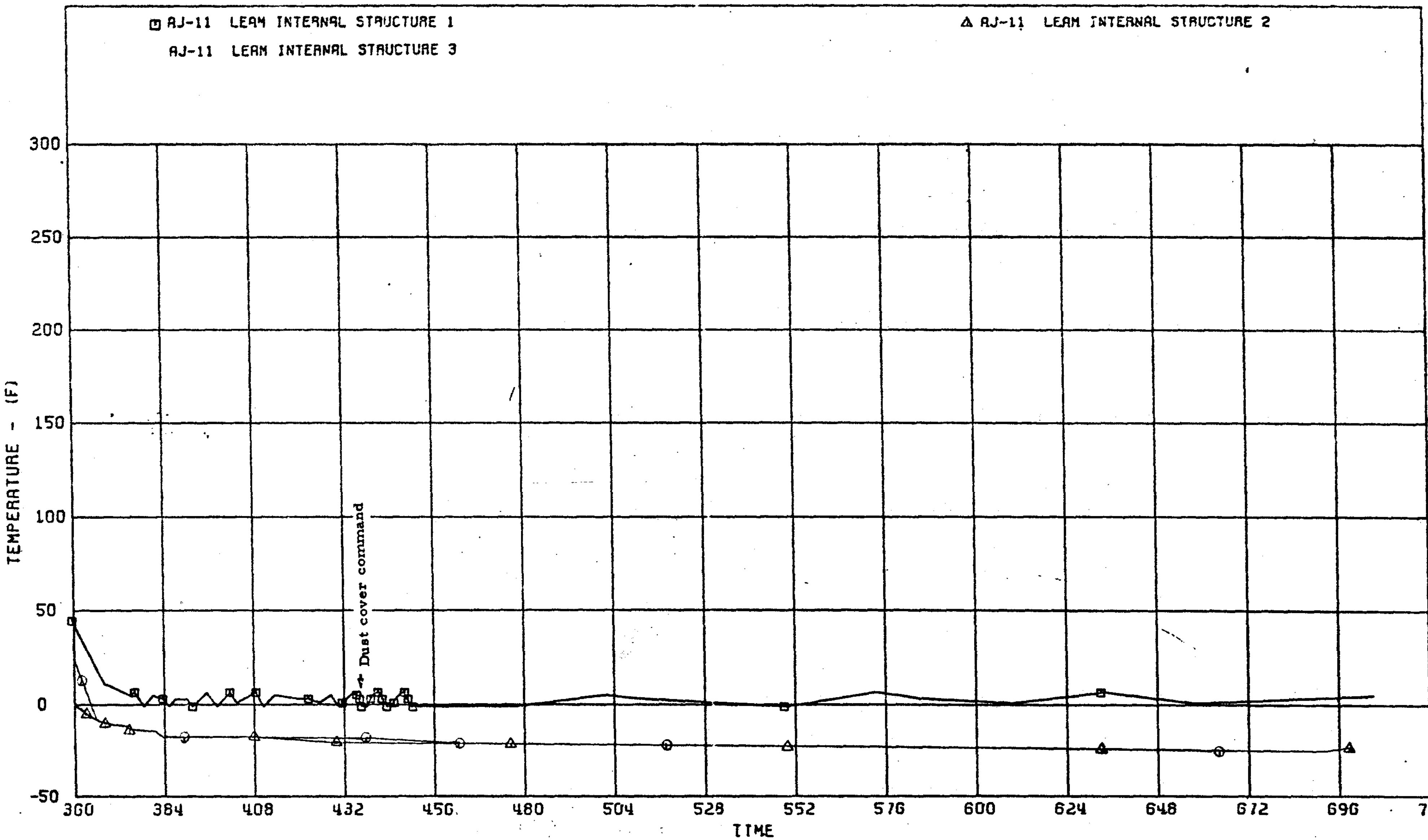
LEAM Power Dissipation

	Power (Watts)	Notes
Functional	2.99 3.18 3.40	@ +150°F @ +68°F @ -22°F
Heater	3.20	(0-9°F) Control Range
Total	6.6	(3.4 + 3.2) Watts
Contingency	0.21	Commandable
Standby	4.96	1.8 Fixed + 3.2 Controlled

BENDIX AEROSPACE SYSTEMS DIVISION
APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ARRAY E - APOLLO 17)
FIRST, SECOND AND THIRD LUNAR DAYS



BENDIX AEROSPACE SYSTEMS DIVISION
APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ARRAY E - APOLLO 17)
FIRST, SECOND AND THIRD LUNAR NIGHTS



LEAM ANOMALY INVESTIGATION

NUMBER	OBSERVATION	DETAILS	COMMENTS
1	LEAM cooling rate increased when radiator cover was removed.	Prior to cover removal at 130° sun angle during the first lunar afternoon the LEAM cooling rate was -0.5°F/hr. After cover removal the cooling rate increased to -2.5°F/hr.	The increased cooling rate demonstrated a successful radiator cover removal.
2	No change in LEAM thermal performance during first lunar night prior and subsequent to sensor cover firing on day 363/1957 GMT.	Prior to cover removal AJ11 varied between temperature limits of +6.4°F to -1.3°F. One complete heater cycle required 6 hours, 35 minutes. Subsequent to cover removal one complete heater cycle required 6 hours, 30 minutes.	Probably the sensor cover squibs fired but the covers did not retract. Second day and night thermal performance for the LEAM is significantly different than first day indicating that the sensor dust covers retracted during 2nd lunar morning. Also the chamber night performance (covers off) of continuous heater power and -12°F structure temperature was not achieved.
3	Excessive LEAM warm up rate of 16°F/hr during second morning.	LEAM warm up rate for an insulated thermal mass is 9.2°F/hr for the 6.49 watt night time dissipation and 4.5°F/hr for the 3.18 watt day time dissipation.	The implication is that in addition to electronic power dissipation, LEAM absorbs a considerable heat load from the environment probably through the east sensor. If the heater is off, approximately 9 watts of environmental heat load is absorbed.
4	Structure temperature is higher for dust covers off than for dust covers on.	LEAM temperatures were a maximum of 85°F cooler for the first morning (covers on) as compared to the second morning (covers off). Afternoon data exhibits the same trend.	The east cover is aluminized teflon outside (α/ϵ = .2/.7) and the top and west cover is aluminized Kapton outside (α/ϵ = .40/.57). Both surfaces run cooler than the exposed sensor surfaces whose α/ϵ = 2.5
5	Significant eclipse cool-down rate during second day.	LEAM cool down rate with the electronic power off is 3°F - 4°F during second day eclipse.	The LEAM thermal time constant is small and the experiment is in quasi-state thermal equilbrium.
6	Heater is constantly on during second lunar night.	LEAM structural temperature stabilized at -20°F during the second lunar night. Qual and flight structure temperatures were -10°F and -12°F, respectively. In all cases the heater was on constantly.	The cold lunar night temperature is to be expected due to differences between the chamber and lunar surface. Considering the colder lunar environment the -20°F structure temperature may not be unreasonable.
7	Third morning warmup rate is significantly less than the second morning rate.	At 15° sun angle the 2nd day and 3rd day survival operating temperatures were 170°F and 120°F, respectively.	Dust accretion may have changed the sensor α/ϵ

Historical Summary of LEAM Experiment Development Program

The following is a chronological listing of the major tests performed on the LEAM experiment during the development programs. The significant meetings held during the period are also identified.

1. 16-17 February 1971, Preliminary Design Review
2. March 1971, Design Verification Test Model, Phase I, Thermal Test
3. 15-18 June 1971, Critical Design Review
4. June-July 1971, DVT Model, Phase II, Mechanical Test
5. November 1971, Program Review
6. February 1972, Program Review
7. May 1972, Flight Model, Acceptance Vibration
8. May-June 1972, Qual. Model, Thermal Vacuum Test, System Level
9. June 1972, Qual. Model, Vibration Tests, System Level
10. June 1972, Thermal Design Review at Bendix and MSC
11. July 1972, Flight Model, Thermal Vacuum Test, System Level
12. 18-20 September 1972, Customer Acceptance Review (CARR)
13. 20-21 September 1972, Qual. Model Acceptance Review (QAR)
14. September 1972, Taurus-Littrow Site Evaluation

EXPERIMENT TEST DATA

	DVT		QUAL		FLIGHT
	Acceptance Level	Increased Sun Condition	Acceptance Level	Design Limit	Acceptance Level
Flux source	Carbon Arc	Carbon Arc	IR	IR	IR
Flux incident on S/S Mirrors (watts/ft^2)	130	Up to 182	130 (546)	430.3	340.3
Flux incident on Parylene Film (watts/ft^2)	130	Up to 182	4.68 (78.0)	48.0	30
Power (watts)	a) 2 b) 3 c) 4	3	3.17	3.17	3.17
Lunar Surface Temp (^oF)	250 ± 10	250 ± 10	250 ± 10	250 ± 10	250 ± 10
Cold Wall (^oF)	-300 ± 10	-300 ± 10	-300 ± 10	-300 ± 10	-300 ± 10
Chamber Pressure (Torr)	$< 1 \times 10^{-5}$	$< 1 \times 10^{-5}$	2.6×10^{-7}	2.5×10^{-7}	3×10^{-7}

Lunar Ejecta and Meteorites Experiment

Configuration Differences

1) Design Verification Test Model to Qual and Flight Models.

   a) Redesign of the interface bracket from fiberglass instead of titanium.

   b) Movement of the squib attach points to the external structure.

   c) Movement of the bubble level away from the interface bracket.

   d) Redesign of the East and West sensor openings to cover the frame edges.

   e) Redesign of the masking to cover the thermal bag flange which is now part of the interface bracket.

   f) Front film thickness increased to 3050 Å parylene.

   g) Front film frame has foam strips added to both sides.

   h) Thermal mask over radiator changed to leave 5 square inches of mirror uncovered.

   i) Dual sensor suppressors changed to aluminum tape on outer frame.

   j) Sensor wiring changed to manganin on outer frame.

   k) Bottom of outer structure changed from aluminum to S13G paint.

2) Qual Model to Flight Model - No differences.

Test Verification

All changes were verified during Qual and Flight Acceptance testing and Qual design limit testing.

Film Development Criteria

Objectives

The objectives of the program, as defined by the Statement of Work were:

a. To develop a thin Parylene C film laminate and structural attachment which will withstand the prelaunch, test, storage and translunar flight environments, and perform normally for two years under lunar environmental conditions.

b. To develop a thin Parylene C film laminate and structural attachment which will yield a maximum supply of ions and electrons when impacted by hypervelocity microparticles.

c. To develop a thin Parylene C film laminate and structural and attachment which will satisfy (a) and (b) and result in the smallest mass cross section; thus minimizing the microparticle kinetic energy threshold for penetration of the film.

4.0 Conclusions

The conclusions made from the evaluations are that:

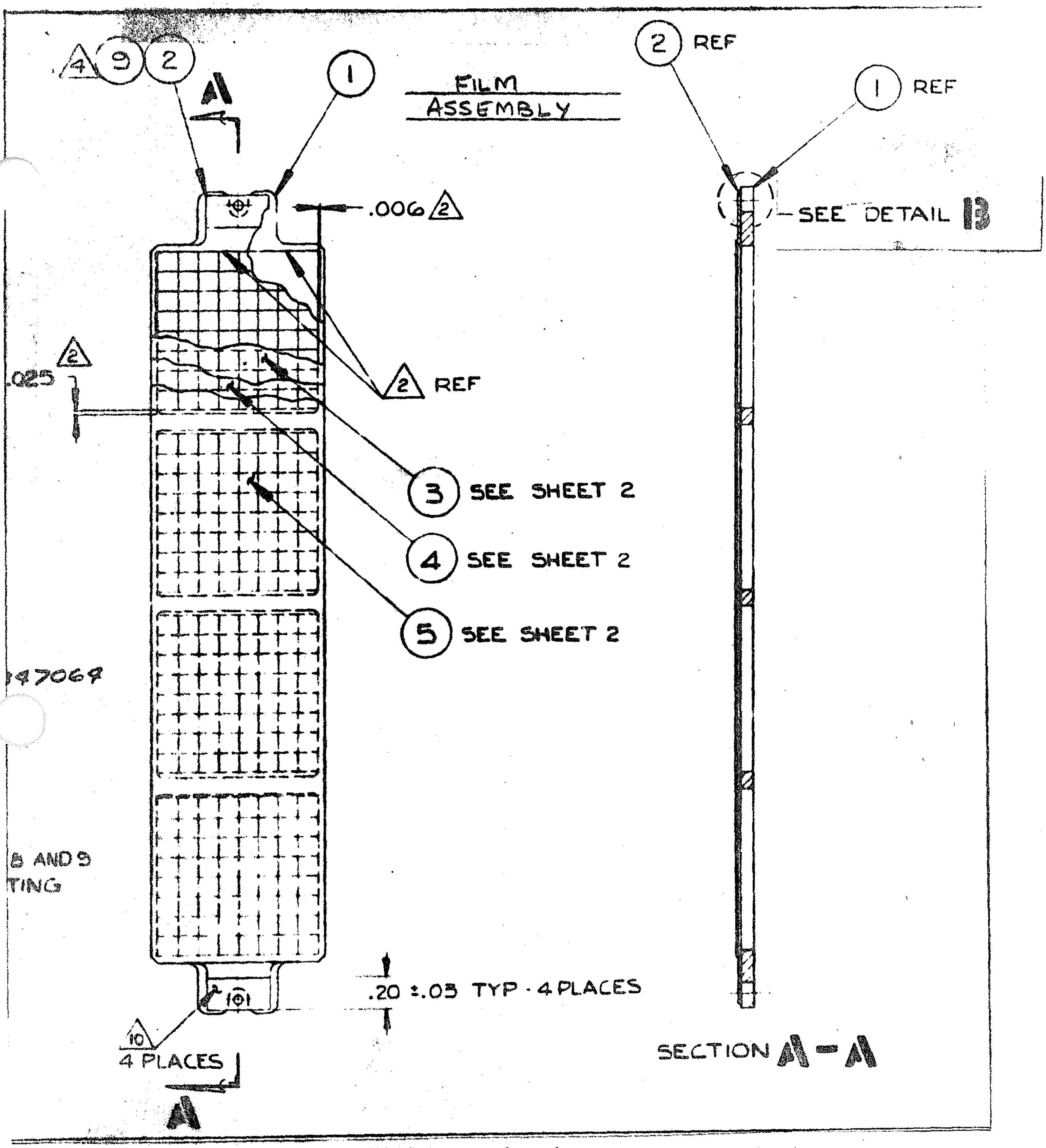
a. The deposit should be 3000 to 4000 Angstrom units thickness of Silicon oxide over 600 to 700 Angstrom units of Aluminum on a 2800 to 3300 Angstrom units thick Parylene substrate. The laminate is to be mounted on a 97% transparent, beryllium copper grid. The aluminum and Silicon oxide are to be vacuum deposited while the Parylene C and grid are free standing on frames. This laminate has the optical and thermal properties required to endure the lunar environment and to allow thermal control of the experiment electronics.

b. A support grid is required to provide mechanical strength and to provide thermal conductivity from the film to the film support frame.

c. The deposition provides adequate ionized plasma upon impact by a hypervelocity particle.

d. Free standing deposition resulting in slightly wrinkled film is desirable for low temperature survival.

