B. Mercer

ASE OFF-EQUATORIAL THERMAL STUDY

The purpose of this ATM is to summarize the results of an in-house thermal study conducted to evaluate the thermal performance of the Active Seismic Experiment (ASE) for the current landing site latitude specification range of ± 5 degrees for Apollo flights 11 through 13 as compared to the revised landing site requirement of ± 45 degrees latitude for Apollo flights 14 through 19. The study was conducted under BxA CCP 229 in response to NASA MSC/LSPO Letter No. BG 931-L323-T97 (95223) dated 17 November 1969.

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ILLUSTRATIONS

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1.0 INTRODUCTION

The MSC direction of reference 1 required that Bendix perform a preliminary study to determine the impact on the ASE Mortar Box thermal design for proposed landing sites up to 45 degrees latitude. The detailed tasks conducted for the study are summarized below:

1. Determine the maximum deployment constraints for current Flight ASE.
2. Determine the thermal impact of the increased latitude sites on experiment performance.
3. Identify possible quick fixes (if required).

The ASE experiment, shown in Figure 1.1, has been designed to operate per the original Exhibit B specification requirement for landing sites within ± 5^{o} latitude of the equator. In addition, the ASE has a vertical alignment requirement of ± 10^{o} and a deployment requirement of ± 3^{o} from assumed geophone deployment lines at the landing sites. Both of these alignments are performed by the crew on an eyeball basis. In order to evaluate the effect on the ASE thermal performance of off-equatorial deployment at latitudes up to 45 degrees, thermal analyses were performed for both nominal and degraded thermal control surfaces at these latitudes using an existing computerized thermal model. This report documents the present thermal model of the ASE Mortar Box, the boundary conditions used in the model, and results obtained for the off-equatorial thermal study.

2.0 SUMMARY

From the analysis performed it was determined that the current ASE thermal design is adequate for all deployment latitudes currently under consideration as the resulting temperatures of the mortar centers, the critical experiment temperature, were well within the specification range of -76°F to 186°F for a nominal thermal control coating condition as well as for 50% dust coverage. In the case of 100% dust coverage the thermal performance of the ASE approaches the upper design limit established for the experiment of 186°F at lunar noon for latitudes greater than 25 degrees. A preliminary report, presented in reference 2, includes the results of the initial analysis.

3.0 THERMAL MODELOF ASE MORTAR BOX

3.1 Node Description

The thermal model consists of 35 nodes representing the various components of the ASE and two infinite nodes corresponding to the lunar surface and space, both of which are held at constant temperature. Table 3.1 contains a listing of the various nodes and their physical significance. The relative positions of the nodes are located in Figure 3.1.

3.2 Resistors

The nodes are interconnected by means of a network of resistors which were previously calculated for the original ASE thermal model used for thermal analyses at equatorial deployment sites (see references 3, 8, 9 and 10). A listing of the resistors is found in Table 3.2.

3.3 Lunar Surface Temperature

In the course of the deployment analysis, the variation of lunar surface temperature as a function of deployment latitude was considered. The same value of the lunar surface temperature was used irregardless of the amount of dust degradation simulated on the ASE. Temperatures of the lunar surface used in the analysis are found in Table 3.3 and are illustrated in Figure 3.2. For lunar night analyses, a lunar surface temperature of -300°F was used at all deployment latitudes.

3.4 Electronic Power

There is no internal power dissipation by electronics in the ASE mortar box, but survival heater power is required during the lunar night and was considered in the thermal model.

3.5 Solar Flux

In the determination of the absorbed solar flux it was assumed that the ASE was oriented so as to present the maximum area to the incident solar energy, (i.e. oriented in a broadside position). It was further assumed that the outer surfaces of the ASE receiving solar flux had an absorptance of 0.2. Using these assumptions, the absorbed solar flux was calculated and input to the model in the form of heat flux tables. These absorbed solar fluxes are listed in Table 3.4 as a function of deployment latitude and dust coverage.

3.6 Correlation

Temperature predictions made with the analytical thermal model of the ASE were correlated with actual test data as indicated in reference 4. Good agreement exists between the predicted internal temperatures and the test results, with the predicted mortar electronics temperature falling in the middle of the range of the electronics thermocouple data in the lunar noon degraded test.

4.0 RESULTS

Using the previously mentioned values and assumptions, a series of computer runs were made to determine the temperature of the mortar centers as a function of both deployment latitude and dust coverage. The resulting temperatures are indicated in Table 4.1 and plotted in Figure 4.1.

From this figure it is apparent that the temperature of the mortar centers can be considerably influenced by non-equatorial deployment, with this temperature decreasing from 128°F at the equator to 104°F at 45 degrees latitude. When a 50% dust coverage was assumed on the thermal control coatings, the mortar center temperature increased from 128°F to 140°F at the equator and from 104°F to 146°F at 45 degrees latitude. The maximum temperature of 156°F was achieved at a 30 degree deployment latitude as compared to 128°F at the equator for the non-degraded case. The analysis was then repeated assuming 100% dust coverage on all exterior surfaces. This degraded condition resulted in a temperature of 156°F at the equator and a maximum of 184°F at 30 degrees latitude.

For a 22 degree landing site, which represents the current F4 landing site at Littrow Rille, the temperature of the centers of the mortars will be 128°F for a nominal thermal control surface coating. In the case of 50% dust coverage this temperature will increase to 152°F. Figures 4.2, 4.3 and 4.4 indicate the variations of outer surface temperatures as a function of experiment deployment latitude and dust coverage.

