Bendix

Aerospace Systems Division

NO.	REV. NO
EATM 48	

Final Isotope Heater Locations and Masking Pattern -- PSEP Central Station

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DATE 1-27-69

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1.0 INTRODUCTION

The parametric studies begun in Reference 1 have been completed. Of the three heater configurations, Configuration I was selected for the flight configuration. Since the thermal characteristics of the three configurations were so similar, the selection was primarily based upon mechanical considerations.

2.0 SUMMARY

A unique rectangular masking pattern has been found which, within the assumptions discussed below, satisfy the specified thermal plate average temperature limits of -65 F to +140 F.

3.0 DISCUSSION

Several changes have been incorporated into the analytical model of Reference 1. The significant ones are discussed in detail below and the final analytical model is presented in Appendix A.

3.1 THERMAL ISOLATORS

In Reference 1, the night time heat leak was assumed to be 5 watts. Of this 5 watts, approximately 1 watt was allotted to the thermal isolators between the thermal plate and the primary structure. However, as shown in Reference 2, the isolator with the required thermal resistance does not satisfy the structural requirements and vice-versa.

Figure 1 illustrates the effect of thermal resistance on the night time heat leak and the night time thermal plate temperature. Thus, the low-resistance thermal isolators with their increased heat leak of 4 watts lowers the night time thermal plate temperature by approximately 12 F.

3.2 C/S HEAT LEAK

As stated in the previous section, the night time heat leak not including the isolators was assumed to be 4 watts. However, a detailed estimate of each individual heat leak has been made based upon the present design, and the results are as follows:

Item	Night Time Heat Leak (W)
PSE Insulation	0.6
Heater Insulation (2)	1.1
Mask (A = 1.0 ft^2)	1.1
Thermal Bag	0.4
Cables	2.1*
TOTAL	5.3

The additional 1.3 watts is primarily due to the PSE instrument cables and the insulation covering the heaters. In Reference 1 the heater insulation was considered as part of the mask and the PSE instrument cables were neglected. Thus, the additional 1.3 watt heat leak will lower the thermal plate temperature approximately 5^0F.

3.3 PSE MOUNTING PLATE SKIN THICKNESS

The thickness of the upper skin of the PSE mounting plate was increase from 0.016 inches to 0.032 inches in order to reduce the temperature gradient as discussed in Reference 3.

3.4 RECTANGULAR MASKING PATTERN

The temperature profiles shown in References 1 and 3 were based upon ideal mirror/masking patterns. However, the second surface mirrors are composed of 1-inch squares which will result in rectangular rather than curvilinear patterns. When these rectangular patterns are incorporated into the analytical model, the temperature gradients are increased as shown below:

*Based upon insulated manganin PSE instrument cables. Present design, however, will use insulated copper PSE instrument cables.

Item	Day Time Gradient (F)		Night Time Gradient (F	
	Ideal Pattern	Rectangular Pattern	Ideal Pattern	Rectangular Pattern
Thermal Plate	10	15	15	19
PSE Mtg. Plate	19	26	23	27

3.5 REGULATOR

The data in Reference 1 was based upon the ALSEP 55-watt regulator which resulted in a C/S thermal dissipation of 35.8 W. Subsequently, a 30-watt regulator was proposed which lowered the C/S dissipation by 5 watts for a total of 30.8 W. The 30-watt regulator was incorporated into the analytical model and the results were published in Reference 4. Further discussion of these results are not presented here because systems considerations indicated a larger regulator would be required. The analysis (Reference 5) showed that a 36-watt regulator would be required. The 36-watt regulator increased the C/S thermal dissipation by 2 watts for a total of 32.8 W. The higher thermal dissipation requires a greater radiating area to maintain the 140°F day time temperature. The larger radiator, however, lowers the night time thermal plate temperature approximately 3 F.

4.0 RESULTS

With all of the changes of the previous section incorporated into the analytical model, several runs were made to determine the masking pattern. The mirror/masking pattern was chosen to achieve an average thermal plate temperature of +140°F at lunar noon while minimizing the temperature gradients across the plate and be consistant with the assembly procedures developed for the mirrors, PSE, PSE shroud, isotope heaters, heater insulation and insulation masks.

The final mirror/masking pattern and the resulting day/night temperature profiles for both the thermal plate and the PSE mounting plate are shown in Figures 2 and 3.

5.0 CONCLUSIONS

The estimated total night time heat leak, including the thermal isolator is 9.5 watts. Thus, of the 30 watts of isotope heater power, 1/3 of thi

total is lost in heat leaks leaving only 20 watts to maintain the night time survival temperature. Due to the small amount of thermal energy available the night time thermal plate temperature is extreme sensitive to the radiator area and the total heat leak. By referring to Figure 1, it will be noted that in the present design a variation of 1 watt in the heat leak results in a $5^{\circ}F$ change in the average night time thermal plate temperature. If the heat leak can be reduced, the night time temperature is raised, the slope of the temperature curve is reduced, thereby making the design less sensitive to small changes in heat leak.

