Bendix
Aerospace
Systems Division

NO.	REV. NO.
ATM-1068	

HFE POWER OFF DURING LUNAR NIGHT

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DATE 5 Nov 1971

This ATM responds to an MSC request that Bendix review the unscheduled operation of the HFE with power off during lunar night, provide an assessment of the low temperature to which the instrument was exposed and appraise the possible impairment of Reliability.

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1.0 BACKGROUND INFORMATION

On 15 September 1971, at 10:26 GMT, Apollo 15 ALSEP experienced a spurious command which transferred the Heat Flow Experiment from OPERATE to STANDBY. At this time there was no real time support at the Mission Control Center since "Phase III" operation (post 45 days) was in effect. When MSFN Station personnel detected a change in AB-05 status, Houston Network personnel were notified; they in turn notified Flight Control by telephone. Following discussion and instructions from Flight Control, at 11:30 GMT the MSFN station initiated a command from the station console to transfer the experiment back to operate; however, the command sent was Octal 057 which turns the experiment OFF. Interestingly, the AB-05 status change observed when the System responds to Command 057 is identical to the change that would have occurred had the proper command (Octal 055) been sent. Since the site could not check HFE data in the telemetry bit stream, the operator apparently assumed, from observing AB-05, that the HFE was correctly transferred to its operational mode. The error was not discovered until later and for approximately 2 hours 20 minutes the HFE electronics were exposed to the low temperature extreme of the lunar night without the application of any survival power from the ALSEP Central Station.

At approximately 13:50 GMT the HFE OPERATE Select Command (Octal 055) was sent. System response confirmed that operational power had been applied to the HFE; however, when real time support was initiated an attempt to play back the HFE data was unsuccessful. These data tapes have not been fully analyzed and it is not known whether the HFE data was invalid or if the unsuccessful play-back is attributable to network/MCC data processing problems.

Since the data records are unlikely to reveal the actual instrument temperature immediately following turn-on the temperature is estimated by thermal modeling.

At 15:17 GMT, approximately 1 1/2 hours after the application of operating power the HFE Instrument appeared to return to normal operation, giving normal data, and continues to function satisfactorily.

Some questions posed by these events are:

a) What was the thermal behavior of the electronics?

b) Was anything degraded by the cooling experienced?

c) Is there any long term affect on instrument reliability?

This ATM documents a review of the unscheduled HFE operation and provides information to answer the above questions.

2.0 TEMPERATURE PROFILE

The HFE was transferred to Standby at 1026 GMT (15 Sept 1971) and for a subsequent period of 4.85 hours experiment data was not available. A simplified thermal/mathematical model of the HFE was constructed to define the thermal plate temperature excusion during the period when flight data were not available. This temperature profile is used in assessing whether any damage was incurred which could lead to degraded performance or premature failure of any part of the instrument.

For the purpose of HFE thermal analysis the following assumptions were made:

1. The functional and standby HFE internal power dissipation were 9.35 and 4.07 watts, respectively.

2. The thermal plate and attached electronics were assumed to be an isothermal mass of 3.3 pounds.

3. The HFE thermal plate initial temperature was taken as 50.0°F based on flight data.

4. A single radiation heat sink temperature for the HFE of -460.0°F was selected to simplify the analysis. The assumption is conservative in that lower limit temperature responses will be promoted.

Results of the thermal analysis indicate that the minimum thermal plate temperature was -33.5°F. The entire HFE temperature history is shown in Figure 1 and tabulated in detail in Table 1. Pertinent events are annotated on Figure 1. The plot covers a time span of one (1) hour before the anomaly to after the HFE thermal plate temperature has restabilized. At 1715 GMT (5.85 hours) flight data indicated that the thermal plate temperature was at -7°F. The HFE mathematical model predicts a corresponding temperature of -6°F.