5.0 CONCLUSIONS

Based on the analysis results described above, it is felt that the thermal design of the ASE is adequate for nominal (clean) and 50% dust coverage conditions at any deployment latitudes out to a maximum of 60 degrees. However, in the case of 100% dust coverage the mortar temperatures approach their upper design limit at latitudes greater than

25 degrees. However, it is not anticipated that the 100% dust coverage situation will arise.

6.0 REFERENCES

1. MSC TWX 061A EA/22/T375/S/B-350, dated September 1969.

2. Wright, N., "ASE Thermal Deployment Study," Bendix IM 70-210-33, 4 Feb. 1970.

3. Psaros, G., "Thermal Analysis of the Active Seismic Experiment," Bendix ATM-682, 19 July 1967.

4. Psaros, G., "ASE MPA Thermal Control - ALSEP T/V Tests," Bendix IM 9713-12-1013, 24 April 1969.

5. Psaros, G., "ALSEP Active Seismic Experiment Thermal Control," Bendix ATM-314, 7 July 1966.

6. Psaros, G., "Thermal Analysis of the ALSEP Thumper," Bendix ATM-477, 25 Aug. 1966.

7. Psaros, G., "Thermal Analysis of the ALSEP Active Seismic Mortar Box," Bendix ATM-564, 10 Nov. 1966.

8. Psaros, G., "ASE Mortar Package Assembly Lunar Surface Simulation," Bendix IM 9713-12-944, 30 October 1968.

9. L. Hartter/G. Psaros, "Results of the ASE DVT Lunar Day Test Conditions—Thermal Performance", 9713-12-871, 19 June 1968

10. L. Hartter/G. Psaros, "Thermal Performance Results of the ASE DVT Lunar Night Survival Test Condition", 1 May 1968, 9713-12-850