REFERENCES

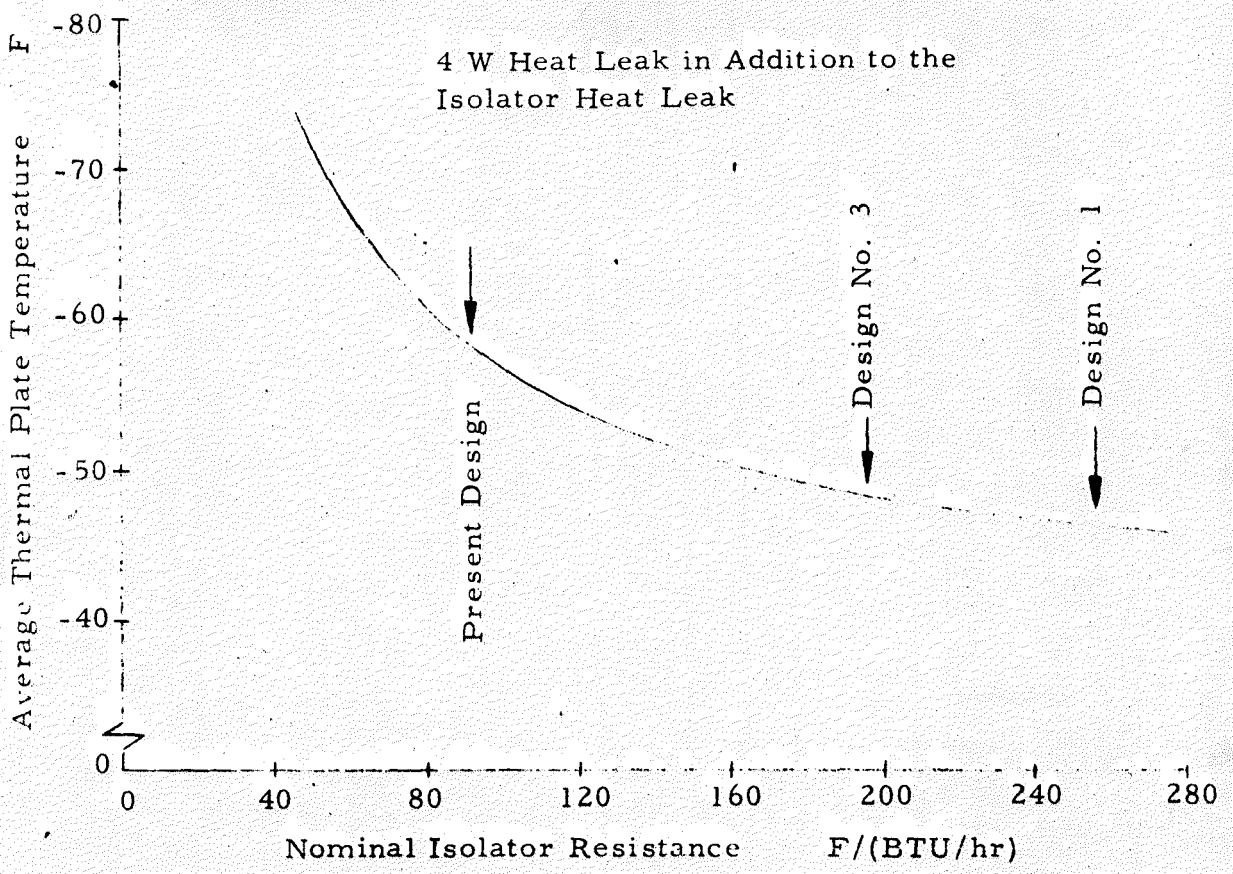
1. Preliminary Isotope Heater Locations and Masking Pattern, PSEP Central Station, EATM-10, 12-16-68.

