Bendix

Aerospace Systems Division

LEAM Film Development Test Report

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Prepared by: R. J. Simms

R. Simms

L. S. Mills

L. Mills

Approved by: P. Pilon

P. Pilon

Luis Galan

L. Galan

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ILLUSTRATIONS

TABLES

1. PURPOSE

The purpose of the test is to provide thermal vacuum test data to allow computation of the film temperature and verify the measured optical properties of the film. A secondary purpose is to verify the thermal effects of using a beryllium-copper support grid between the film and frame.

2. SCOPE

The test program used three developmental front films bonded to plastic frames which were mounted in instrumented calorimeter enclosures. The test articles were mounted in the 4 x 8 ft space chamber and subjected to a simulated lunar environment.

Two calorimeter configurations were tested—one for heat leak measurement and the other to verify the thermal properties of the test film. Internal heaters were operated at three different power levels in both configurations. At each heater power level, the test films were subjected to carbon arc solar simulation. The simulated solar energy was varied to produce three values of incident energy: 0.0, 0.1, and 0.2* solar constants.

3. OBJECTIVES

The objectives of the test program were to measure and record, for each set of conditions, the following data:

1. Heater input power
2. Incident solar energy
3. Cold wall temperature distribution
4. Calorimeter temperature distribution.

4. EQUIPMENT DESCRIPTION

4.1 TEST ARTICLE

Each test article is an assembly consisting of four developmental film frames bonded to a larger plastic frame which is, in turn, mounted to a calorimeter enclosure.

* The 0.2 solar constant was used only in conjunction with the high heater power level.

4.1.1 Film and Film Frame

The assembly details of the film and film frame are shown in Figure 4-1. The detail construction of each film is shown in Figure 4-2. Test Item No. 1, P/N 2347014-4, has a film laminate consisting of four layers: 500 Å of gold (external surface); 100 Å of parylene C; 500 Å of gold; and a 6 x 2.5 mil BeCu grid where the gold together with the grid make up the internal surface. The first three layers of the film laminate of test Item No. 2, P/N 2347014-14, are identical to those of Test Item No. 1. The fourth layer, however, is a 1000 Å thick layer of parylene C. Test Item No. 3, P/N 2347014-10, has a film laminate identical to the first three layers of the laminate of Test Item No. 1.

Test Items 2 and 3 each contain only three 1 x 4 in. test films. The fourth 1 x 4 in. film in each case is a special film in which a pair of copper-constantan thermocouples were vacuum deposited on the film in place of the external deposition of gold.

Figure 4-3 shows Test Items 1, 2, and 3 during assembly and instrumentation. After these photographs were taken, however, Item 3 was damaged.

4.1.2 Calorimeter

The calorimeter, shown in Figure 4-4, consists of a cubical box, with one side open, painted with Midland Black on the inside. The open side of the box is designed to hold the test film and frame assembly. The side opposite the film is painted black on the outside also and is designated as the radiator. The remaining four sides have heaters attached and are covered with multilayer reflective insulation (25 layers of 1/4-mil crinkled aluminized mylar separated by 24 layers of nylon netting). The entire unit was instrumented with 30-gauge chromel-constantan thermocouples as shown in Figure 4-5. The special thermocouples that were vacuum deposited on the film (location No. 28) did not function.

Three calorimeter enclosures were fabricated so that three developmental films could be tested simultaneously to minimize test time in the space chamber. The test setup is shown in Figure 4-6.

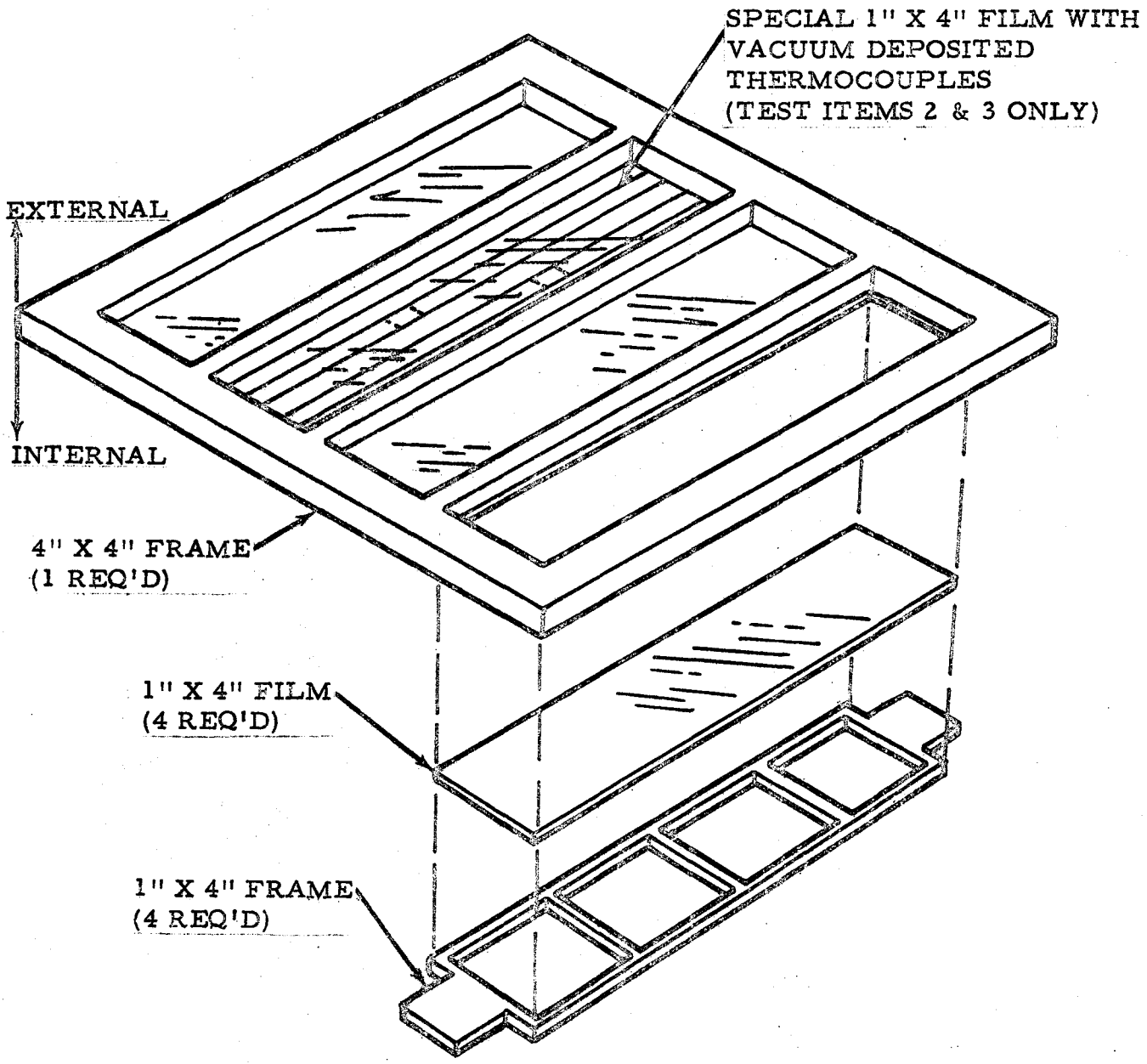
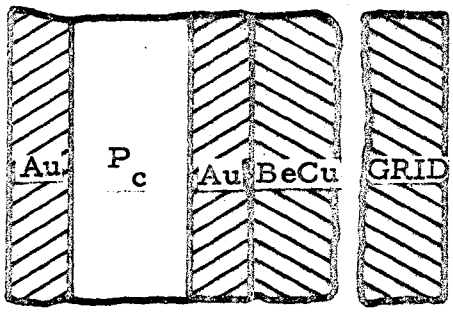
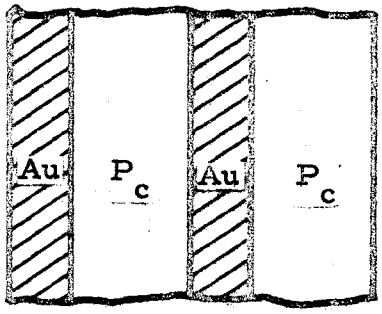


Figure 4-1 Film and Film Frame Assembly Details

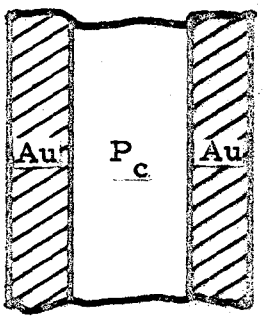


TEST ITEM NO. 1
(FILM NO. 4)
500 Å GOLD
1000 Å PARYLENE C
500 Å GOLD
6 X 2.5 MIL BeCu GRID

EXTERNAL TO THE CALORIMETER ENCLOSURE



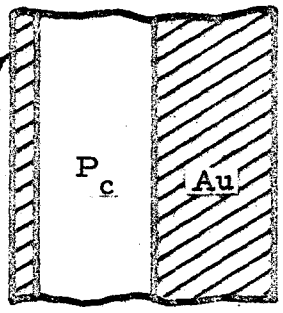
TEST ITEM NO. 2
(FILM NO. 14)
500 Å GOLD
1000 Å PARYLENE C
500 Å GOLD
1000 Å PARYLENE C



TEST ITEM NO. 3
(FILM NO. 10)
500 Å GOLD
1000 Å PARYLENE C
500 Å GOLD
(BROKEN DURING INSTRUMENTATION)

INTERNAL TO THE CALORIMETER ENCLOSURE

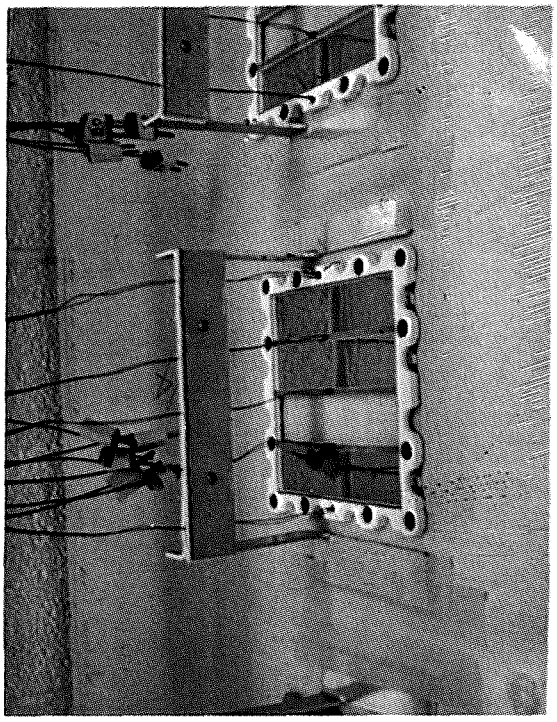
THERMOCOUPLE



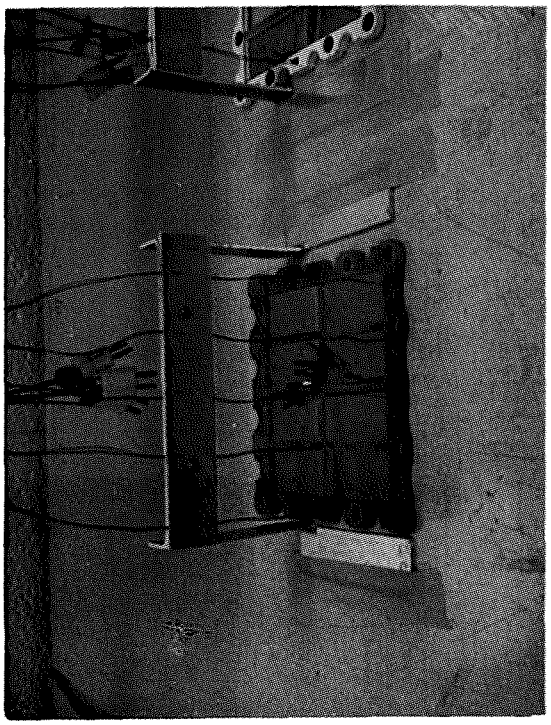
THERMOCOUPLE FILM
(FILM NO. 21-1)
200 Å Cu/CONST T/C
1000 Å PARYLENE C
1000 Å GOLD

