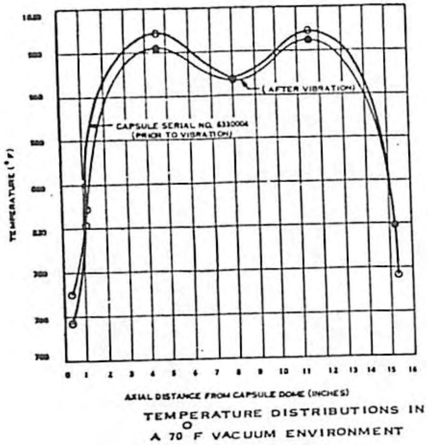


Figure 11-28. Temperature Distribution in a 70°F Vacuum Environment

11.4 ALSEP CASK ASSEMBLY (ACA) INTEGRATED QUALIFICATION TESTS

A flight quality ALSEP cask assembly was subjected to a qualification test program in accordance with the requirements of References 11-5 and 11-6. The assembly was comprised of the following test articles mated into a flight configuration:

a. Graphite LM Fuel Cask, S/N 6406001

b. Fuel Capsule Assembly, S/N 6330004

c. ALSEP Structure Assembly, S/N 3

d. ALSEP Band Assembly, S/N 4

e. Astronaut Guard Assembly, S/N 4.

The test program was initiated on July 3, 1968 and completed on March 29, 1969. It consisted of the following tests in the order shown:

a. Weight and CG Measurements (with a dummy fuel capsule)

b. Flight Acceptance Level Vibration Test

c. Tilt Test

d. Thermal Air Test

e. Thermal Vacuum Test

f. Qualification Level Vibration and Shock Tests

g. Tilt Test (repeat)

A summary of the results follows.

11.4.1 WEIGHT AND CENTER OF GRAVITY MEASUREMENTS

Due to radiation safety precautions, the weight and cg measurements of the qualification ACA were made with a simulated fuel capsule instead of Fuel Capsule Assembly S/N 6330004. The simulated FCA was of the same weight and physical dimensions as a flight fuel capsule assembly. Results are shown in Table 11-3.

TABLE 11-3. QUALIFICATION ALSEP CASK ASSEMBLY WEIGHT AND CENTER OF GRAVITY MEASUREMENTS

Weight:	53.562 pounds
C.G:	53.562 pounds
"A" Dimensions	+ 0.836 inches
"B" Dimensions	+ 0.103 inches
"C" Dimensions	- 0.556 inches

11.4.2 FLIGHT ACCEPTANCE LEVEL VIBRATION TEST

The heavily instrumented ACA was tested while mounted within a contamination safety enclosure (Figures 11-29 and 11-30) which was supported above the shaker head for vertical vibration, or over the team table for lateral vibration. This enclosure was intended to provide radiological protection in the event of fuel capsule rupture. Figure 11-31 shows the assembly mounted horizontally to the shaker head

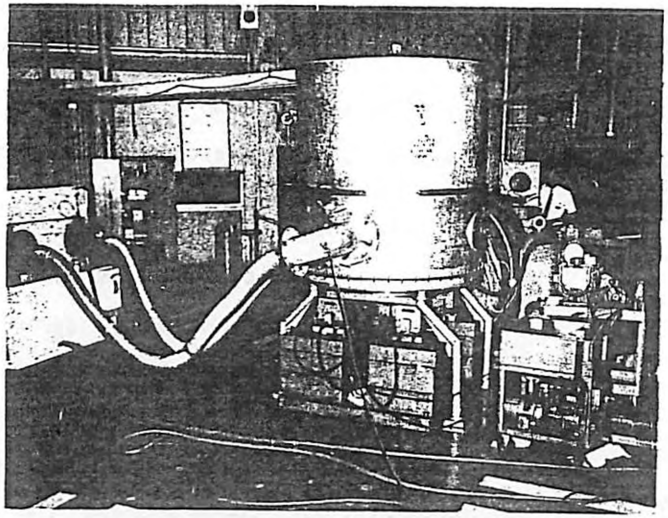


Figure 11-29. Safety Enclosure and Heat Transfer System Mounted Over the Vibration Team Table

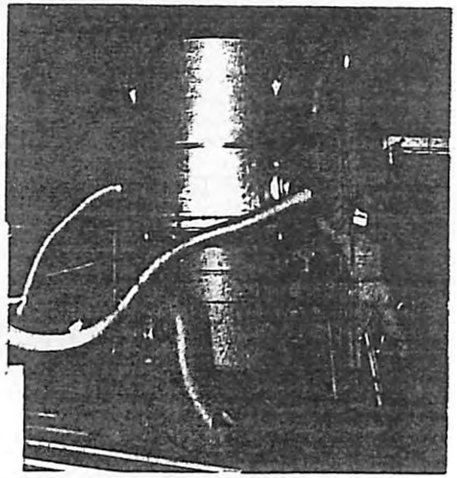


Figure 11-30. Safety Enclosure Mounted on Vibration Machine

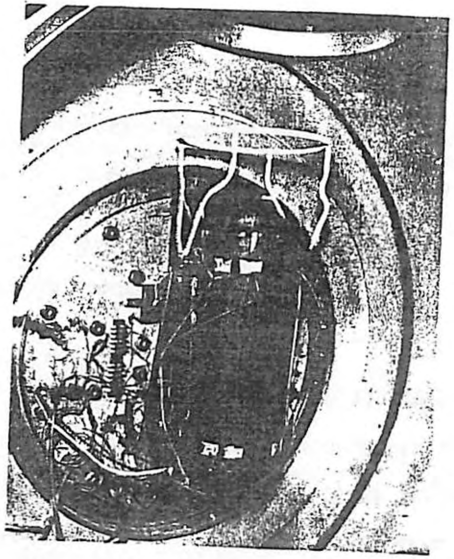


Figure 11-31. View of ALSEP Cask Assembly Mounted to Shaker Head Inside Safety Enclosure

head inside the safety enclosure. The safety enclosure consists of a large cylindrical cover, five-foot diameter by five-foot high, which bolts to a four-legged support stand. Air inlet and outlet ports, viewports, and instrumentation plates have been provided in the canister wall. Inside the enclosure is an adaptor plate with a rubber diaphragm which attaches to the canister to provide a sealed assembly and isolate the dynamic input from the canister. A closed loop forced convection air cooling system consisting of a heat exchanger and blower assembly is located external to the canister. The unit is coupled to the inlet and outlet ports of the canister by means of flexible metal hose capable of maintaining the required hermetic seal. The cooling air flow inside the canister is directed across the GLFC to maintain the GLFC surface temperature at 280°F or lower. An Eberline Model AIM-3 alpha air monitor probe continually samples the air at the exhaust duct for possible plutonium contamination. The FCA is completely sealed in this safety enclosure during all the vibration and shock testing. During the functional tilt test, the canister was removed and a portable absolute filter system installed nearby to minimize the spread of contamination in the event of an FCA rupture.

During test in all three axes, the GLFC was mounted in a horizontal position and the external graphite surface was maintained at a nominal temperature of 350°F to simulate on-pad cooling conditions. Cooling was accomplished using the contamination enclosure's air circulation system.

The ACA was subjected to the following sinusoidal vibration in each of its three orthogonal axes at a sweep rate of three octaves per minute - up scale only. (See Figure 11-32 for vibration profile.)

Sinusoidal Vibration

Frequency	Amplitude
5 to 14 Hz	0.154 in. DA
14 to 75 Hz	1.54 g
75 to 100 Hz	2.3 g

The ACA was then subjected to the following random vibration for 2.5 minutes per axis. (See Figure 11-33 for vibration profile.)

Random Vibration

Frequency	Power Spectral Density
20 to 100 Hz	9 db/octave increase
100 to 500 Hz	0.089 g^2/cps
500 to 2000 Hz	6 db/octave decrease

Immediately after the last axis of vibration, Z-axis, the C-210 shaker, on which the last axis of vibration had been completed, was rotated 90 degrees and a tilt test demonstration was performed.

11.4.3 TILT TEST

This test was performed to verify that the operational integrity of the ACA had not been compromised due to the preceding vibration test. This was accomplished by rotating the shakers so that the attached ACA was vertical. A counterbalance fixture was then assembled over the ACA to compensate for earth gravity so that the effects of a 1/6 g lunar gravity condition could be simulated. The arrangement is depicted in Figures 11-34 and 11-35. A series of steps were then performed to determine the various forces and torques required to accomplish the

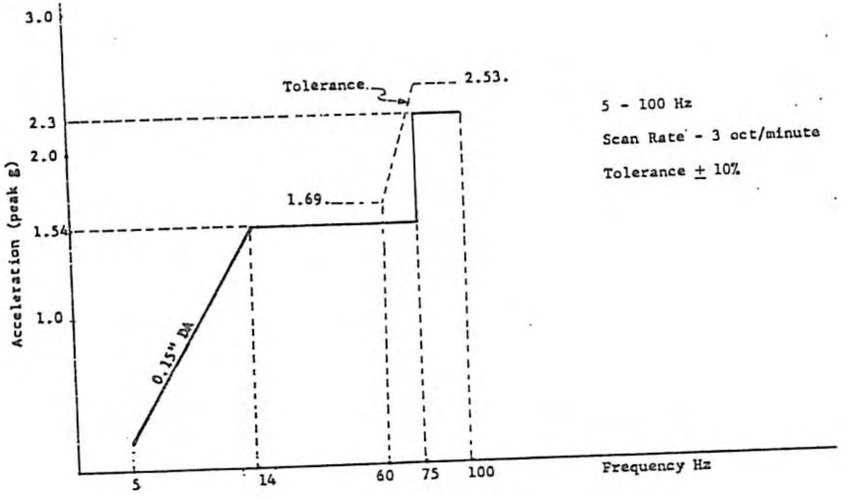


Figure 11-32. ACA Flight Level Sine Wave Vibration

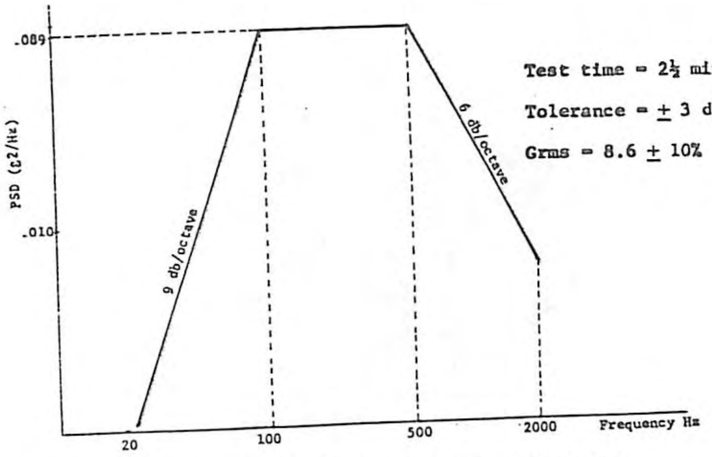


Figure 11-33. ACA Flight Level Random Vibration

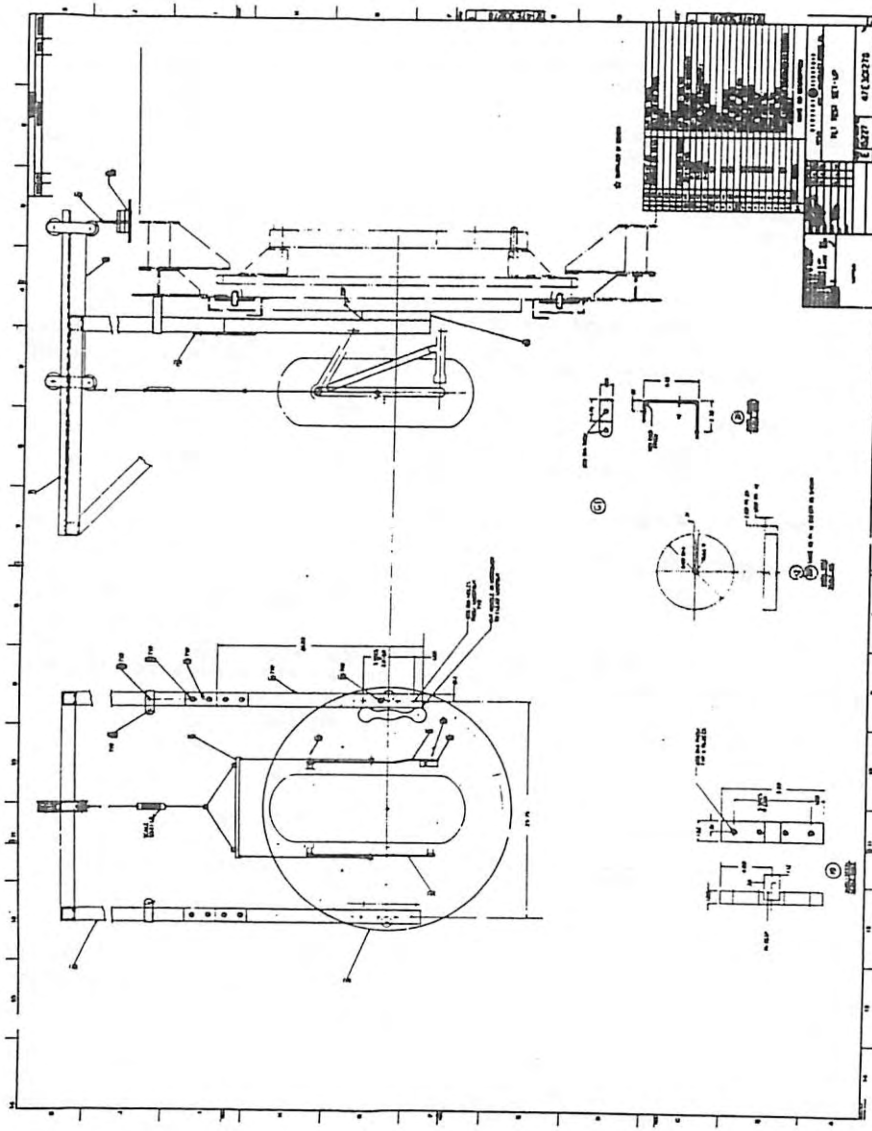


Figure 11-34. Tilt Test Setup

Figure 11-35. Tilt Test Setup Showing Earth G Counterbalance Fixture

different activities associated with deployment. The tests were intended to provide demonstrations which would:

a. Measure the force required to shear each trunnion shear pin

b. Measure the force required to remove the aft spline lock from the aft GLFC dome

c. Verify the functional mechanical operation and the required operating force of the lanyard which operates tilt gear box assembly

d. Measure the force required to engage the dome removal tool with the GLFC dome and to depress the plunger

e. Measure the torque required to remove the GLFC dome utilizing the removal tool

f. Measure the torque required to engage the flight handling tool with the FCA during the qualification test and on the ground handling tools for all testing

Table 11-4 lists the steps and values recorded for both the post acceptance level vibration tests and the post qualification level vibration and shock tests.

11.4.4 THERMAL AIR SOAK TEST

The test was conducted in accordance with the requirements of Reference 11-7 to verify that the approach to on-pad cooling of the fueled GLFC, when installed in the SLA, was capable of maintaining the GLFC's surface temperature below 350°F. The test setup is shown in Figures 11-36 and 11-37. A series of runs were made for different parameters of air flow and distance of the air nozzle from the bottom of the GLFC. All testing was performed at room abmient conditions.

The results of the test validated the overall thermal predictions for the ACA. The cooling system proved itself readily capable of maintaining the GLFC's surface below 300°F in various cooling configurations. Figure 11-38 shows the transient heatup of the ACA without cooling, following deenergization of the blower system.

11.4.5 THERMAL VACUUM TEST

The purpose of this test was to subject the ACA to a thermal vacuum environment simulating launch and translunar phases of the mission.

The qualification ACA was installed on the LM/SLA simulator and subjected to a thermal vacuum environment of 1 x 10^{-5} torr or less in the SLA-ON configuration for ten hours. After ten hours at steady state, the LM/SLA simulator with the ACA installed was removed from the vacuum chamber and the SLA and canister panels were removed. A solar array was then installed on the remaining LM/SLA structure and the modified assembly was then subjected to a thermal vacuum environment of 1 x 10^{-5} torr, or less, for thirty-six hours of steady state operation with the solar simulator energized and thirty-six hours of steady state operation with the solar simulator deenergized.

Figures 11-39 through 11-42 illustrate the thermal vacuum testing of the ACA. Figures 11-43 through 11-48 illustrate the data obtained from the test.

11.4.6 QUALIFICATION LEVEL VIBRATION AND SHOCK TESTS

The test setup for the ACA qualification vibration testing was as shown for the preceding acceptance-level vibration testing. The sequence of qualification dynamic testing was as follows:

TABLE 11-4. QUALIFICATION ALSEP CASK ASSEMBLY TILT TEST DATA

	POST ACCEPTANCE LEVEL VIBRATION (A)	POST QUALIFICATION LEVEL DYNAMIC TESTING (B)
Force to remove lanyard from left retaining clip (lb)	(C)	3.5
Force to remove lanyard from right retaining clip (lb)	(C)	0.5
Maximum force to shear right trunnion shear pin (lb)	31.0	17.0
Maximum force to shear left trunnion shear pin (lb)	30.0	18.0
Maximum force to remove dome spline lock (lb)	6.0	8.5
Maximum force to lower cask 120° (lb)	17.5	9.0
Maximum force to raise cask to FCA removal position (lb)	32.0	26.0
Maximum force to engage dome removal tool (lb)	36.0	15.3
Maximum force to depress plunger on dome (lb)	19.0	10.6
Maximum torque to rotate cask nut (in-lb)	(D)	30.0
Maximum torque to rotate dome 60° (in-lb)	75	15.0
Maximum torque to engage handling tool to FCA in three positions (in-lb)	5,5,6 (A)	8,9,8 (B)

(A) Utilized Bendix supplied flight handling tool (GE S/N 6331011).

(B) Utilized GE ground handling tool.

(C) Retaining clips not installed on these units prior to test.

(D) Not measured.

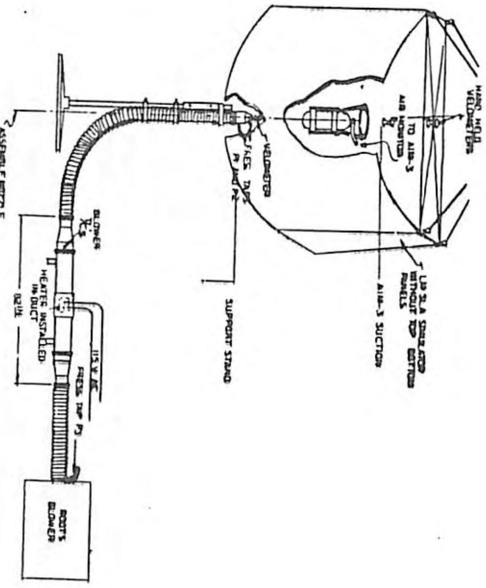


Figure 11-36. Air Soak Test Setup

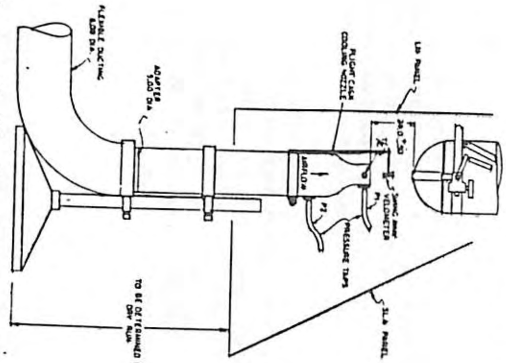


Figure 11-37 Nozzle Stand Assembly

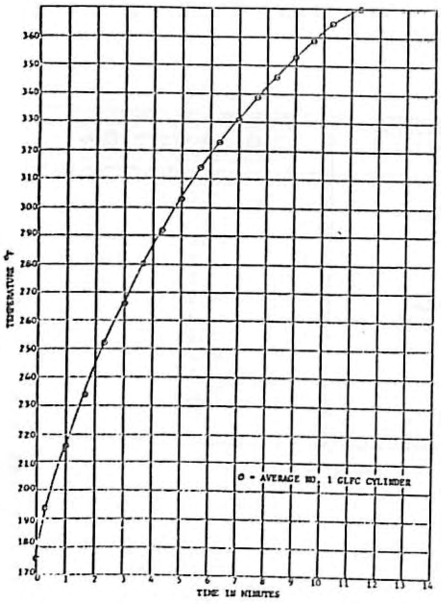


Figure 11-38. Transient Heatup (Blower Off)

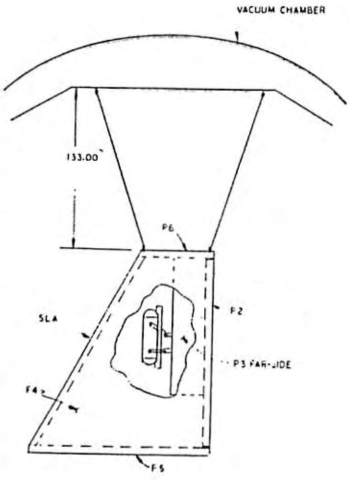


Figure 11-39. Thermal Vacuum Test with SLA on (Inside 39 Foot Vacuum Chamber)

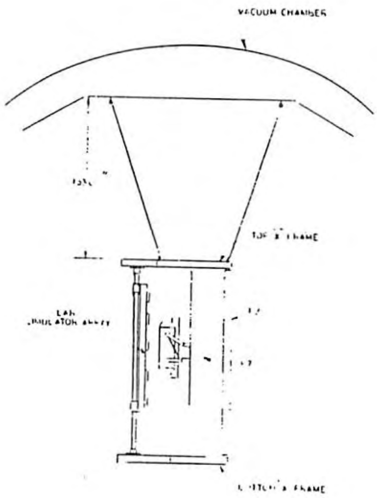


Figure 11-40. Thermal Vacuum Test with SLA off (Inside 39 Foot Vacuum Chamber with Solar Simulator