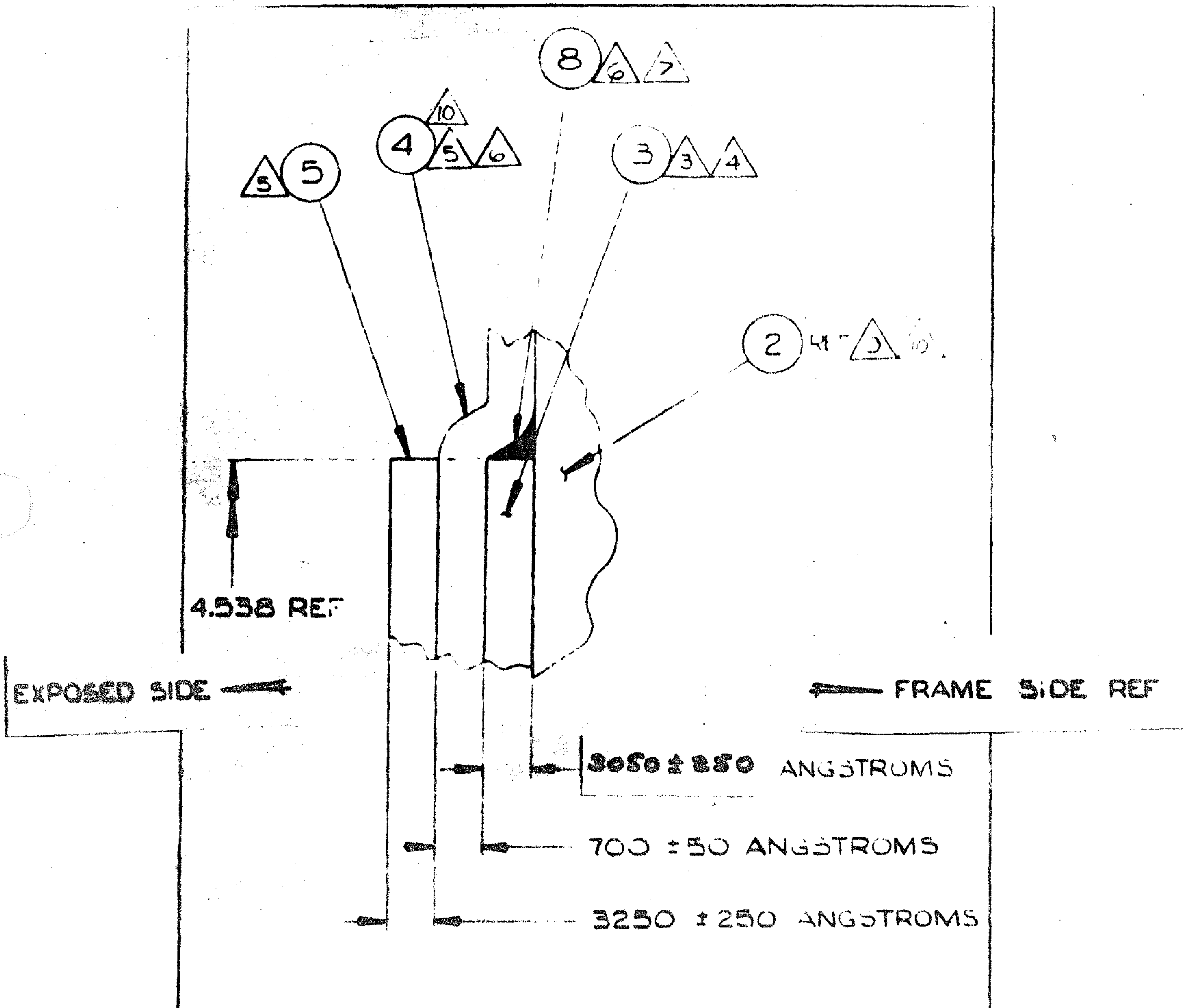
Film Assembly - See attached Figures.



QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM
AR	ADHESIVE		SILASTIC 140	9
AR	ADHESIVE		ECCOBOND 56C	8
				7
				6
1	SILICON OXIDE		2347938-3	5
1	ALUMINUM		2347938-2	4
1	PARYLENE		2347938-1	3
1	GRID, COLLECTOR, ETCHED		2347934	2
1	FRAME, 1x4 MOLDED		2347330-1	1

LIST OF MATERIALS

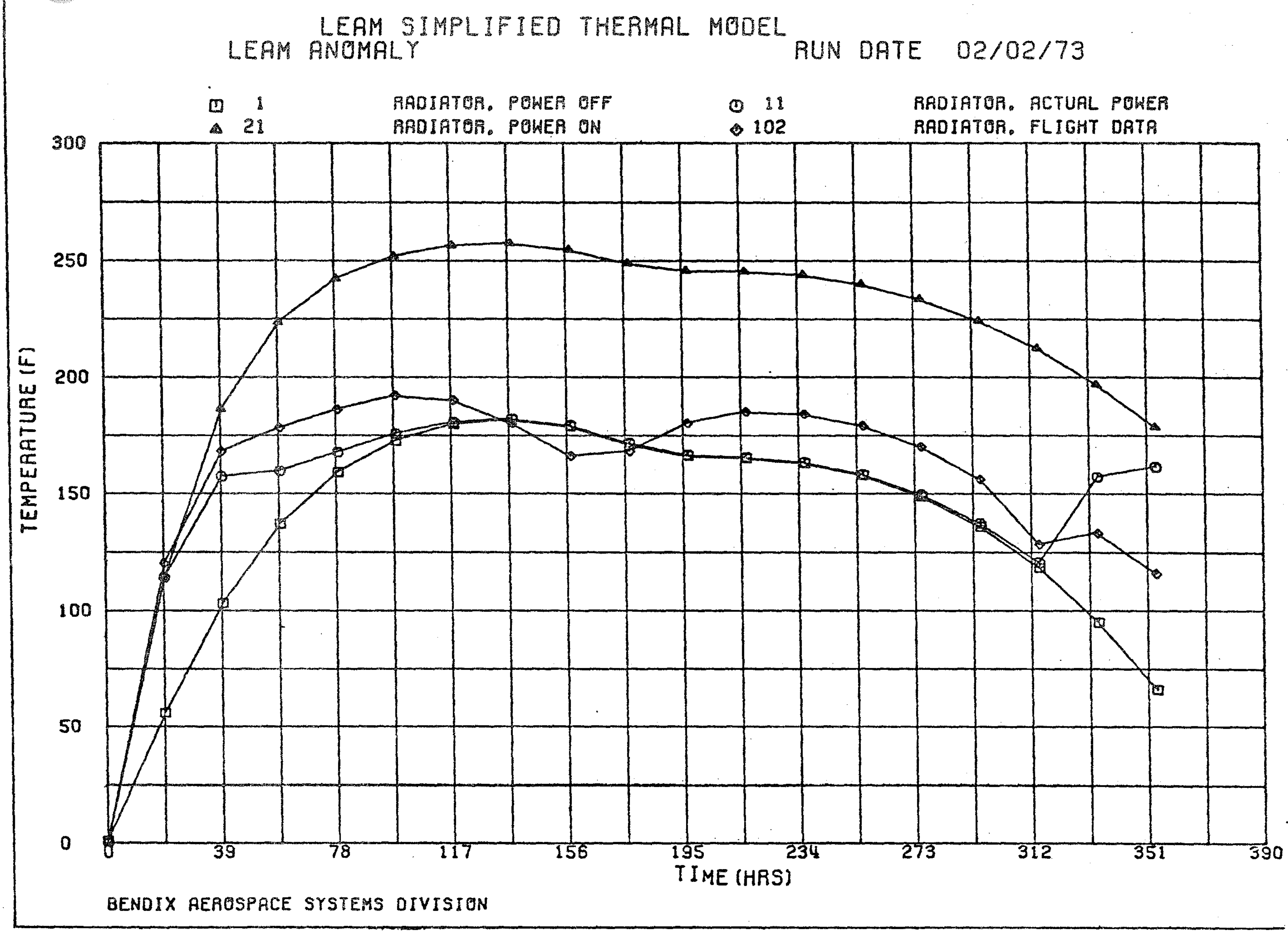
LAMINATE CONSTRUCTION



DETAIL B TYP 2 PLACES
SCALE: NONE

THERMAL MATH MODEL

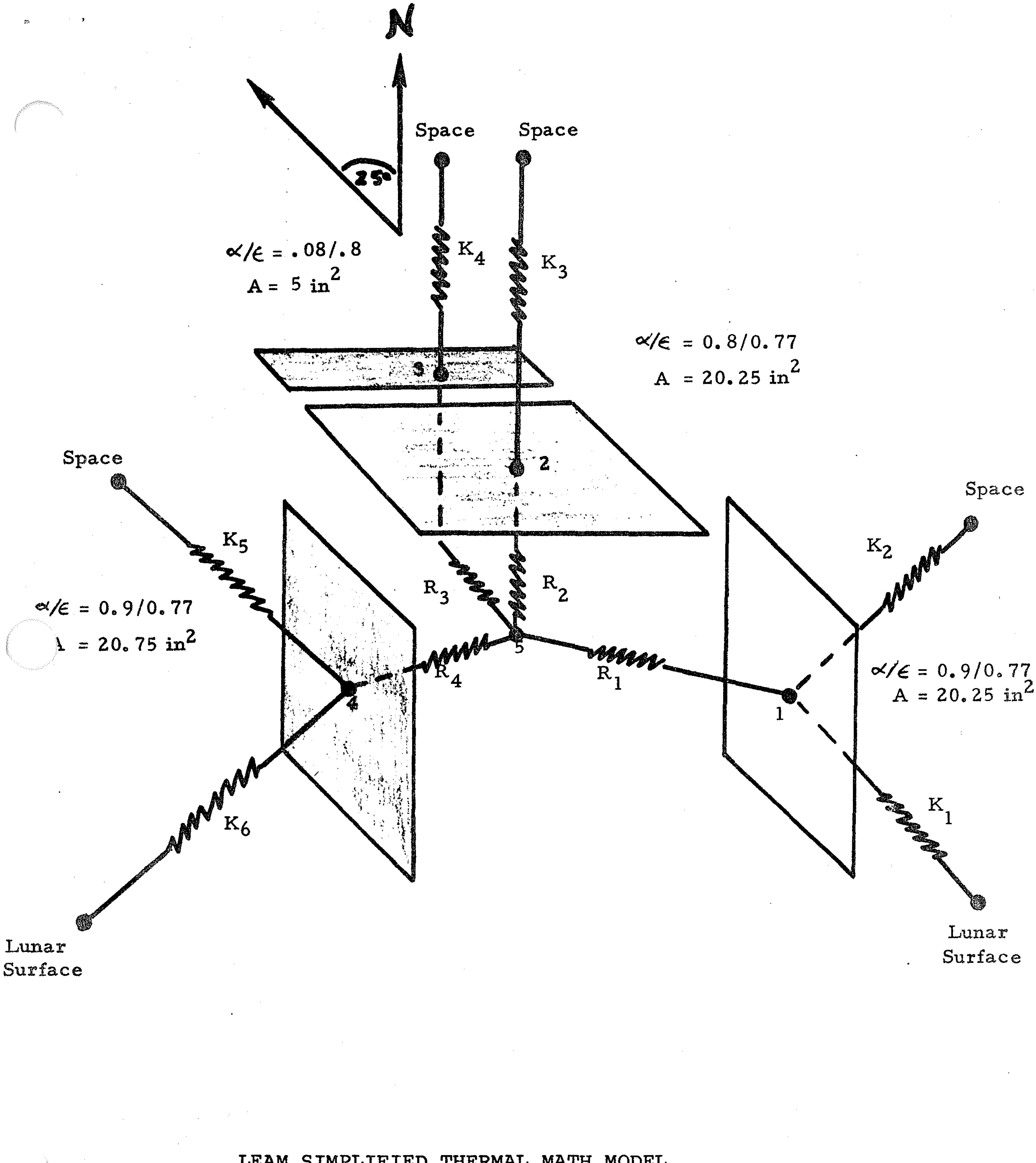
CORRELATION WITH LUNAR DATA


LEAM SIMPLIFIED THERMAL MODEL
LEAM ANOMALY
RUN DATE 02/02/73
1 RADIATOR, POWER OFF
21 RADIATOR, POWER ON
11 RADIATOR, ACTUAL POWER
102 RADIATOR, FLIGHT DATA
TEMPERATURE (F)
300
250
200
150
100
50
0
0
39
78
117
156
195
234
273
312
351
390
TIME (HRS)
BENDIX AEROSPACE SYSTEMS DIVISION