9015-2

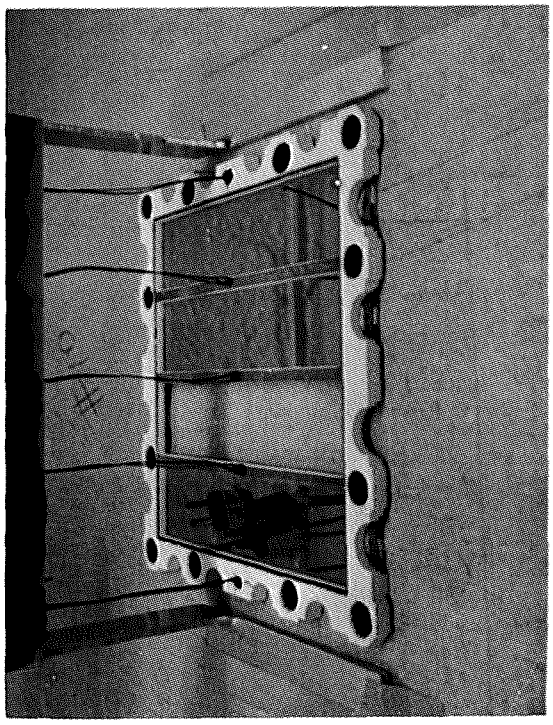
Figure 4-2 Film Construction Details



TEST ITEM 2



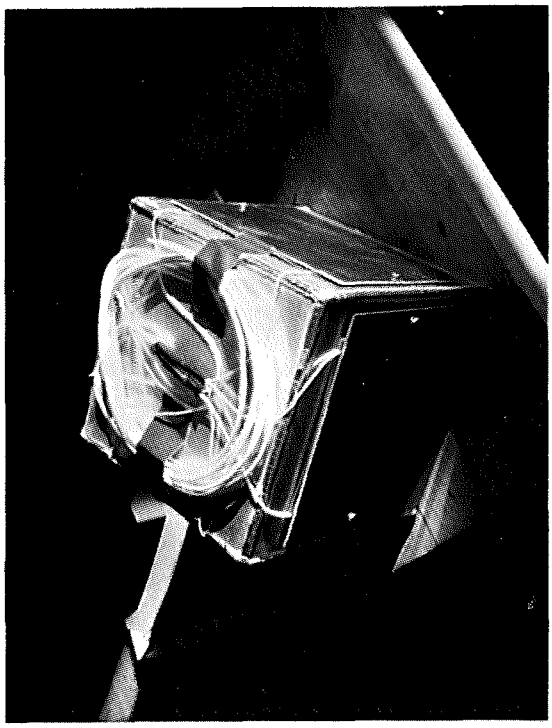
TEST ITEM 1



TEST ITEM 3

9015-3

Figure 4-3 Test Items Assembly and Instrumentation-Film Development Tests



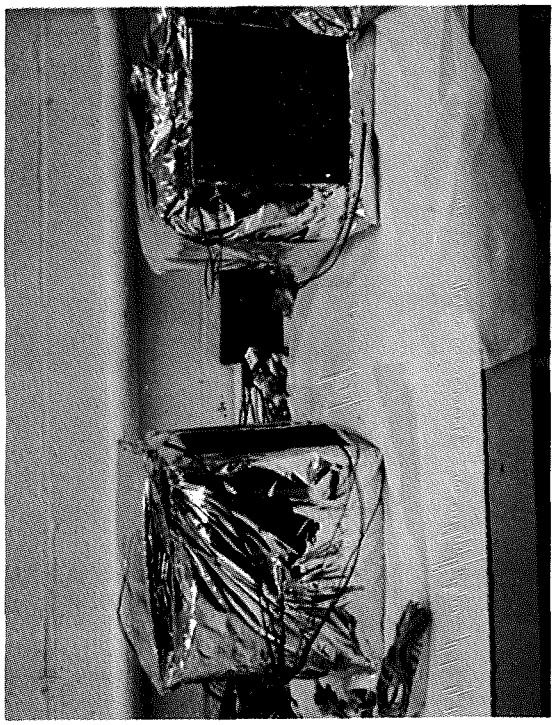
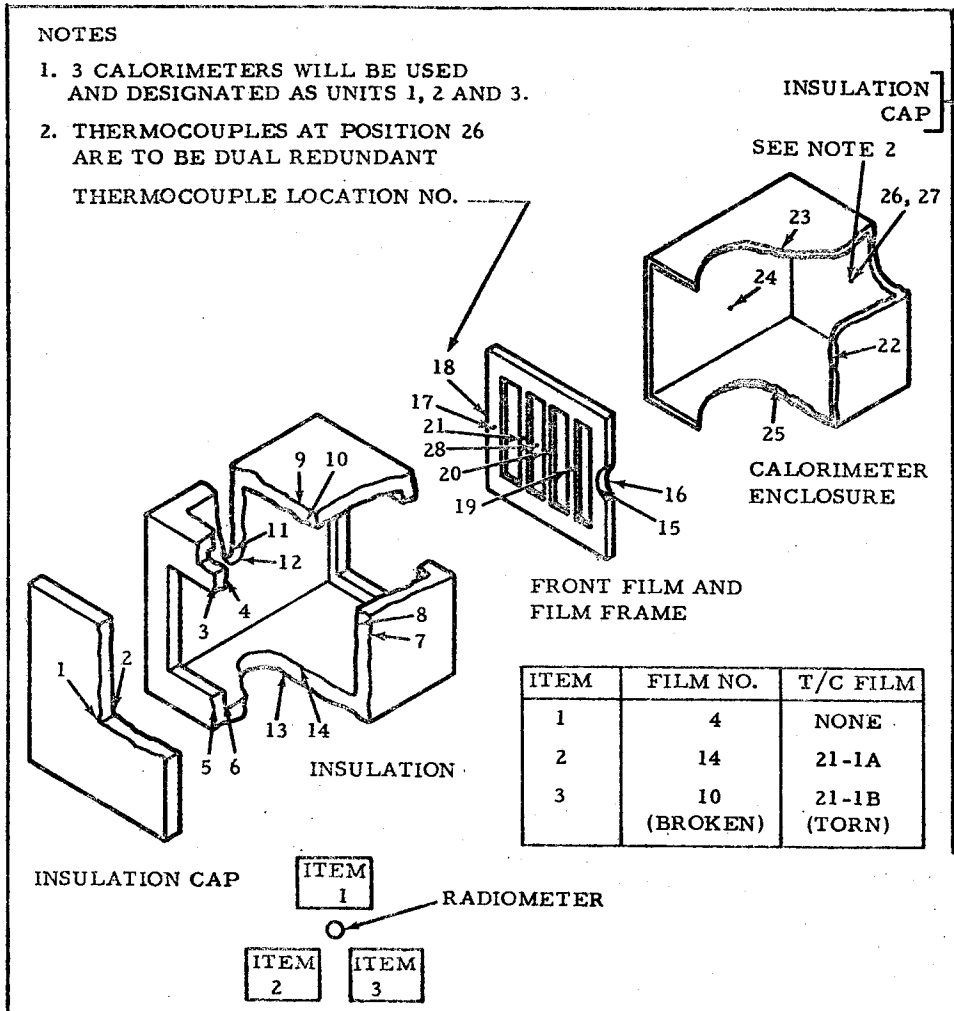


Figure 4-4 Calorimeter Assembly-Film Development Tests

NOTES

1. 3 CALORIMETERS WILL BE USED AND DESIGNATED AS UNITS 1, 2 AND 3.
2. THERMOCOUPLES AT POSITION 26 ARE TO BE DUAL REDUNDANT



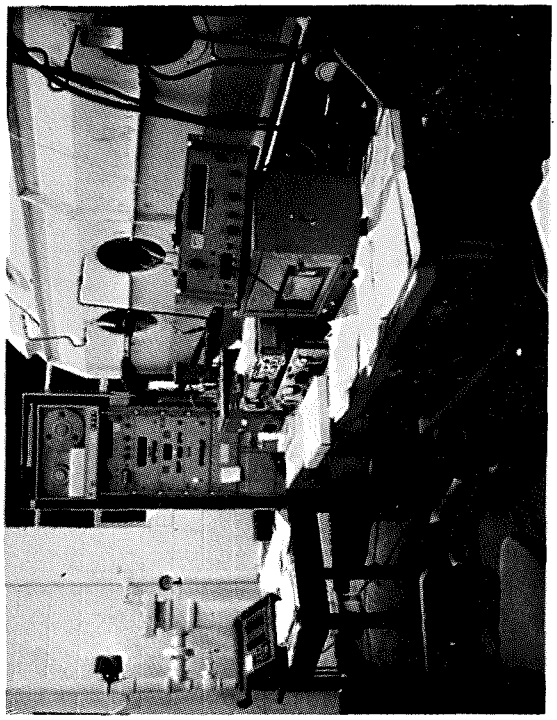
ITEM	FILM NO.	T/C FILM
1	4	NONE
2	14	21-1A
3	10 (BROKEN)	21-1B (TORN)

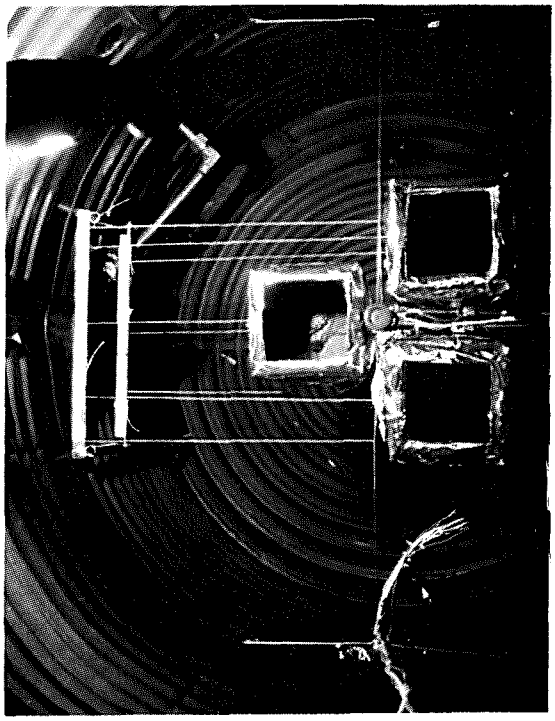
	T/C LOCATION NO.	DAS CHANNEL ITEM 1	ITEM 2	ITEM 3
	1	01	31	61
	2	02	32	62
INSULATION	3	03	33	63
	4	04	34	64
	5	05	35	65
	6	06	36	66
	7	07	37	67
	8	08	38	68
	9	09	39	69
	10	10	40	70
	11	11	41	71
	12	12	42	72
	13	13	43	73
	14	14	44	74
FILM FRAME	15	15	45	75
	16	16	46	76
	17	17	47	77
	18	18	48	78
	19	19	49	79
	20	20	50	80
	21	21	51	81
ENCLOSURE	22	22	52	82
	23	23	53	83
	24	24	54	84
	25	25	55	85
	26	26	56	86
	27	27	57	87
FILM	28	-	-*	88**