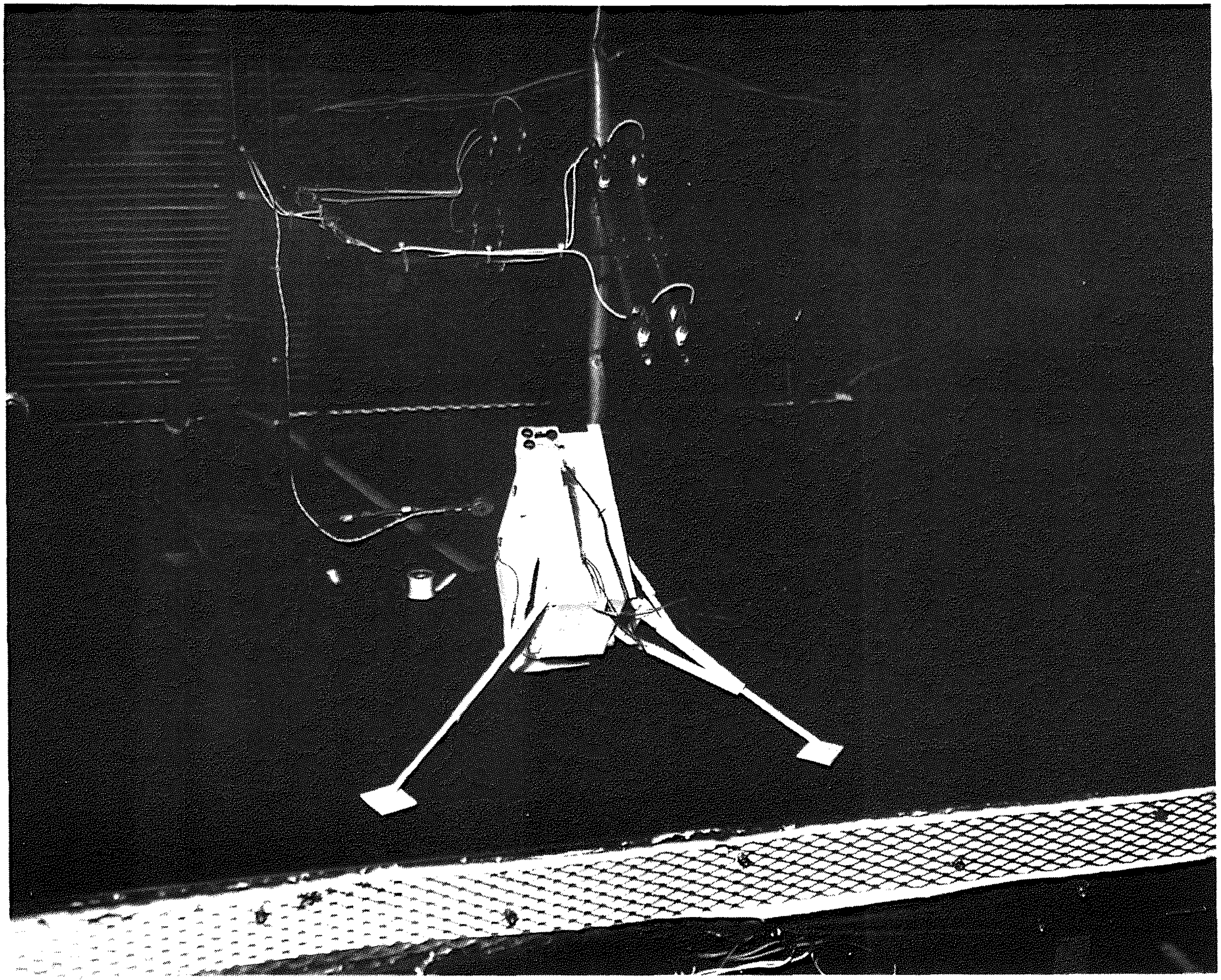

Figure 1.1 ASE MORTAR BOX DEPLOYED FOR THERMAL VACUUM TEST

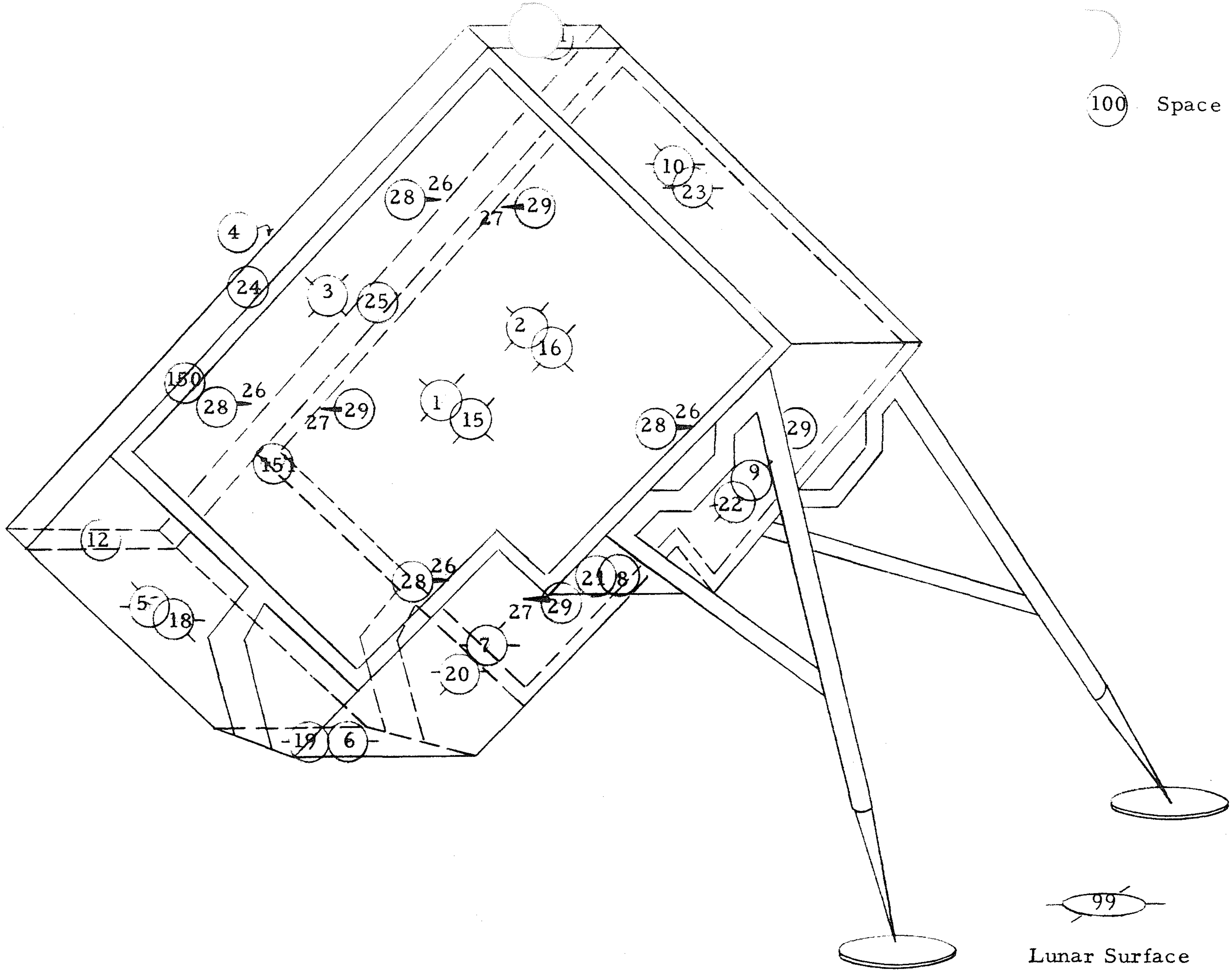

Figure 3.1 ASE Node Locations

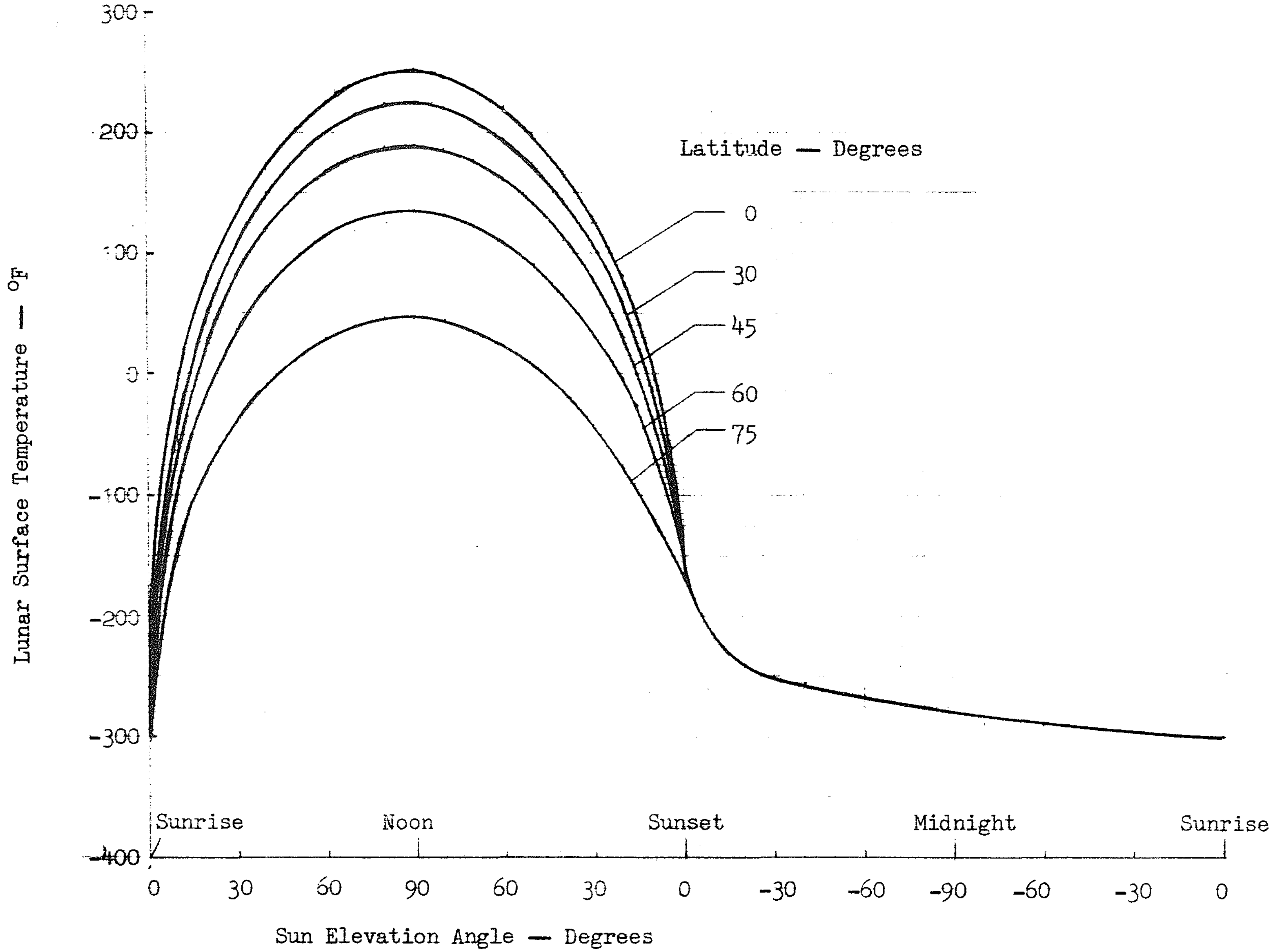

Figure 3.2 Lunar Surface Temperature vs Sun Angle and Latitude

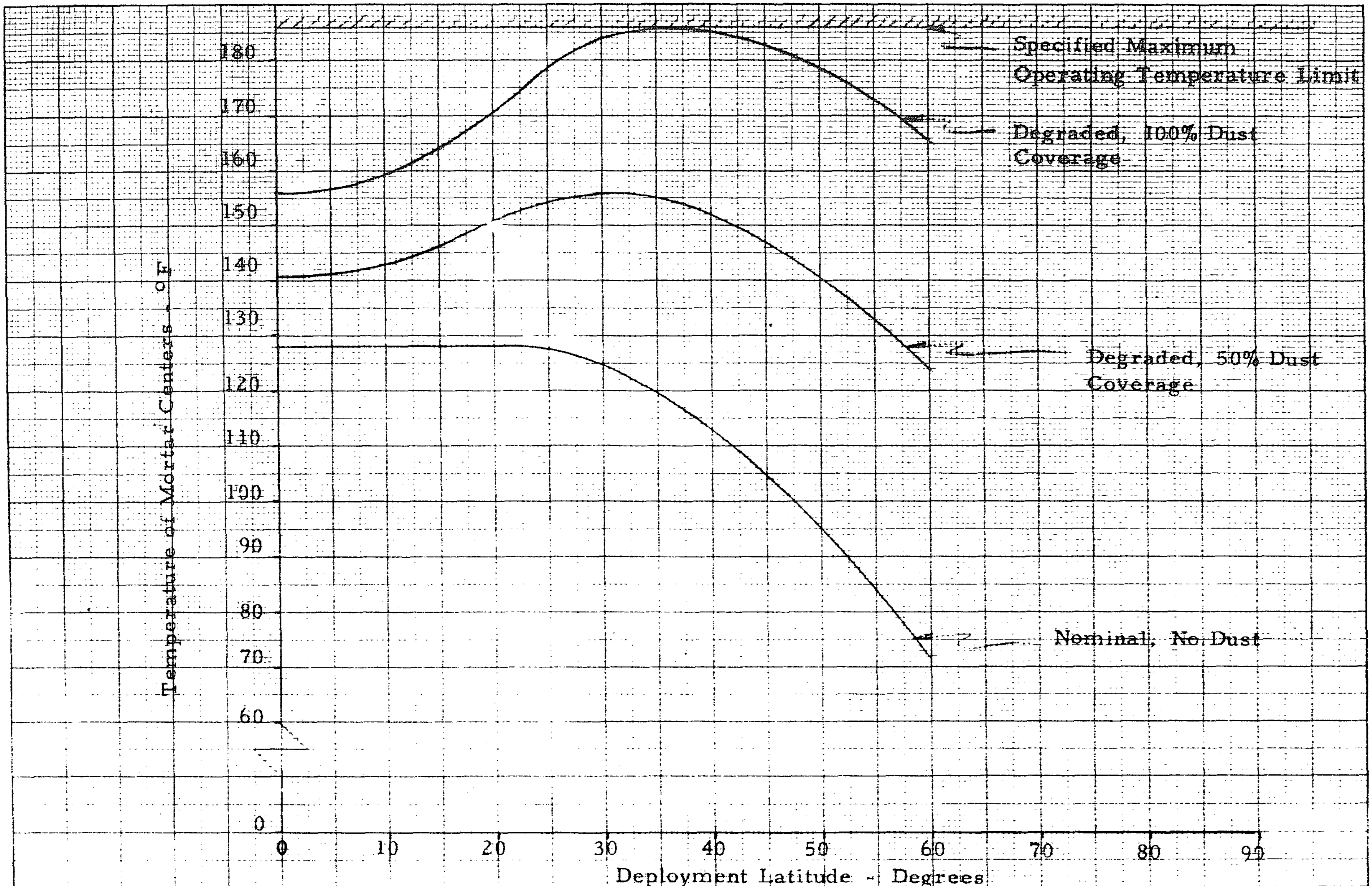

Figure 4.1 MORTAR CENTER TEMPERATURES AS A FUNCTION OF DEPLOYMENT LATITUDE AND DUST COVERAGE

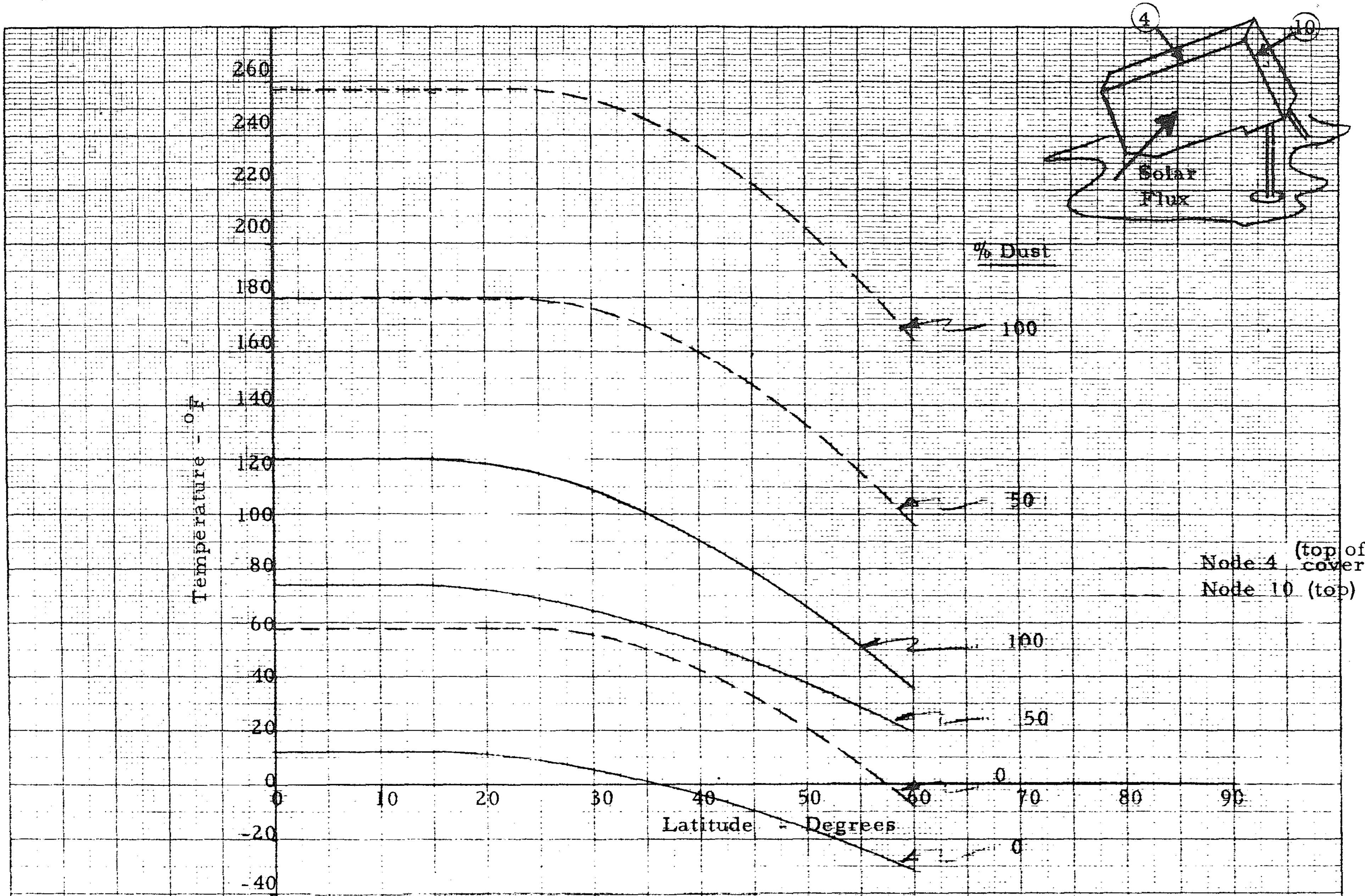

Figure 4.2 TEMPERATURE OF TOP AND TOP OF DUST COVER AS A FUNCTION OF DUST COVERAGE AND DEPLOYMENT LATITUDE

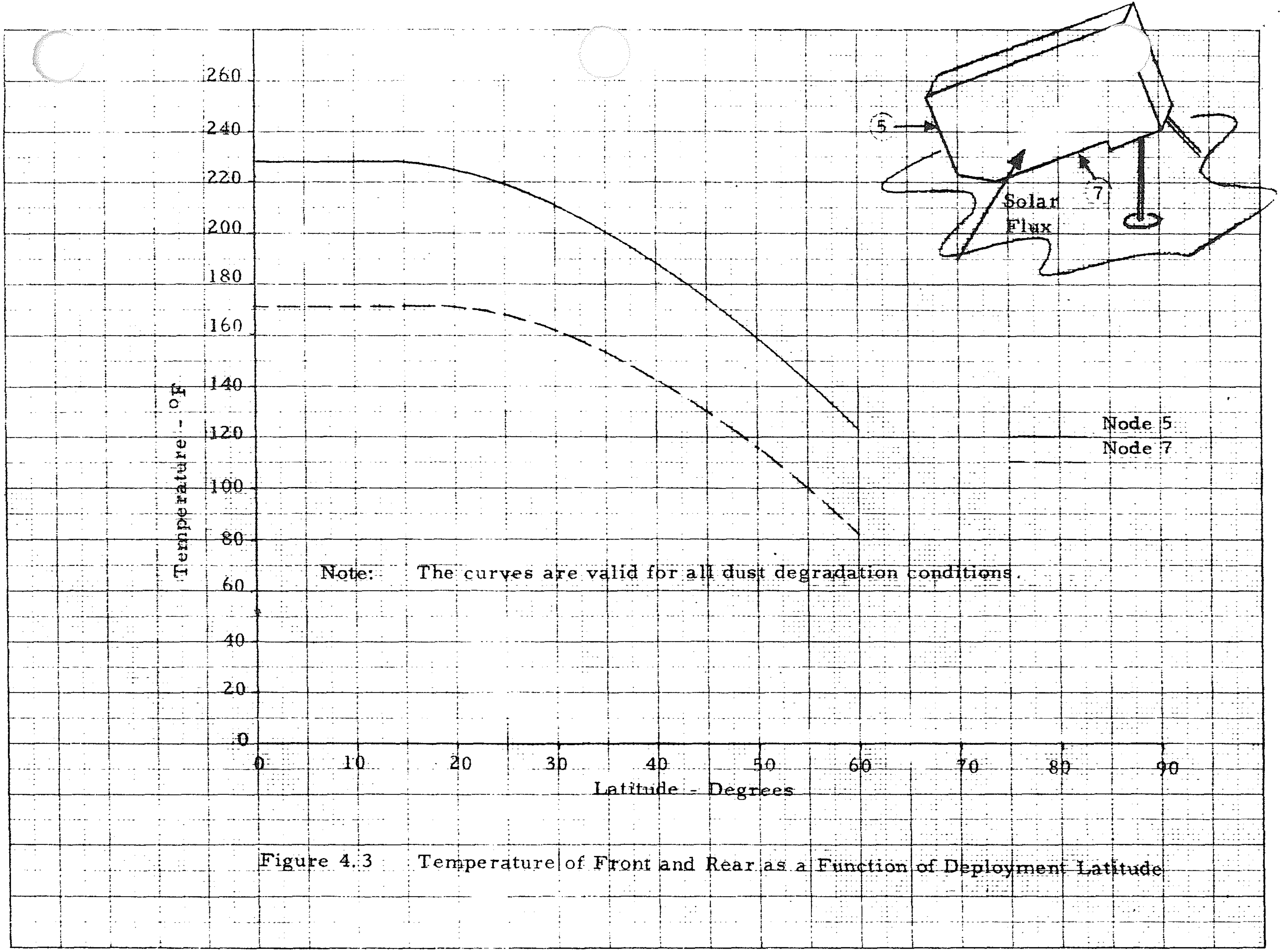

Figure 4.3 Temperature of Front and Rear as a Function of Deployment Latitude

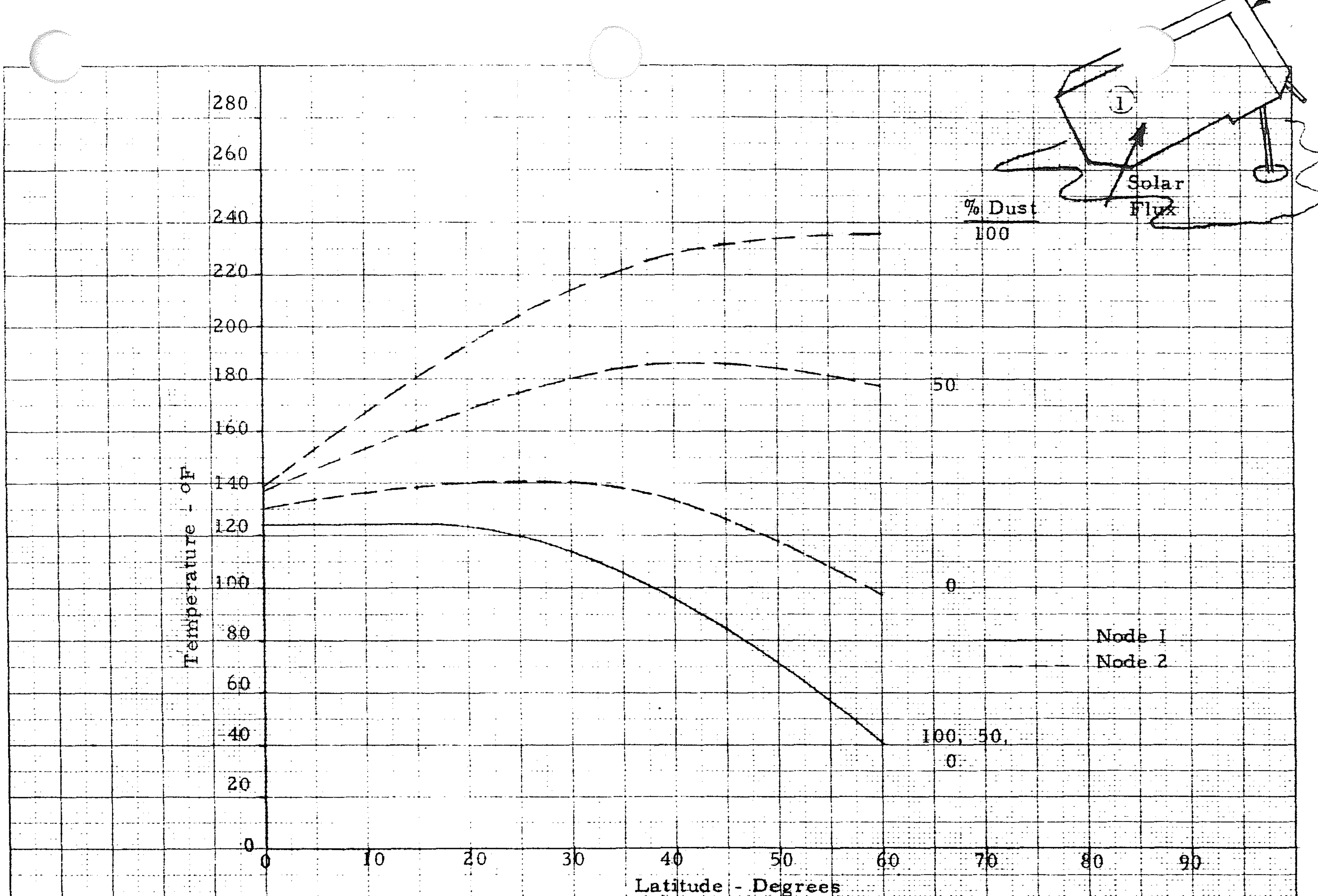

Figure 4.4 Temperature of ASE Sides as a Function of Latitude and Dust Coverage