LEAM ANOMALY INVESTIGATION

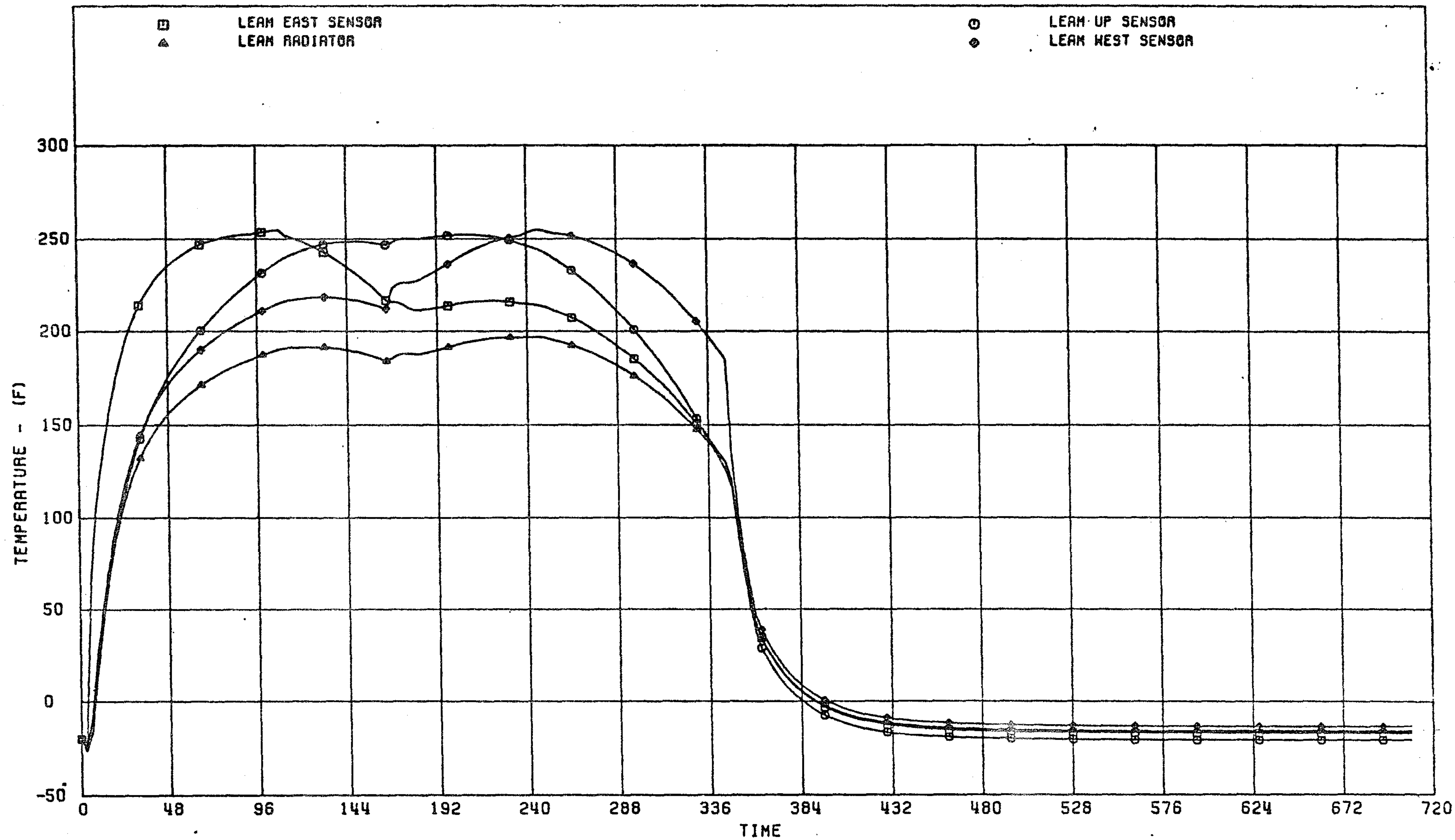
SIMPLIFIED MATH MODEL RESULTS

Solar Angle (degrees)	Time (hrs.)	No Electronic Power		Actual Electronic Power		Electronic Power On	
		Radiator Temp (°F)	Sensor Temp (°F)	Radiator Temp (°F)	Sensor Temp (°F)	Radiator Temp (°F)	Sensor Temp (°F)
0	0.0	1.00	1.00	1.00	1.00	1.00	1.00
10	19.67	55.80	123.60	113.97	186.69	113.99	186.70
20	39.34	102.85	170.60	157.08	206.62	186.16	246.18
30	59.01	136.76	202.45	159.55	216.86	223.43	276.91
40	78.68	158.97	223.20	167.63	228.36	242.12	293.53
50	98.34	172.50	234.72	175.44	236.36	251.73	301.76
60	118.01	179.65	239.33	180.56	239.83	256.31	304.28
70	137.68	181.64	237.50	182.02	237.82	257.24	302.54
80	157.35	178.62	228.72	179.09	229.27	254.68	295.31
90	177.02	170.97	214.49	171.75	215.39	248.93	283.36
100	196.69	166.13	214.59	166.65	214.87	245.66	284.23
110	216.36	165.13	213.91	165.45	214.13	245.29	283.74
120	236.03	163.02	210.01	163.36	210.30	243.82	280.81
130	255.70	157.72	200.62	158.29	201.27	239.90	273.47
140	275.35	148.64	186.65	149.56	187.66	233.32	262.43
150	295.01	135.72	167.28	137.07	168.78	224.22	247.88
160	314.66	118.36	142.58	120.57	148.93	212.33	229.65
170	334.29	94.90	108.42	157.01	177.94	196.72	205.03
180	353.93	66.06	71.54	161.39	168.14	178.50	180.11

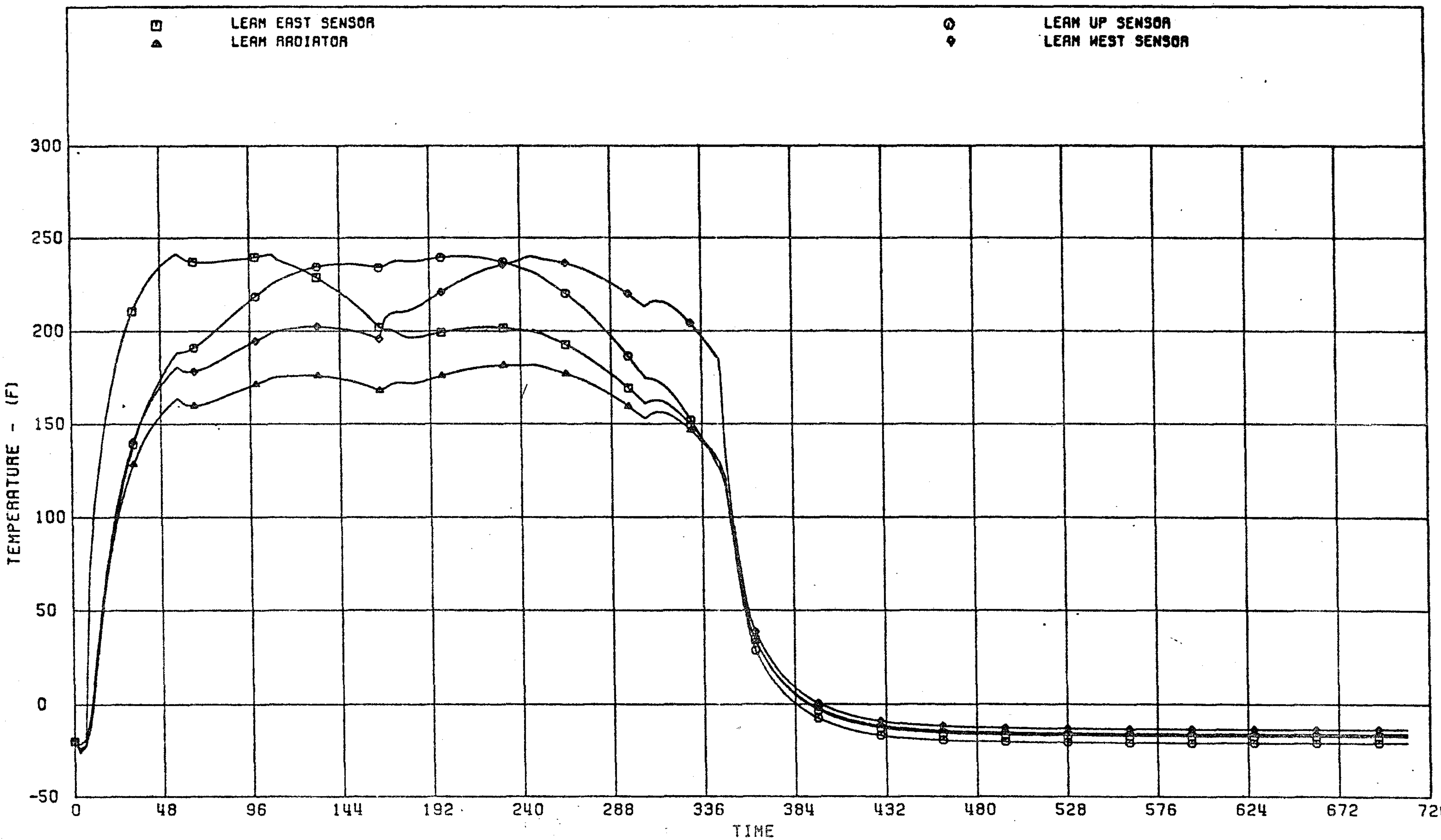


LEAM SIMPLIFIED THERMAL MATH MODEL

BENDIX AERO[illegible]CE SYSTEMS DIVISION
APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ARRAY E - APOLLO 17)
3.18 WATTS POWER DAY

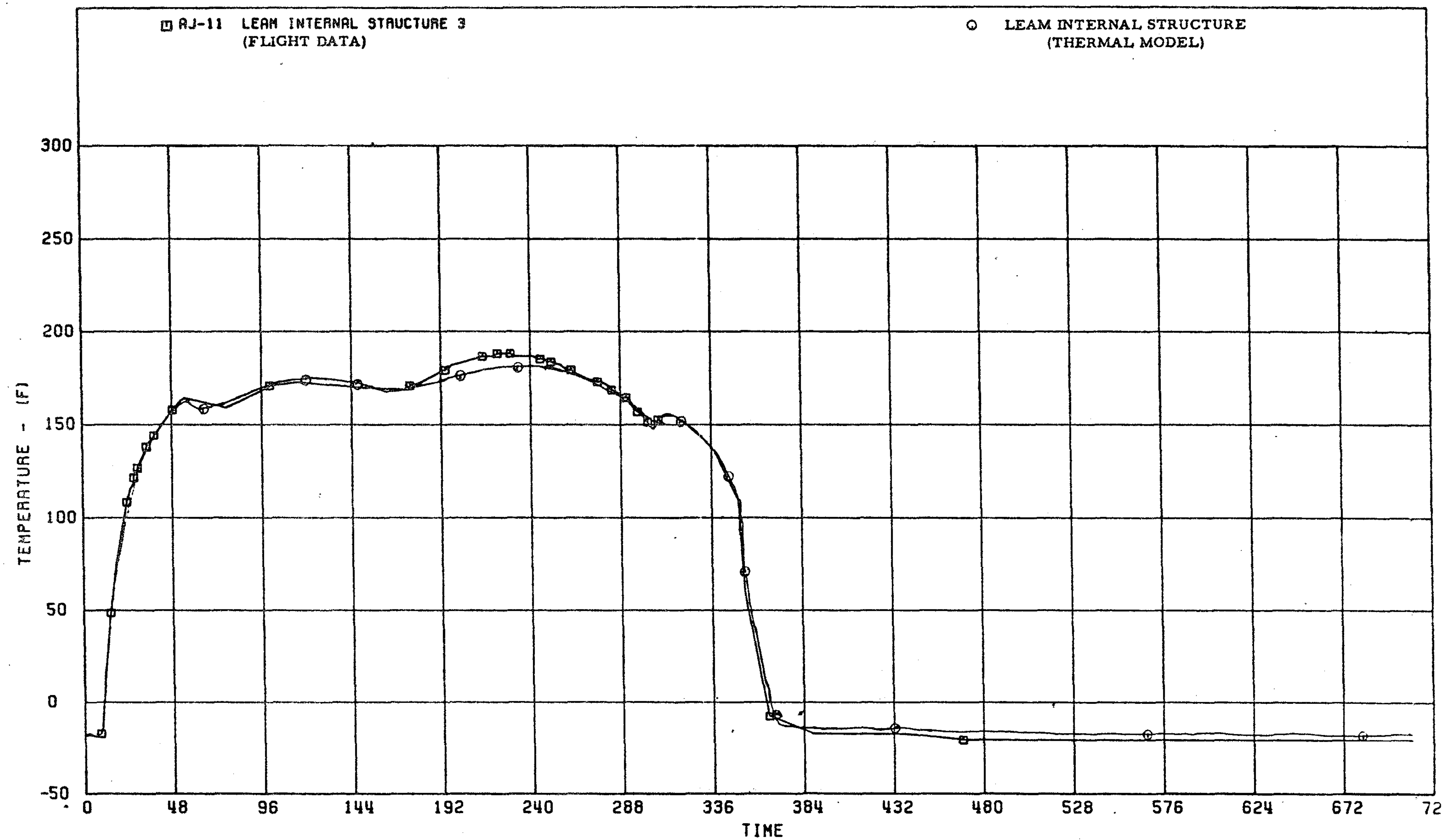


BENDIX AEROSPACE SYSTEMS DIVISION
APOLLO LUNAR SURFACE EXPERIMENTS PACKAGE (ARRAY E - APOLLO 17)
THIRD DAY CORRELATION



15

BENDIX AE[illegible]ACE SYSTEMS DIVISION
APOLLO LUNAR SURFACE EXPE[illegible]ENTS PACKAGE (ARRAY E - APOLLO 17)
THIRD LUNAR DAY



LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE

POTENTIAL CAUSES OF DISCREPANCY BETWEEN OBSERVED AND PREDICTED FLIGHT PERFORMANCE ARE AS FOLLOWS:

- ACTUAL THIN FILM THERMAL/OPTICAL PROPERTIES DIFFERENT FROM THOSE ASSUMED IN MODEL
- BOOST FAILURE OF FILMS (ACOUSTICAL/PRESSURE/VIBRATION INDUCED)
- ANOMALOUS DEPLOYMENT
- EXPERIMENT MISLEVELING/MISALIGNMENT CAUSED BY COVER RELEASE
- FAILURE OF COVERS TO RELEASE
- HEATER ON DURING DAY
- TAURUS LITTROW SITE EFFECTS
- DUST ACCRETION ON SENSOR AND/OR RADIATOR
- ERRORS IN TELEMETERED TEMPERATURE DATA

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE ERRONEOUS THIN FILM OPTICAL PROPERTIES

- MEASURED FILM OPTICAL PROPERTIES

TEST FACILITY	α_s	ϵ_{irh}	ϵ_{irn}
NBS	0.26	N/A	0.05
BxA	0.25	0.1 - 0.13	N/A
IIT	0.31	N/A	N/A
TRW	0.278	0.13	0.08 - 0.19

- IN ORDER FOR FILMS TO MELT* α/ϵ MUST DEGRADE FROM $\alpha/\epsilon = 2.5$ TO $\alpha/\epsilon = 3.8$, AN APPROXIMATE CHANGE OF 50% (SEE FIGURE 1).