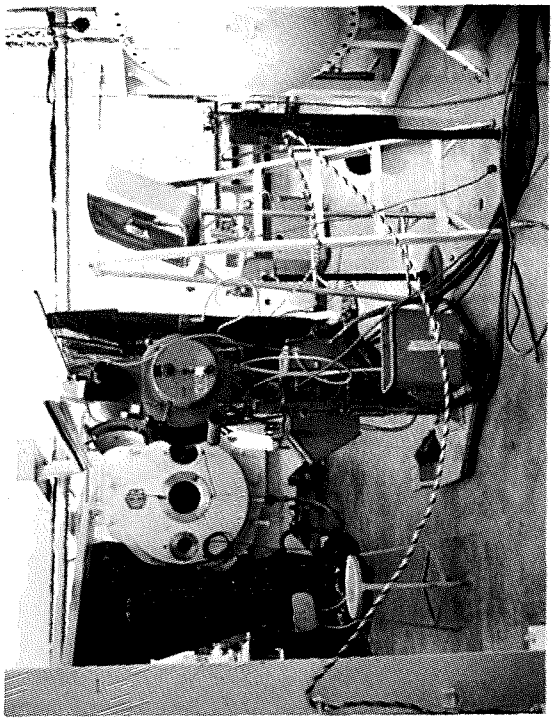
*NOT CONNECTED TO DAS

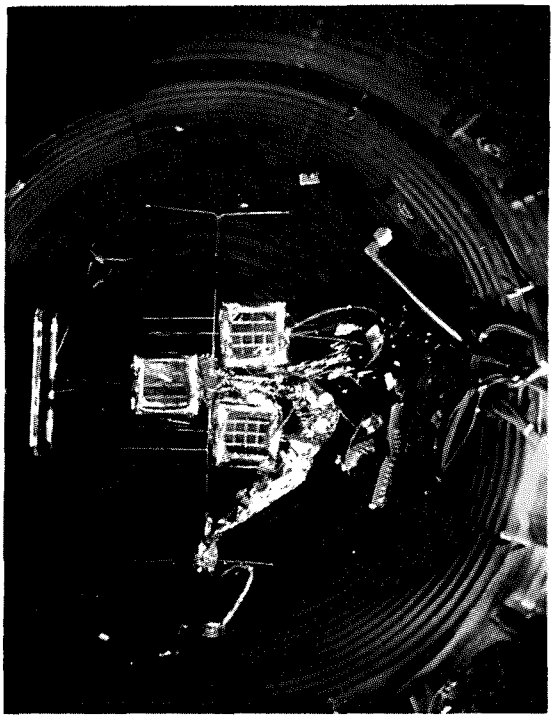
**OPEN CIRCUIT NOT CONNECTED TO DAS

Figure 4-5 LEAM Calorimeter Thermocouple Locations









9015-6

Figure 4-6 Film Development Test Setup

4.2 INSTRUMENTATION

The following instrumentation was used:

1. Data Acquisition System (DAS); Hewlett-Packard, Model 2010J, S/N 14329
2. 150°F thermocouple reference junctions; RI Controls, Model J4801, S/N's 13725, 13722, and 14301
3. Pyroheliometer; Hy-cal Engr., Model P8410, S/N 33172
4. Current Shunts; Weston Inst., Model 0042210, no S/N's
5. Digital Volt Meter; Hewlett-Packard, Model 2401C, S/N 14398.

4.3 TEST EQUIPMENT

The following equipment was used:

1. 4 x 8 ft space chamber; CB&I, no model or S/N
2. LN_2 System; AIRCO, no model or S/N
3. Cold Shroud; Bendix, no model or S/N
4. Arc Lamp; Genarco, Model ME-6, S/N 12389
5. Heater Exchanger; Nes Lab, Model T3, S/N 660194
6. DC Power Supply; N.J.E., Model QR 60-2.5, S/N 10663
7. DC Power Supply; Power Design, Model 5015, S/N 07992
8. DC Power Supply; Sorensen, Model QR 36-4A, S/N 11517.

5. TEST DATA

The following data were recorded as a function of time on both magnetic and paper tape:

1. Test item T/C voltages

2. Cold shroud T/C voltages

3. Radiometer T/C voltages

4. Radiometer output voltage

5. Heater voltage

6. Shunt voltage.

Polaroid photographic coverage was provided for the following:

1. Multilayer insulation fabrication

2. Assembly of test item showing thermocouple installation and locations

3. Test item installed in the 4 x 8 ft space chamber

4. Test setup and instrumentation.

6. TEST METHODS

The energy absorbed and re-radiated by the front film and frame assembly will establish a unique equilibrium temperature distribution within the calorimeter enclosure. The thermal equilibrium condition was systematically perturbed by successively dissipating three different power levels in the heaters.

6.1 HEAT LEAK TEST

The insulation cap was placed over the film and film frame assembly. Equilibrium conditions were established and recorded for three heater powers.

6.2 FILM TESTS

The insulation cap was removed, thus exposing the film and film frame assembly to the space chamber environment:

1. No Sun - Equilibrium conditions were established and recorded for three heater powers.

2. 0.1 Sun - Equilibrium conditions were established and recorded for three heater powers.

3. 0.2 Sun - An equilibrium condition was established and recorded for one heater power.

7. TEST RESULTS

7.1 SUMMARY

Figures 7-1, 7-2, and 7-3 present a temperature history of the calorimeter radiator plates as recorded during the test. The thermal equilibrium conditions shown on each graph were taken for a time-temperature change of less than 1°F per hour. Figure 7-4 shows the three test items before and after the solar tests.

Pretest predictions indicated that the films would exceed safe operating temperatures when exposed to an incident flux greater than 0.125 solar constants. During the 0.10 sun runs, no degradation was noticed for the three sets of films. However, during the run for 0.20 sun the films in calorimeters No. 2 and No. 3 showed a wrinkling effect indicating that film annealing temperatures had been reached. Calorimeter No. 1, with the film grid installed, showed no film degration. Analysis indicates that film with the grid reached 131°F while the films with no grid reached 277°F. Tabulated test data are presented in the Appendix.

7.2 TEST ITEM NO. 1

Figure 7-5 shows Test Item No. 1 at various stages during the test. Prior to the test, the grid on the back side of the film is barely noticeable; however, after the test the grid can be readily seen. This effect may have been caused by thermal distortion. It is predicted that a 30 to 40°F temperature gradient exists between the unsupported and supported portions of the film.

Tables 7-1, 7-2, and 7-3 show a comparison for Box No. 1 between temperatures recorded during the tests and temperatures derived for each group of thermal conditions. The analysis in each case fixed the outside of the insulation as boundary conditions and solved the energy balance for the remaining network. Table 7-1 compares temperatures for the heat leak test and shows good correlation of data. Table 7-2 illustrates the night condition

9015-7

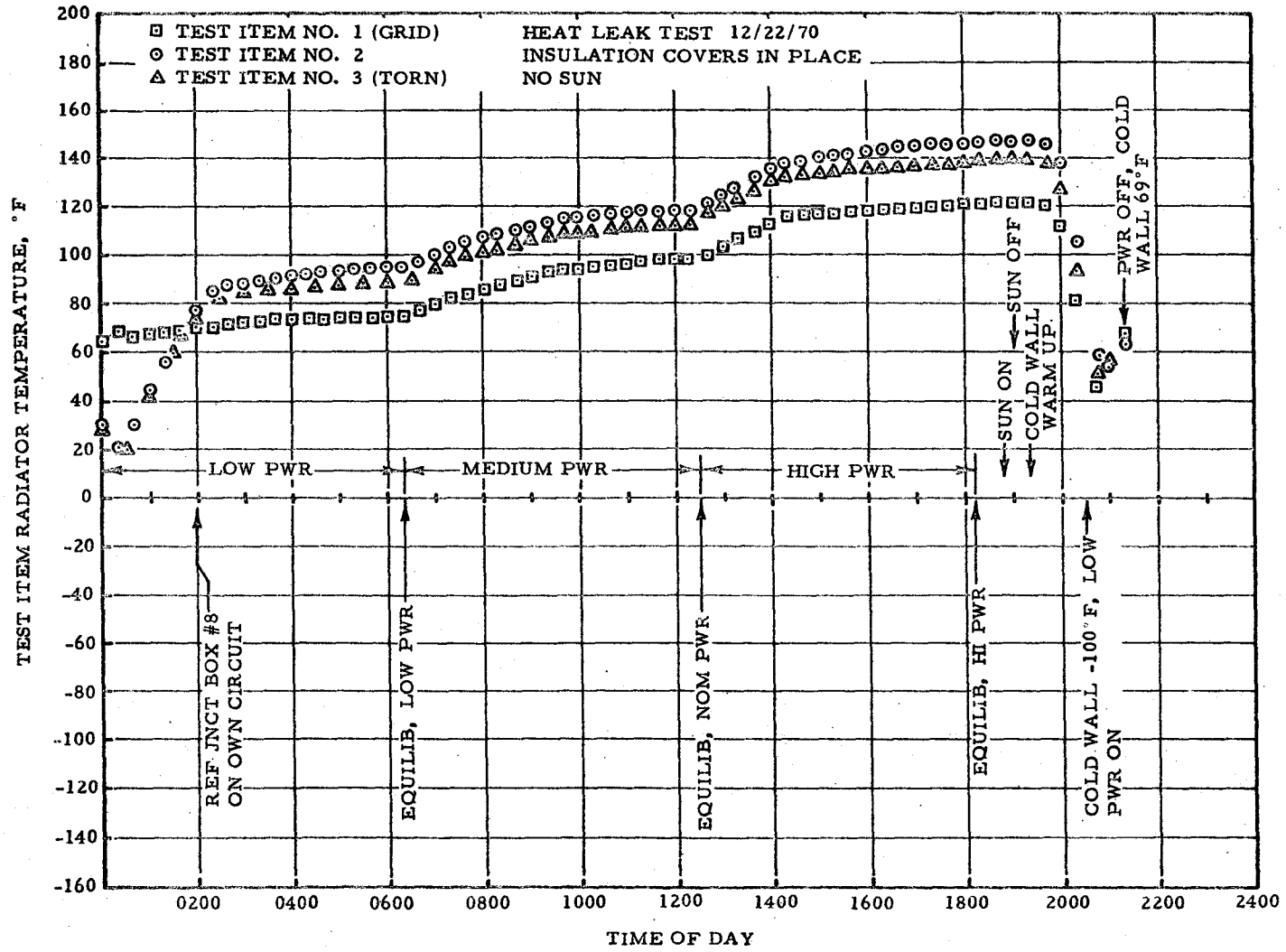


Figure 7-1 LEAM Film Tests (22 Dec 1970)