Figure 1

FLIGHT A-2, HFE TEMPERATURE ANOMALY
RUN DATE 10/27/71

RESULTS OF THERMAL ANALYSIS

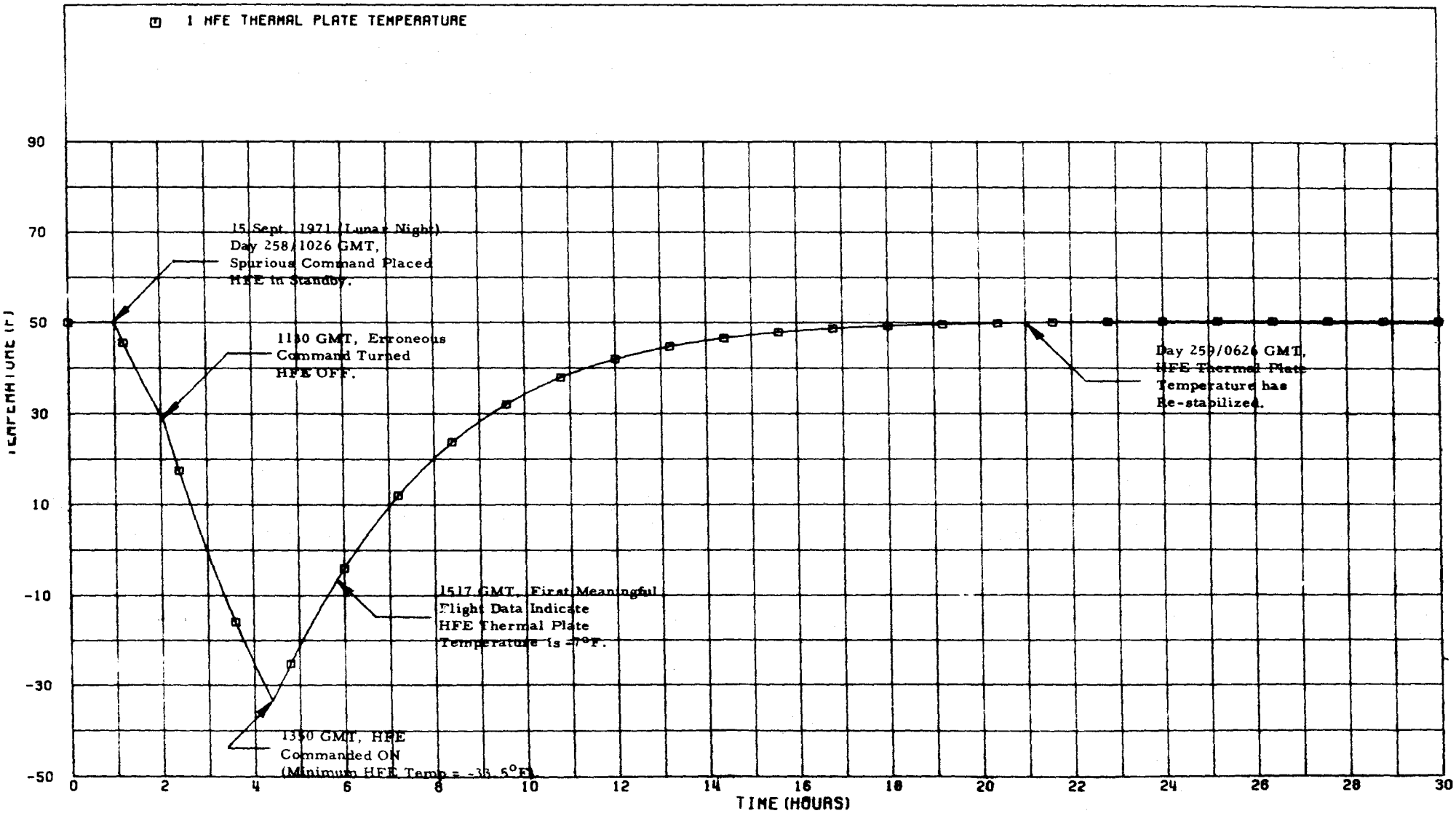

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Table 1

HFE Anomaly

Thermal Plate Temperature History*

(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)	(hrs) TIME	HFE Temp (°F) T(1)
0.0	50.00	4.60	-29.29	9.10	28.90	13.60	45.40	18.10	49.27	22.60	50.14	27.10	50.33
0.10	50.01	4.70	-27.23	9.20	29.56	13.70	45.56	18.20	49.31	22.70	50.15	27.20	50.33
0.20	50.02	4.80	-25.20	9.30	30.21	13.80	45.72	18.30	49.34	22.80	50.15	27.30	50.33
0.30	50.04	4.90	-23.22	9.40	30.83	13.90	45.87	18.40	49.38	22.90	50.16	27.40	50.33
0.40	50.05	5.00	-21.28	9.50	31.44	14.00	46.02	18.50	49.41	23.00	50.17	27.50	50.34
0.50	50.06	5.10	-19.37	9.60	32.03	14.10	46.16	18.60	49.44	23.10	50.18	27.60	50.34
0.60	50.07	5.20	-17.51	9.70	32.60	14.20	46.30	18.70	49.48	23.20	50.18	27.70	50.34
0.70	50.08	5.30	-15.69	9.80	33.16	14.30	46.43	18.80	49.51	23.30	50.19	27.80	50.34
0.80	50.09	5.40	-13.91	9.90	33.70	14.40	46.56	18.90	49.53	23.40	50.20	27.90	50.34
0.90	50.10	5.50	-12.16	10.00	34.23	14.50	46.69	19.00	49.56	23.50	50.20	28.00	50.34
1.00	50.11	5.60	-10.46	10.10	34.73	14.60	46.81	19.10	49.59	23.60	50.21	28.10	50.34
1.10	47.78	5.70	-8.79	10.20	35.23	14.70	46.92	19.20	49.62	23.70	50.21	28.20	50.35
1.20	45.52	5.80	-7.16	10.30	35.71	14.80	47.04	19.30	49.64	23.80	50.22	28.30	50.35
1.30	43.34	5.90	-5.57	10.40	36.17	14.90	47.15	19.40	49.67	23.90	50.22	28.40	50.35
1.40	41.22	6.00	-4.01	10.50	36.62	15.00	47.25	19.50	49.69	24.00	50.23	28.50	50.35
1.50	39.17	6.10	-2.49	10.60	37.06	15.10	47.36	19.60	49.71	24.10	50.24	28.60	50.35
1.60	37.18	6.20	-1.01	10.70	37.48	15.20	47.46	19.70	49.73	24.20	50.24	28.70	50.35
1.70	35.25	6.30	0.44	10.80	37.90	15.30	47.55	19.80	49.76	24.30	50.24	28.80	50.35
1.80	33.38	6.40	1.86	10.90	38.29	15.40	47.64	19.90	49.78	24.40	50.25	28.90	50.35
1.90	31.56	6.50	3.24	11.00	38.68	15.50	47.73	20.00	49.80	24.50	50.25	29.00	50.35