- FIGURES 2 AND 3 DEPICT FILM STABILIZATION TEMPERATURE DEPENDENCE ON SOLAR ABSORPTIANCE AND INFRARED EMITTANCE.

- RESULTS OF THERMAL ANALYSIS SHOW THAT BERYLLIUM/COPPER FILM SUPPORT GRID BONDED TO S-13G FORWARD FILM FRAME WILL LOWER FILM α/ϵ of 2.5 TO 1.2.

FIGURE 1

LEAM ANOMALY INVESTIGATION

SENSOR FILM STABILIZATION TEMPERATURE VERSUS SOLAR ABSORPTANCE/INFRARED EMITTANCE RATIO

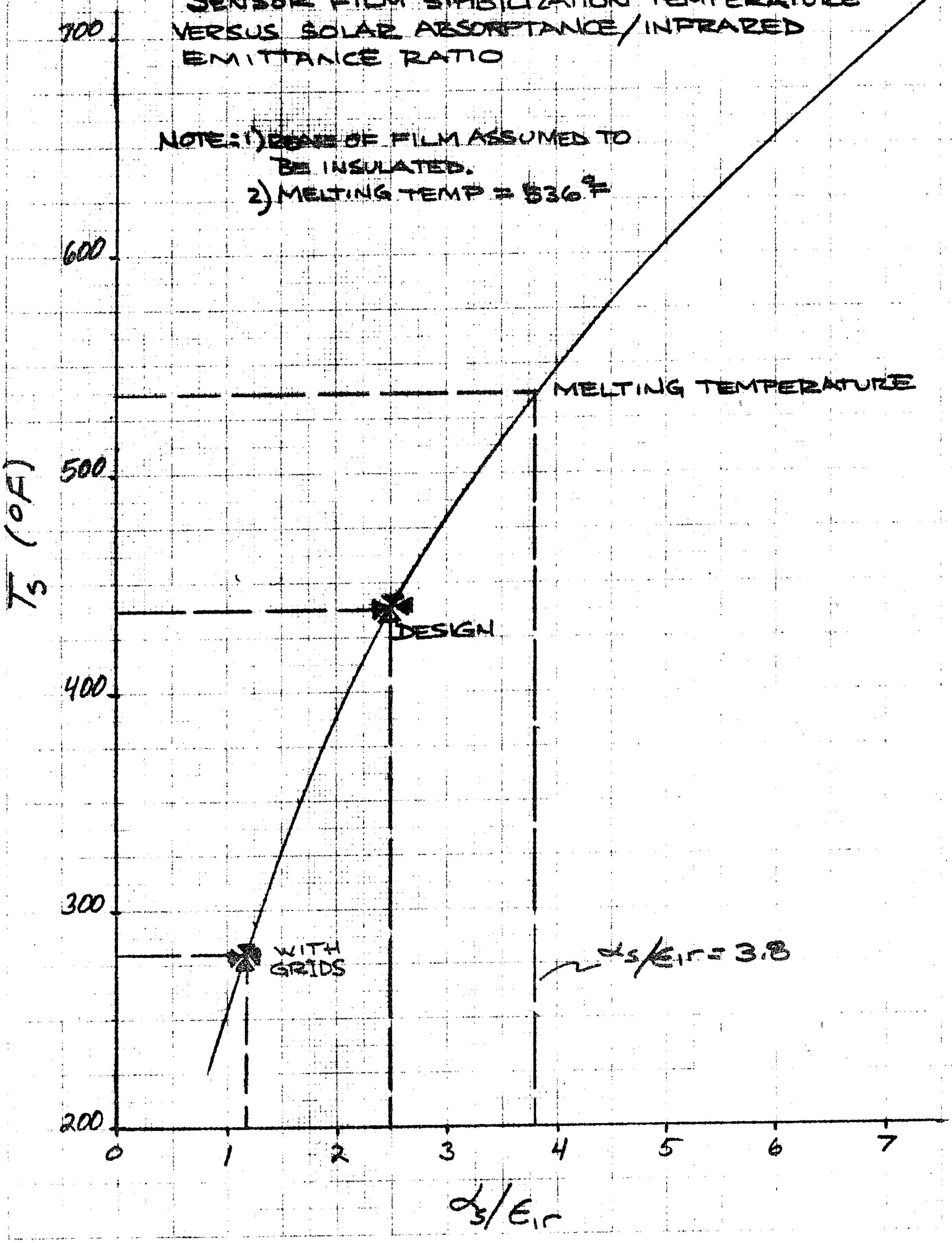


FIGURE 2

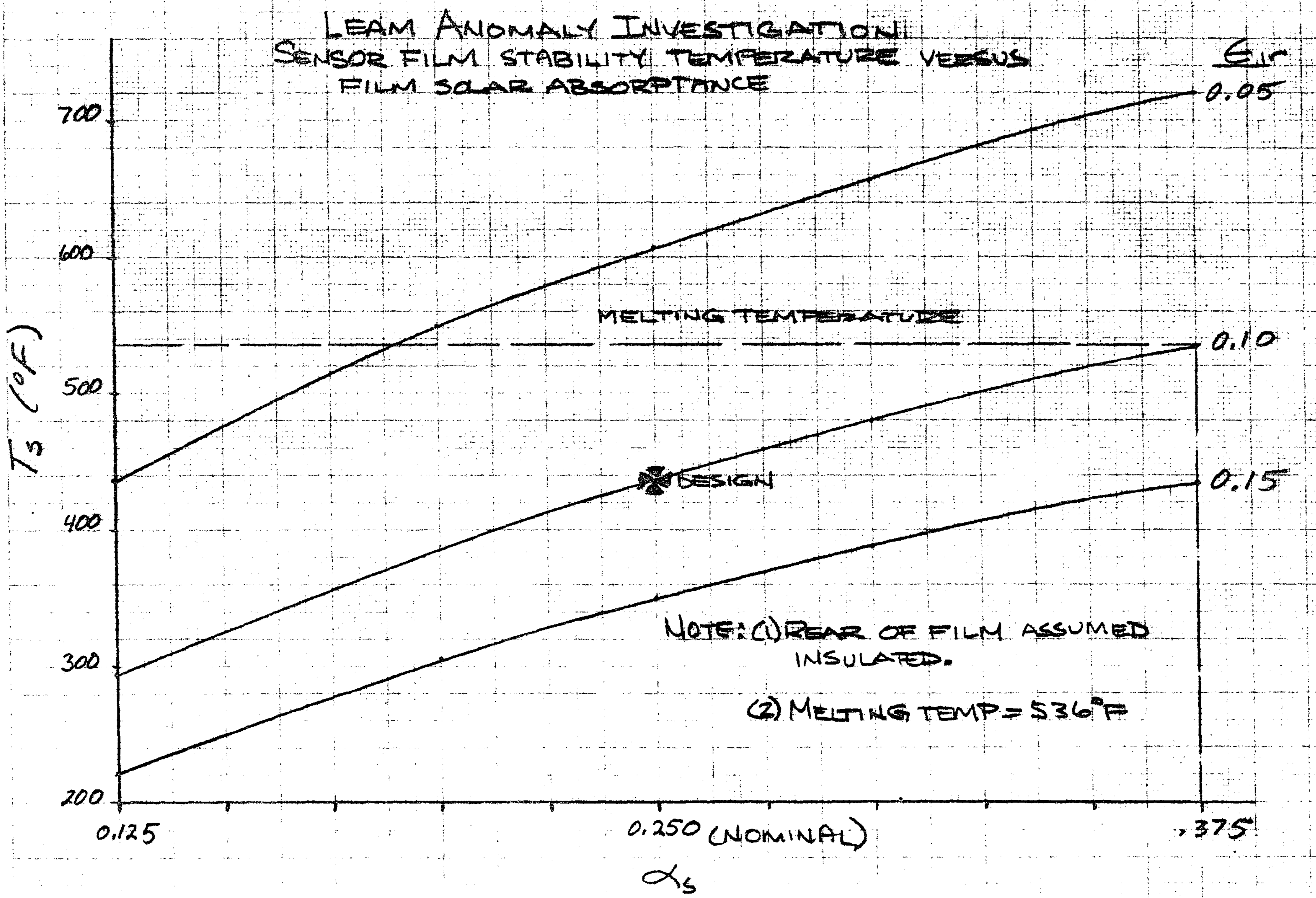
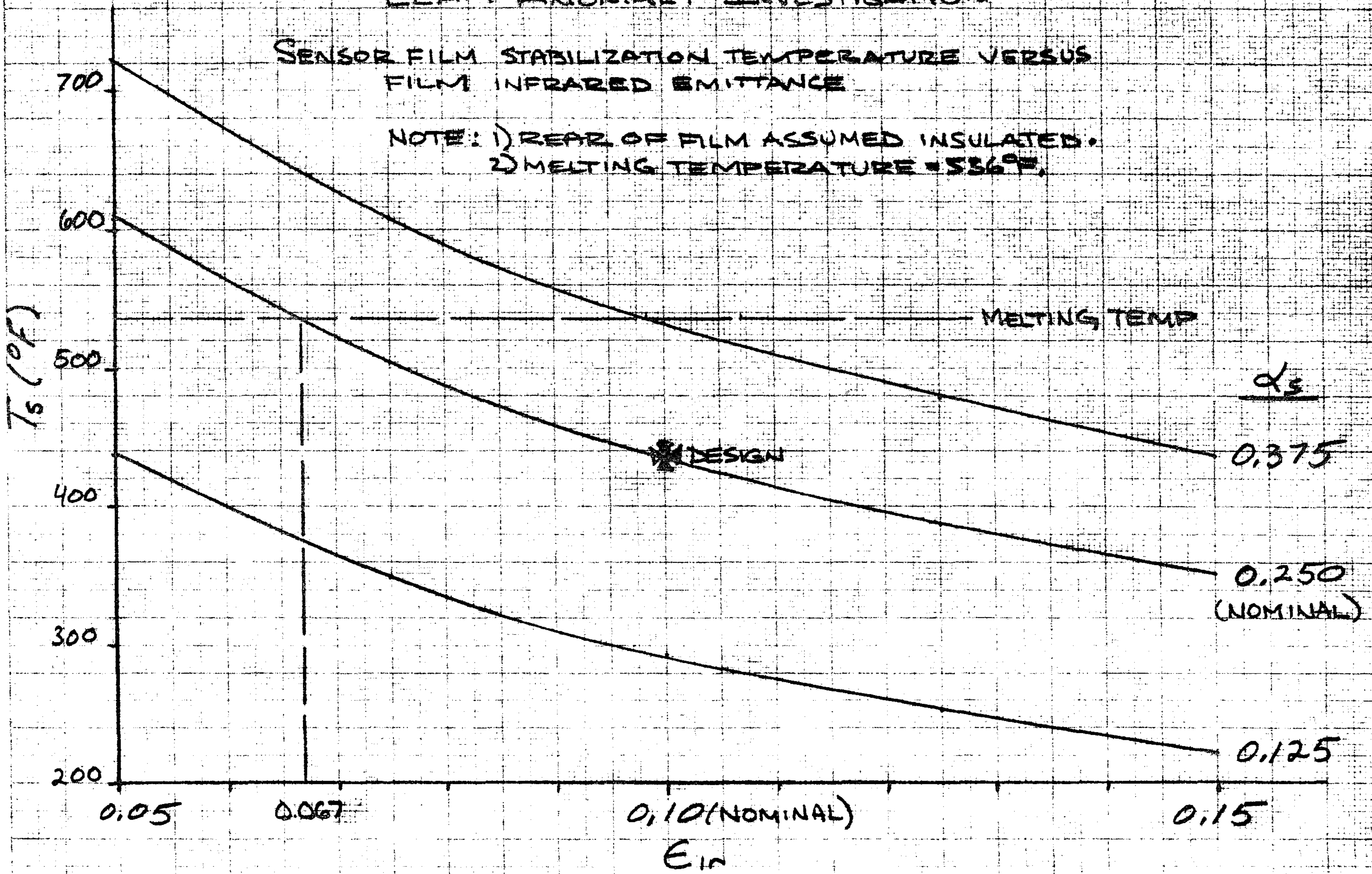

LEAM ANOMALY INVESTIGATION
SENSOR FILM STABILITY TEMPERATURE VERSUS
FILM SOLAR ABSORPTANCE
ϵ_{ir}
0.05
0.10
0.15
MELTING TEMPERATURE
DESIGN
NOTE: (1) REAR OF FILM ASSUMED INSULATED.
(2) MELTING TEMP = 536°F
700
600
500
400
300
200
T_s (°F)
0.125
0.250 (NOMINAL)
.375
α_s

FIGURE 3

LEAM ANOMALY INVESTIGATION

SENSOR FILM STABILIZATION TEMPERATURE VERSUS FILM INFRARED EMITTANCE

NOTE: 1) REAR OF FILM ASSUMED INSULATED.
2) MELTING TEMPERATURE = 536°F.



LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE

BOOST FAILURE OF FILMS

- ACOUSTICAL

  PIONEER ACOUSTICAL LOAD 141 db PEAK.
  SATURN ACOUSTICAL LOAD 138 db PEAK.
  ACOUSTICAL LOAD INCIDENT ON LEAM SENSOR IS FURTHER ATTENUATED BY OVERALL AND SENSOR DUST COVERS TO 135 db.

- VIBRATION

  IF FILM IS MOUNTED TO BERYLLIUM COPPER GRID (P/N 2347935), 1 X 1 INCH FILM WINDOWS WILL WITHSTAND DESIGN LIMIT RANDOM VIBRATIONS.

- PRESSURE

  LOCALIZED FILM RUPTURE MAY OCCUR AT PRESSURE DIFFERENTIALS OF GREATER THAN 2 PSI. CROSSECTIONAL LEAKAGE AREA OF 1.7 IN^2 IS SUFFICIENT TO PREVENT FILM RUPTURE.