TABLE 3.1

ASE NODE DESCRIPTION

Node Number	Node Description
1	Outer surface of left side
2	Outer surface of right side
3	Top of mortars and launch tubes
4	Top of dust cover
5	Outer surface of slanted front plate
6	Outer surface of base
7	Outer surface of slanted rear plate
8	Outer surface of eave
9	Outer surface of back plate
10	Outer surface of top
11	Top end of dust cover
12	Lower end of dust cover
15	Inner surface of left side
16	Inner surface of right side
17	Centers of mortars and launch tubes
18	Inner surface of slanted front plate
19	Inner surface of base
20	Inner surface of slanted front plate
21	Inner surface of eave
22	Inner surface of back plate
23	Inner surface of top
24	Left side of dust cover
25	Right side of dust cover
26	Screw heads - left
27	Screw heads - right
28	Screw caps - left
29	Screw caps - right
41	Radiosity node for internal MLI (dust cover)
99	Lunar surface
100	Space
111	Dust cover radiosity node - top end
121	Dust cover radiosity node - bottom end
124	Radiosity node - left side of dust cover
125	Radiosity node - right side of dust cover
141	Radiosity node for internal MLI
150	Support frame - left
151	Support frame - right

TABLE 3.2

ASE THERMAL RESISTORS

Resistor No.	Interconnected Nodes	Transfer Mode	Conduction R or Radiation A	Radiation $\mathcal{F}$, $\mathcal{F}$ A or $\mathcal{F} A \sigma$
1	1 - 99	Radiation	.7017	.4464
2	2 - 99	↓	.7017	.4464
3	4 - 99		.4408	.12819
4	5 - 99			.5025 E-9
5	6 - 99			.04321
6	7 - 99			.2124 E-9
7	8 - 99			.91 E-10
8	9 - 99			.98 E-9
9	10 - 99			.3992 E-10
11	12 - 99			.2210 E-10
12	24 - 99		.06358	.4449
13	25 - 99		.06358	.4449