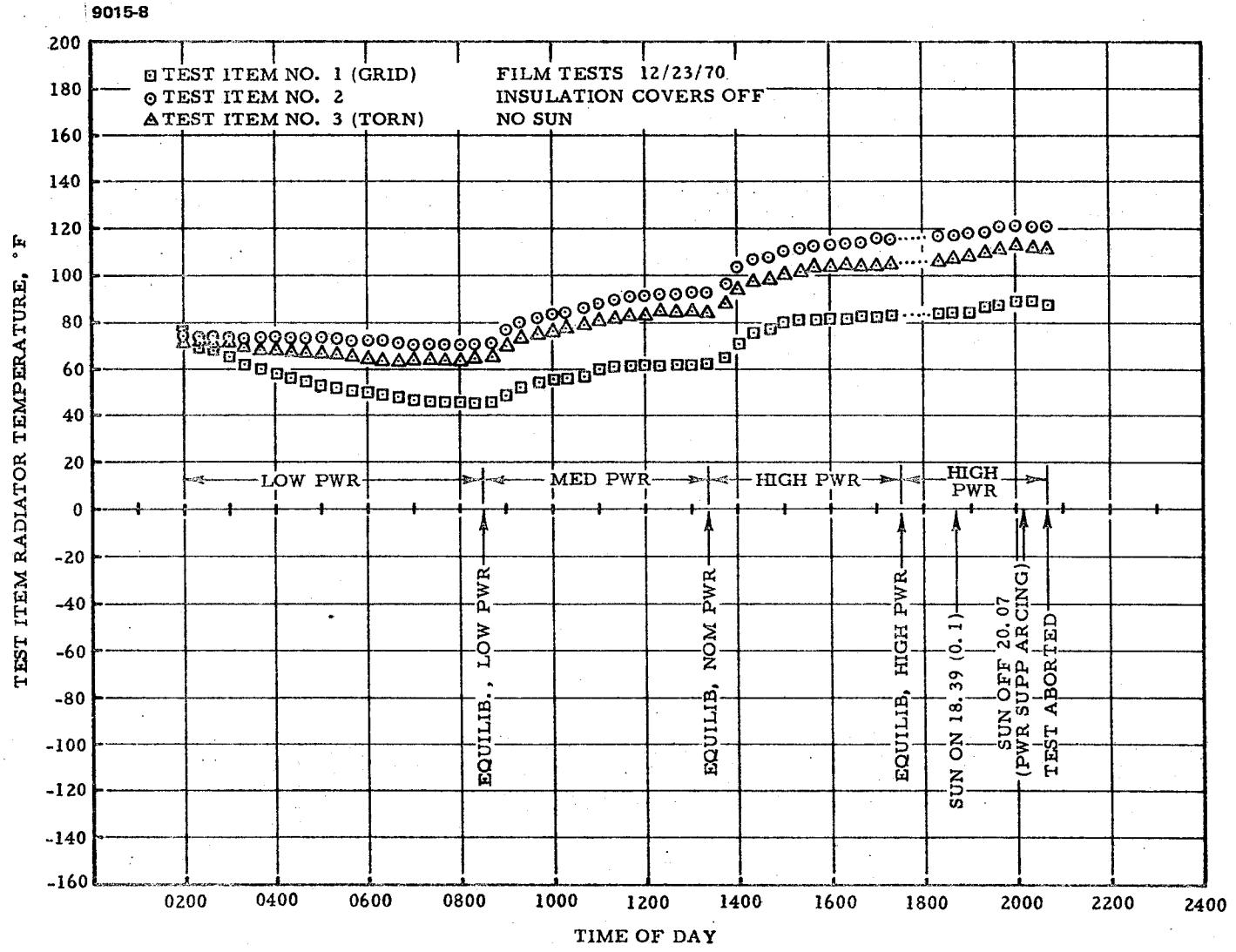


Figure 7-2 LEAM Film Tests (23 Dec 1970)

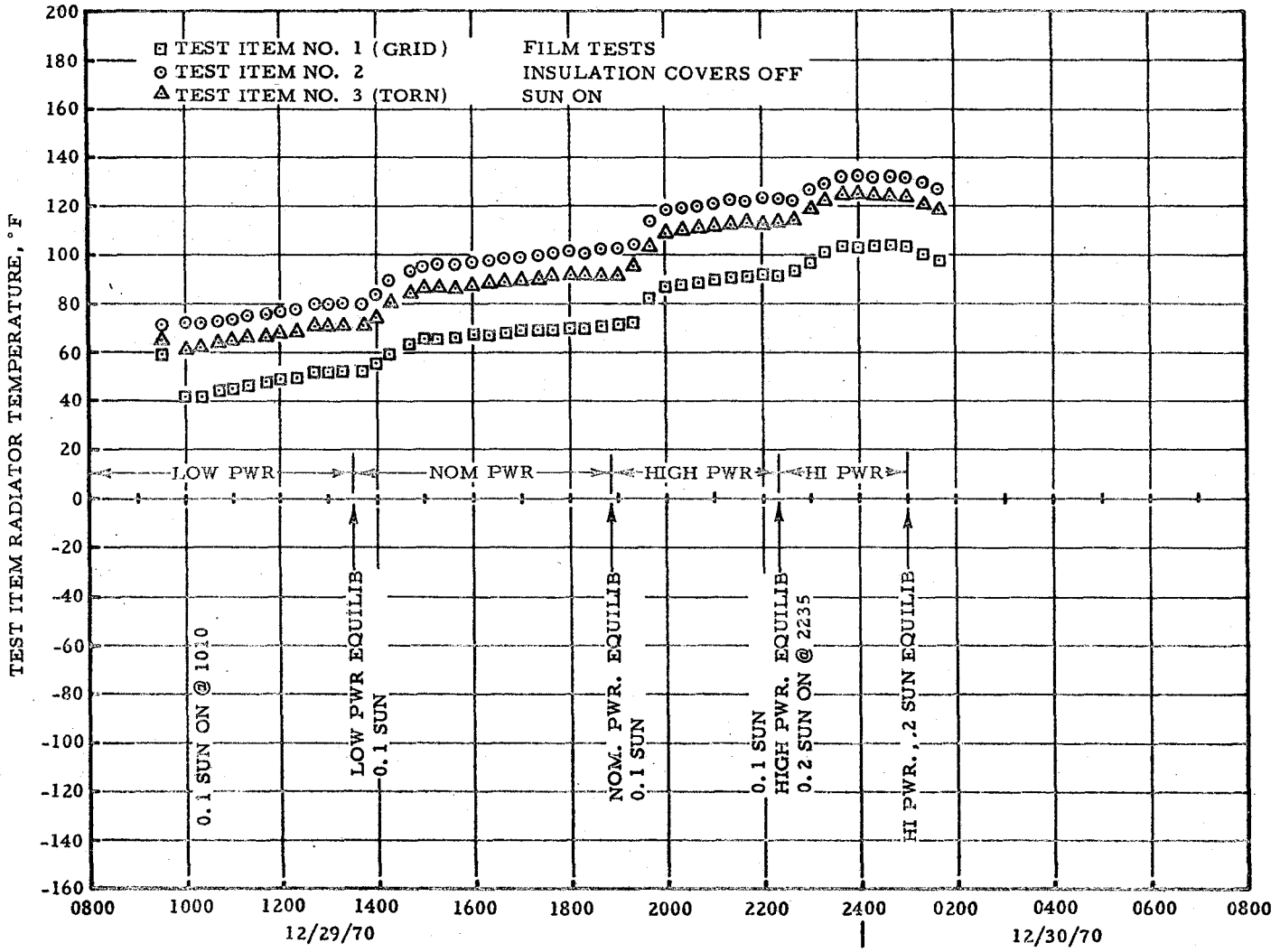
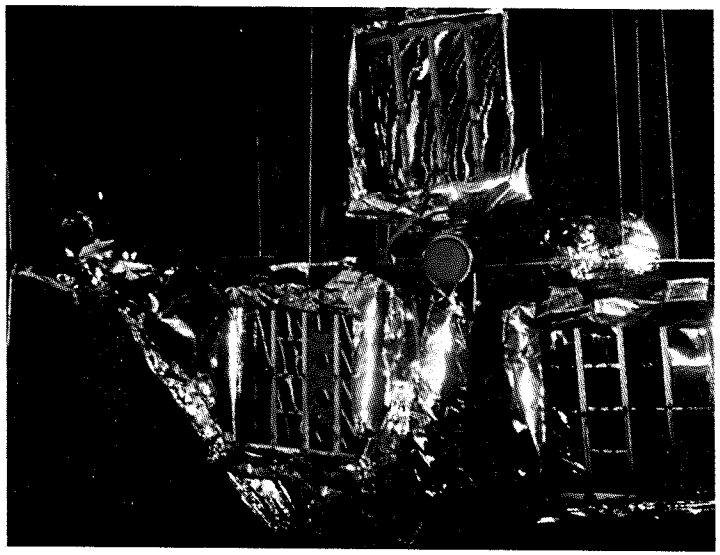


Figure 7-3 LEAM Film Tests (29-30 Dec 1970)

9015-10

1



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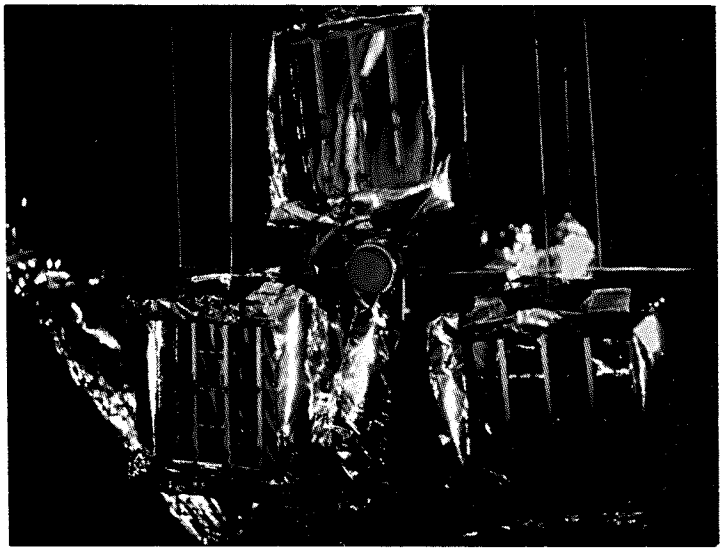


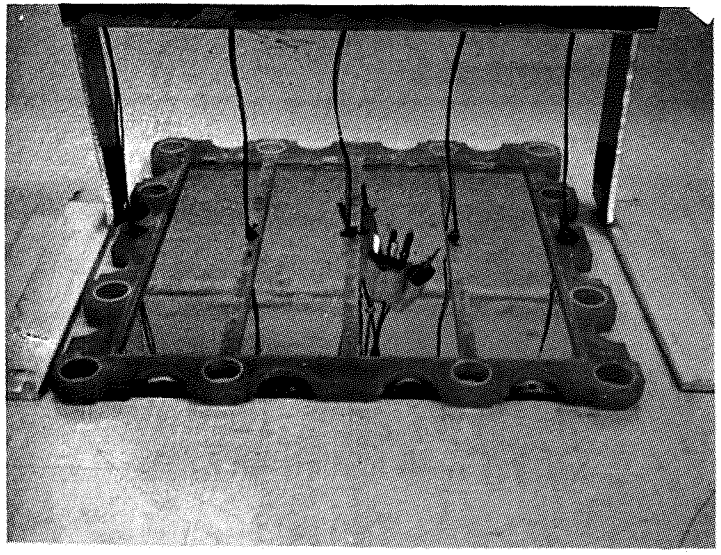
3

1 PRIOR TO SOLAR TEST

2 AND 3 AFTER SOLAR TEST

Figure 7-4 Film Development Tests Prior to and After Solar Test

9015-11



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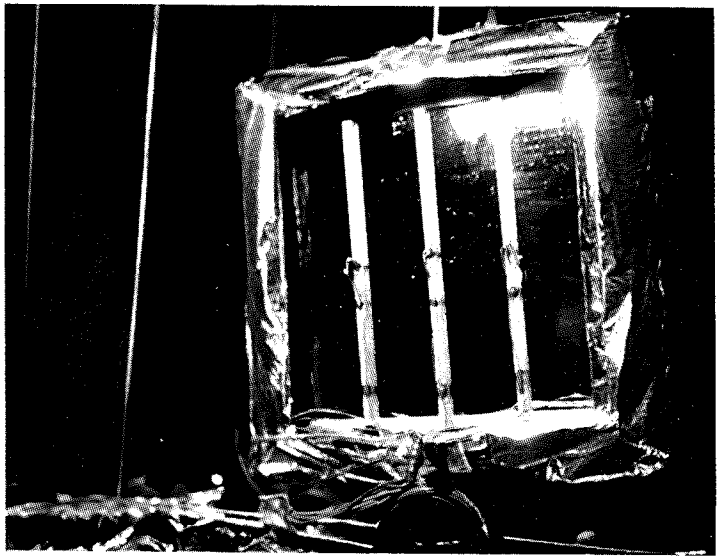