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE

ANOMALOUS DEPLOYMENT

- MSC-07629 (APOLLO TECHNICAL AIR-TO-GROUND VOICE TRANSCRIPTION) AT GET 04/21/24/54 LMP REPORTED "THE LEAM'S DEPLOYED, ALIGNED; AND THE BUBBLE LEVEL IS JUST TOUCHING THE INNER RING".
- ON 10 JANUARY 1973 AT THE CREW SYSTEMS DEBRIEFING, SCHMITT INDICATED LEAM DEPLOYMENT TO BE NOMINAL.
- PHOTOGRAPH #28174 SHOWS LEAM TO BE DEPLOYED FREE OF DUST.

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE

EXPERIMENT MISLEVELING/MISALIGNMENT CAUSED BY DUST COVER RELEASE

- DUST COVER ROLL-UP ACCOMPLISHED BY TWO NEG'ATOR B MOTOR SPRINGS (AMETEK-HUNTER CATALOG TYPE 20002).
- MAXIMUM COVER ROLL-UP FORCE = 1.62 LBS.
- UNLESS LEAM DEPLOYED IN A NEARLY UNSTABLE CONDITION (30° SLOPE) THE PACKAGE WILL REMAIN UNDISTURBED BY COVER ROLL-UP.

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF LEAM EXCESSIVE TEMPERATURES

FAILURE OF COVERS TO RELEASE

- FLIGHT VERSUS TEST DATA INDICATE THAT COVERS DID NOT RELEASE ON COMMAND DURING FIRST NIGHT.

CONDITION	SURVIVAL TEMP (AJ11)	HEATER
FLIGHT, PRIOR TO SENSOR COVER RELEASE	$-1.3^{\circ}F \leq T_s \leq 7.8^{\circ}F$	HEATER CYCLE 6 HR, 35 MIN
FLIGHT, AFTER SENSOR COVER RELEASE COMMAND	$-1.3^{\circ}F \leq T_s \leq 7.8^{\circ}F$	HEATER CYCLE 6 HR, 30 MIN
QUAL TEST, NIGHT	$-10^{\circ}F$	100% DUTY CYCLE
FLIGHT TEST, NIGHT	$-12^{\circ}F$	100% DUTY CYCLE

- COVERS RELEASED EARLY DURING SECOND DAY AS EVIDENCED BY:

  GENERALLY HIGH SECOND DAY STRUCTURE TEMPERATURES

  LOWER SECOND NIGHT STRUCTURE TEMPERATURE ($-20^{\circ}F$) AND 100% HEATER DUTY CYCLE

- POSSIBILITY OF PARTIAL COVER RELEASE

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF EXCESSIVE LEAM TEMPERATURE

HEATER ON DURING DAY

- INITIAL TEMPERATURE RISE DURING SECOND LUNATION WAS 10 - 16^{o}F/ HR.
- LEAM DATA PRINT OUT SHEET SHOWS HEATER TO BE IN OFF STATUS DURING THE DAY AND OPERATING CORRECTLY AT NIGHT, WHEN COMPARED WITH TEMPERATURE PROFILE.
- CENTRAL STATION MEASUREMENTS SHOW RESERVE POWER REDUCTIONS OF CORRECT MAGNITUDES FOR ON, OFF AND STANDBY WITH HEATER OFF.

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF LEAM EXCESSIVE TEMPERATURE

TAURUS LITTROW SITE EFFECTS

- NORTH MASSIF, SCULPTURED HILLS, EAST MASSIF AND SOUTH MASSIF FORM A DEPRESSION WHOSE ASPECT RATIO IS 10:1.
- LUNAR NOON SURFACE TEMPERATURE FOR TAURUS LITTROW NORTH MASSIF (THE DEPRESSION HOT SPOT) IS 250°
- THERMAL PERFORMANCE OF ARRAY E (OTHER THAN LEAM) WITH EXCEPTION OF THE SLIGHT OVER-TEMPERATURE FOR LMS RADIATOR WAS NOMINAL.
- VERTICAL SURFACES ARE TEMPERATURE SENSITIVE TO TAURUS LITTROW DEPRESSION THERMAL EFFECTS.

LEAM ANOMA[illegible] INVESTIGATION

ARRAY E SECOND DAY N[illegible]N THERMAL PERFORMANCE

(OTHER THAN LEAM)

DATA CHANNEL	DESCRIPTION	FLIGHT LEVEL	PREDICTED LEVEL	REMARKS
CS-37	AVG THERMAL PLATE TEMP	125.4°F	104°F	INCREASE IN TEMP DUE TO LEAM & LMS TURNED OFF AT NOON AND HIGHER THAN EXPECTED RTG OUTPUT.
AT-11	PDM PANEL	286.3°F	268°F	PDM PANEL DUST DEGRADED, TO BE EXPECTED.
AM-41	LMS ELECT TEMP	74.4°F (OFF)	125°F	EXTRAPOLATED FLIGHT DATA INDICATE ELECTRONICS TEMP OF 140°F. INCREASE IN TEMP MAY BE DUE TO SITE EFFECTS, LEVELING & ALIGNMENT, AND DUST ACCRETION.
TCR-1	HFE THERMAL PLATE *	328.0K	328°K	ALL THERMAL EFFECTS ACCURATELY EVALUATED.
DG04	LSG SENSOR	49.2°C	48-52°C	ALL THERMAL EFFECTS ACCURATELY EVALUATED.
AP01	LSPE ELECTRONICS	126.7°F	109°F	SEE ABOVE C/S THERMAL PLATE REMARK.

* FIRST DAY, OPERATION IN MODE 1

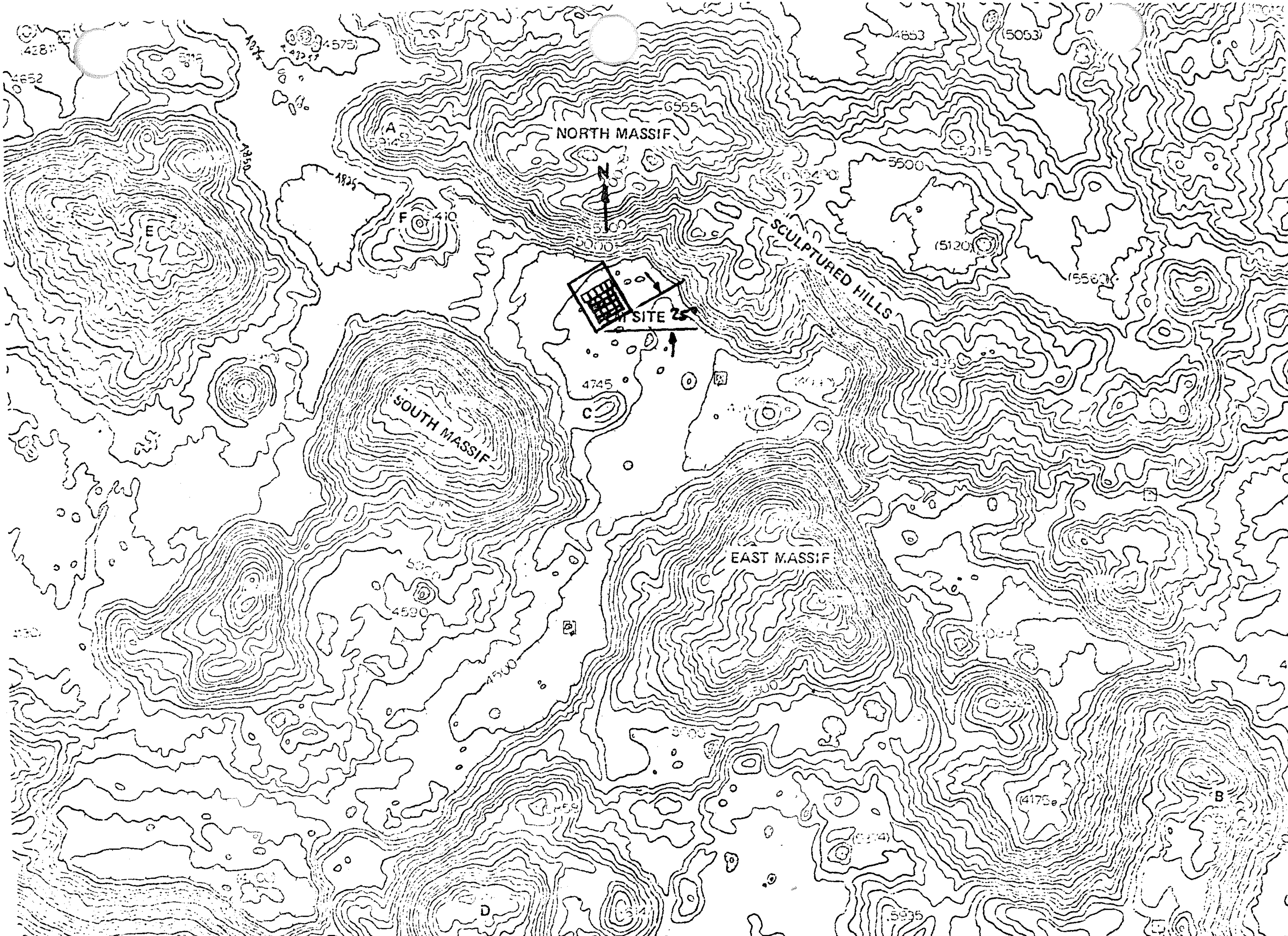


FIGURE 2 - 100 METER CONTOUR MAP OF TAURUS-LITTROW REGION

LEAM ANOMALY INVESTIGATION

LUNAR SURFACE THERMAL EFFECTS

DESCRIPTION	LUNAR SURFACE TEMP (°F)	SLOPE (DEGREES)	T STABILIZATION (°F)
VERTICAL SURFACE	235	0	124
	235	7.5	143
	235	15.0	159
	250	0	137
	250	7.5	156
	250	15.0	172
HORIZONTAL SURFACE			
(α / ϵ = 0.2/0.9)	235	0	30
	235	7.5	34
	235	15.0	46
	250	0	30
	250	7.5	34
	250	15.0	47

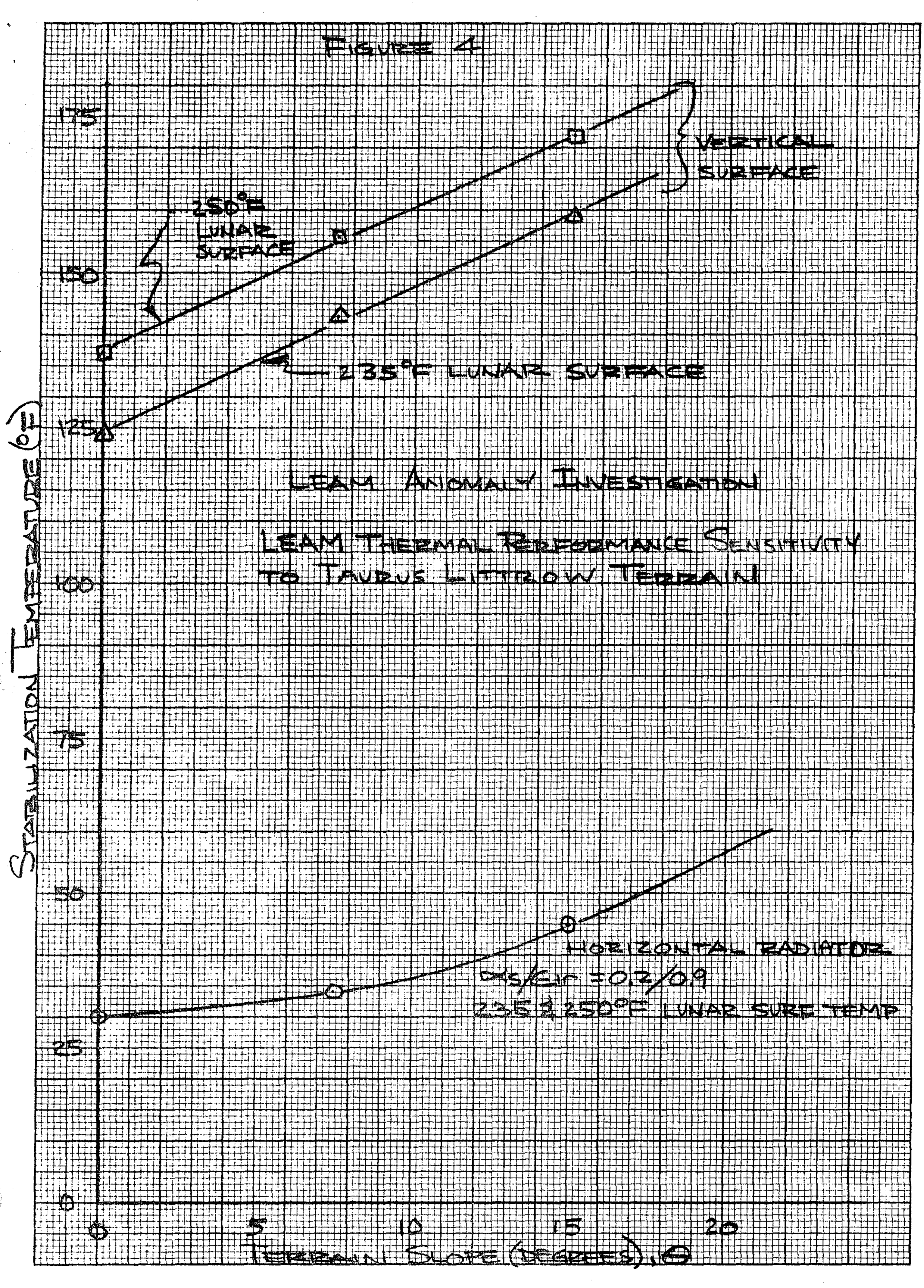


FIGURE 4
175
150
125
100
75
50
25
0
0
5
10
15
20
VERTICAL SURFACE
250°F LUNAR SURFACE
235°F LUNAR SURFACE
LEAM ANOMALY INVESTIGATION
LEAM THERMAL PERFORMANCE SENSITIVITY TO TAURUS LITTROW TERRAIN
HORIZONTAL RADIATOR
αs/εir = 0.2/0.9
235 & 250°F LUNAR SURF TEMP
STABILIZATION TEMPERATURE (°F)
TERRAIN SLOPE (DEGREES), θ

LEAM ANOMALY INVESTIGATION

CAUSES OF EXCESSIVE LEAM TEMPERATURE

SENSOR DUST ACCRETION

- EVALUATION OF SECOND AND THIRD DAY DATA INDICATES THAT EAST SENSOR OPTICAL PROPERTIES HAVE CHANGED. TOP AND WEST SENSORS OPTICAL PROPERTIES APPEAR TO BE UNCHANGED.