14	3 - 111			.9173 E-11
15	3 - 121			.9173 E-11
16	3 - 124			.2230 E-10
17	3 - 125			.2230 E-10
18	3 - 41			.6923 E-9
19	14 - 111			.9173 E-11
20	41 - 121			.9173 E-11
21	41 - 120			.2230 E-10
22	41 - 125			.2230 E-10
23	111 - 121			.1721 E-13
24	111 - 124			.5353 E-12
25	111 - 125			.5353 E-12
26	121 - 120			.5353 E-12
27	121 - 125			.5353 E-12
28	124 - 125			.1131 E-11
29	1 - 100		.7017	.4536
30	2 - 100		.7017	.4464
31	4 - 100		.4408	.7718
32	5 - 100			.4250 E-10
34	7 - 100			.1135 E-9
35	8 - 100			.3460 E-11
36	9 - 100			.2440 E-10
37	10 - 111			.3995 E-9
39	12 - 100			.4639 E-11
40	24 - 100		.06358	.512
41	25 - 100	↓	.06358	.469

TABLE 3.2

ASE THERMAL RESISTORS (CONT)

Resistor No.	Interconnected Nodes	Transfer Mode	Conduction R or Radiation A	Radiation ℱ, ℱA or ℱAσ
42	15 - 17	Radiation		.1275E-9