2.00	29.80	6.60	4.58	11.10	39.05	15.60	47.82	20.10	49.82	24.60	50.26	29.10	50.36
2.10	27.51	6.70	5.89	11.20	39.42	15.70	47.90	20.20	49.83	24.70	50.26	29.20	50.36
2.20	24.05	6.80	7.17	11.30	39.77	15.80	47.99	20.30	49.85	24.80	50.27	29.30	50.36
2.30	20.70	6.90	8.42	11.40	40.11	15.90	48.06	20.40	49.87	24.90	50.27	29.40	50.36
2.40	17.43	7.00	9.64	11.50	40.44	16.00	48.14	20.50	49.89	25.00	50.27	29.50	50.36
2.50	14.26	7.10	10.82	11.60	40.76	16.10	48.21	20.60	49.90	25.10	50.28	29.60	50.36
2.60	11.16	7.20	11.98	11.70	41.07	16.20	48.29	20.70	49.92	25.20	50.28	29.70	50.36
2.70	8.15	7.30	13.10	11.80	41.37	16.30	48.35	20.80	49.93	25.30	50.28	29.80	50.36
2.80	5.21	7.40	14.20	11.90	41.66	16.40	48.42	20.90	49.95	25.40	50.29	29.90	50.36
2.90	2.34	7.50	15.27	12.00	41.94	16.50	48.49	21.00	49.96	25.50	50.29	30.00	50.36
3.00	-0.45	7.60	16.31	12.10	42.21	16.60	48.55	21.10	49.98	25.60	50.29	30.10	50.36
3.10	-3.18	7.70	17.32	12.20	42.47	16.70	48.61	21.20	49.99	25.70	50.30		
3.20	-5.85	7.80	18.31	12.30	42.73	16.80	48.67	21.30	50.00	25.80	50.30		
3.30	-8.45	7.90	19.26	12.40	42.98	16.90	48.72	21.40	50.02	25.90	50.30		
3.40	-10.99	8.00	20.20	12.50	43.22	17.00	48.78	21.50	50.03	26.00	50.30		
3.50	-13.48	8.10	21.10	12.60	43.45	17.10	48.83	21.60	50.04	26.10	50.31		
3.60	-15.91	8.20	21.99	12.70	43.67	17.20	48.88	21.70	50.05	26.20	50.31		
3.70	-18.29	8.30	22.84	12.80	43.89	17.30	48.93	21.80	50.06	26.30	50.31		
3.80	-20.62	8.40	23.68	12.90	44.10	17.40	48.98	21.90	50.07	26.40	50.31		
3.90	-22.90	8.50	24.49	13.00	44.31	17.50	49.03	22.00	50.08	26.50	50.32		
4.00	-25.13	8.60	25.28	13.10	44.50	17.60	49.07	22.10	50.09	26.60	50.32		
4.10	-27.32	8.70	26.04	13.20	44.69	17.70	49.11	22.20	50.10	26.70	50.32		
4.20	-29.47	8.80	26.79	13.30	44.88	17.80	49.16	22.30	50.11	26.80	50.32		
4.30	-31.57	8.90	27.51	13.40	45.06	17.90	49.20	22.40	50.12	26.90	50.33		
4.40	-33.54	9.00	28.22	13.50	45.23	18.00	49.24	22.50	50.13	27.00	50.33		
4.50	-31.40												