- PROPERTY CHANGE DUE TO:

  - THIN FILM DAMAGE - HIGHLY UNLIKELY FOR PREVIOUSLY DISCUSSED REASONS.

  - ACCRETION OF DUST ON SUPRESSOR GRID - DUST COULD BE TRANSPORTED TO LEAM BY STATIC CHARGES (PI'S THEORY).

  - CHANGES IN AMOUNT OF DUST DEGRADATION DUE TO ON/OFF OPERATING MODES AT SUNRISE AND SUNSET.

LEAM ANOMALY INVESTIGATION

POTENTIAL CAUSES OF LEAM EXCESSIVE TEMPERATURE

TELEMETRY ERRORS

TELEMETRY DATA BELIEVED TO BE CORRECT BECAUSE:

- C/S CALIBRATION CHANNELS AE01 AND AE02 INDICATE THAT FLIGHT DATA IS BEING TELEMETERED ACCURATELY.
- AGREEMENT BETWEEN SURVIVAL TEMPERATURE (AJ11) AND ELECTRONICS TEMPERATURES AJ6-AJ9.
- AGREEMENT BETWEEN AJ11 AND EXPECTED HEATER OPERATING TEMPERATURES.
- EXPT. VOLTAGE READINGS NOMINAL

Internal
Memorandum

Bendix Aerospace Systems Division

Ann Arbor, Michigan

Date 13 Feb 1973 Letter No. 73-252-03

To Distribution

From S. J. Ellison

Subject LEAM Thermal Anomaly - Reliability Analysis

The objective of this reliability analysis for the LEAM operational profile is to delineate the temperature/time conditions of reliable operation.

The failure rates for the LEAM experiment as well as the reliability mathematical model were taken from the documents previously submitted by the subcontractor, i.e. time zero.

The thermal profile used as the basis for this analysis is shown in Figure 1 - the power on analysis curve. For analytical simplicity, this curve has been modified by ignoring the small dip at the 90° sun angle. Figure 2 represents graphically the temperature/time relationship of the modified thermal profile for one lunar cycle. The first 160 hours shown in Figure 2 represent the time at maximum temperature between 50° and 130° sun angle. This worst case condition is shown in Figure 2 at 125° C for 160 hours. The next portion of the curve has been averaged out at 100°C for 150 hours. The remaining 390 hours of the lunar cycle have been averaged out at 40°C based on the failure rates for lunar night and lunar day temperatures.

Table 1 tabularizes the K factors that were applied against the time zero failure rates at various temperatures, i.e. 40°C, 100°C and 125°C in order to calculate the failure rates at these temperatures.

Figure 3 depicts the probability of successful operation at temperatures of 40°C, 100°C, 110°C, 115°C and 125°C. The 40°C curve is a prediction based upon the expected thermal profile prior to LEAM anomaly experienced on the Lunar Surface. Essentially, this is the time zero reliability prediction for successful operation. The other curves are based upon the new thermal profile with maximum temperatures as shown.

Comparing the 125°C to the 40°C curve at the 6th lunar cycle (the probability of operating for six lunar cycles), we see that the reliability decreases from 94% to 83%. However, the change from 100°C to 125°C is rather small, i.e. 88% to 83%. Figure 4 delineates the probability of success for degraded operation at 125°C, i.e. the probability of no failures other than loss of a single sensor and housekeeping. If we compare the P_S for "Less single sensor and housekeeping" to the P_S at 125°C in Figure 3, we find that the reliability for six cycles increase from 83% to 90%. The differential is even more significant for two years of operation.

Figure 5 is a reverse reliability curve, i.e. it shows the probability of successfully completing two years of operation if successful at a particular cycle in time. This P_S for two years is read directly from the cycle completion point. For example, if after operating successfully at 100°C for six cycles, the probability of successfully completing two years of operation (i.e. another 18 months) at 125°C is seen to be 56%. The P_S for two years of operation after ten months of success is seen to be 63%.

Figure 6 - dotted line curve, shows the P_S of the LEAM if the power is shut off between the 50° and 130° sun angle. The P_S for six cycles goes from approximately 83% to 93%.

Figure 7 shows the LEAM system failure rate curve based on stresses for each part and associated temperature.

S. J. Ellison

SJE/db

Distribution
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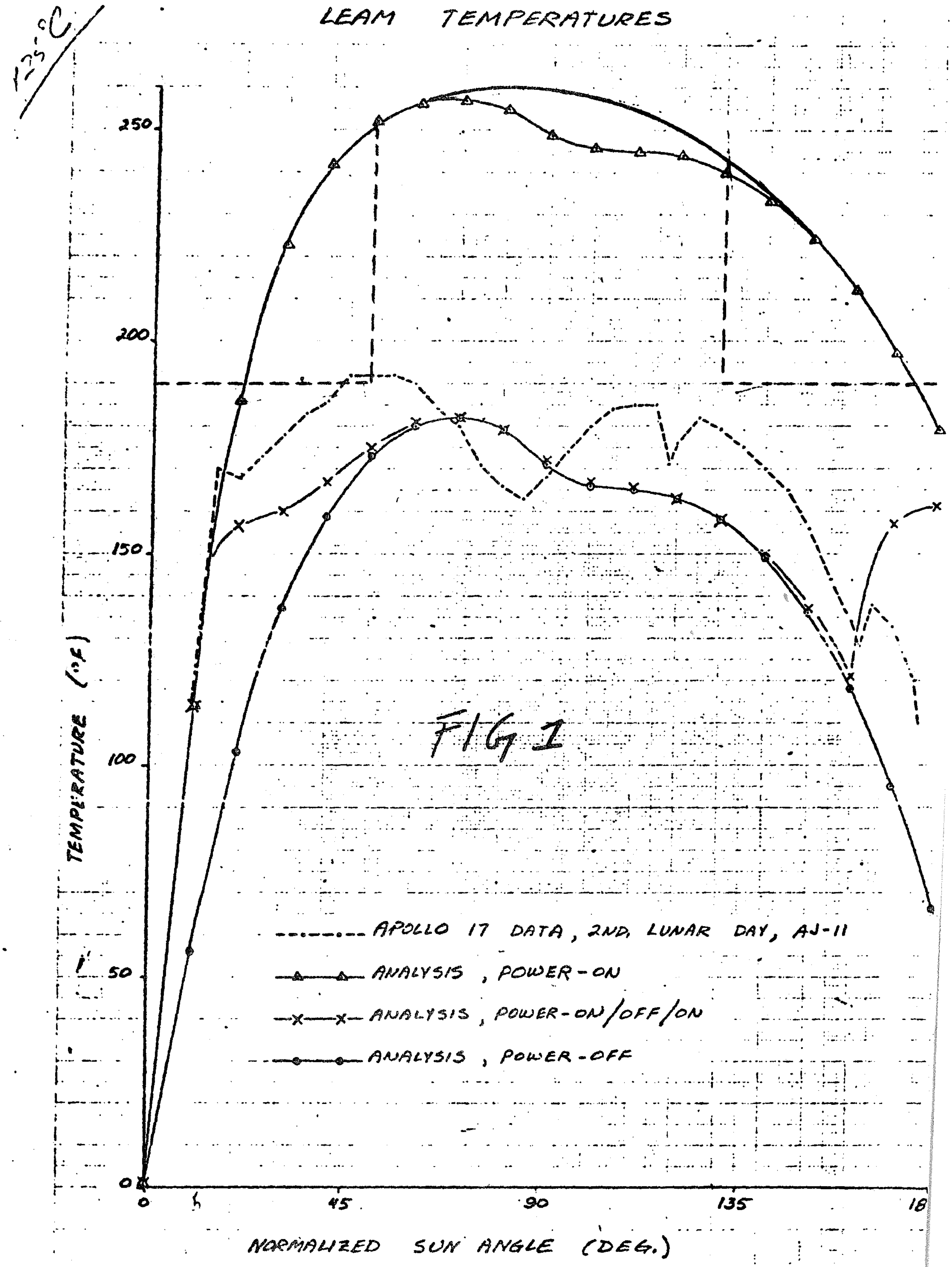
LEAM TEMPERATURES



1-25-73

LEAM Temperatures and Time at Temperature - one lunar day

255°F for 80° Sun Angle or 80° x 2 hrs/°F = 160 hrs.

255°F ≈ 125°C

$$\frac{250^\circ - 180^\circ F}{2} = \frac{70}{2} = 35^\circ F$$

Average 180 + 35 = 215 ≈ 100°C

30° Angle x 2 hr/°F = 60 hrs.

45° Angle x 2 hr/°F = 90 hrs.

40°C for ≈ 390 hrs.

T_1 = 125°C	t_1 = 160 hrs.
T_2 = 100°C	t_2 = 150 hrs.
T_3 = 40°C	t_3 = 390 hrs.

t_0 = 17520 hrs.

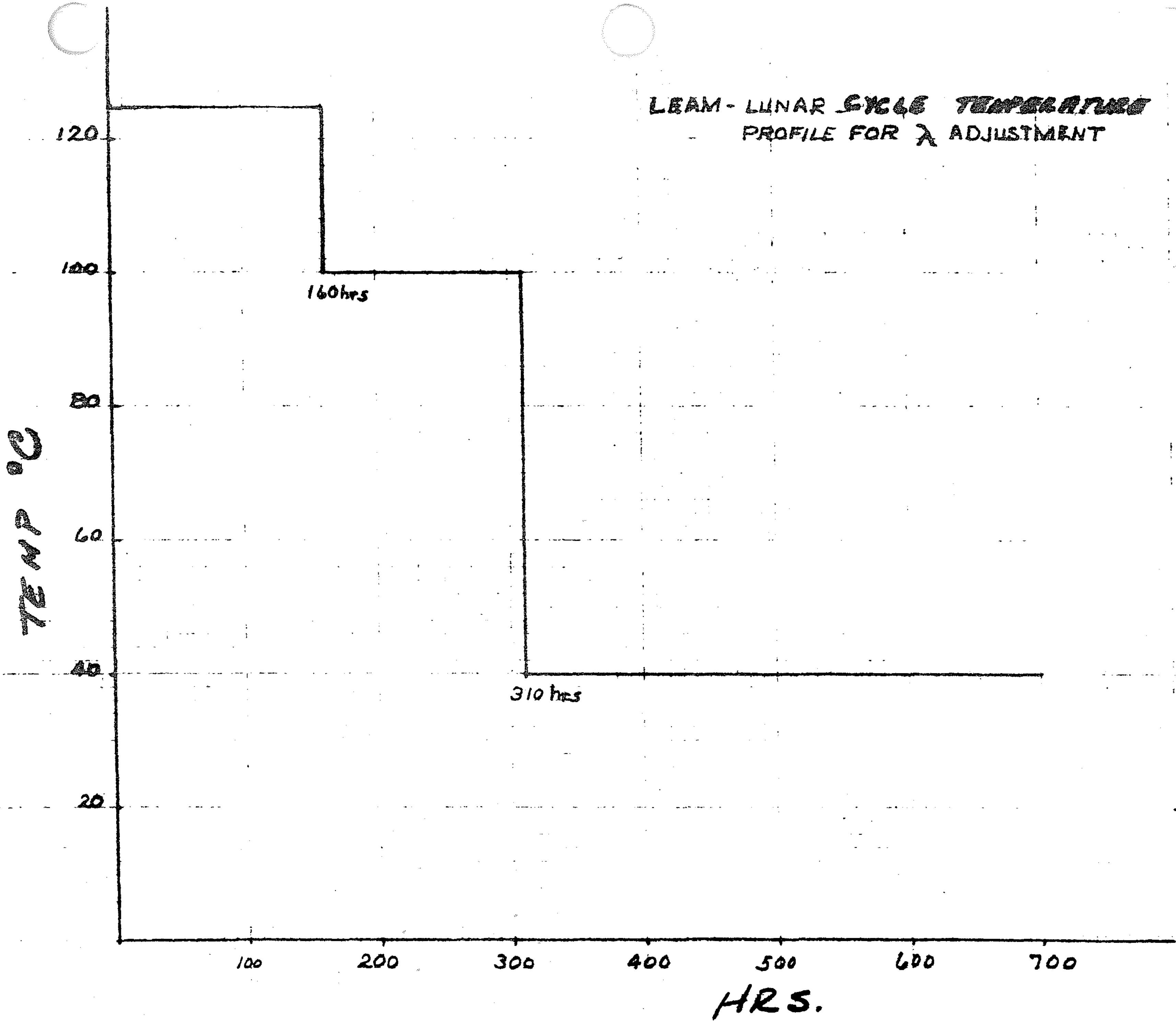

LEAM - LUNAR CYCLE TEMPERATURE
PROFILE FOR λ ADJUSTMENT
TEMP °C
120
100
80
60
40
20
160hrs
310 hrs
100
200
300
400
500
600
700
HRS.