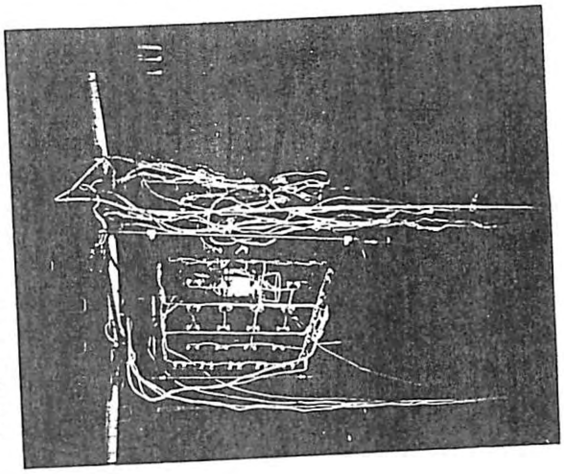


Figure 11-41. Solar Array Setup

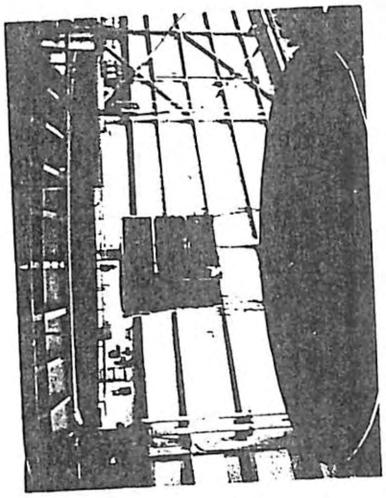


Figure 11-42. Loading LM/SLA into Vacuum Chamber

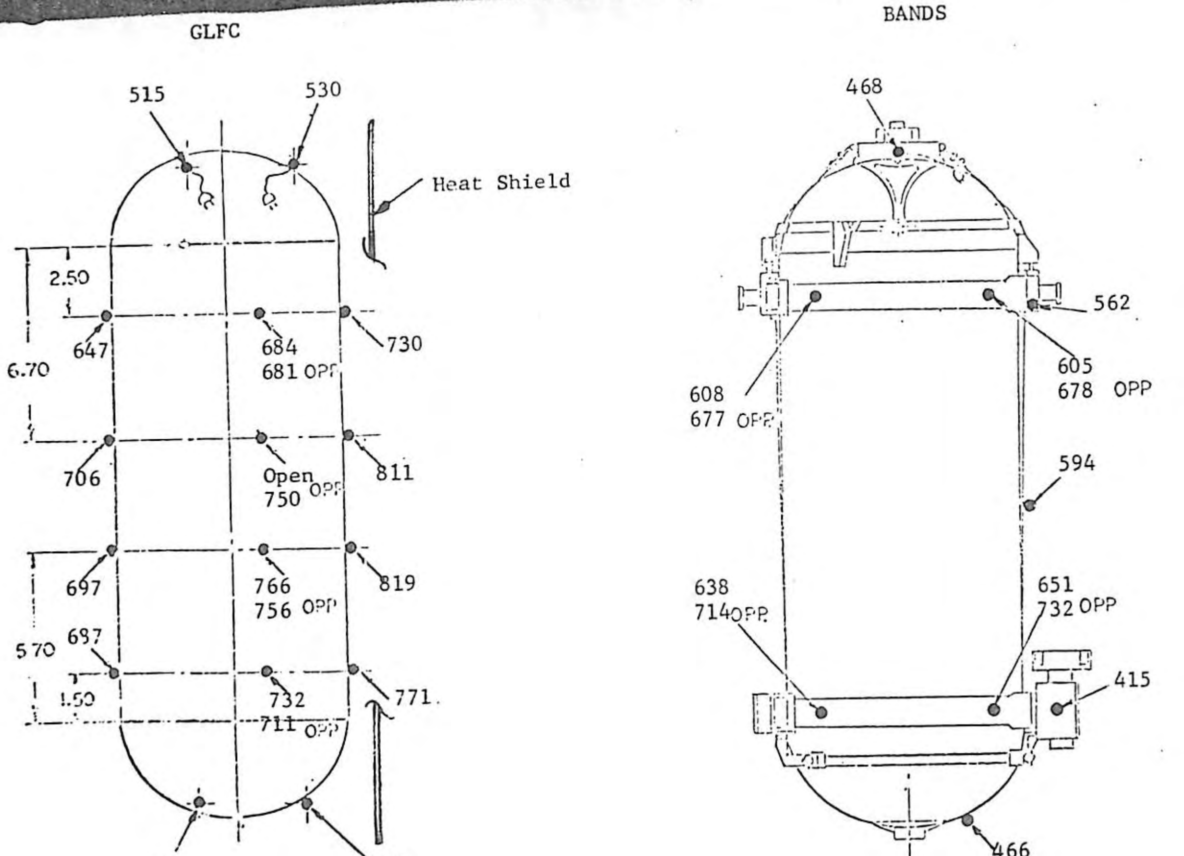
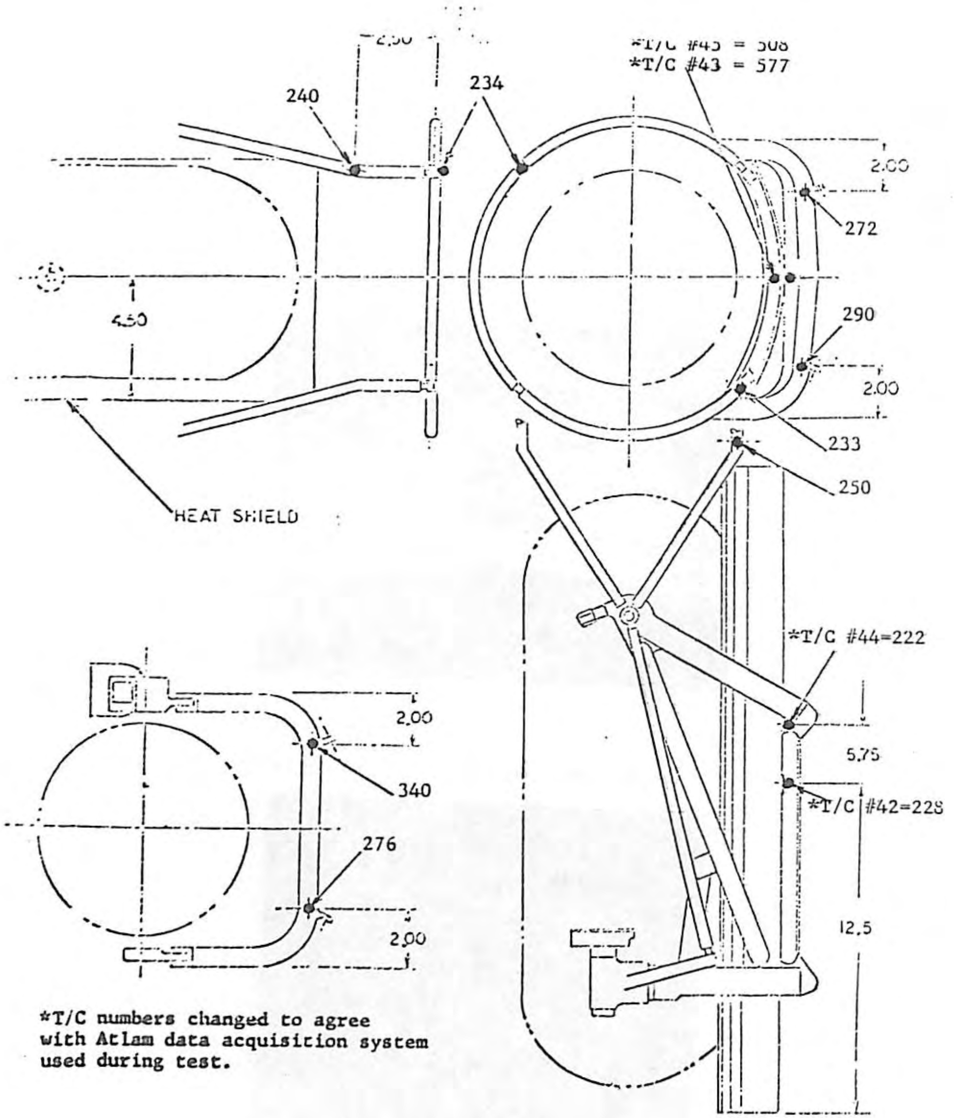


Figure 11-43. Thermocouple Temperatures ($^{\circ}F$) and Location on GLFC and Bands During Ten Hour Thermal Vacuum Test With LM/SLA Canister On



*T/C numbers changed to agree with Atlam data acquisition system used during test.

Figure 11-44. Thermocouple Temperatures (°F) and Location on Struts, Heat Shield and Astronaut Protective Guard During Ten Hour Thermal Vacuum Test With LM/SLA Canister On

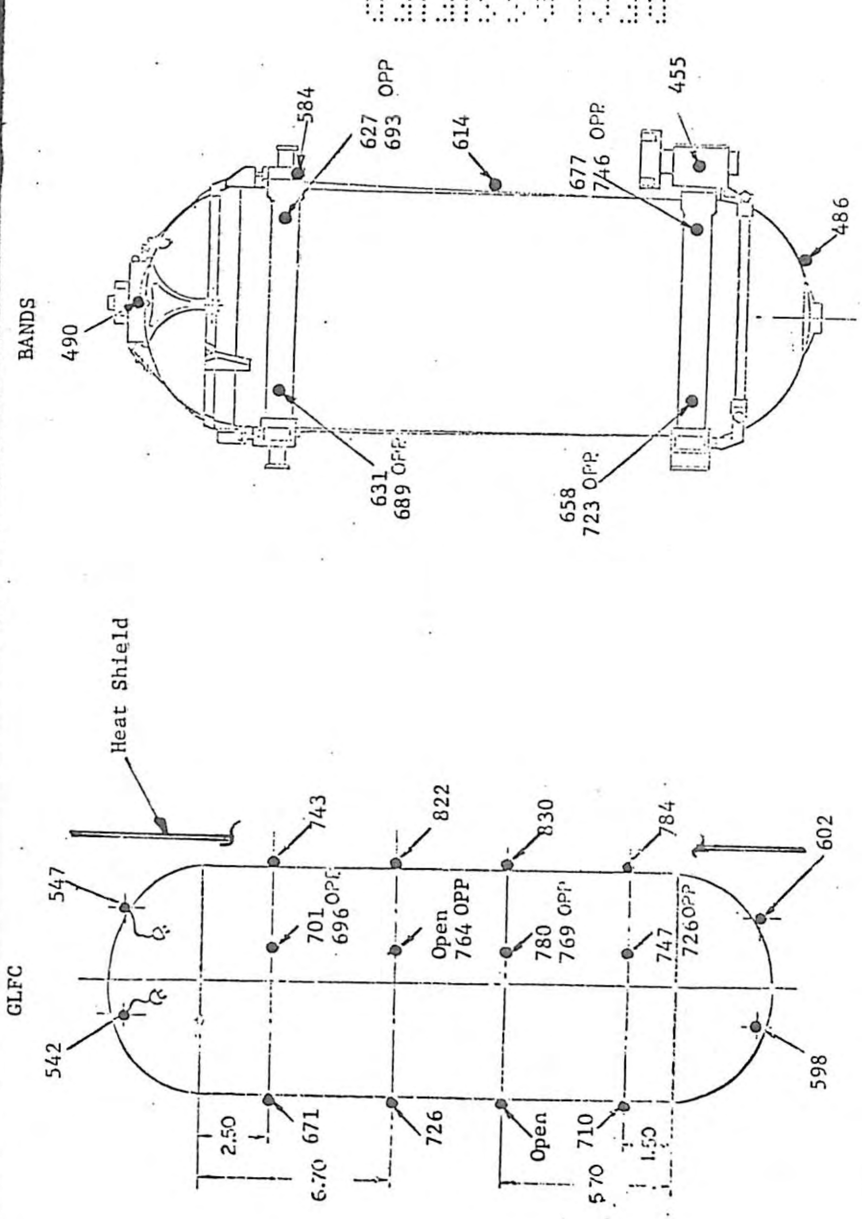
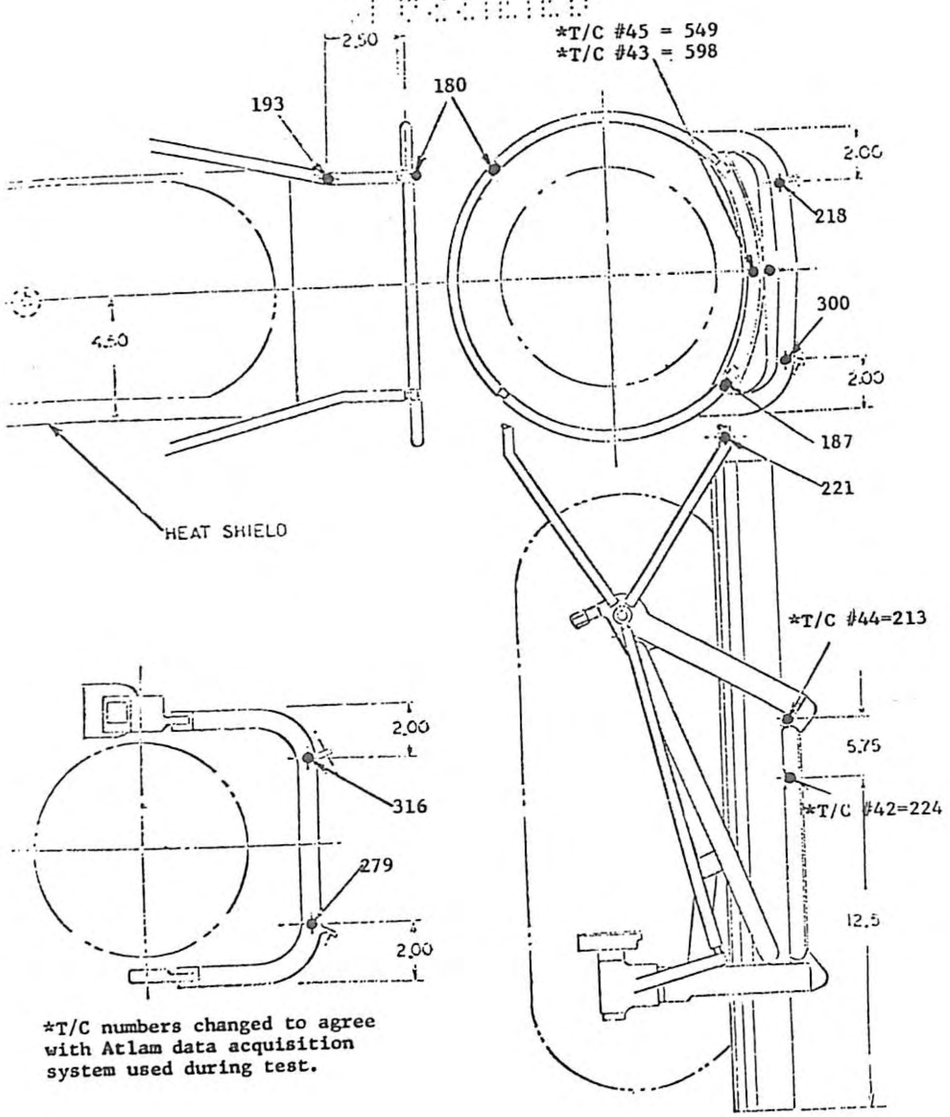


Figure 11-45. Thermocouple Temperatures (°F) and Location on GLFC and Bands During 36 Hour Thermal Vacuum Test With SLA Off and Solar Simulator Turned On



*T/C numbers changed to agree with Atlam data acquisition system used during test.

Figure 11-46. Thermocouple Temperatures (°F) and Locations on Struts, Heat Shield, and Astronaut Protective Guard During 36 Hour Thermal Vacuum Test With SLA Off and Solar Simulator Turned On.