2. Thermal Isolator Design and Selection, PSEP Central Station, EATM-23, 1-7-69.

3. PSE Mounting Plate Skin Thickness Study, EATM-39, 1-13-69.

4. PSEP C/S Temperature Profiles, Letter No. 981-87, 1-13-69.

5. PSEP Power Balance, EATM-33, 1-11-69.



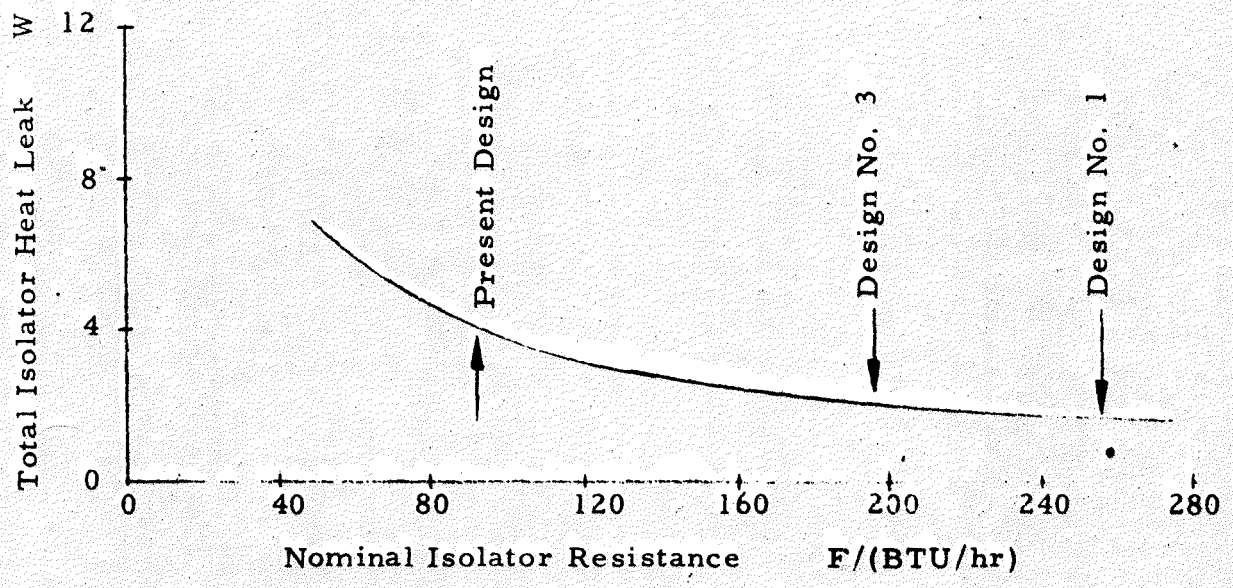
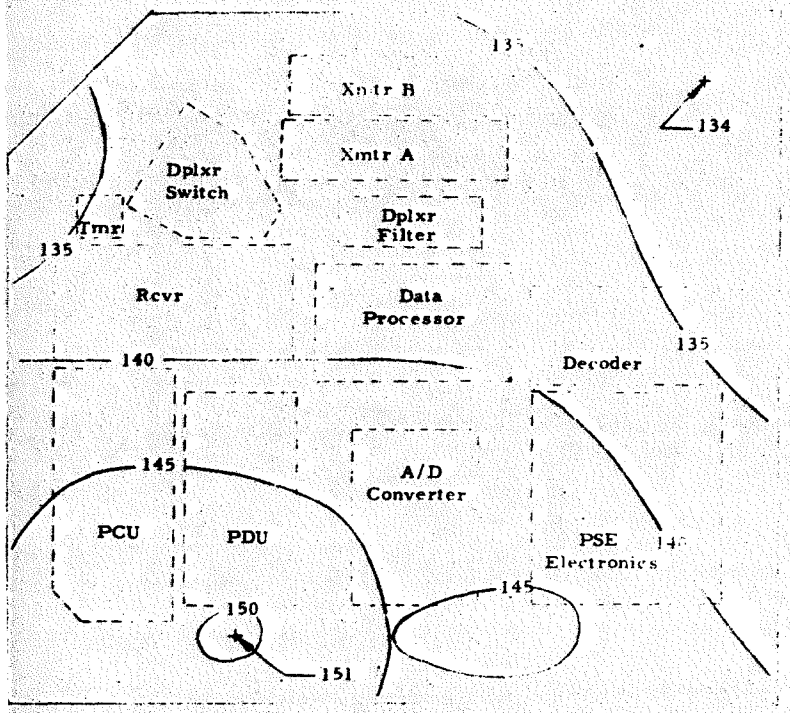
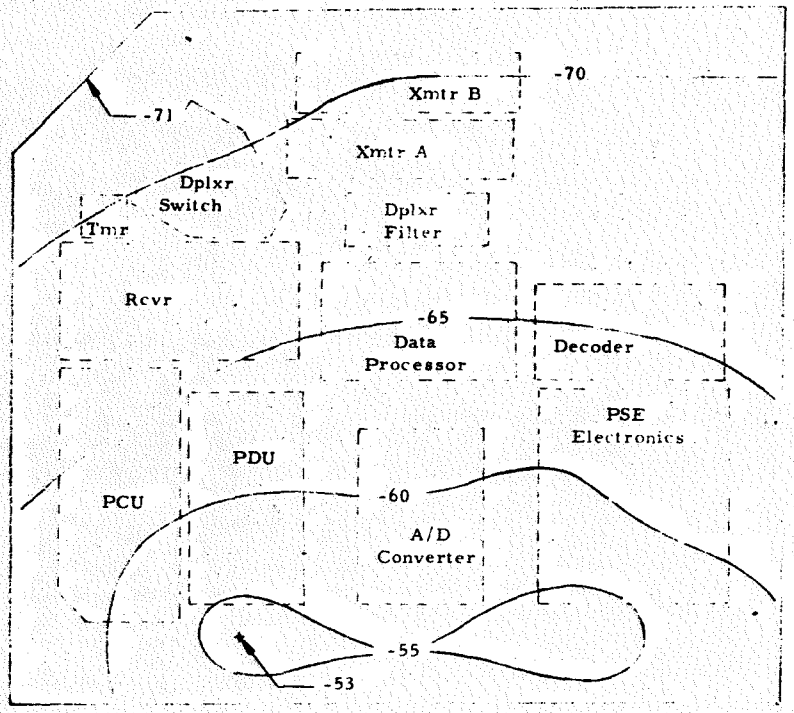


Figure 1

Night Time Heat Leak and Thermal Plate Temperature as a Function of the Nominal Isolator Resistance

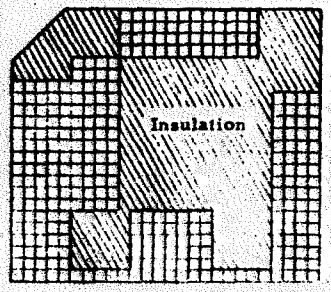


Lunar Noon: $\bar{T}$ = 140 F; ΔT = (151 - 134) = 17 F



Lunar Night: $\bar{T}$ = -65 F; ΔT = [-53 - (-71)] = 18 F

Day/Night Temperature Swing
205 F



PSE Mtg Plate
Mirror/Masking Pattern
Mirror Area = 2.0 Ft^2

Figure 2

Thermal Plate Temperature Profiles (F)