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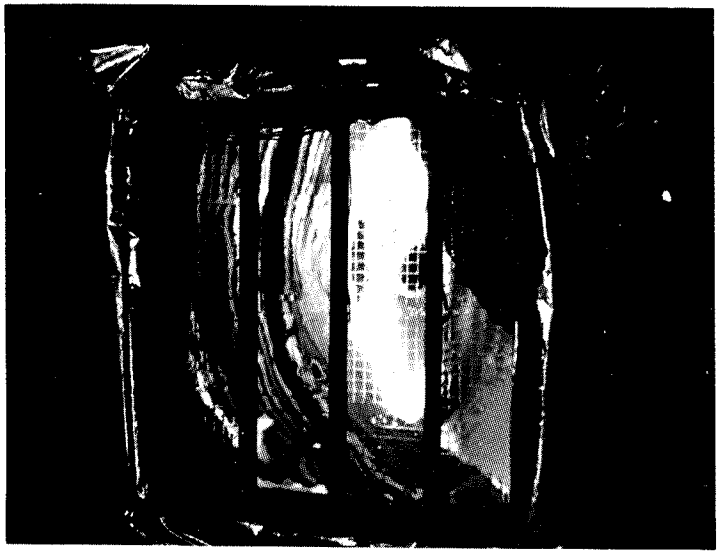


3

1 DURING INSTRUMENTATION

2 INSTALLED IN CALORIMETER PRIOR TO TEST

3 AFTER SOLAR TEST

Figure 7-5 Test Item No. 1 Film Development Tests

TABLE 7-1 HEAT LEAK TEST — BOX NO. 1

Description	Node		Low Test	Power Anal		Med Test	Power Anal		High Test	Power Anal					
Front Insulation	3		-58	-46		-40	-40		-15	-15					
West Insulation	7		-228	-228		-223	-223		-218	-218					
Top Insulation	9		-218	-218		-214	-214		-208	-208					
East Insulation	11		-236	-236		-232	-232		-228	-228					
Bottom Insulation	13		-146	-146		-143	-143		-141	-141					
Frame Edge	15		73	79		98	105		121	130					
Frame Strut-Left	19		65	76		88	104		110	128					
Frame Strut-Center	20		63	75		86	103		108	127					
Frame Strut-Right	21		64	76		86	104		109	128					
Endlosure - West	22		83	82		108	109		131	133					
Enclosure - Top	23		83	82		108	109		131	133					
Enclosure - East	24		83	82		108	109		132	133					
Enclosure-Bottom	25		83	82		108	109		132	133					
Enclosure - Back	26		75	74		98	100		121	124					
Film	101		---	77		---	104		---	129					
Cold Wall	200		-302	-300		-302	-300		-302	-300					

TABLE 7-2 NIGHT CONDITION - BOX NO. 1

Description	Node		Low Power Test	Low Power Anal		Med Power Test	Med Power Anal		High Power Test	High Power Anal
Front Insulation	3		-210	-210		-208	-208		-204	-204
West Insulation	7		-238	-238		-236	-236		-234	-234
Top Insulation	9		-226	-226		-230	-230		-225	-225
East Insulation	11		-244	-244		-243	-243		-240	-240
Bottom Insulation	13		-148	-148		-148	-148		-146	-146
Frame Edge	15		18	34		34	45		55	68
Frame Strut-Left	19		- 10	- 6		4	7		25	27
Frame Strut-Center	20		- 16	- 8		- 4	6		14	24
Frame Strut-Right	21		- 13	- 6		1	7		19	27
Enclosure-West	22		52	58		69	76		93	99
Enclosure-Top	23		52	58		69	76		93	99
Enclosure - East	24		52	58		70	76		93	99
Enclosure-Bottom	25		52	58		70	76		93	99
Enclosure-Back	26		45	52		62	68		83	90
Film	101		-	- 7		-	20		-	41
Cold Wall	200		-302	-300		-302	-300		-302	-300

TABLE 7-3 PARTIAL SUN CASES - BOX NO. 1

Description	Node		Low Test	Power Anal		Med Test	Power Anal		High Test	Power Anal		High Test	Power Anal		
Front Insulation	3		-164	-164		-163	-163		-165	-165		-128	-128		
West Insulation	7		-212	-212		-212	-212		-212	-212		-192	-192		
Top Insulation	9		-221	-221		-220	-220		-216	-216		-206	-206		
East Insulation	11		-198	-198		-200	-200		-204	-204		-170	-170		
Bottom Insulation	13		-117	-117		-	-120		-122	-122		-100	-100		
Frame Edge	15		31	46		48	63		67	84		83	101		
Frame Strut-Left	19		16	23		28	36		42	53		67	80		
Frame Strut-Center	20		10	12		22	26		35	50		60	78		
Frame Strut-Right	21		12	23		24	36		38	53		61	80		
Enclosure-West	22		59	68		79	87		101	108		113	121		
Enclosure-Top	23		59	68		79	87		101	108		113	121		
Enclosure-East	24		60	68		80	87		102	108		114	121		
Enclosure-Bottom	25		60	68		79	87		102	108		113	121		
Enclosure-Back	26		53	61		71	79		92	99		103	112		
Film	101		-	55		-	69		-	86		-	132		
Cold Wall	200		-302	-300		-302	-300		-302	-300		-302	-300		
# of Suns			1/10			1/10			1/10			2/10			

film test summary, and the temperature comparison indicates the validity of the measured infrared emittance of the films. The validity of the measured film solar absorptance is indicated by the temperature comparisons for the partial sun cases listed in Table 7-3.

7.3 TEST ITEM NO. 2

The changes that occurred in Test Item No. 2 are recorded in Figure 7-6. Note the extreme stretch marks in the second 1 x 4 in. frame from the right. Note also the smaller stretch marks in the other frames where the film is bonded to the supports of the 1 x 4 in. frames.

Thermal analysis had predicted that the two center 1 x 4 in. films would reach temperatures higher than those of the 1 x 4 in. films at the edge. This effect is due to the better heat transfer from the edge films to the 4 x 4 in. frame. The fact that the thermocouple film did not distort as much as the other center film may be due to the unique optical properties of the thermocouple film. It will be recalled from Figure 4-2 that the external surface of the film is composed of the thermocouples and 1000 Å of parylene C.

7.4 TEST ITEM NO. 3

Figure 7-7 shows the changes that occurred in Test Item No. 3. Note that the damage, which occurred during instrumentation, was intensified as a result of the solar tests. The stretch marks, however, on the center film are not as pronounced as those on Test Item No. 2, indicating lower temperatures. The most probable cause of this effect is the damaged film. The holes in the film permitted the calorimeter enclosure to "see" the cold wall and thus operate at lower temperatures as evidenced by Figure 7-3.

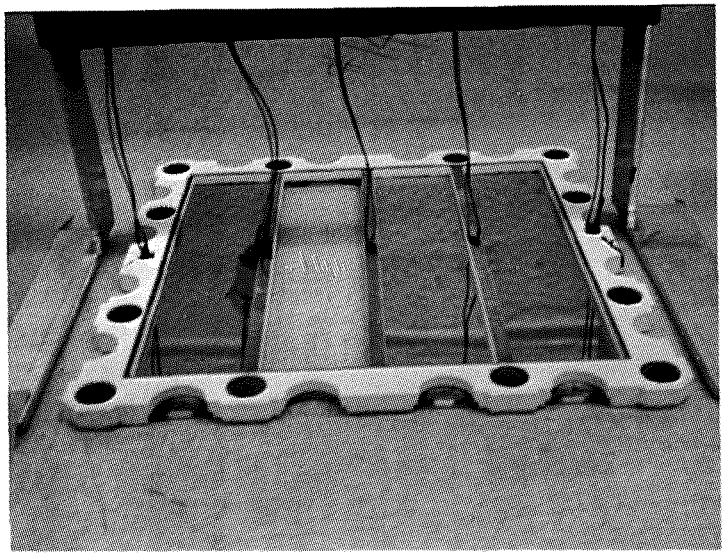
Tables 7-4 and 7-5 show Box No. 2 temperature comparisons for the night and partial sun cases. The night condition temperature comparisons again indicate the validity of the measured infrared emittance of the film, while the partial sun comparisons again show the validity of the measured film solar absorptance.

8. CONCLUSIONS

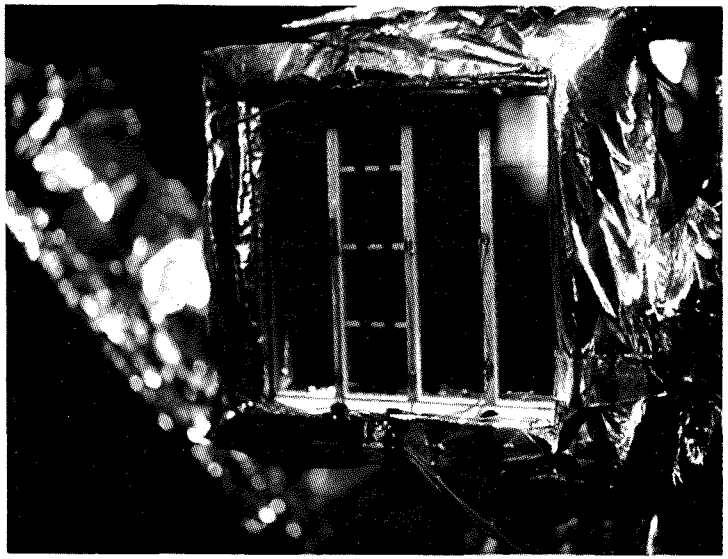
These are:

1. The optical properties of the thin gold films as measured at Goddard are verified by the calorimeter test data analysis.