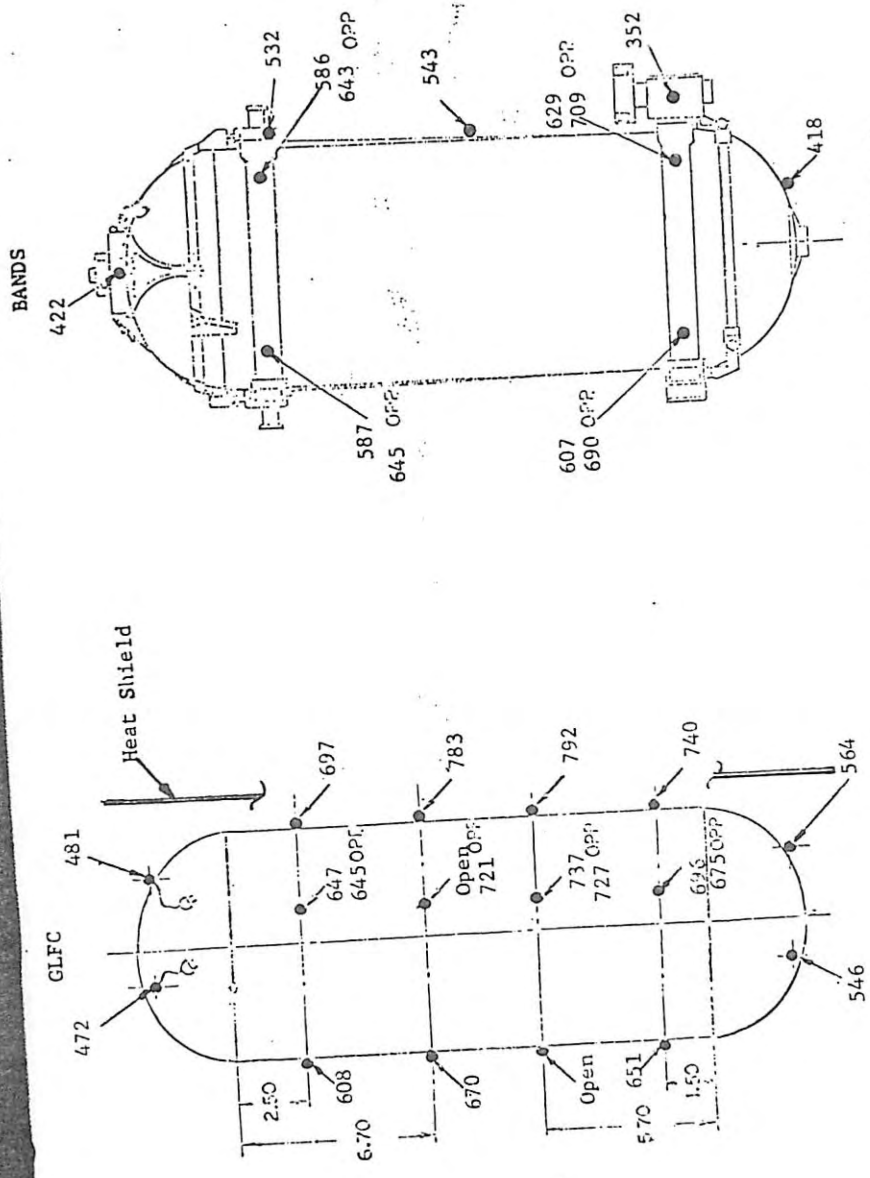
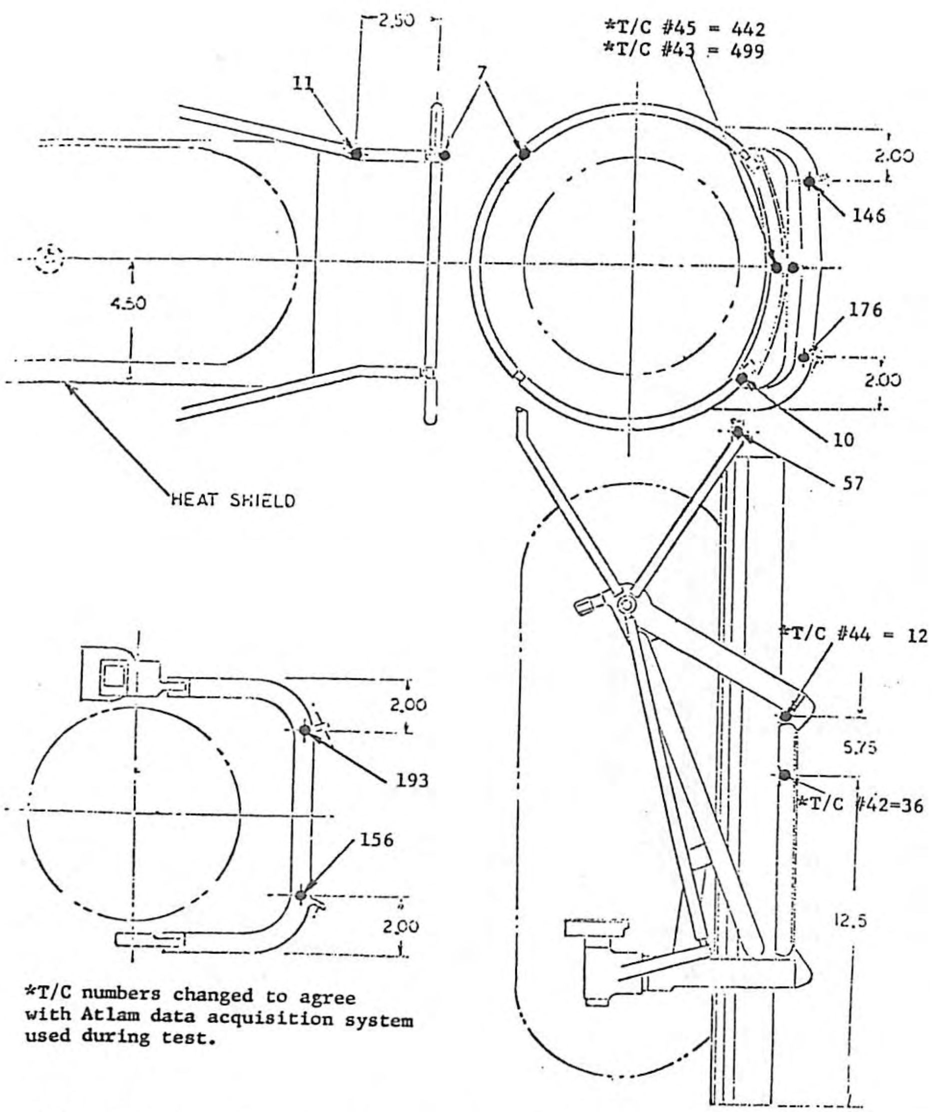


Figure 11-47. Thermocouple Temperatures (°F) and Location on GLFC and Bands During 36 Hour Thermal Vacuum Test With SLA Off and Solar Simulator Turned Off



*T/C numbers changed to agree with Atlam data acquisition system used during test.

Figure 11-48. Thermocouple Temperatures (°F) and Locations on Struts, Heat Shield, and Astronaut Protective Guard During 36 Hour Thermal Vacuum Test With SLA Off and Solar Simulator Turned Off

a. Qual level sinusoidal and random launch boost vibration - Z axis

b. Qual level sinusoidal and random launch boost vibration - Y axis

c. Qual level sinusoidal and random launch boost vibration - X axis

d. Qual level sinusoidal and random lunar descent vibration - X axis

e. Shock - +X axis

f. Qual level sinusoidal and random lunar descent vibration - Y axis

g. Shock - ± Y Axis

h. Qual level sinuosidal and random lunar descent vibration - Z axis

i. Shock - ± Z axis

The qualification level vibration requirements employed during the test are summarized below:

LAUNCH BOOST

Sinusoidal

Frequency Range	Amplitude
5 to 14 Hz	0.2 in. DA
14 to 75 Hz	2.0 g ± 0.2 g
75 to 100 Hz	3.0 g ± 0.3 g

Sweep rate of 3 octaves/minute, up and down, along each of the ACA's three orthogonal axes.

Random

Frequency	Power Spectral Density
20 to 100 Hz	9 db/octave increase
100 to 500 Hz	0.15 g^2/cps
500 to 2000 Hz	6 db/octave decrease

2-1/2 minutes/axis, tolerance = ± 3 db, ± 10% grms, three orthogonal axes.

LUNAR DESCENT

Sinusoidal

Frequency	Amplitude
5 to 30 Hz	0.03 in. DA
30 to 100 Hz	1.4 g ± 0.14 g

Sweep rate of 1 octave/minute up and down along each of the ACA's three orthogonal axes.

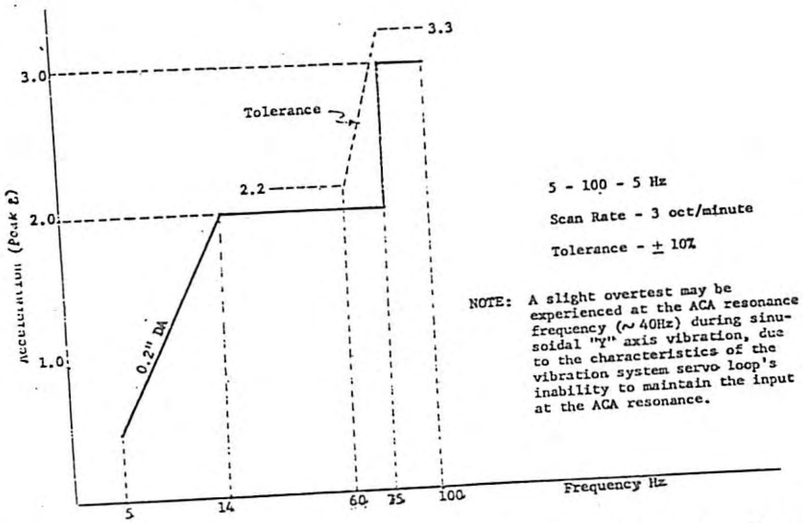
Random

Frequency	Power Spectral Density
5 to 20 Hz	12 db/octave increase
20 to 100 Hz	0.01 g^2/cps
100 to 120 Hz	12 db/octave decrease
120 to 2000 Hz	0.005 g^2/cps

12-1/2 minutes/axis, tolerance = 3 db, ± 10% gms, three orthogonal axes.

Test results verified the ability of the ACA to withstand the simulated dynamic conditions. Figures 11-49 through 11-52 show the vibration profiles.

Qualification shock tests to simulate lunar loading were performed with the ACA mounted on the shaker. The shaker exciter was programmed to



NOTE: A slight overtest may be experienced at the ACA resonance frequency (~ 40Hz) during sinusoidal "Y" axis vibration, due to the characteristics of the vibration system servo loop's inability to maintain the input at the ACA resonance.

Figure 11-49. ACA Qualification Level Sine Wave Vibration, Launch and Boost Phase

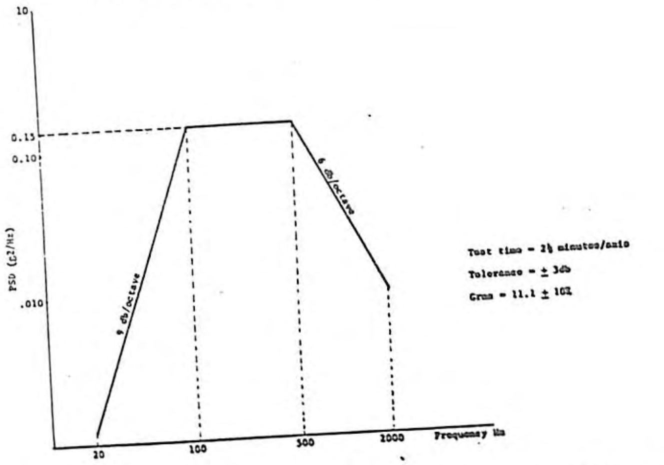
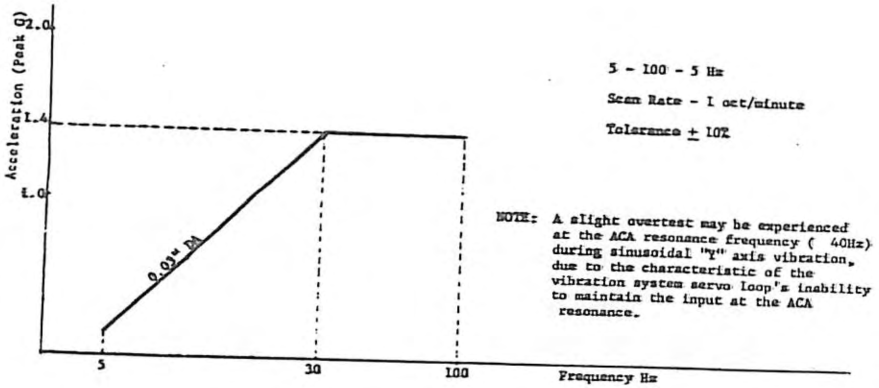


Figure 11-50. ACA Qualification Level Random Vibration, Launch and Boost Phase



NOTE: A slight overtest may be experienced at the ACA resonance frequency (40Hz) during sinusoidal "Y" axis vibration, due to the characteristic of the vibration system servo loop's inability to maintain the input at the ACA resonance.