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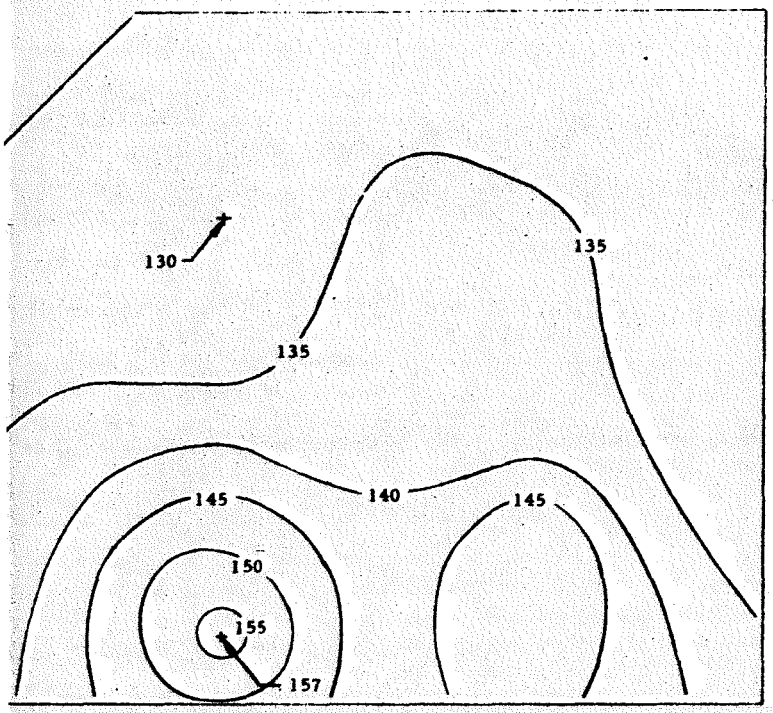
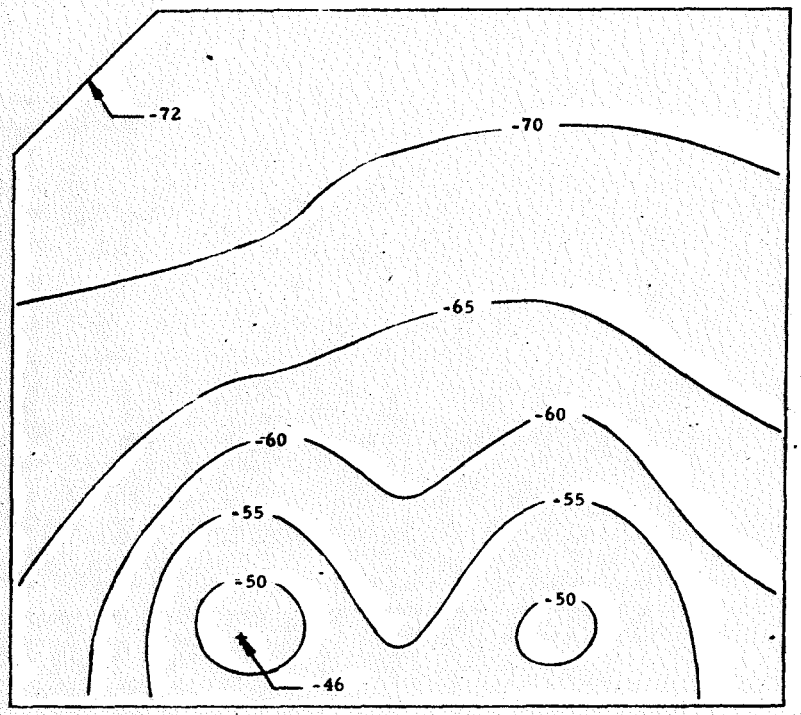
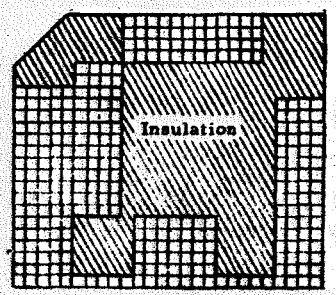


Lunar Noon: $\bar{T}$ = 137 F; ΔT = (157 - 130) = 27 F



Lunar Night: $\bar{T}$ = -64 F; ΔT = [-46 - (-72)] = 26 F

Day/Night Temperature Swing
201 F



PSE Mtg Plate
Mirror/Masking Pattern
Mirror Area = 2.0 Ft^2

Figure 3
PSE Mounting Plate Temperature Profiles (F)

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ANALYTICAL MODEL

Isotope Heater Location, Mirror - Masking Study
Lunar Noon; 36 W Regulator

HEATER, SUNSHIELD* AND THERMAL PLATE NODES

Node No.	Initial Temp. (°F)	Heat Input (Watts)	Component
1	100.	15.0	Heater No. 1
10	100.	15.0	Heater No. 2
19	100.		Sunshield
20	100.	1.877	
21	100.	1.877	
22	100.	.6032	
23	100.		
24	100.	1.426	
25	100.	1.895	
26	100.	2.036	
27	100.	2.063	
28	100.	.577	
29	100.	1.958	
30	100.	.868	
31	100.	2.096	
32	100.	1.824	
33	100.	1.698	
34	100.	.8867	
35	100.		
36	100.		
37	100.	1.373	
38	100.	1.394	
39	100.	1.127	
40	100.	.705	
41	100.	.190	
42	100.		
43	100.		
44	100.		Thermal Plate
45	100.	1.7694	
46	100.	6.3894	
47	100.	1.0813	
48	100.		
49	100.	.1225	
50	100.	3.1203	
51	100.	6.7687	
52	100.	2.9862	
53	100.	.6813	
54	100.	.3054	
55	100.	.3381	
56	100.	.3572	