*See Figure 1 for annotation of anomaly events.

There is a high degree of confidence that the mathematical model has accurately defined the HFE temperature history during the period of concern; and is therefore considered to be an accurate basis for a Reliability analysis.

Table 2 presents time intervals which the HFE thermal plate spent below specific temperature levels.

TABLE 2

Temperature Level (^{o}F)	Time Spent Below Specified Temperature Level (Hours)
50	20.0
40	9.90
30	7.20
20	5.66
10	4.40
0	3.30
-10	2.26
-20	1.30
-30	0.32

3.0 TEMPERATURE SENSITIVE PARTS

The HFE electronics is built from a variety of part types used in circuits for amplification, A/D Conversion, Multiplexing, DC to DC Conversion, Power Supplies and miscellaneous signal conditioning and processing circuits. Most common active circuit elements are Amelco FET switches and Fairchild series 90 and 99 integrated circuits. These may be stored to -65°C (they were essentially in storage during Power Off operation) and operated to -55°C. Other types of active and passive parts have equivalent ratings; therefore, operation at -33°F does not indicate incipient failure or that the ability of the instrument to function without failure for the duration of the Mission has been compromised.

Schematics were reviewed in an effort to determine what circuits might degrade the instruments data at off limit low temperature operation. None were identified.

In summary no suspect part was identified which should cause any concern for the future performance of the Instrument.

4.0 CONCLUSIONS AND RECOMMENDATIONS

a. Based on reports of the instrument's continued excellent performance following occurrence of the anomaly, it is apparent that no immediate damage was sustained.

b. Evaluation of parts within the Heat Flow Electronics Package confirms that all are adequately rated to survive the low temperature to which they were exposed. Additionally, there is no indication of degradation of the instruments long term reliability.

c. Although no indications of hazardous conditions due to operation at temperatures well below the test range were uncovered during the reliability analysis, without additional evaluation, including tests, it cannot be conclusively stated that none exist. Consequently, it is recommend that for similar conditions in the future, consideration should be given to the application of survival power and delaying application of operational power until the instrument temperature has reached a level of at least $-20^{\circ}C$.

d. The specified HFE operating temperature range is $0^{\circ}C$ to $+60^{\circ}C$. During the test program where HFE units have been subjected to lower temperatures, data usually becomes "garbled" at (and below) about $-8^{\circ}C$. The cause of this condition, which appears to have also occurred on the moon, has not been identified. Tests using HFE SN02 or SN03 models could yield information on circuit performance at temperatures below the specified operating limit.

e. It is recommended that Experiment OFF commands should be placed in a "critical category" to preclude inadvertent experiment switch off.