Figure 11-51. ACA Qualification Level Sine Wave Vibration, Lunar Descent Phase

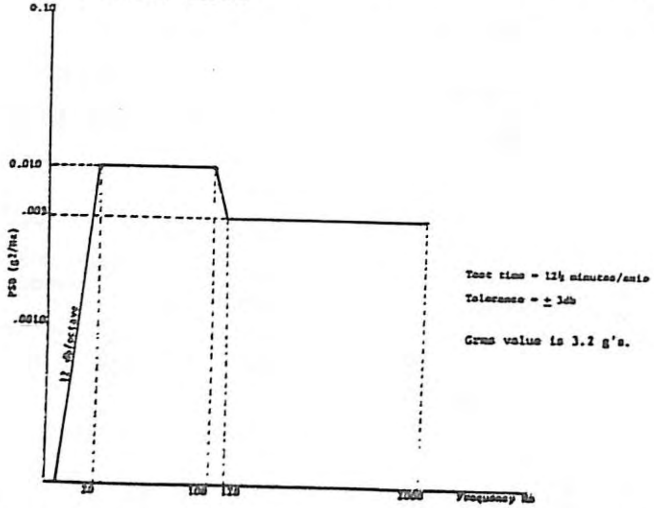


Figure 11-52. ACA Qualification Level Random Vibration, Lunar Descent Phase

produce half-sine shocks according to the profile shown in Figure 11-53. The ACA was subjected to three half-sine shocks of 15 g's along each of its three orthogonal axes, except the -X axis. During the application of the shocks, the GLFC was housed within the safety enclosure and its surface temperature was maintained at a nominal temperature of 600°F.

Test results verified the ability of the ACA to withstand the simulated dynamic conditions.

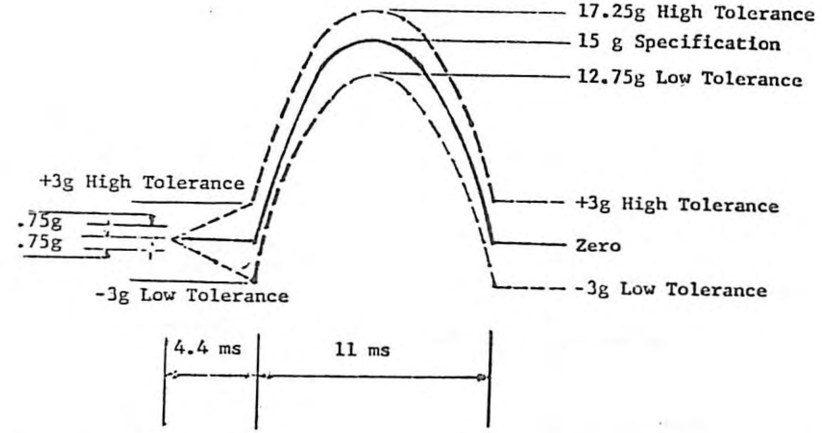


Figure 11-53. Half Sine Shock Pulse Configuration and Tolerance Limits (+X, ± Y, ± Z Direction)

11.4.7 TILT TEST (REPEAT)

At the completion of the dynamic qualification tests, the ACA was subjected to a repeat of the tilt test in the same manner as before. The results are summarized in Table 11-4.

11.5 D2/M5 MECHANICAL FLIGHT MOCKUP ASSEMBLY INTEGRATED QUALIFICATION TESTS

The SNAP-27 M5 mechanical flight mockup assembly included a GLFC and an inert fuel capsule simulator possessing mechanical and configurational characteristics representative of flight equipment. The GLFC, with fuel capsule simulator installed, was mated with a flight-type ALSEP support structure to make up the assembly designated as D2/M5. The qualification testing effort of this mockup hardware was as follows:

a. Weight and Center of Gravity Measurements

b. Flight Acceptance Level Vibration Testing

c. Qualification Level Vibration Testing

This test program satisfied the requirements of GE Specifications, References 11-8 and 11-9.

11.5.1 WEIGHT AND CENTER OF GRAVITY MEASUREMENTS

The weight and center of gravity measurements of the qualification D2/M5 mechanical flight mockup are summarized in Table 11-5.

TABLE 11-5. WEIGHT AND CENTER OF GRAVITY VALUES

Weight	52.578 pounds
"A" Dimension	+ 0.960 inches
"B" Dimension	- 0.098 inches
"C" Dimension	- 0.551 inches

11.5.2 FLIGHT ACCEPTANCE AND QUALIFICATION LEVEL VIBRATION TESTING

No failures were experienced when the D2/M5 assembly was vibrated at the conditions shown below:

Sinusoidal (Acceptance Level) Vibration

Frequency	Amplitude
5 to 17.5 Hz	0.15 in. DA
17.5 to 100 Hz	2.3 g ± 0.23 g

(sweep rate of 3 octaves/minute, upscale only)

Random (Acceptance Level) Vibration

Frequence	Amplitude
20 to 100 Hz	9 db/octave increase
100 to 500 Hz	0.089 g^2/cps
500 to 2000 Hz	6 db/octave decrease

(2-1/2 minutes/axis)

Sinusoidal (Qualification Level) Vibration

Frequency	Amplitude
5 to 17.5 Hz	0.02 in. DA
17.5 to 100 Hz	3.0 g ± 0.3 g

(3 octaves/minute - both up and down scale)

Random (Qualification Level) Vibration

Frequency	Power Spectral Density
20 to 100 Hz	9 db/octave increase
100 to 500 Hz	0.15 g^2/cps
500 to 2000 Hz	6 db/octave decrease

(2-1/2 minutes/axis)

11-6 REFERENCES

11-1 "Performance and Design Requirements for the Generator Assembly, SNAP-27 Program", General Electric, NS 6115-30-01, June 1967.

11-2 "Qualification Test Plan for Generator Assembly Mod 10", General Electric, SI 249155.

11-3 "Phase II Test Report for Qualification Testing Performed on Generator Assembly Mod 10", General Electric, 6300-288, June 1968.

11-4 "Final Report for Magnetic Field Measurement and Analysis, Part 3, SNAP-27 Program", General Electric, GEMS-401, July 1968.

11-5 "Performance and Design Requirements for the Graphite LM Fuel Cask (GLFC), SNAP-27 Program", General Electric, NS 0110-07-04, July 1968.

11-6 "Test Plan for the ACA Integrated Test Program", Bendix Corporation, TM-157, Rev. D.

11-7 "ALSEP Cask Assembly Air Soak Procedure", General Electric, SI 249204, August 1968.

11-8 "Performance, Design and Test Requirements for the M5 Graphite LM Fuel Cask Mockup", General Electric NS 0220-02-15.

11-9 "Performance, Design and Test Requirements for the M5 Fuel Capsule Assembly Mockup", General Electric, NS 0220-02-16.

12. FLIGHT ACCEPTANCE TEST PROGRAMS

12. 1 ALSEP SYSTEM TEST GENERATORS, MODS 14 AND 15 ACCEPTANCE TESTS

Generator Mod 14 was designated for use in the ALSEP System Prototype Tests at the Bendix Corporation; Mod 15 was designated for the ALSEP System Qualification Tests.

Mod 14 was one of the early generators, built concurrently with Mod 5 and similar to it in construction. A considerable number of thermocouples were present in its interior, but were not connected to the header pins. Also present was a pressure transducer similar to Mod 5. Mod 15, on the other hand, was a prime unit identical in design and construction to the flight generators.

Both generators were subjected to acceptance tests at General Electric prior to shipment to Bendix. No failures were experienced during the acceptance vibration tests. The acceptance test flow for Mod 14 and Mod 15 are shown in Figures 12-1 and 12-2, respectively. Performance curves for both air and vacuum are given in Figures 12-3 through 12-7. Corresponding data sheets are included in Appendix C.

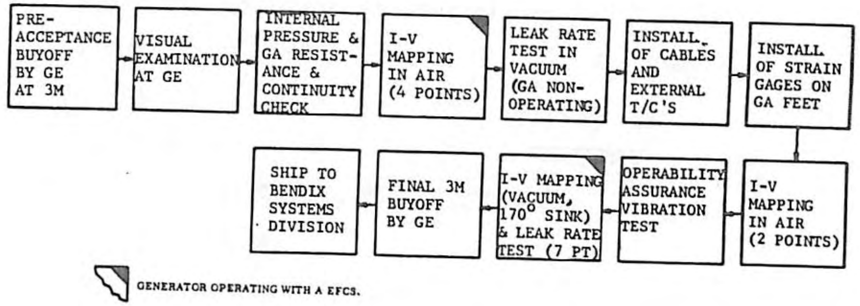


Figure 12-1. GA Model No. 14 Test Flow Chart

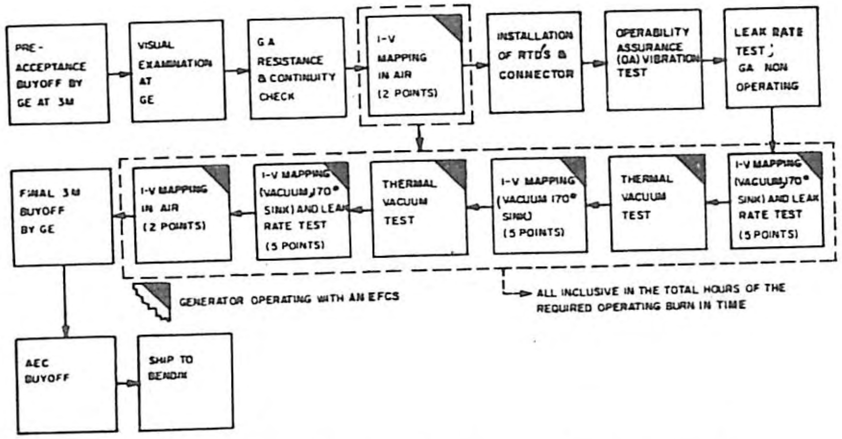


Figure 12-2. GA Model No. 15 Test Flow Chart

12.2 FLIGHT GENERATORS ACCEPTANCE TESTS

Acceptance tests of the flight generators at General Electric were conducted in accordance with the procedures defined in "Flight Acceptance Test Plan for Generator Assemblies 13, 19, 21, 22 and 23, SNAP-27 Program", SI 249168, which was based on the requirements of Specification NS 6115-03-01, "Performance and Design Requirements for the Generator Assembly SNAP-27 Program", and subsequent test requirements, TR No. 6314-051 and TR No. 6314-052. Prior to delivery to General Electric, the generators were previously subjected to pre-acceptance tests at the 3M Company, which included 300 hours of air operational "burn-in".

The flight generators, when received at General Electric, were complete except for the Bendix Connector Assembly (for the power/instrumentation cable) and the six RTD's. Final assembly was accomplished at General Electric to GE Drawing 47R300779, which included installation of the connector and RTD's. This work was completed after the generator had been accepted at General Electric following the initial current-voltage (I-V) mapping in air.