*PSE Mounting Plate Assembly

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Lunar Noon; 36 W Regulator

HEATER, SUNSHIELD* AND THERMAL PLATE NODES

Node No.	Initial Temp. (°F)	Heat Input (Watts)	Component
57	100.	.2631	Thermal Plate
58	100.	.9226	
59	100.		
60	100.	.02255	
61	100.	.08374	
62	100.	.1559	
63	100.	.9109	
64	100.	1.9643	
65	100.	1.0691	
66	100.	1.2119	
67	100.	.94131	
68	100.	.33497	
69	100.	0.7	PSE
100	-460.		Space
101	158.		Primary Structure

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
15	1	30	0.38476*
16	1	31	2.03941
17	1	41	1.8733
18	10	28	.3185
19	10	39	2.070
20	19	20	4.56
21	19	34	3.55
22	19	44	.294
23	20	21	4.56
24	20	35	5.843
25	20	45	.39
26	21	22	4.56
27	21	36	5.843
28	21	46	.39
29	22	23	3.145
30	22	37	5.843

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Lunar Noon; 36 W Regulator

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
31	22	47	.39
32	23	24	3.145
33	23	48	3.535
34	24	25	3.55
35	24	37	7.673
36	24	49	.42
37	25	26	3.55
38	25	38	7.673
39	25	50	.420
40	26	27	3.55
41	26	39	7.673
42	26	51	.42
43	27	28	4.56
44	27	52	.294
45	28	29	4.56
46	28	39	5.843
47	28	53	.39
48	29	30	4.56
49	29	40	5.843
50	29	54	.39
51	30	31	4.56
52	30	41	5.843
53	30	55	.39
54	31	32	3.55
55	31	56	.294
56	32	33	3.55
57	32	41	7.673
58	32	57	.42
59	33	34	3.55
60	33	42	7.673
61	33	58	.42
62	34	35	7.673
63	34	59	.42
64	35	36	7.673
65	35	42	5.843
66	35	60	1.29
67	36	37	7.673
68	36	43	5.843
69	36	61	1.29
70	37	38	5.843

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Isotope Heater Location, Mirror - Masking Study
Lunar Noon; 36 W Regulator

SUNSHIELD*- THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
71	37	62	1.29
72	38	39	5.843
73	38	43	7.673
74	39	63	1.29
75	39	40	7.673
76	39	64	1.29
77	40	41	7.673
78	40	43	5.843
79	40	65	1.29
80	41	42	5.843
81	41	66	1.29
82	42	43	7.673
83	42	67	1.29
84	43	68	1.29
85	44	45	.915
86	44	59	.693
87	45	46	.915
88	45	60	.743
89	46	47	.915
90	46	61	.743
91	47	48	.673
92	47	62	.743
93	48	49	.673
94	49	50	.693
95	49	62	.995
96	50	51	.693
97	50	63	.995
98	51	52	.693
99	51	64	.995
100	52	53	.915
101	53	54	.915
102	53	64	.743
103	54	55	.915
104	54	65	.743
105	55	56	.915
106	55	66	.743
107	56	57	.915
108	57	58	.693
109	57	66	.995
110	58	59	.693

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Isotope Heater Location, Mirror - Masking Study
Lunar Noon; 36 W Regulator

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
111	58	67	.995
112	59	60	.995
113	60	61	.995
114	60	67	.743
115	61	62	.995
116	61	68	.743
117	62	63	.743
118	63	64	.743
119	63	68	.995
120	64	65	.995
121	65	66	.995
122	65	68	.743
123	66	67	.743
124	67	68	.995
125	69	35	5.15
126	69	36	5.15
127	69	40	5.15
128	69	41	5.15
200	19	20	4.241
201	19	34	3.384
202	20	21	4.241
203	20	35	3.384
204	21	22	4.241
205	21	36	3.384
206	22	23	3.788
207	22	37	3.384
208	23	24	3.788
209	24	25	3.384
210	24	37	4.241
211	25	26	3.384
212	25	38	4.241
213	26	27	3.384
214	26	39	4.241
215	27	28	4.241
216	28	29	4.241
217	28	39	3.384
218	29	30	4.241
219	29	40	3.384
220	30	31	4.241
221	30	41	3.384
222	31	32	3.384

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Lunar Noon; 36 W Regulator

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
223	32	33	3.384
224	32	41	4.241
225	33	34	3.384
226	33	42	4.241
227	34	35	4.241
228	35	36	4.241
229	35	42	3.384
230	36	37	4.241
231	36	43	3.384
232	37	38	3.384
233	38	39	3.384
234	38	43	4.241
235	39	40	4.241
236	40	41	4.241
237	40	43	3.384
238	41	42	3.384
239	42	43	4.241

THERMAL ISOLATORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
182	44	101	92.0
183	47	101	92.0
184	48	101	92.0
185	49	101	92.0
186	52	101	92.0
187	52	101	92.0
188	56	101	92.0
189	56	101	92.0
190	44	101	92.0

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Isotope Heater Location, Mirror - Masking Study
Lunar Noon; 36 W Regulator