FIG 2

TABLE I

LEAM Failure Rate (λ) Temperature K Factors

Component	Stress Level	λ_{40}	λ_{100}	K_{100}	λ_{125}	K_{125}
Resistors:						
Film RNR MIL-R-55182B	0.5	0.218	0.440	2	0.645	3
Film RLR MIL-R-39017	0.5	0.288	0.715	2.5	-	3.4
W/W PWR MIL-R-39007	0.5	0.240	0.402	1.6	0.500	2
Comp. RCR MIL-R-39008	0.5	0.025	1.000	40.0	-	40
WW Accurate MIL-R-39005	0.5	0.158	0.370	2.3	0.710	4.5
Capacitors:						
Solid Tantalum MIL-C-39003 (CSR)	0.5	0.0400	0.143	3.5	0.265	6.6
Sintered Tantalum MIL-C-39006	0.5	0.0014	0.0145	10	0.112	8
Paper MIL-C-14157D (CPU)	0.5	0.040	0.040	1	0.064	1.6
Glass MIL-C-23269A	0.5	0.0016	0.025	15	0.080	50
Ceramic MIL-C-39014 (CKR)	0.5	0.006	0.054	9	0.125	20
Foil Tantalum MIL-C-39006 (KSR)	0.5	0.025	0.081	3.2	0.190	7.6
MICA MIL-C-39001	0.5	0.017	0.017	1	0.017	1
Diodes $\leq$ 1 w and Zener		.25	.85	3.5	1	5
$>$ 1 w				5.0		10
Transistors:						
PNP		.25	.85	4.0	1	7.0
NPN		.25	.85	3.0		4
Micro Ckts.		.25	.85	4	1	7

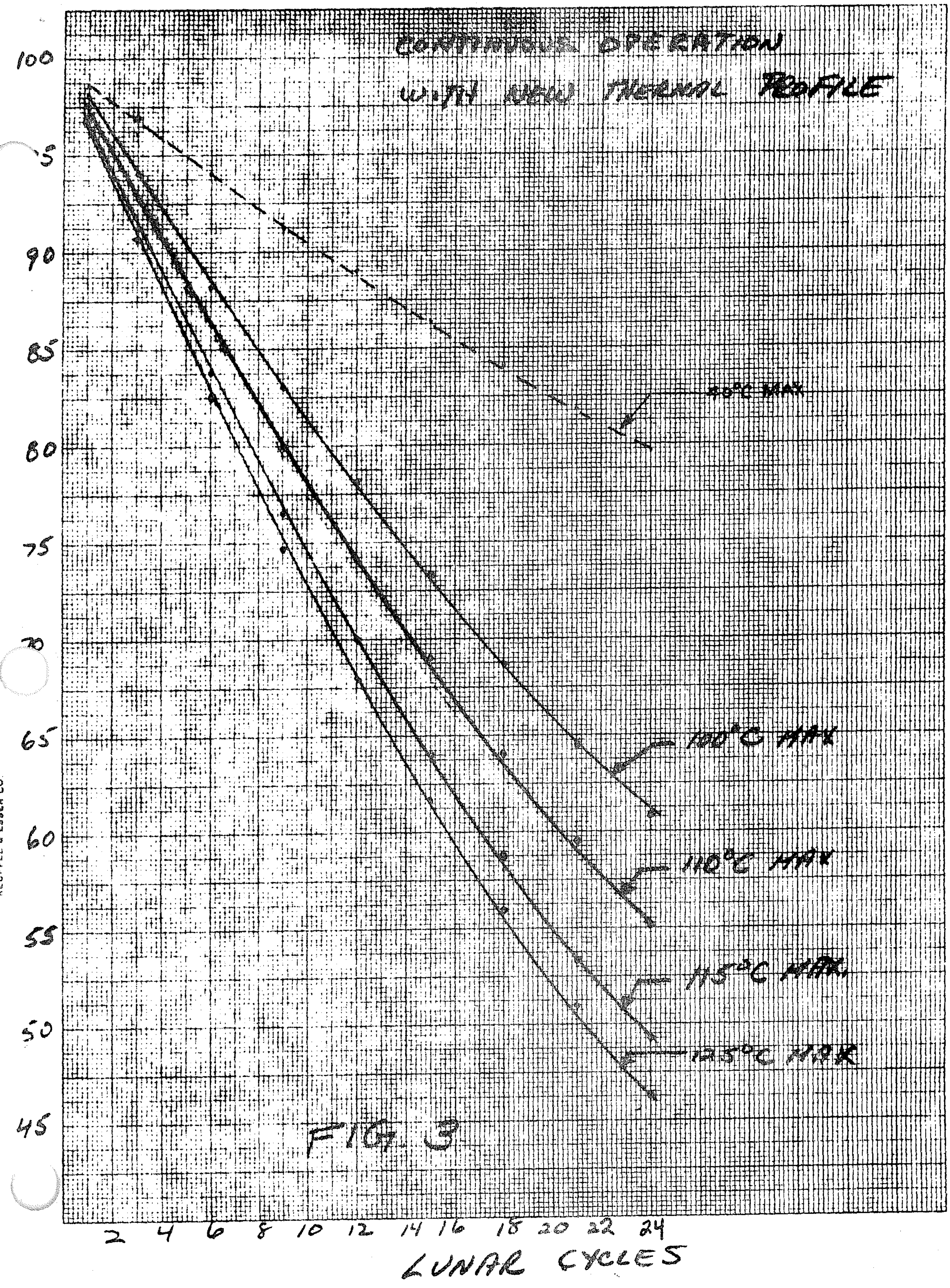

CONTINUOUS OPERATION
WITH NEW THERMAL PROFILE
100
95
90
85
80
75
70
65
60
55
50
45
100°C MAX
110°C MAX
115°C MAX
125°C MAX
2 4 6 8 10 12 14 16 18 20 22 24
LUNAR CYCLES

FIG. 3

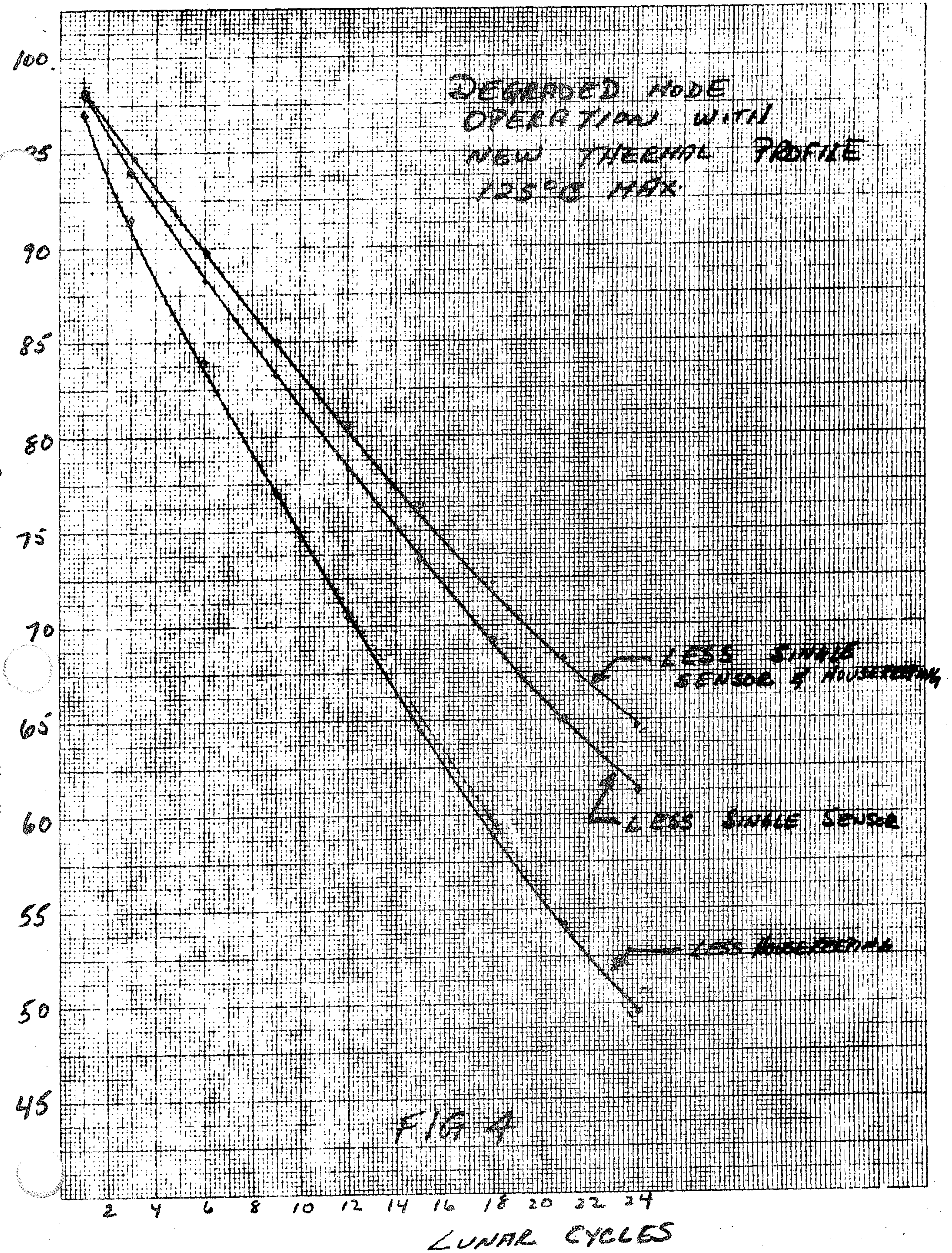

DEGRADED MODE
OPERATION WITH
NEW THERMAL PROFILE
125°C MAX
100
95
90
85
80
75
70
65
60
55
50
45
LESS SINGLE
SENSOR & HOUSEKEEPING
LESS SINGLE SENSOR
LESS HOUSEKEEPING
2 4 6 8 10 12 14 16 18 20 22 24
LUNAR CYCLES

FIG 4

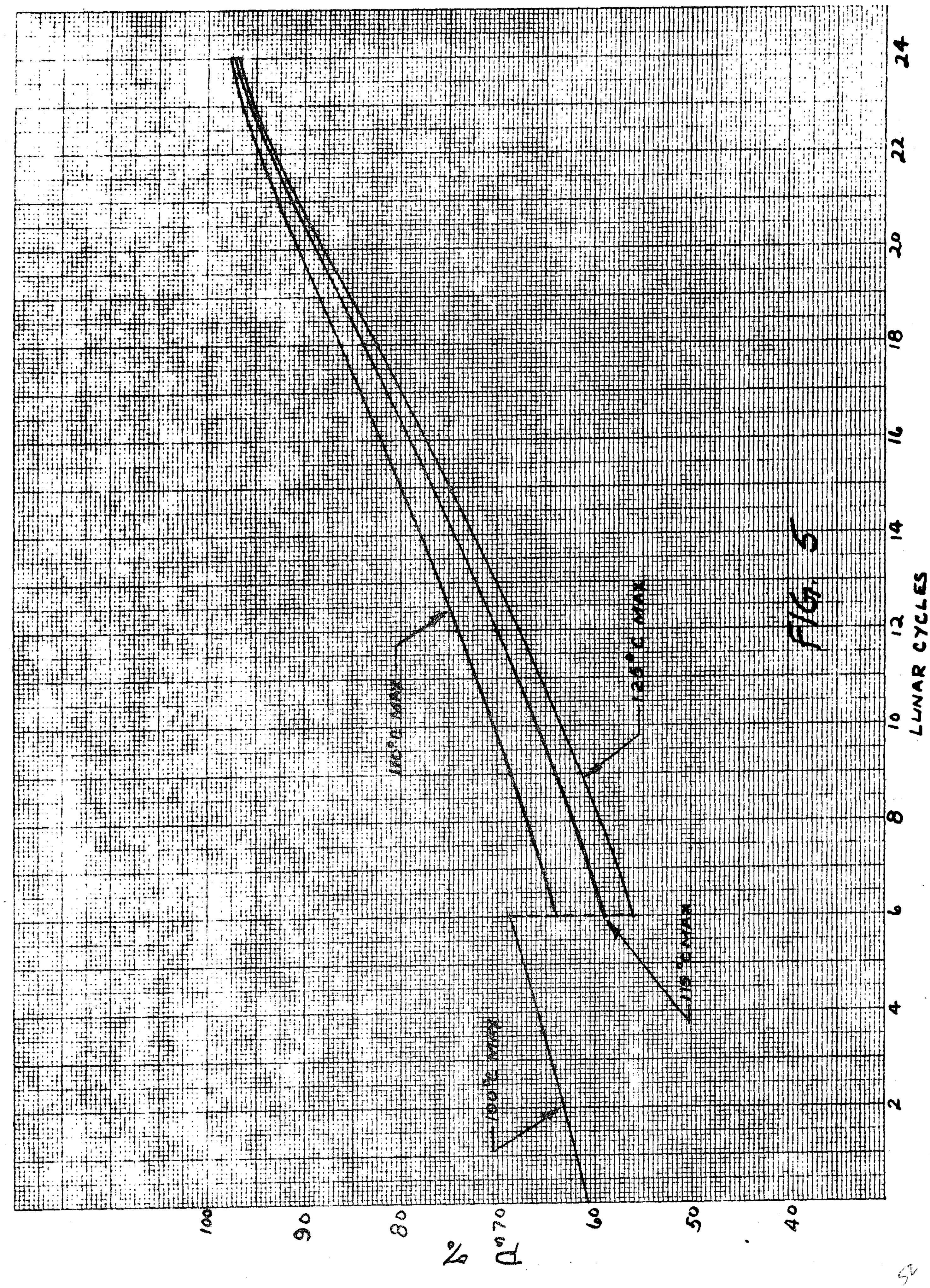

K+E 10 X 10 TO THE CENTIMETER 46 1513
KEUFFEL & ESSER CO.
MADE IN U.S.
100°C MAX
110°C MAX
115°C MAX
125°C MAX
LUNAR CYCLES
2
4
6
8
10
12
14
16
18
20
22
24
% D
40
50
60
70
80
90
100