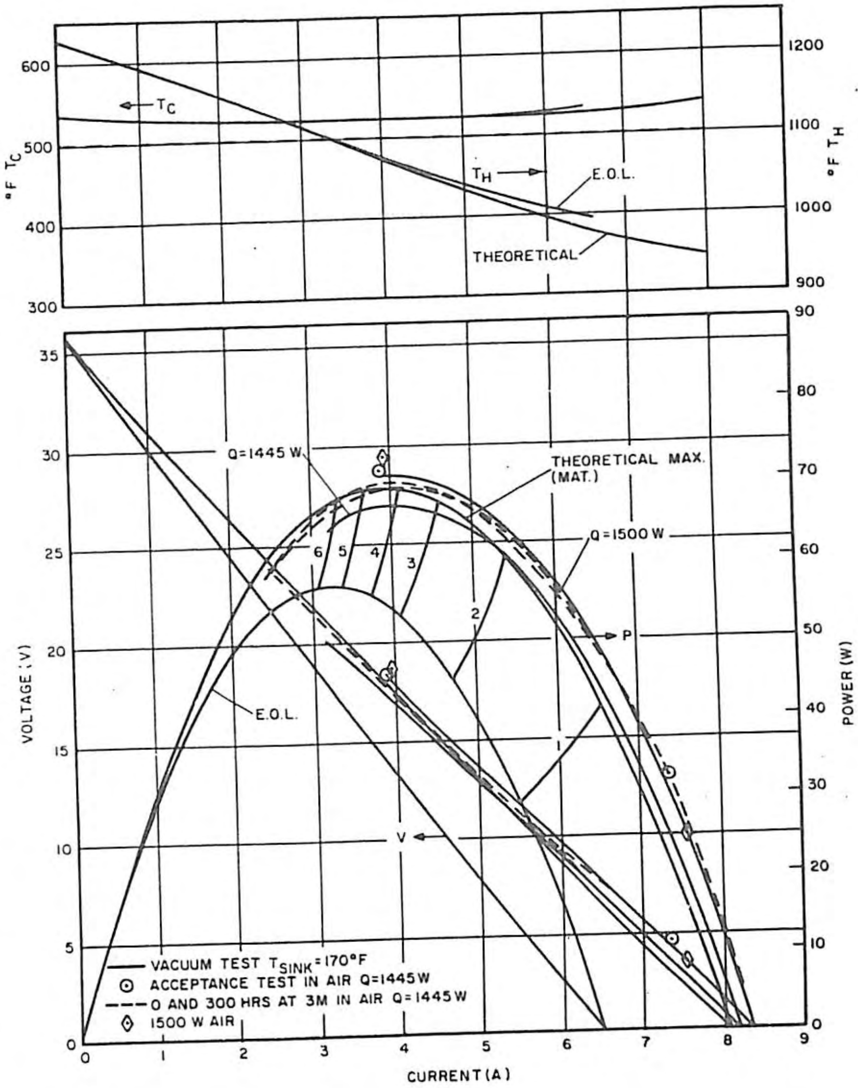


Figure 12-3. Mod 14 I-V Mapping

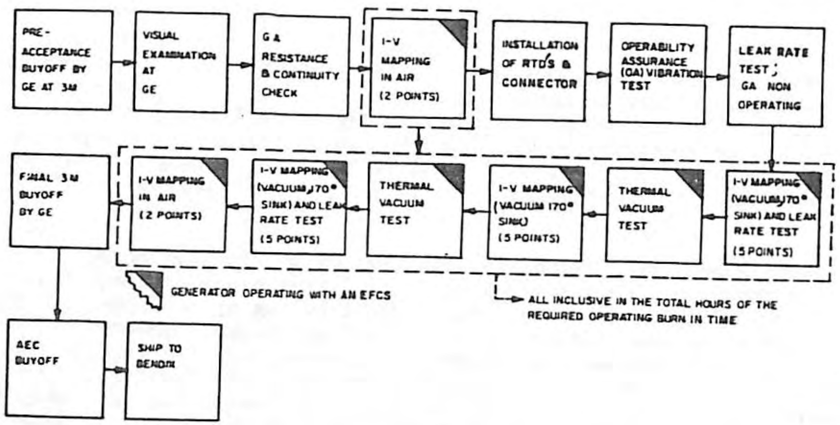


Figure 12-2. GA Model No. 15 Test Flow Chart

12.2 FLIGHT GENERATORS ACCEPTANCE TESTS

Acceptance tests of the flight generators at General Electric were conducted in accordance with the procedures defined in "Flight Acceptance Test Plan for Generator Assemblies 13, 19, 21, 22 and 23, SNAP-27 Program", SI 249168, which was based on the requirements of Specification NS 6115-03-01, "Performance and Design Requirements for the Generator Assembly SNAP-27 Program", and subsequent test requirements, TR No. 6314-051 and TR No. 6314-052. Prior to delivery to General Electric, the generators were previously subjected to pre-acceptance tests at the 3M Company, which included 300 hours of air operational "burn-in".

The flight generators, when received at General Electric, were complete except for the Bendix Connector Assembly (for the power/instrumentation cable) and the six RTD's. Final assembly was accomplished at General Electric to GE Drawing 47R300779, which included installation of the connector and RTD's. This work was completed after the generator had been accepted at General Electric following the initial current-voltage (I-V) mapping in air.

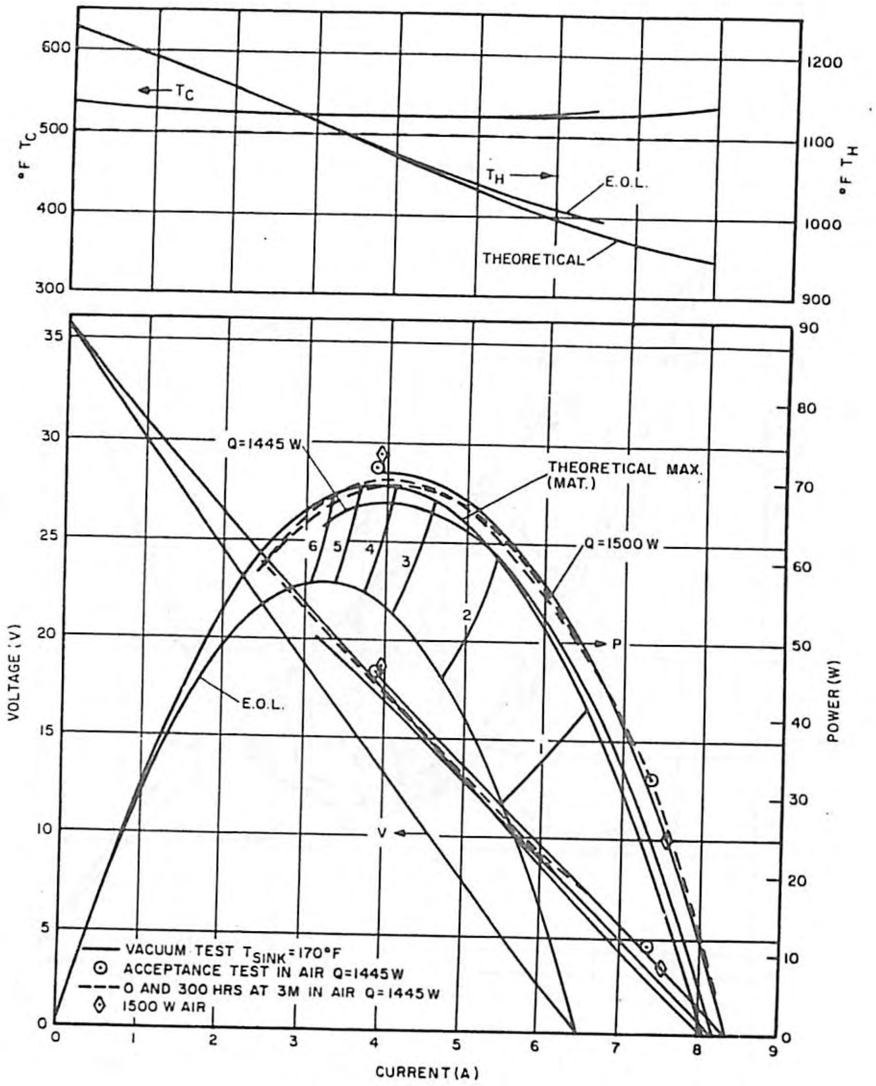


Figure 12-3. Mod 14 I-V Mapping

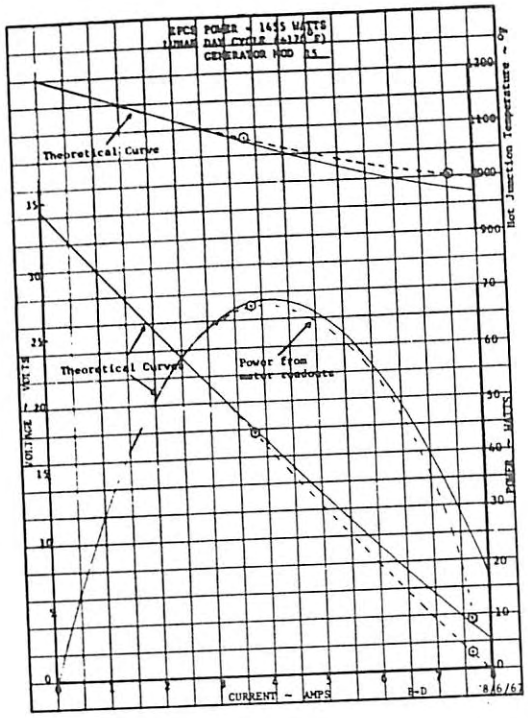


Figure 12-4. Mod 15 First I-V Mapping in Air

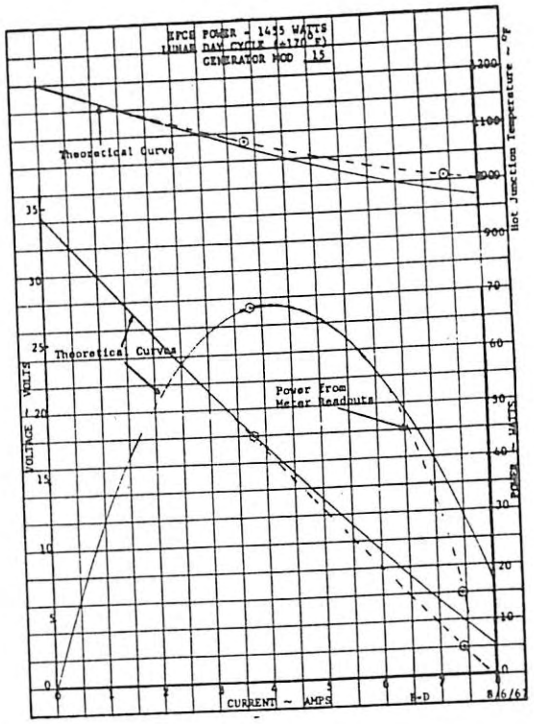


Figure 12-5. Mod 15 Final I-V Mapping in Air

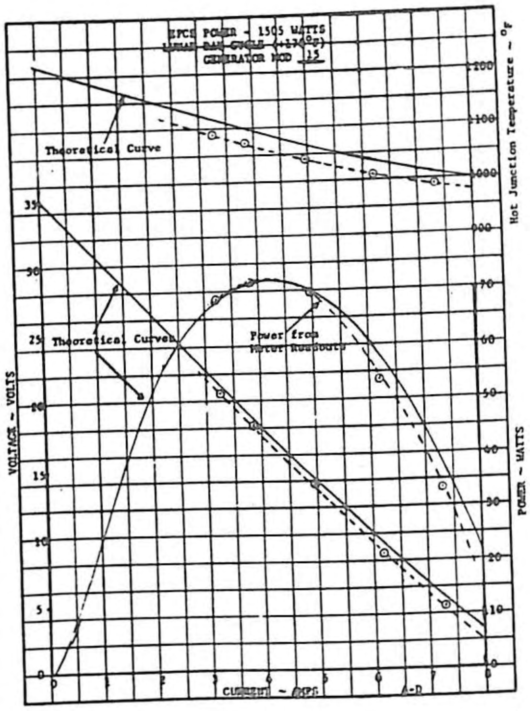


Figure 12-6. Mod 15 First I-V Mapping In Vacuum

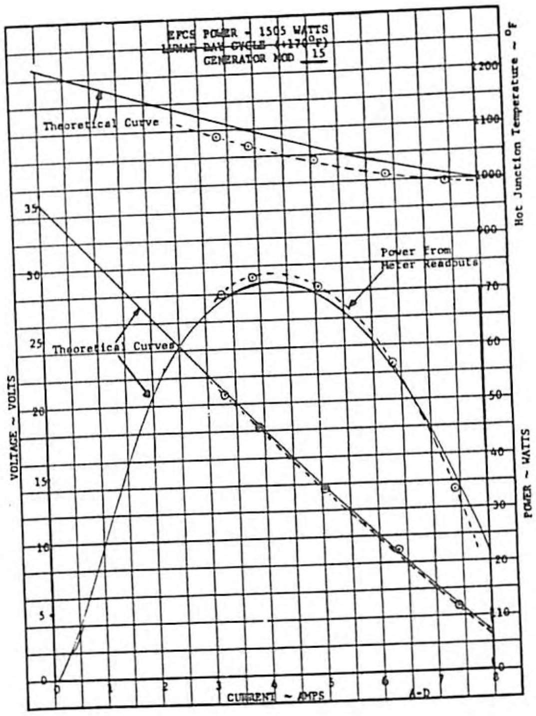


Figure 12-7. Mod 15 Final I-V Mapping In Vacuum

The tests performed and their sequence are depicted in the flow chart of Figure 12-8. Testing was accomplished at the General Electric facility located in Valley Forge, Pennsylvania.

All performance testing of the generators during flight acceptance was carried out with electric instead of nuclear fueled capsules.