MIRRORS

Resistor No.	Connecting Node No.	to Node No.	Area (ft^2)	Radiant Interchange Factor
151	20	100	.1444	.6992
152	21	100	.1444	.6992
153	22	100	.0464	.6992
155	24	100	.1097	.6992
156	25	100	.1458	.6992
157	26	100	.1566	.6992
158	27	100	.1587	.6992
159	28	100	.0444	.6992
160	29	100	.1506	.6992
161	30	100	.0668	.6992
162	31	100	.1612	.6992
163	32	100	.1403	.6992
164	33	100	.1306	.6992
165	34	100	.0682	.6992
168	37	100	.1056	.6992
169	38	100	.1072	.6992
170	39	100	.0867	.6992
171	40	100	.0542	.6992
172	41	100	.0146	.6992

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Isotope Heater Location, Mirror - Masking Study
Lunar Night; 36 W Regulator

HEATER, SUNSHIELD* AND THERMAL PLATE NODES

•Node No.	Initial Temp. (°F)	Heat Input (Watts)	Component
1	0.	14.45	Heater No. 1
10	0.	14.45	Heater No. 2
19	0.	-.208	Sunshield
20	0.		
21	0.		
22	0.	-.1576	
23	0.	-.0861	
24	0.	-.0845	
25	0.		
26	0.		
27	0.		
28	0.	-.1743	
29	0.		
30	0.	-.4435	
31	0.	-.0138	
32	0.	-.0210	
33	0.		
34	0.	-.0857	
35	0.		
36	0.		
37	0.		
38	0.		
39	0.	-.0716	
40	0.		
41	0.	-.0573	
42	0.		
43	0.		
44	0.	-.088	Thermal Plate
45	0.	-.088	
46	0.	-.088	
47	0.	-.088	
48	0.	-.088	
49	0.	-.088	
50	0.	-.088	
51	0.	-.088	
52	0.	-.088	
53	0.	-.088	
54	0.	-.088	
55	0.	-.088	
56	0.	-.088	

*PSE Mounting Plate Assembly

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Isotope Heater Location, Mirror - Masking Study
Lunar Night; 36 W Regulator

HEATER, SUNSHIELD* AND THERMAL PLATE NODES

Node No.	Initial Temp. (°F)	Heat Input (Watts)	Component
57	0.	-.088	Thermal Plate
58	0.	-.088	
59	0.	-.088	
60	0.	-.088	
61	0.	-.088	
62	0.	-.088	
63	0.	-.088	
64	0.	-.088	
65	0.	-.088	
66	0.	-.088	
67	0.	-.088	
68	0.	-.088	
69	0.	-.6	PSE
100	-460.		Space
101	-200.		Primary Structure

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
15	1	30	6.38474
16	1	31	2.03941
17	1	41	1.8732
18	10	28	.3185
19	10	39	2.070
20	19	20	4.56
21	19	34	3.55
22	19	44	.294
23	20	21	4.56
24	20	35	5.843
25	20	45	.39
26	21	22	4.56
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Lunar Night; 36 W Regulator

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
31	22	47	.39
[illegible]	23	24	3.145
33	21	48	3.535
34	24	25	3.55
35	24	37	7.673
36	24	49	.42
37	25	26	3.55
38	25	38	7.673
39	25	50	.420
40	26	27	3.55
41	26	39	7.673
42	26	51	.42
43	27	28	4.56
44	27	52	.294
45	28	29	4.56
46	28	39	5.843
47	28	53	.39
48	29	30	[illegible]
49	29	40	5.843
50	29	54	.39
51	30	31	4.56
52	30	41	5.843
53	30	55	.39
54	31	32	3.55
55	31	56	.294
56	32	33	3.55
57	32	41	7.673
58	32	57	.42
59	33	34	3.55
60	33	42	7.673
61	33	58	.42
62	34	35	7.673
63	34	59	.42
64	35	36	7.673
65	35	42	5.843
66	35	60	1.29
67	36	37	7.673
68	36	43	5.843
69	36	61	1.29
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Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
71	37	62	1.29
72	38	39	5.843
73	38	43	7.673
74	38	63	1.29
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76	39	64	1.29
77	40	41	7.673
78	40	43	5.843
79	40	65	1.29
80	41	42	5.843
81	41	66	1.29
82	42	43	7.673
83	42	67	1.29
84	43	68	1.29
85	44	45	.915
86	44	59	.693
87	45	46	.915
88	45	60	.743
89	46	47	.915
90	46	61	.743
91	47	48	.673
92	47	62	.743
93	48	49	.673
94	49	50	.693
95	49	62	.995
96	50	51	.693
97	50	63	.995
98	51	52	.693
99	51	64	.995
100	52	53	.915
101	53	54	.915
102	53	64	.743
103	54	55	.915
104	54	65	.743
105	55	56	.915
106	55	66	.743
107	56	57	.915
108	57	58	.693
109	57	66	.995
110	58	59	.693