43	16 - 17	Radiation		.1275 E-9
44	18 - 17	↓		.2109 E-10
45	19 - 17			.4991 E-11
46	20 - 17			.2461 E-10
47	21 - 17			.9415 E-11
48	22 - 17			.2402 E-10
49	23 - 17			.3405 E-10
50	7 - 8			.2937 E-10
51	26 - 28			.6265 E-11
52	27 - 29			.6265 E-11
53	28 - 99			.5458 E-11
54	28 - 100			.7389 E-11
55	29 - 99			.6020 E-11
56	29 - 100			.6826 E-11
57	141 - 41			.3977 E-10
58	11 - 111			.6315 E-12
59	12 - 121			.6515 E-12
60	24 - 124			.2390 E-11
61	25 - 125	Radiation		.2390 E-11
70	1 - 5	Conduction	651.	
71	2 - 5	↓	651	
72	15 - 18		717	
73	16 - 18		717	
74	1 - 6		920	
75	2 - 6		920	
76	15 - 19		1460	
77	16 - 19		1460	
78	1 - 7		352	
79	2 - 7		352	
80	15 - 20		372	
81	16 - 20		372	
82	1 - 8		893	
83	2 - 8		893	
84	15 - 21		943	
85	16 - 21		943	
86	1 - 9		366	
87	2 - 9		366	
88	15 - 22		440	