Table 12-1 summarizes the acceptance test results of all five flight generators. Performance curves for the flight generators are given in Figures 12-9 through 12-53. Corresponding data sheets are included in Appendix C.

12.2.1 INITIAL I-V MAPPING

This two-point operational check of the generator's performance (immediately after its receipt from the 3M Company) is run in air while installed in a shroud as per Figures 12-54 and 12-55. Generator instrumentation during this test consists of temporary hot frame thermocouples (installed at 3M) and 12 temporary fin-root thermocouples installed on the fins by GE with soft copper washers. The generator's power output cable is terminated in a resistance load adjusted to 4.7 ± 0.47 ohms.

The shroud environmental heaters and the input power to the generator's electric fuel capsule are simultaneously varied until 1450 ± 15 watts is present across the electric fuel capsule, and the generator is stabilized at a calculated average hot junction temperature of 1085 ± 10°F and calculated average cold junction temperature of 525 ± 10°F. (NOTE: The cold electrode temperature is determined by averaging the 12 fin root thermocouples and converting from a supplied temperature graph. The hot electrode temperature is calculated from a graph using the cold electrode temperature versus the instantaneous open current voltage.) Readings are then made under stabilized temperature conditions for the 4.7-ohm load and the load reduced to a minimum value.

2.2.2 INSTALLATION OF RTD'S AND CONNECTOR

ix platinum RTD's are installed on the generator following initial -V mapping per GE Drawing 47R300946, as follows:

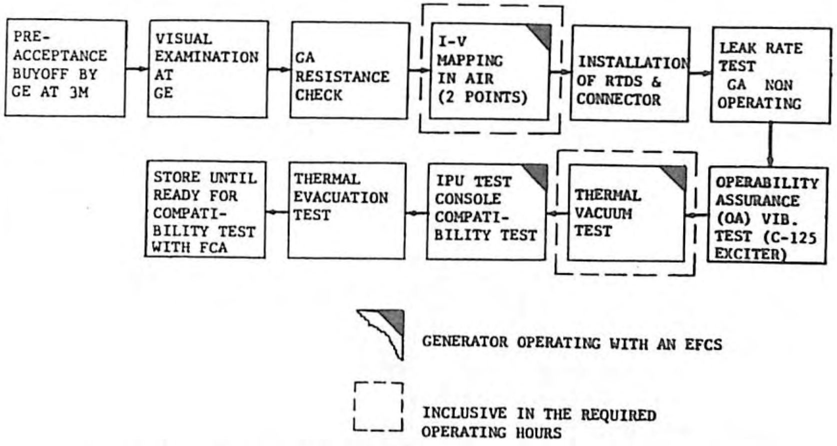


Figure 12-8. Typical Flight GA Test Flow Chart

TABLE 12-1. TEST SUMMARY FOR SNAP-27 FLIGHT GENERATOR ASSEMBLIES

OPERATING CONDITIONS			GENERATOR POWER OUTPUT (WATTS)				
POWER INPUT (WATTS)	EQV. LOAD	SINK TEMP. (°F)	MOD 13 GA S/N 6320006	MOD 19 GA S/N 6320009	MOD 21 GA S/N 6320011	MOD 22 GA S/N 6320012	MOD 23 GA S/N 6320013
1505	16 VOLTS	+170	69.8	69.1	68.2	68.3	70.7
1455	16 VOLTS	+170	67.1	67.5	66.0	66.2	67.9
1415	16 VOLTS	+170	64.3	64.7	63.2	63.2	65.0
1505	16 VOLTS	-280	72.5	72.9	71.3	71.3	72.9
1455	16 VOLTS	-280	68.8	68.8	66.7	67.3	68.9
1415	16 VOLTS	-280	65.3	65.3	64.0	64.1	65.1
1450	4.7 OHMS	AMBIENT	69.6	69.7	67.9	69.1	70.2
Total Accumulated Operational Time (Air and Vacuum) (Hours)			550	593	581	640	571
Operational Time in Vacuum (Hrs)			240	264	256	303	233
Final GA Leak Rate in std cc/sec of Argon while Operating in a +170°F Sink at 4.7 ohm load			2.50×10^{-6}	4.36×10^{-7}	1.09×10^{-6}	3.7×10^{-7}	Less Than 3.92×10^{-7}
Storage Container Serial No.			6287007	6287004	6287006	6287005	6287003
Total Weight (Pounds) (Less Protective Cable Sleeving)			27.83	27.77	27.96	27.86	27.80

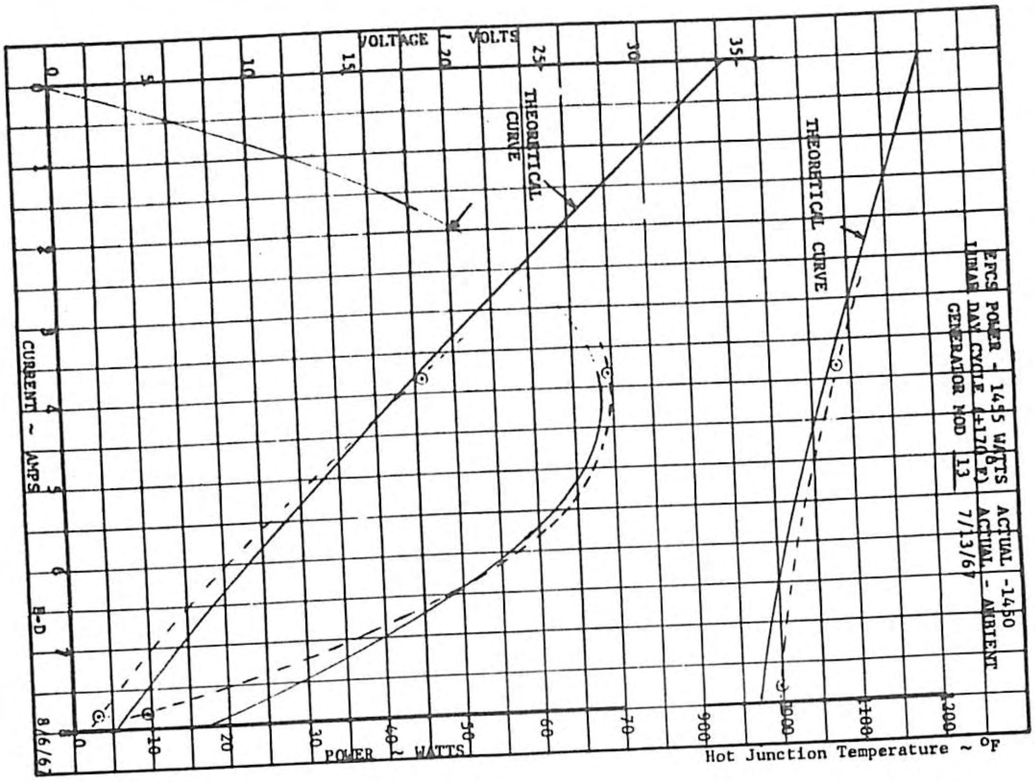


Figure 12-9. Mod 13 I-V Mapping in Air

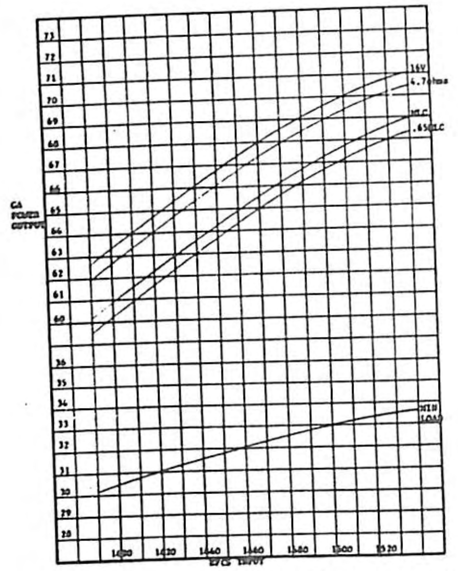


Figure 12-10. Mod 13 GA Output Power Versus EFCS Input at Lunar Day Conditions

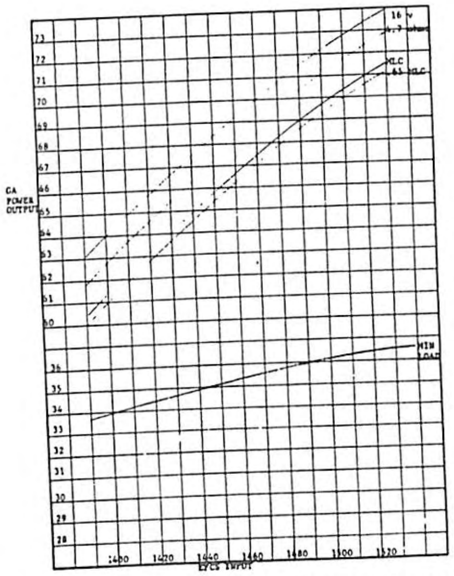


Figure 12-11. Mod 13 GA Output Power Versus EFCS Input at Lunar Night Conditions

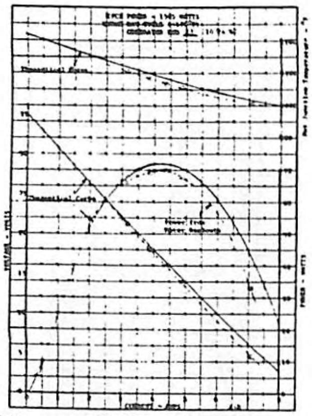


Figure 12-12. Mod 13
I-V Map - Lunar Day Cycle
(EFCS Power 1505 Watts)

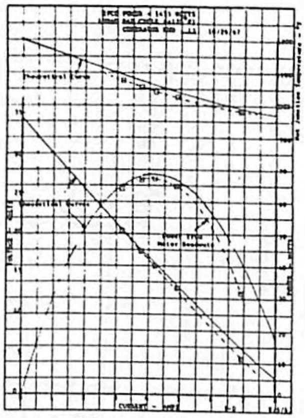


Figure 12-13. Mod 13
I-V Map - Lunar Day Cycle
(EFCS Power 1455 Watts)

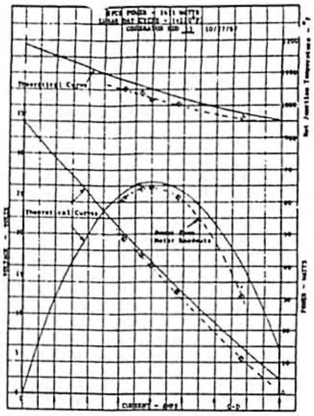


Figure 12-14. Mod 13
I-V Map - Lunar Day Cycle
(EFCS Power 1415 Watts)

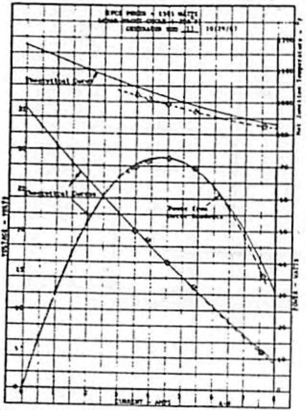


Figure 12-15. Mod 13
I-V Map - Lunar Night Cycle
(EFCS Power 1505 Watts)

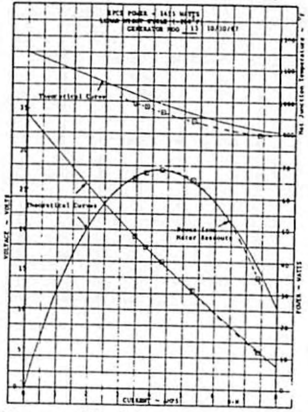


Figure 12-16. Mod 13
I-V Map - Lunar Night Cycle
(EFCS Power 1455 Watts)

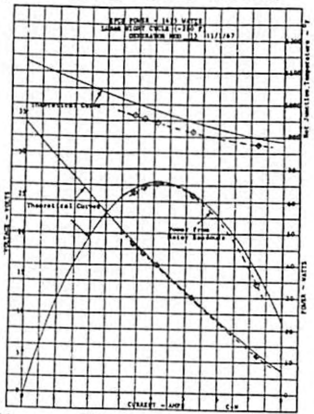


Figure 12-17. Mod 13
I-V Map - Lunar Night Cycle
(EFCS Power 1415 Watts)