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Lunar Night; 36 W Regulator

SUNSHIELD*- THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
[illegible]	[illegible]	67	.995
[illegible]	[illegible]	60	.995
[illegible]	[illegible]	61	.995
[illegible]	[illegible]	67	.743
115	61	62	.995
116	61	68	.743
117	[illegible]	63	.743
118	63	64	.743
119	[illegible]	68	.995
120	[illegible]	[illegible]	.995
121	[illegible]	66	.995
122	[illegible]	68	.743
123	[illegible]	67	.743
124	67	68	.995
125	69	35	5.15
126	69	36	5.15
127	69	40	5.15
128	69	41	5.15
200	19	20	4.241
201	19	34	3.384
202	20	21	4.241
203	20	35	3.384
204	21	22	4.241
205	21	36	3.384
206	22	23	3.788
207	22	37	3.384
208	23	24	3.788
209	24	25	3.384
210	24	37	4.241
211	25	26	3.384
212	25	38	4.241
213	26	27	3.384
214	26	39	4.241
215	27	28	4.241
216	28	29	4.241
217	28	39	3.384
218	29	30	4.241
219	29	40	3.384
220	30	31	4.241
221	30	41	3.384
222	31	32	3.384

APPENDIX

ANALYTICAL MODEL

Isotope Heater Location, Mirror - Masking Study
Lunar Night; 36 W Regulator

SUNSHIELD* - THERMAL PLATE RESISTORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
223	32	33	3.384
224	32	41	4.241
225	33	34	3.384
226	33	42	4.241
227	34	35	4.241
228	35	36	4.241
229	35	42	3.384
230	36	37	4.241
231	36	43	3.384
232	37	38	3.384
233	38	39	3.384
234	38	43	4.241
235	39	40	4.241
236	40	41	4.241
237	40	43	3.384
238	41	42	3.384
239	42	43	4.241

THERMAL ISOLATORS

Resistor No.	Connecting Node No.	to Node No.	Resistance (°F/BTU/hr)
182	44	101	92.0
183	47	101	92.0
184	48	101	92.0
185	49	101	92.0
186	52	101	92.0
187	52	101	92.0
188	56	101	92.0
189	56	101	92.0
190	44	101	92.0

APPENDIX

ANALYTICAL MODEL

Isotope Heater Location, Mirror - Masking Study
Lunar Night; 36 W Regulator

MIRRORS

Resistor No.	Connecting Node No.	to Node No.	Area (ft^2)	Radient Interchange Factor
151	20	100	.1444	.830
152	21	100	.1444	.830
153	22	100	.0464	.830
155	24	100	.1097	.830
156	25	100	.1458	.830
157	26	100	.1566	.830
158	27	100	.1587	.830
159	28	100	.0444	.830
160	29	100	.1506	.830
161	30	100	.0668	.830
162	31	100	.1612	.830
163	32	100	.1403	.830
164	33	100	.1306	.830
165	34	100	.0682	.830
168	37	100	.1056	.830
169	38	100	.1072	.830
170	39	100	.0867	.830
171	40	100	.0542	.830
172	41	100	.0146	.830