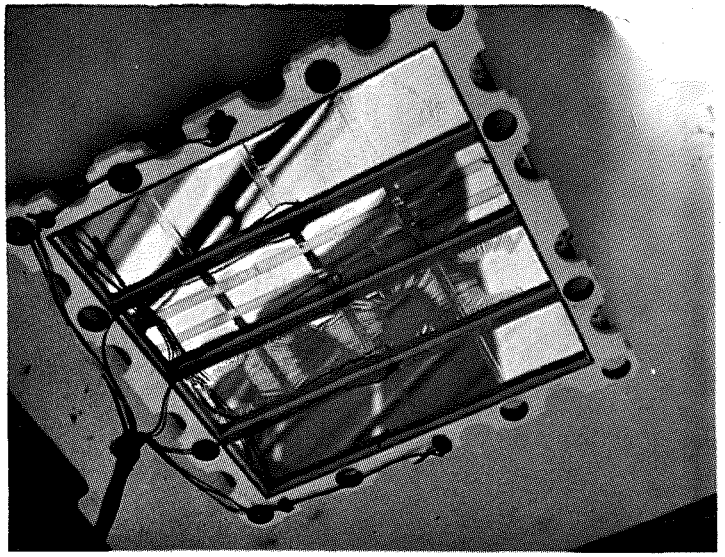
9015-12



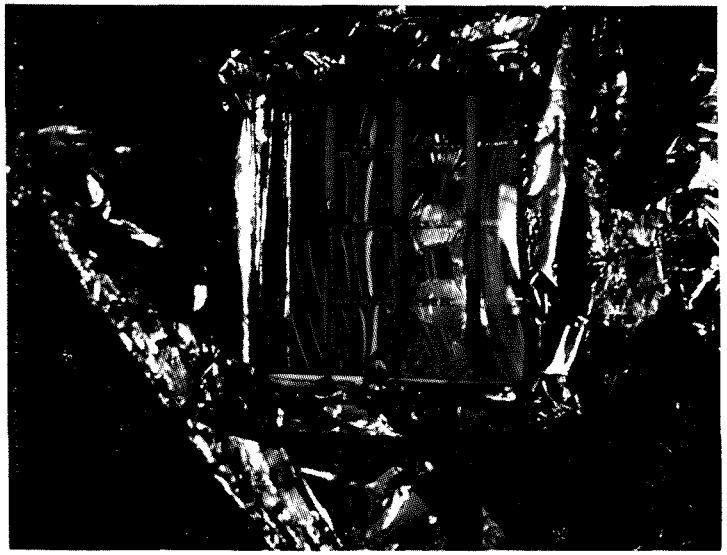
1



2



3

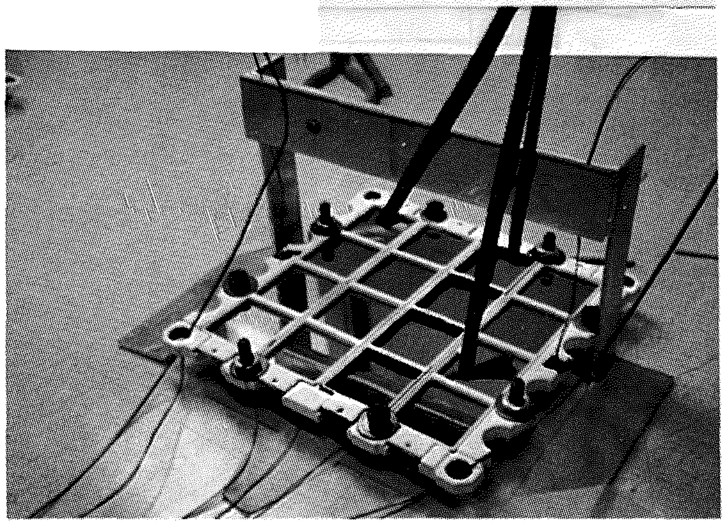


4

1 DURING INSTRUMENTATION; 2 INSTALLED IN CALORIMETER PRIOR TO SOLAR TEST
3 AND 4 AFTER SOLAR TEST

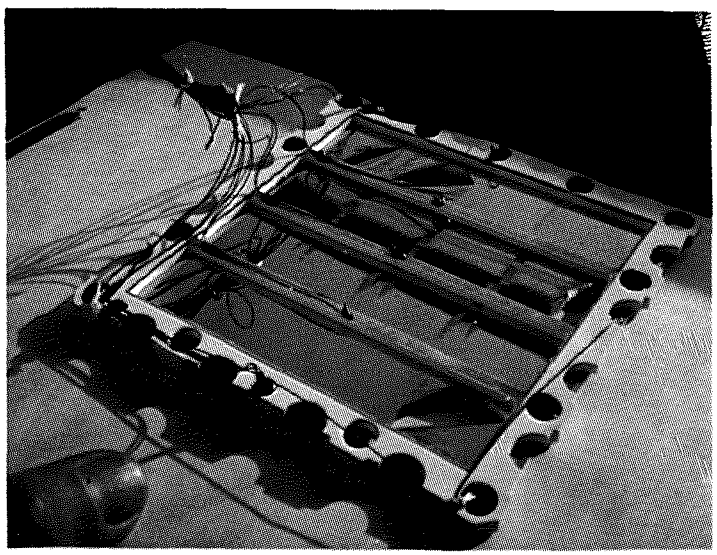
Figure 7-6 Test Item No. 2-Film Development Tests

DAMAGED DURING INSTRUMENTATION



1

2



3

4

1 DURING INSTRUMENTATION; 2 INSTALLED IN CALORIMETER PRIOR TO TEST

3 AND 4 AFTER SOLAR TEST

Figure 7-7 Test Item No. 3-Film Development

TABLE 7-4 NIGHT CONDITION - BOX NO. 2

Description	Node	Low Test	Power Anal	Med Test	Power Anal	High Test	Power Anal
Front Insulation	3	-214	-214	-211	-211	-207	-207
West Insulation	7	-187	-187	-184	-184	-182	-182
Top Insulation	9	-232	-232	-230	-230	-228	-228
East Insulation	11	-236	-236	-234	-234	-232	-232
Bottom Insulation	13	-228	-228	-230	-230	-228	-228
Frame Edge	15	38	58	58	73	81	93
Frame Strut-Left	19	-9	3	8	20	26	38
Frame Strut-Center	20	-22	2	-6	18	12	36
Frame Strut-Right	21	-19	3	-2	20	16	38
Enclosure-West	22	79	83	102	106	127	131
Enclosure-Top	23	79	83	102	106	127	131
Enclosure-East	24	79	83	102	106	127	131
Enclosure-Bottom	25	78	83	102	106	127	131
Enclosure-Back	26	71	76	93	98	116	121
Film	101	—	8	—	25	—	43
Cold Wall	200	-302	-300	-302	-300	-302	-300

TABLE 7-5 PARTIAL SUN CASES - BOX NO. 2

Description	Node		Low Test	Power Anal		Med Test	Power Anal		High Test	Power Anal		High Test	Power Anal		
Front Insulation	3		-121	-121		-124	-124		-138	-138		-84	-84		
West Insulation	7		-150	-150		-151	-151		-155	-155		-134	-134		
Top Insulation	9		-202	-202		-202	-202		-205	-205		-184	-184		
East Insulation	11		-218	-218		-216	-216		-217	-217		-204	-204		
Bottom Insulation	13		-190	-190		-194	-194		-202	-202		-176	-176		
Frame Edge	15		49	78		69	101		88	122		99	118		
Frame Strut-Left	19		19	30		33	45		43	58		62	70		
Frame Strut-Center	20		9	27		21	43		29	54		52	66		
Frame Strut-Right	21		12	30		26	45		33	58		57	70		
Enclosure-West	22		89	93		111	115		133	137		142	146		
Enclosure-Top	23		89	93		111	115		133	137		142	146		
Enclosure-East	24		88	93		111	115		133	137		142	146		
Enclosure-Bottom	25		88	93		111	115		133	137		141	146		
Enclosure-Back	26		81	85		102	107		123	128		132	137		
Film	101		—			—			—	188		—	278		
Cold Wall	200		-302	-300		-302			-302	-300		-302	-3200		
			1/10			1/10			1/10			2/10			

2. The unsupported gold films, as predicted by the thermal math model analysis, are limited in use to solar constants less than 0.20 and therefore cannot be used on the LEAM.

3. Use of the support grid lowers the film temperatures considerably and therefore should be used on the LEAM.

9. RECOMMENDATIONS

Based on the results of these tests and thermal math model analyses, a silver film is recommended for use in the LEAM. The film should have the following optical properties: $\alpha/\epsilon \leq 4.0$, and $\epsilon = 0.03 \pm 0.002$.

The recommended film laminate configuration for the LEAM "UP" and "EAST" sensors is defined as follows:

1. Film Overcoat (Sun Side): 200 Å of Parylene C.

2. Film Coating: 1000 Å of vacuum deposited silver.

3. Film Base: 1800 Å of Parylene C.

4. Film Support (Inside): beryllium copper grid, 1/8 x 1/8 in. mesh, 0.006 in. thick, and 0.0025 in. ribs.

The beryllium copper grid was chosen to enhance the conduction of heat from the film to the film frame. Analysis (Ref. 1 in Section 10) has shown that maximum film temperatures can be reduced by 150°F with the addition of the grid.

Silver was chosen as the film coating because it exhibits, by theory and test, the lowest ratio of α_s/ϵ_h (solar absorptance/hemispherical infrared emittance) and hence the lowest film temperature of any of the candidate films (Ref. 2). In addition, silver has a low emittance which is needed to minimize the night heat leak.

The 200 Å Parylene overcoat is needed to prevent tarnishing of the silver, thus preventing an increase of solar absorptance.

10. REFERENCES

1. LEAM - 79, "Incorporation of a Grid in the Front Film," to L. Galan from R. Simms, 8 December 1970.

2. BxA 70-210-375, "LEAM Film Development Parametric Study," to L. Galan from R. Simms, 19 November 1970.

APPENDIX

LEAM FILM DEVELOPMENT

THERMAL VACUUM TEST DATA

Heat Leak Test 12/22/70, 0620 Hrs	Test Item 1 T/C	MV	T(°F)	Test Item 2 T/C	MV	T(°F)	Test Item 3 T/C	MV	T(°F)
Low Power	01	-11.70	-262	31	-11.67	-260	61	- 5.65	- 19
Equilibrium	02	- 5.46	- 12	32	- 5.46	- 12	62	-11.68	-261
	03	- 6.83	- 58	33	- 6.65	- 52	63	- 5.82	- 25
Insulation	04	- 2.95	65	34	- 2.31	84	64	- 3.04	62
Caps On	05	- 6.40	- 44	35	- 7.97	-100	65	- 5.75	- 22
	06	- 3.52	48	36	- 3.73	41	66	- 2.82	69
Sun Off	07	-11.03	-228	37	- 9.85	-174	67	-11.43	-248
	08	- 2.42	81	38	- 1.89	97	68	- 2.02	93
	09	-10.84	-218	39	-11.00	-226	69	-10.82	-218
	10	- 2.54	77	40	- 1.87	97	70	- 2.08	91
	11	-11.21	-236	41	-11.03	-228	71	- 9.93	-177
	12	- 2.68	73	42	- 2.16	89	72	- 2.20	87
	13	- 9.17	-146	43	-10.84	-218	73	-11.43	-247
	14	- 2.48	79	44	- 2.03	93	74	- 2.10	90
	15	- 2.67	73	45	- 2.14	89	75	- 2.25	86
	16	- 2.60	75	46	- 2.01	93	76	- 2.20	87
	17	- 2.69	73	47	- 2.02	93	77	- 2.18	88
	18	- 2.65	74	48	- 1.91	96	78	- 2.20	87
	19	- 2.95	65	49	- 2.83	69	79	- 2.83	69
	20	- 3.01	63	50	- 2.93	66	80	- 2.96	65
	21	- 3.00	64	51	- 2.94	66	81	- 3.00	64
	22	- 2.35	83	52	- 1.63	104	82	- 1.87	97
	23	- 2.35	83	53	- 1.63	104	83	- 1.86	98
	24	- 2.34	83	54	- 1.64	104	84	- 1.85	98
	25	- 2.34	83	55	- 1.65	104	85	- 1.85	98
	26	- 2.63	75	56	- 1.93	96	86	- 2.13	89
	27	- 2.57	76	57	- 1.93	96	87	- 2.14	89
	P1	5.62W		P2	5.62W		P3	5.58W	