TABLE 3.2

ASE THERMAL RESISTORS (CONT)

Resistor No.	Interconnected Nodes	Transfer Mode	Conduction R or Radiation A	Radiation $\mathcal{F}$, $\mathcal{F}$A or $\mathcal{F}A\sigma$
89	16 - 22	Conduction	440	
90	1 - 10	↓	397	
91	2 - 10		397	
92	15 - 23		449	
93	16 - 23		449	
94	5 - 6		395	
95	18 - 19		477	
96	6 - 7		420	
97	19 - 20		501	
98	7 - 8		500	
99	20 - 21		705	
100	8 - 9		507	
101	21 - 22		569	
102	9 - 10		890	
103	22 - 23		1053	
104	1 - 15		230.5	
105	2 - 15		230.5	
106	5 - 18		1203	
107	6 - 19		3966	
108	7 - 20		1135	
109	8 - 21		2800.	
110	9 - 22		952	
111	10 - 23		602.5	
112	3 - 17		670.	
115	26 - 17		28.35	
116	27 - 17		28.35	
117	26 - 150		50.60	
118	27 - 151		50.60	
121	17 - 99		11500.	
123	4 - 141		472.6	
152	150 - 1		397	
153	151 - 2		397	
156	150 - 7		1816	
157	151 - 7		1816	
158	150 - 8		2305	
159	151 - 8		2305.	
160	150 - 9		785	
161	151 - 9	↓	785	

TABLE 3.2

ASE THERMAL RESISTORS (CONT)

Resistor No.	Interconnected Nodes	Transfer Mode	Conduction R or Radiation A	Radiation $\mathcal{F}$, $\mathcal{F}A$ or $\mathcal{F}A\sigma$
162	150 - 10	Conduction	602	
163	151 - 10	↓	602	
213	28 - 150	Radiation	.01791	.817
214	29 - 151	↓	.01791	.817
223	28 - 150	Conduction	535	
224	29 - 151		535	
225	150 - 99		2151	
226	151 - 99	↓	2151	
230	160 - 1	Radiation	1.	.05287
231	150 - 7		.1211	.0012
232	150 - 8		.1211	.00135
233	150 - 24		.1211	.07333
234	150 - 99		1.	.1275
235	150 - 100		1.	.1804
236	151 - 2		1.	.05787
237	151 - 7		.1211	.0012
238	151 - 8		.1211	.00135
239	151 - 25		.1211	.07333
240	151 - 99	↓	1.	.1361
241	151 - 100	Radiation	1.	.1718

R = resistance - hr $^{o}F/BTU$

A = area - ft^2

$\mathcal{F}A$ = radiation conductance - ft^2

$\mathcal{F}A\sigma$ = radiation conductance-BTU/hr $^{o}R^4$

$\mathcal{F}$ = radiation interchange factor

σ = Stefan-Boltzmann constant $\left(\frac{BTU}{hr/ft^2\ ^{o}R^4}\right)$

TABLE 3.3

LUNAR SURFACE TEMPERATURES AT VARIOUS LATITUDES

Latitude - Degrees	Temperature - $^{\circ}F$
0	250
15	237
30	225
45	190
60	135

TABLE 3.4

ABSORBED SOLAR FLUX - BTU/HR.

Surface Condition	Table No.	Node No.	Deployment Latitude - Degrees				
			0^{o}	15^{o}	30^{o}	45^{o}	60^{o}
Nominal	1	2		10.35	19.98	28.25	34.60
$\alpha = .2$	2	4	11.272	10.926	9.794	7.996	5.65
	3	10	24.73	21.372	21.41	17.48	12.36
	4	25		1.22	2.33	3.69	4.028
	5	29		.19	.37	.532	.638
	6	151		10.85	20.95	29.63	36.29
50%	1	2		31.15	59.94	84.75	103.81
Degraded	2	4	33.82	32.878	29.382	23.99	17.00
$\alpha = .6$	3	10	74.19	64.116	64.23	52.44	37.09
	4	25		3.66	6.978	11.07	12.08
	5	29		.57	1.11	1.596	1.91
	6	151		32.56	62.85	88.88	108.87
100%	1	2		51.75	99.89	141.25	173.02
Degraded	2	4	56.36	54.63	48.97	39.98	28.27
$\alpha = 1.0$	3	10	123.63	106.86	107.06	87.41	61.81
	4	25		6.102	11.63	18.45	20.14
	5	29		.953	1.84	2.66	3.19
	6	151		54.27	104.77	148.14	181.46

α = solar absorptance

TABLE 4.1

ASE MORTAR CENTER TEMPERATURE WITH INCREASING LATITUDE AND DUST COVERAGE

	Deployment Latitude (Degrees)				Comment
	0	15	30	45	
Mortar Center Temperature - °F	128	128	125	104	Clean Coatings
Mortar Center Temperature - °F	140	146	156	146	50% dust coverage on thermal control coatings
Mortar Center Temperature - °F	156	164	184	183	100% dust coverage on thermal control coatings