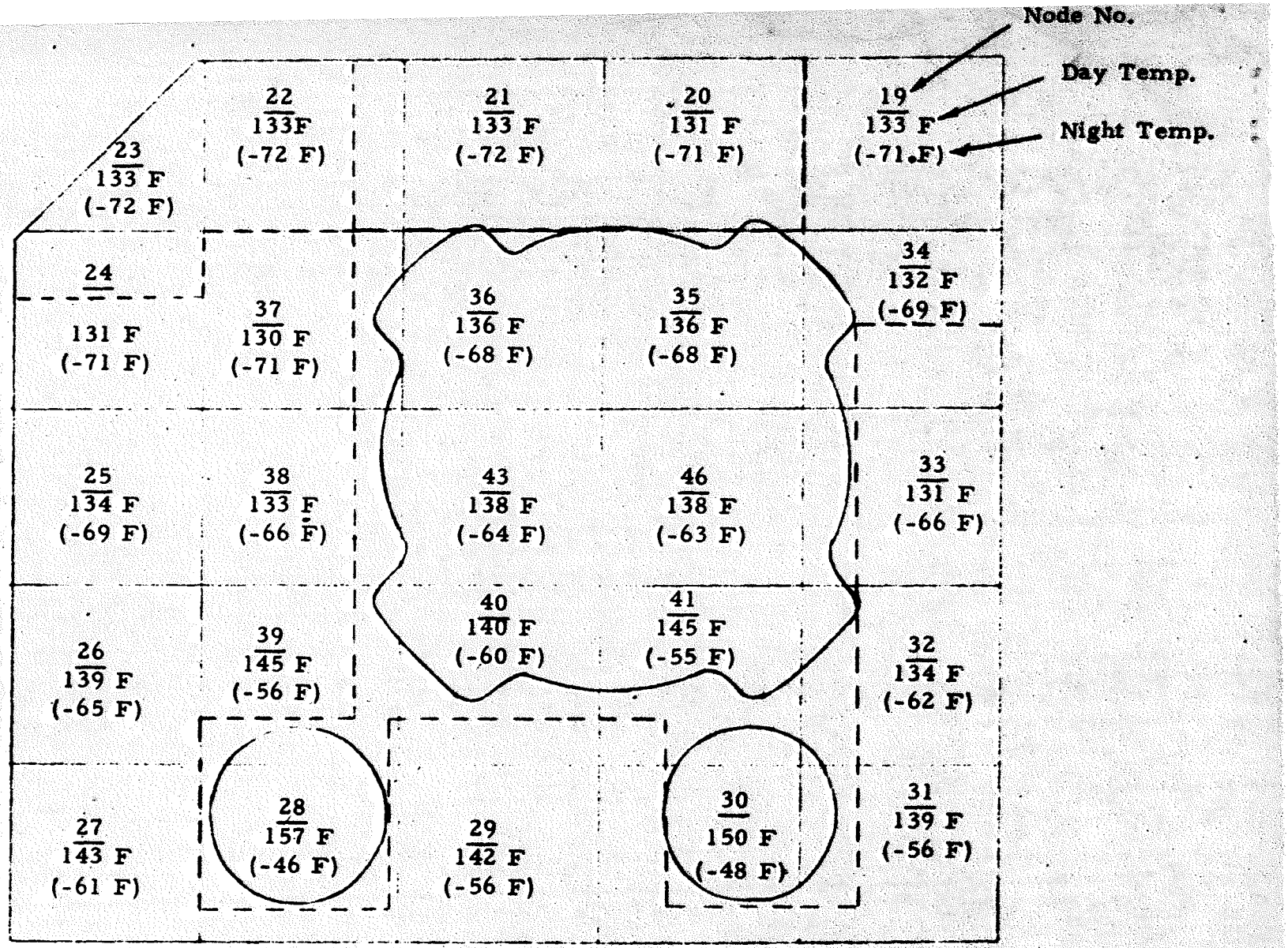

Figure 1 PSE Mounting Plate Day-Night Temperatures
Mirror Area = 2.04 Ft^2
Night Heat Leak = 5.3 Watts + Thermal Isolators
36 W Regulator

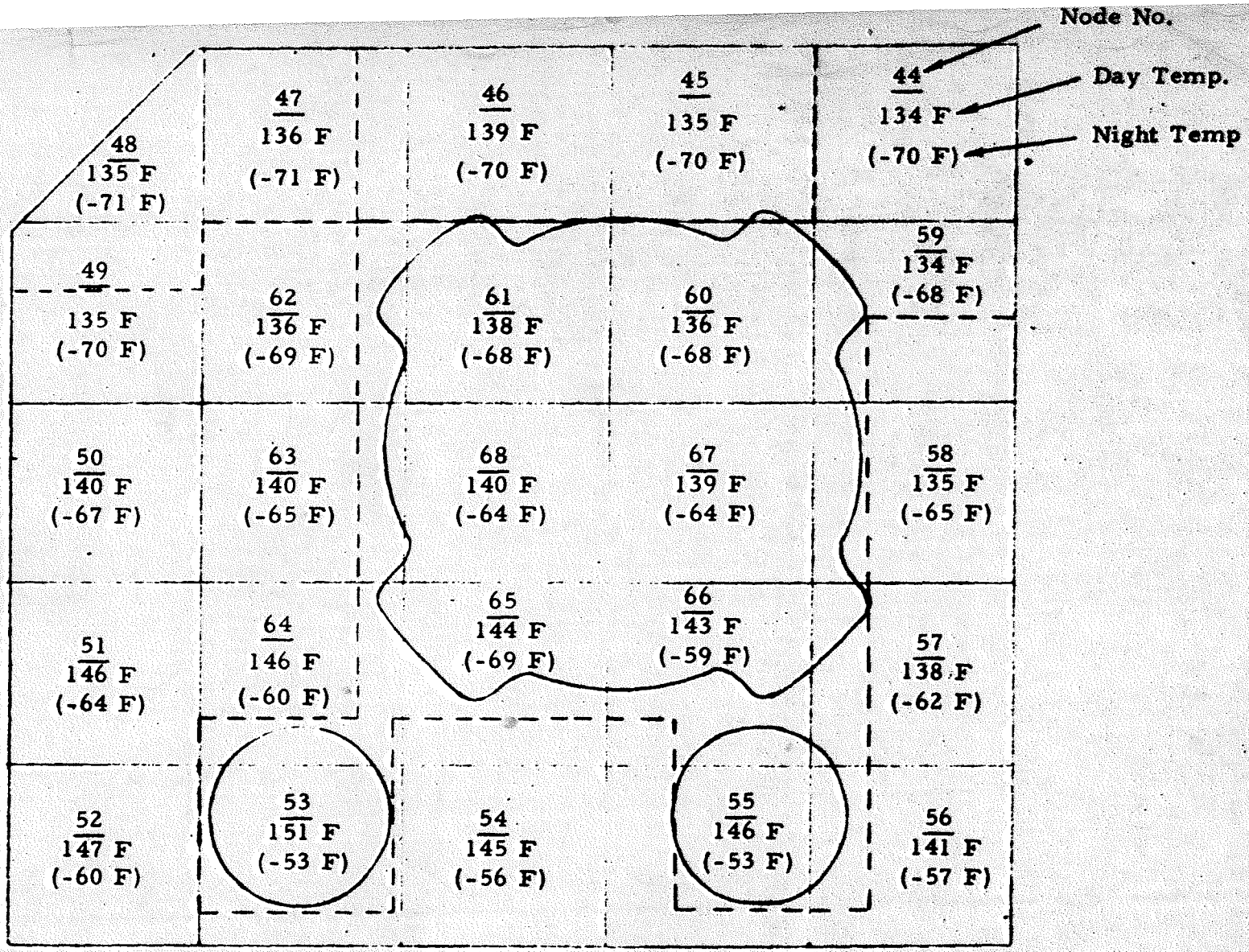

Figure 2 Thermal Plate Day-Night Temperatures
Mirror Area = 2.04 Ft^2
Night Heat Leak = 5.3 Watts + Thermal Isolators
36 W Regulator