Heat Leak Test 12/22/70, 1230 Hrs	Test Item 1 T/C	MV	T(°F)		Test Item 2 T/C	MV	T(°F)		Test Item 3 T/C	MV	T(°F)
	01	-11.71	-262		31	-11.66	-260		61	- 4.79	9
Nominal Power	02	- 4.80	8		32	- 4.72	11		62	-11.71	-263
Equilibrium	03	- 6.29	- 40		33	- 6.19	- 37		63	- 5.17	- 3
	04	- 2.04	92		34	- 1.47	108		64	- 3.07	62
Insulation	05	- 5.97	- 30		35	- 7.58	- 85		65	- 5.19	- 4
Caps On	06	- 2.72	72		36	- 3.01	63		66	- 2.00	94
	07	-10.94	-223		37	- 9.76	-170		67	-11.35	-244
Sun Off	08	- 1.54	107		38	- 1.00	122		68	- 1.11	119
	09	-10.76	-214		39	-10.92	-222		69	-10.77	-215
	10	- 1.70	102		40	- 0.98	122		70	- 1.18	117
	11	-11.13	-232		41	-10.94	-223		71	- 9.84	-173
	12	- 1.82	98		42	- 1.29	114		72	- 1.33	113
	13	- 9.11	-143		43	-10.78	-216		73	-11.41	-246
	14	- 1.62	104		44	- 1.16	118		74	- 1.22	116
	15	- 1.84	98		45	- 1.30	114		75	- 1.42	110
	16	- 1.77	100		46	- 1.15	118		76	- 1.85	98
	17	- 1.87	97		47	- 1.16	118		77	- 1.84	112
	18	- 1.82	99		48	- 1.05	120		78	- 1.35	112
	19	- 2.17	88		49	- 2.08	91		79	- 2.08	91
	20	- 2.23	86		50	- 2.19	88		80	- 2.23	86
	21	- 2.23	86		51	- 2.19	88		81	- 2.27	85
	22	- 1.49	108		52	- .75	129		82	- .98	123
	23	- 1.49	108		53	- .75	129		83	- .98	123
	24	- 1.47	108		54	- .76	129		84	- .96	123
	25	- 1.47	108		55	- .77	128		85	- .96	123
	26	- 1.82	98		56	- 1.11	119		86	- 1.30	113
	27	- 1.75	100		57	- 1.10	119		87	- 1.30	113
	P1	6.72W			P2	6.59W			P3	6.71W	

Heat Leak Test 12/22/70, 1810 Hrs	Test Item 1 T/C	MV	T(°F)	Test Item 2 T/C	MV	T(°F)	Test Item 3 T/C	MV	T(°F)
High Power	01	-11.68	-261	31	-11.62	-258	61	- 3.80	39
Equilibrium	02	- 3.86	38	32	- 3.76	41	62	-11.66	-260
	03	- 5.56	- 15	33	- 5.68	- 20	63	- 4.44	20
Insulation	04	- 1.20	116	34	- 0.47	137	64	- 3.04	62
Caps On	05	- 5.47	- 13	35	- 7.10	- 68	65	- 4.55	16
	06	- 1.91	96	36	- 2.17	88	66	- 1.12	119
Sun Off	07	-10.83	-218	37	- 9.65	-165	67	-11.22	-237
	08	- 0.68	131	38	+ 0.05	151	68	- 0.13	146
	09	-10.62	-208	39	-10.85	-219	69	-10.68	-211
	10	- 0.84	127	40	+ 0.08	152	70	- 0.22	144
	11	-11.05	-228	41	-10.84	-218	71	- 9.73	-168
	12	- 0.97	123	42	- 0.26	143	72	- 0.37	140
	13	- 9.06	-141	43	-10.74	-214	73	-11.36	-244
	14	- 0.76	129	44	- 0.12	147	74	- 0.26	143
	15	- 1.05	121	45	- 0.31	141	75	- 0.52	136
	16	- 0.96	123	46	- 0.15	146	76	- 0.45	138
	17	- 1.07	120	47	- 0.16	145	77	- 0.44	138
	18	- 1.01	122	48	- 0.03	149	78	- 0.45	138
	19	- 1.41	110	49	- 1.19	117	79	- 1.27	114
	20	- 1.49	108	50	- 1.32	113	80	- 1.43	110
	21	- 1.47	109	51	- 1.31	113	81	- 1.47	109
	22	- 0.67	131	52	+ 0.31	159	82	- 0.06	148
	23	- 0.67	131	53	+ 0.31	159	83	- 0.06	148
	24	- 0.64	132	54	+ 0.29	158	84	- 0.04	149
	25	- 0.64	132	55	+ 0.29	158	85	- 0.05	149
	26	- 1.05	121	56	- 0.11	147	86	- 0.44	138
	27	- 0.99	122	57	- 0.11	147	87	- 0.44	138
	P1	7.87W		P2	7.88W		P3	7.93W	

Film Test 12/23/70, 0830 Hrs	Test Item 1 T/C	MV	T (°F)	Test Item 2 T/C	MV	T (°F)	Test Item 3 T/C	MV	T (°F)
Low Power	1	---		31	---		61	---	
Equilibrium	2	---		32	---		62	---	
	3	-10.66	-210	33	-10.75	-214	63	-10.06	-183
Insulation	4	- 5.78	- 23	34	- 5.09	- 1	64	- 2.96	65
Caps Off	5	- 8.94	-137	35	-10.58	-206	65	+ .66	168
	6	- 6.71	- 54	36	- 6.84	- 59	66	- 5.39	- 11
Sun Off	7	-11.23	-238	37	-10.12	-187	67	-11.49	-250
	8	-3.49	49	38	- 2.82	69	68	- 2.91	66
	9	-11.10	-226	39	-11.12	-232	69	-10.84	-218
	10	- 3.67	43	40	- 2.78	70	70	- 2.98	64
	11	-11.35	-244	41	-11.19	-236	71	-10.04	-182
	12	- 3.73	41	42	- 2.97	65	72	- 3.11	60
	13	- 9.22	-148	43	-11.05	-228	73	-11.48	-250
	14	- 3.57	46	44	- 2.9	66	74	- 3.06	62
	15	- 4.50	18	45	- 3.86	38	75	- 3.99	34
	16	- 4.28	25	46	- 3.58	46	76	- 3.83	39
	17	- 4.51	18	47	- 3.59	46	77	- 3.81	39
	18	- 4.36	22	48	- 3.34	55	78	- 3.75	41
	19	- 5.37	- 10	49	- 5.33	- 9	79	- 5.65	- 19
	20	- 5.58	- 16	50	- 5.75	- 22	80	- 6.07	- 33
	21	- 5.47	- 13	51	- 5.65	- 19	81	- 5.94	- 28
	22	- 3.40	52	52	- 2.50	79	82	- 2.77	70
	23	- 3.40	52	53	- 2.49	79	83	- 2.75	71
	24	- 3.39	52	54	- 2.50	79	84	- 2.74	71
	25	- 3.39	52	55	- 2.51	78	85	- 2.75	71
	26	- 3.63	45	56	- 2.75	71	86	- 2.99	64
	27	- 3.57	46	57	- 2.75	71	87	- 2.99	64
	P1	5.59 W			P2	5.56W		P3	5.74W

Film Test 12/23/70, 1320 Hrs.	Test Item 1 T/C	MV	T (°F)	Test Item 2 T/C	MV	T (°F)	Test Item 3 T/C	MV	T (°F)
	01	---		31	---		61	---	
Nominal Power	02	---		32	---		62	---	
Equilibrium	03	-10.61	-208	33	-10.69	-211	63	- 9.95	-178
	04	- 5.34	- 9	34	- 4.49	18	64	- 2.97	65
Insulation	05	- 8.85	-133	35	-10.54	-204	65	---	
Caps Off	06	- 6.35	- 42	36	- 6.42	- 45	66	- 4.84	7
	07	-11.21	-236	37	-10.08	-184	67	-11.45	-248
Sun Off	08	- 2.91	66	38	- 2.08	91	68	- 2.15	89
	09	-11.08	-230	39	-11.09	-230	69	-10.81	-217
	10	- 3.11	60	40	- 2.03	93	70	- 2.27	85
	11	-11.34	-243	41	-11.17	-234	71	-10.02	-182
	12	- 3.16	59	42	- 2.24	86	72	- 2.42	81
	13	- 9.22	-148	43	-11.08	-230	73	-11.53	-253
	14	- 3.00	63	44	- 2.17	88	74	- 2.36	83
	15	- 3.97	34	45	- 3.18	58	75	- 3.35	53
	16	- 3.72	42	46	- 2.87	67	76	- 3.17	59
	17	- 3.97	34	47	- 2.90	67	77	- 3.16	59
	18	- 3.80	39	48	- 2.61	75	78	- 3.08	61
	19	- 4.93	4	49	- 4.81	8	79	- 5.18	- 4
	20	- 5.19	- 4	50	- 5.25	- 6	80	- 5.61	- 17
	21	- 5.04	1	51	- 5.13	- 2	81	- 5.48	- 13
	22	- 2.80	69	52	- 1.71	102	82	- 2.05	92
	23	- 2.79	69	53	- 1.70	102	83	- 2.03	92
	24	- 2.77	70	54	- 1.71	102	84	- 2.02	93
	25	- 2.79	70	55	- 1.72	102	85	- 2.03	92
	26	- 3.06	62	56	- 2.01	93	86	- 2.31	84
	27	- 3.00	64	57	- 2.01	93	87	- 2.31	84
	P1	6.67 W		P2	6.72 W		P3	6.76 W	

Film Test 12/23/70 1730 Hrs	Test Item 1 T/C	MV	T (°F)	Test Item 2 T/C	MV	T (°F)	Test Item 3 T/C	MV	T (°F)
	01	---		31	---		61	---	
High Power	02	---		32	---		62	---	
Equilibrium	03	-10.52	-204	33	-10.59	-207	63	- 9.79	-171
	04	- 4.73	+ 11	34	- 3.93	+ 35	64	- 3.00	+ 64
Insulation	05	- 8.70	-127	35	-10.45	-200	65	- .37	
Caps Off	06	- 5.85	- 26	36	- 5.95	- 29	66	- 4.23	+ 26
	07	-11.15	-234	37	-10.04	-182	67	-11.40	-246
Sun Off	08	- 2.11	+ 90	38	- 1.22	+116	68	- 1.34	+112
	09	-10.98	-225	39	-11.03	-228	69	-10.75	-214
	10	- 2.32	+ 84	40	- 1.16	+117	70	-1.45	+109
	11	-11.29	-240	41	-11.11	-232	71	- 9.96	-178
	12	- 2.37	+ 82	42	- 1.42	+110	72	- 1.62	+104
	13	- 9.19	-146	43	-11.03	-228	73	-11.50	-252
	14	- 2.21	+ 87	44	- 1.34	+112	74	- 1.54	+107
	15	- 3.28	+ 55	45	- 2.43	+ 81	75	- 2.65	+ 74
	16	- 2.99	+ 64	46	- 2.08	+ 91	76	- 2.45	+ 80
	17	- 3.27	+ 55	47	- 2.13	+ 89	77	- 2.44	+ 80
	18	- 3.08	+ 61	48	- 1.80	+ 99	78	- 2.34	+ 83
	19	- 4.27	+ 25	49	- 4.24	+ 26	79	- 4.66	+ 13
	20	- 4.63	+ 14	50	- 4.70	+ 12	80	- 5.08	- 1
	21	- 4.47	+ 19	51	- 4.57	+ 16	81	- 4.96	+ 3
	22	- 2.03	+ 93	52	- .84	+127	82	- 1.26	+115
	23	- 2.02	+ 93	53	- .84	+127	83	- 1.24	+115
	24	- 2.01	+ 93	54	- .84	+127	84	- 1.22	+116
	25	- 2.02	+ 93	55	- .86	+126	85	- 1.24	+115
	26	- 2.34	+ 83	56	- 1.20	+116	86	- 1.56	+106
	27	- 2.27	+ 85	57	- 1.20	+116	87	- 1.57	+106
	P1	7.90	W	P2	7.92	W	P3	7.94	W