FIG. 5

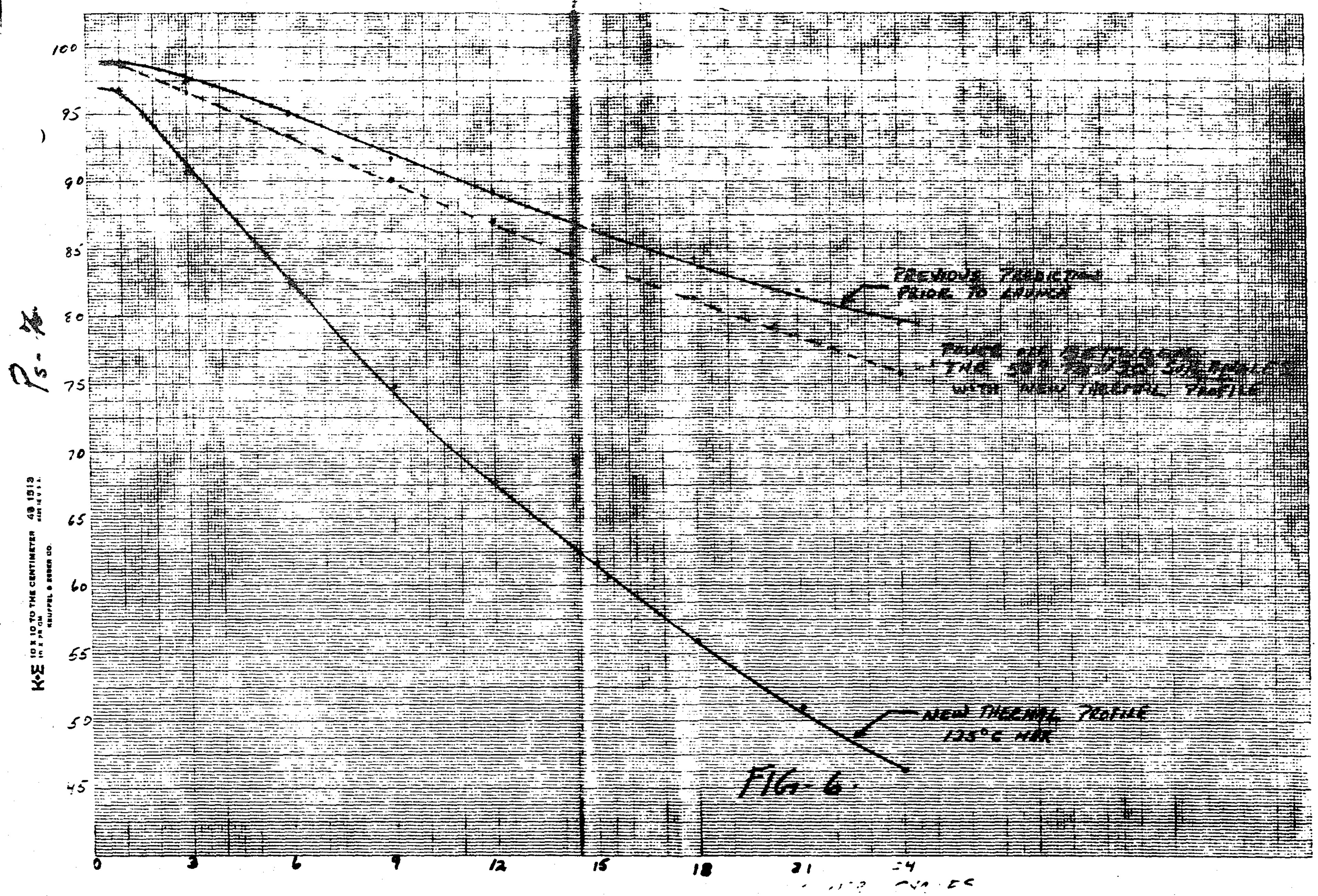
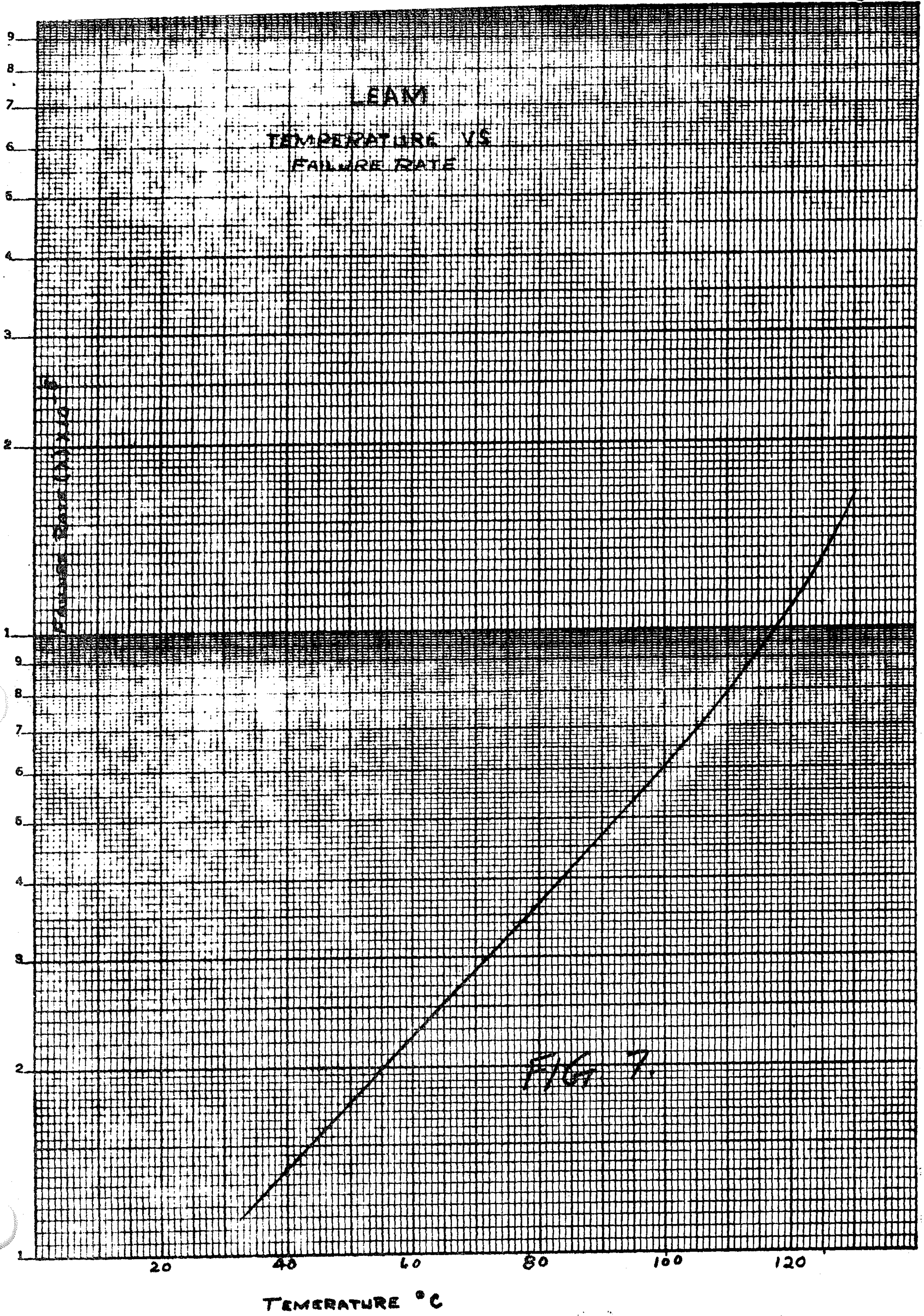

100
95
90
85
80
75
70
65
60
55
50
45
P_S - %
0
3
6
9
12
15
18
21
24
PREVIOUS PREDICTION PRIOR TO LAUNCH
NEW THERMAL PROFILE
125°C MAX

FIG-6.

53



LEAM
TEMPERATURE VS
FAILURE RATE
FAILURE RATE (λ) X 10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
1
20
40
60
80
100
120
TEMERATURE °C

FIG. 7.

TABLE 2

LEAM CONTINUOUS OPERATION

P_S Total System for Max Temperature (°C)

LUNAR CYCLE	40	100	110	115	120	125
1	.9905	.9794	.9755	.9708	.9697	.9683
3	.9718	.9396	.9283	.9151	.9118	.9080
6	.9445	.8829	.8618	.8375	.8314	.8245
9	.9179	.8296	.8001	.7665	.7581	.7487
12	.8921	.7796	.7428	.7015	.6913	.6798
15	.8670	.7325	.6896	.6420	.6304	.6173
18	.8426	.6883	.6402	.5879	.5748	.5605
21	.8189	.6468	.5944	.5377	.5241	.5090
24	.7959	.6078	.5518	.4921	.4779	.4622

7BLE 3

LEAM - DEGRADED MODE

LUNAR CYCLE	P_S Continuous Operation at 40°C Total System	Less HK	Less SS	Less HK & SS	P_S Continuous Operation at 125°C Total System	Less HK	Less SS	Less HK & SS
1	.99053	.9914	.9937	.9944	.9683	.9712	.9797	.9821
3	.9718	.9746	.9813	.9834	.9080	.9162	.9404	.9473
6	.9445	.9499	.9630	.9671	.8345	.9394	.8845	.8974
9	.9179	.9258	.9450	.9511	.7487	.7691	.8318	.8501
12	.8921	.9023	.9273	.9354	.6798	.7046	.7823	.8054
15	.8670	.8794	.9100	.9199	.6173	.6456	.7358	.7629
18	.8426	.8571	.8930	.9047	.5605	.5915	.6920	.7228
21	.8189	.8353	.8763	.8897	.5090	.5419	.6508	.6847
24	.7959	.8141	.8600	.8750	.4622	.4965	.6121	.6486

TABLE 4

LEAM DEGRADED MODE

P_S Altered Oper Cycle*

LUNAR CYCLE	TOTAL SYSTEM	LESS HK	LESS SS	LESS HK & SS
1	.9885	.9904	.9944	.9969
3	.9660	.9713	.9834	.9909
6	.9332	.9435	.9670	.9819
9	.9014	.9164	.9510	.9730
12	.8708	.8902	.9352	.9642
15	.8412	.8646	.9197	.9555
18	.8126	.8398	.9045	.9468
21	.7849	.8157	.8894	.9382
24	.7579	.7924	.8746	.9297

Altered Oper Cycle - Off at 50° Sun Angle

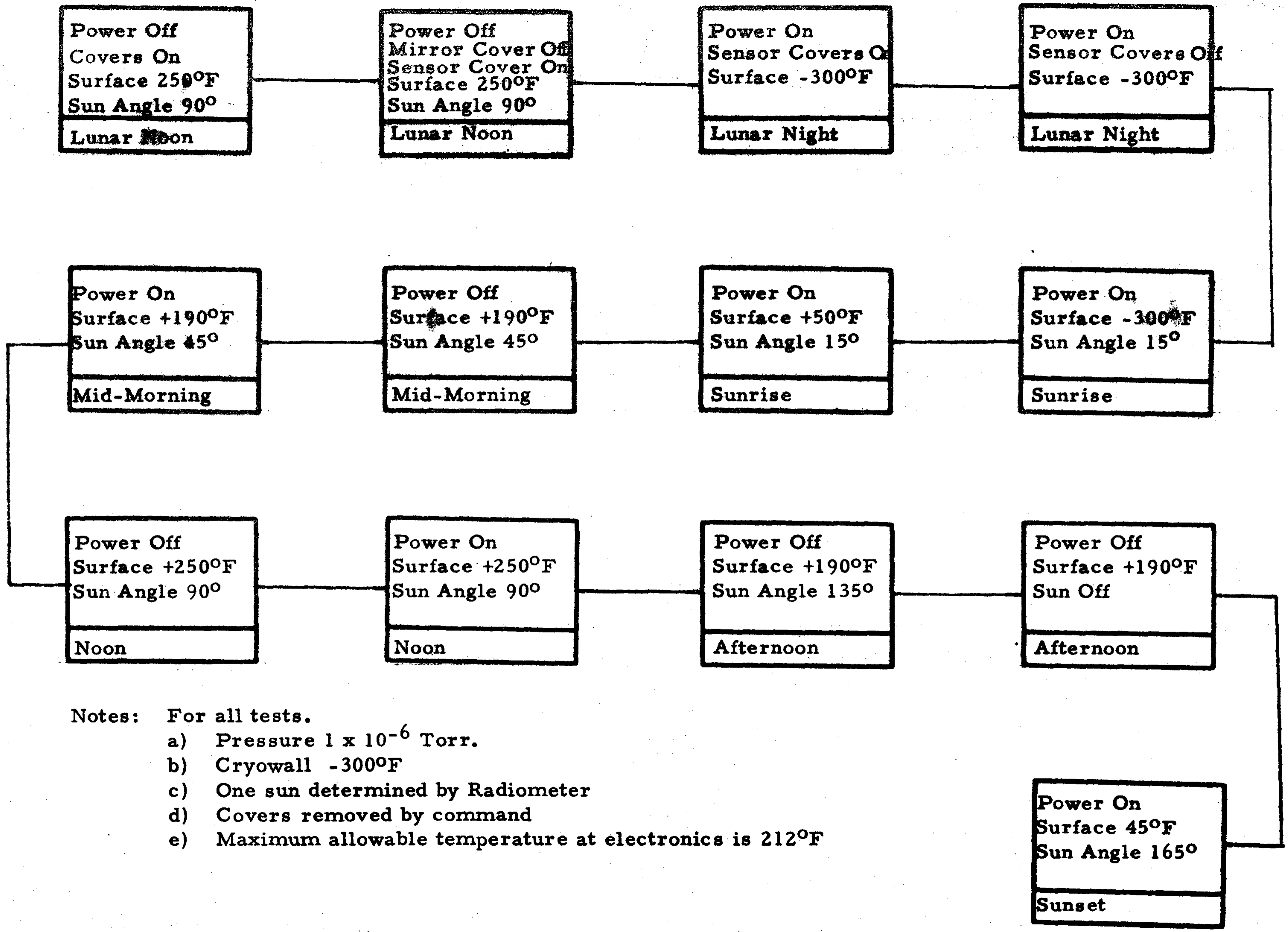
On at 130° Sun Angle

LEAM ANOMALY INVESTIGATION

RECOMMENDATIONS

- CONTINUE TO EVALUATE FLIGHT DATA AND CORRELATE WITH MATH. MODEL.
- UPDATE PLAN FOR LEAM OPERATION BASED ON TEMPERATURE PROFILE, RELIABILITY CONSIDERATIONS AND P.I. REQUIREMENTS.
- CONSIDER NECESSITY FOR A TEST AFTER REVIEWING SEVERAL MORE CYCLES OF TEMPERATURE AND SCIENCE DATA.

RECOMMENDED LEAM THERMAL CUUM TEST FLOW CHART



Notes: For all tests.

a) Pressure 1×10^{-6} Torr.
b) Cryowall -300°F
c) One sun determined by Radiometer
d) Covers removed by command
e) Maximum allowable temperature at electronics is 212°F

Instrumentation for LEAM Thermal Vacuum Test

In addition to the standard flight temperature sensor the following instrumentation is required:

1. Twelve thermocouples attached in accordance with Bendix drawing 2373193.

2. Additional thermocouples attached to points indicated below:

   a. Up Sensor.

      (i) Outer forward grid frame, west edge
      (ii) Forward film frame, outer edge

   b. East Sensor

      (i) Outer forward grid frame, bottom edge
      (ii) Forward film frame, outer edge

   c. West Sensor

      (i) Grid frame, bottom edge

   d. (i) Thermal bag, inside, North
      (ii) Thermal bag, outside, North

   e. Center of Second surface mirror, under insulation mask.