Film Test 12/29/70, 1330 Hrs.	Test Item 1 T/C	MV	T (°F)		Test Item 2 T/C	MV	(°F)		Test Item 3 T/C	MV	T (°F)
	01	---			31	---			61	---	
Low Power	02	---			32	---			62	---	
Equilibrium	03	- 9.60	-164		33	- 8.54	-121		63	- 8.44	-117
	04	- 9.46	-158		34	- 4.53	+ 17		64	- 3.06	+ 62
	05	- 7.75	- 91		35	- 8.51	-120		65	---	---
Insulation	06	- 6.04	- 32		36	- 6.01	- 31		66	- 4.80	+ 9
Caps Off	07	-10.69	-212		37	- 9.26	-150		67	-10.83	-218
	08	- 3.22	+ 57		38	- 2.46	+ 80		68	- 2.61	+ 75
Sun On @	09	-10.89	-221		39	-10.50	-202		69	- 9.96	-178
0.1S (13 W/ft^2)	10	- 3.42	+ 51		40	- 2.42	+ 81		70	- 2.69	+ 73
	11	-10.39	-198		41	-10.82	-218		71	- 9.11	-143
	12	- 3.47	+ 49		42	- 2.65	+ 74		72	- 2.81	+ 69
	13	- 8.44	-117		43	-10.22	-190		73	-10.93	-222
	14	- 3.29	+ 55		44	- 2.57	+ 76		74	- 2.76	+ 71
	15	- 4.07	+ 31		45	- 3.48	+ 49		75	- 3.61	+ 45
	16	- 3.87	+ 37		46	- 3.20	+ 58		76	- 3.47	+ 48
	17	- 4.03	+ 32		47	- 3.16	+ 59		77	- 3.48	+ 49
	18	- 3.89	+ 37		48	- 2.91	+ 66		78	- 3.41	+ 51
	19	- 4.56	+ 16		49	- 4.47	+ 19		79	- 4.85	+ 7
	20	- 4.74	+ 10		50	- 4.78	+ 9		80	- 5.19	- 4
	21	- 4.70	+ 12		51	- 4.68	+ 12		81	- 5.12	- 2
	22	- 3.14	+ 59		52	- 2.16	+ 89		82	- 2.49	+ 79
	23	- 3.14	+ 59		53	- 2.16	+ 89		83	- 2.48	+ 79
	24	- 3.13	+60		54	- 2.17	+ 88		84	- 2.47	+ 79
	25	- 3.13	+ 60		55	- 2.18	+ 88		85	- 2.48	+ 79
	26	- 3.37	+ 53		56	- 2.43	+ 81		86	- 2.73	+ 72
	27	- 3.31	+ 54		57	- 2.43	+ 81		87	- 2.73	+ 72
	P1	5.74	W		P2	5.44	W		P3	5.62	W

Film Test 12/29/70, 1850 Hrs	Test Item 1 T/C	MV	T	Test Item 2 T/C	MV	T	Test Item 3 T/C	MV	T
Nominal Power	01	-	-	31	-	-	61	-	-
Equilibrium	02	-	-	32	-	-	62	-	-
	03	-9.60	-163	33	-8.63	-124	63	-8.50	-120
Insulation	04	-10.21	-190	34	-3.98	+ 34	64	-3.00	+ 64
Caps Off	05	-7.72	- 90	35	-9.61	-164	65	-	-
	06	-5.70	- 21	36	-5.66	- 19	66	-4.32	+ 24
Sun on @	07	-10.70	-212	37	-9.31	-151	67	-10.90	-221
0.1S (13W/ft^2)	08	-2.56	+ 77	38	-1.71	+102	68	-1.87	+ 97
	09	-10.86	-220	39	-10.49	-202	69	-10.01	-181
	10	- 2.77	+ 70	40	- 1.65	+103	70	- 1.96	+ 95
	11	-10.44	-200	41	-10.80	-216	71	- 9.20	-147
	12	- 2.82	+ 69	42	- 1.91	+ 96	72	- 2.11	+ 90
	13	- 2.48	+ 79	43	-10.31	-194	73	-11.06	-229
	14	- 2.63	+ 75	44	- 1.82	+ 99	74	- 2.05	+ 92
	15	- 3.51	+ 48	45	- 2.82	+ 69	75	- 3.00	+ 64
	16	- 3.28	+ 55	46	- 2.50	+ 79	76	- 2.83	+ 69
	17	- 3.48	+ 49	47	- 2.50	+ 79	77	- 2.84	+ 68
	18	- 3.31	+ 54	48	- 2.20	+ 87	78	- 2.76	+ 71
	19	- 4.17	+ 28	49	- 4.01	+ 33	79	- 4.50	+ 18
	20	- 4.38	+ 22	50	- 4.41	+ 21	80	- 4.84	+ 7
	21	- 4.30	+ 24	51	- 4.25	+ 26	81	- 4.80	+ 9
	22	- 2.48	+ 79	52	- 1.38	+111	82	- 1.77	+100
	23	- 2.48	+ 79	53	- 1.37	+111	83	- 1.75	+101
	24	- 2.46	+ 80	54	- 1.38	+111	84	- 1.74	+101
	25	- 2.47	+ 79	55	- 1.39	+111	85	- 1.75	+101
	26	- 2.75	+ 71	56	- 1.70	+102	86	- 2.04	+ 92
	27	- 2.70	+ 73	57	- 1.70	+102	87	- 2.05	+ 92
	P_1	6.70W		P_2	6.71W		P_3	6.69W	

Film Test 12/29/70 2220 Hrs	Test Item 1 T/C	MV	T	Test Item 2 T/C	MV	T	Test Item 3 T/C	MV	T
	01	-	-	31	-	-	61	-	-
High Power	02	-	-	32	-	-	62	-	-
Equilibrium	03	- 9.64	-165	33	- 8.98	-138	63	- 8.45	-118
	04	-10.26	-192	34	- 3.45	+ 50	64	- 2.97	+ 65
Insulation	05	- 7.73	- 91	35	- 9.08	-142	65	-	-
Caps Off	06	- 5.31	- 8	36	- 5.42	- 12	66	- 3.77	+ 40
	07	-10.72	-212	37	- 9.40	-155	67	-10.89	-221
Sun On @	08	- 1.79	+ 99	38	- 9.40	+124	68	- 1.06	+120
0.1S (13W/ft.^{2})	09	-10.80	-216	39	-10.55	-205	69	-10.01	-181
	10	- 2.01	+ 93	40	- .869	+126	70	- 1.15	+118
	11	-10.53	-204	41	-10.81	-217	71	- 9.26	-150
	12	- 2.06	92	42	- 1.16	+117	72	- 1.23	+115
	13	- 8.56	-122	43	-10.48	-202	73	-11.10	-231
	14	- 1.87	97	44	- 1.06	+120	74	- 1.25	+115
	15	- 2.88	67	45	- 2.17	88	75	- 2.33	84
	16	- 2.60	75	46	- 1.81	99	76	- 2.13	89
	17	- 2.85	68	47	- 1.84	98	77	- 2.14	89
	18	- 2.65	74	48	- 1.51	107	78	- 2.04	92
	19	- 3.71	42	49	- 3.69	43	79	- 4.04	32
	20	- 3.95	35	50	- 4.14	29	80	- 4.47	19
	21	- 3.85	38	51	- 4.00	33	81	- 4.37	22
	22	- 1.72	101	52	- .605	133	82	- .987	122
	23	- 1.72	101	53	- .600	133	83	- .969	123
	24	- 1.70	102	54	- .607	133	84	- .953	123
	25	- 1.71	102	55	- .627	133	85	- .968	123
	26	- 2.04	92	56	- .979	123	86	- 1.31	113
	27	- 1.98	94	57	- .975	123	87	- 1.31	113
	P_1	7.93	W	P_2	7.93	W	P_3	7.95	W

Film Test 12/30/70, 0100 Hrs	Test Item 1			Test Item 2			Test Item 3		
	T/C	MV	T	T/C	MV	T	T/C	MV	T
High Power	01	-	-	31	-	-	61	-	-
Equilibrium	02	-	-	32	-	-	62	-	-
	03	- 8.72	-128	33	- 7.54	- 84	63	- 7.47	- 81
Insulation	04	- 9.80	-172	34	- 2.99	+ 64	64	- 2.97	+ 65
Caps Off	05	- 6.74	- 55	35	- 7.78	- 92	65	NG	-
	06	- 4.63	+ 14	36	- 4.80	+ 9	66	- 3.25	+ 56
Sun On @	07	-10.27	-192	37	- 8.86	-134	67	-10.39	-198
0.1S (26W/ft.^{2})	08	- 1.34	+112	38	- 0.59	+134	68	- 0.63	+133
	09	-10.58	-206	39	-10.08	-184	69	- 9.41	-155
	10	- 1.56	+106	40	- 0.52	+136	70	- 0.71	+130
	11	- 9.77	-170	41	-10.53	-204	71	- 8.72	-128
	12	- 1.63	+104	42	- 0.82	+127	72	- 0.91	+125
	13	- 7.98	-100	43	- 9.91	-176	73	-10.80	-216
	14	- 1.42	+110	44	- 0.71	+130	74	- 0.81	+127
	15	- 2.34	83	45	- 1.82	99	75	- 1.89	97
	16	- 2.07	91	46	- 1.46	109	76	- 1.68	103
	17	- 2.28	85	47	- 1.45	109	77	- 1.73	101
	18	- 2.08	91	48	- 1.11	119	78	- 1.62	104
	19	- 2.88	67	49	- 3.04	62	79	- 3.40	52
	20	- 3.11	60	50	- 3.38	52	80	- 3.80	39
	21	- 3.08	61	51	- 3.21	57	81	- 3.77	40
	22	- 1.31	113	52	- 0.28	142	82	- 0.59	134
	23	- 1.30	113	53	- 0.27	142	83	- 0.57	134
	24	- 1.28	114	54	- 0.28	142	84	- 0.56	135
	25	- 1.30	113	55	- 0.30	141	85	- 0.58	134
	26	- 1.65	103	56	- 0.66	132	86	- 0.93	124
	27	- 1.59	105	57	- 0.66	132	87	- 0.93	124
	P_1	7.91	W	P_2	7.76	W	P_3	7.92	W