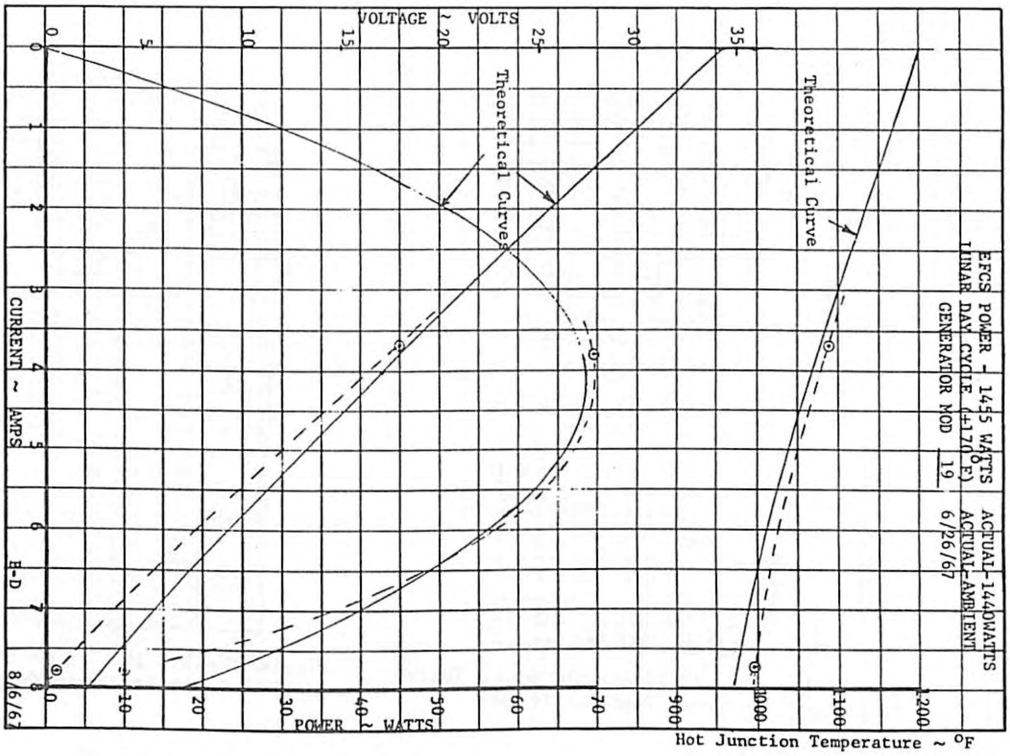


Figure 12-18. Mod 19 I-V Mapping in Air

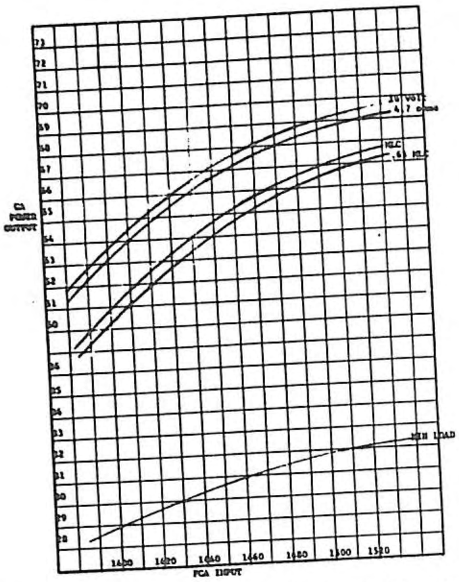


Figure 12-19. Mod 19 GA Output Power Versus FCA Input at Lunar Day Conditions

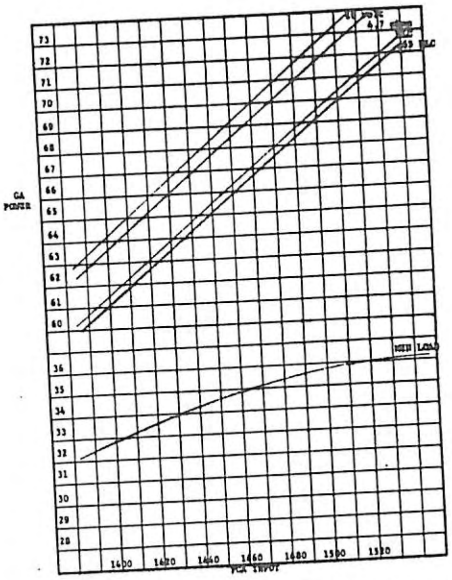


Figure 12-20. Mod 19 GA Output Power Versus FCA Input at Lunar Night Conditions

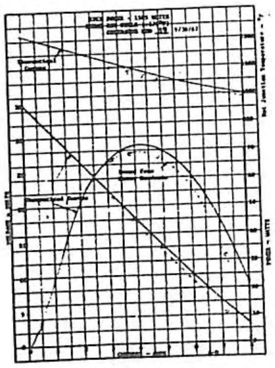


Figure 12-21. Mod 19 Thermal Vacuum Test - Lunar Day Cycle (EFCS Pwr 1505W)

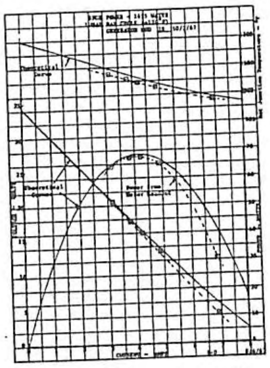


Figure 12-22. Mod 19 Thermal Vacuum Test - Lunar Day Cycle (EFCS Pwr 1455W)

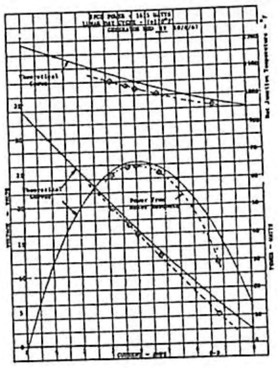


Figure 12-23. Mod 19 Thermal Vacuum Test - Lunar Day Cycle (EFCS Pwr 1415W)

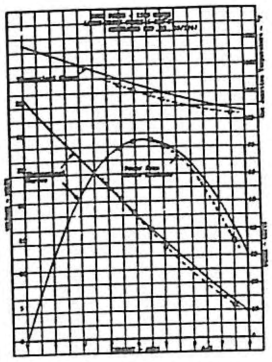


Figure 12-24. Mod 19 Thermal Vacuum Test - Lunar Night Cycle (EFCS Pwr 1505W)

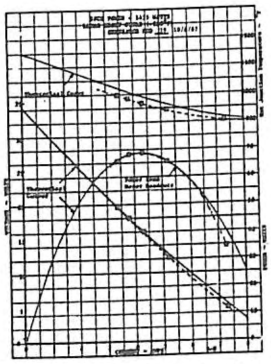


Figure 12-25. Mod 19 Thermal Vacuum Test Lunar Night Cycle (EFCS Pwr 1455W)

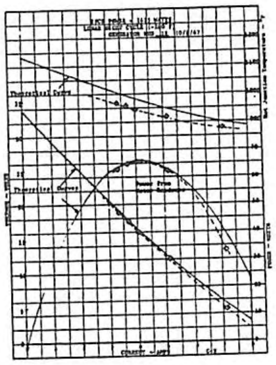


Figure 12-26. Mod 19 Thermal Vacuum Test - Lunar Night Cycle (EFCS Pwr 1415W)

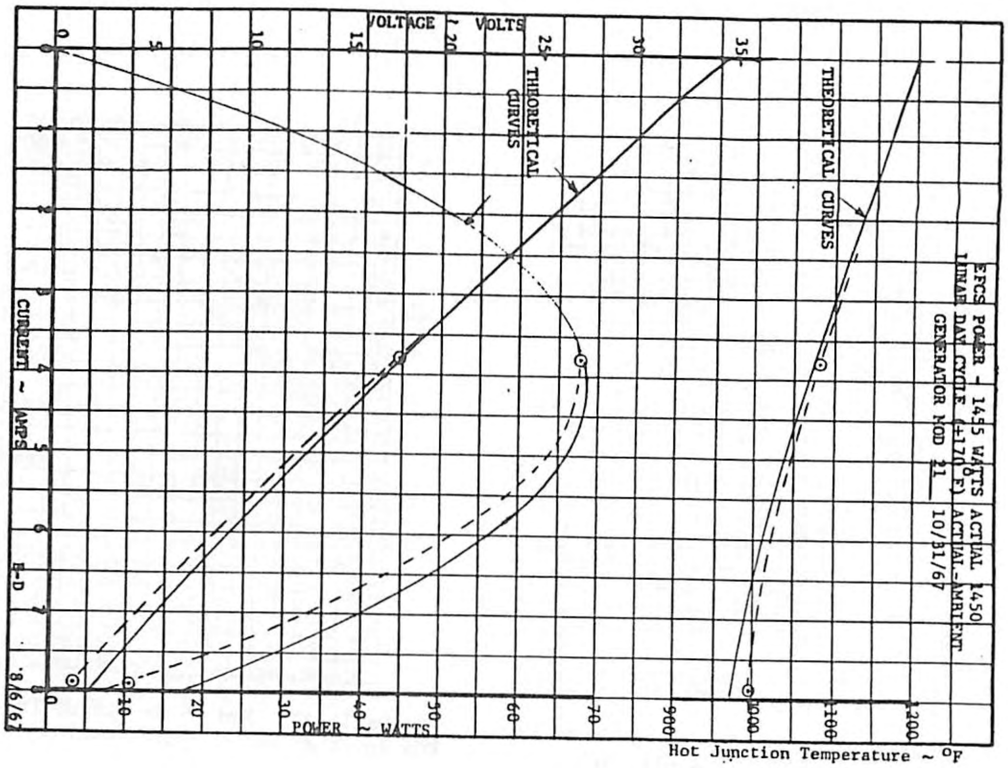


Figure 12-27. Mod 21 I-V Mapping In Air

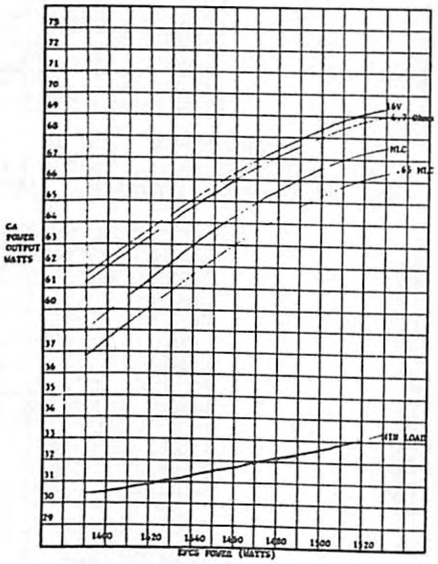


Figure 12-28. Mod 21 GA Output Power Versus EFCS Input at Lunar Day Conditions

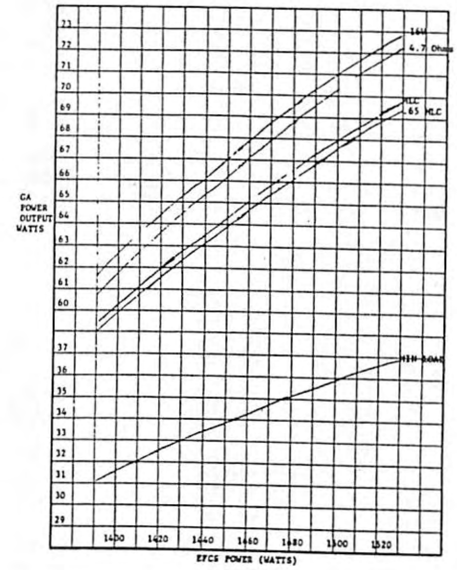


Figure 12-29. Mod 21 GA Output Power Versus EFCS Input at Lunar Night Conditions

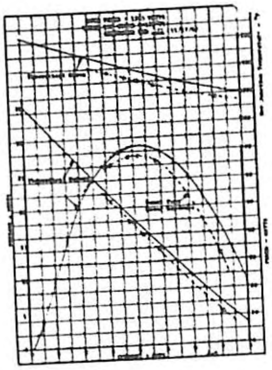


Figure 12-30. Mod 21 I-V Map - Lunar Day Cycle (EFCS Power 1505 Watts)

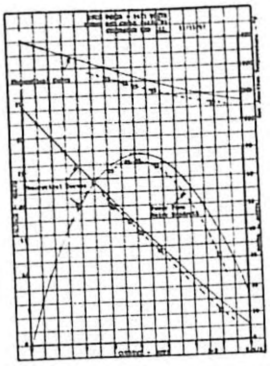


Figure 12-31. Mod 21 I-V Map - Lunar Day Cycle (EFCS Power 1455 Watts)

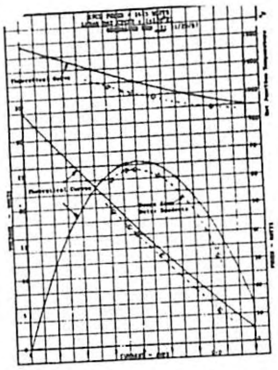


Figure 12-32. Mod 21 I-V Map - Lunar Day Cycle (EFCS Power 1415 Watts)

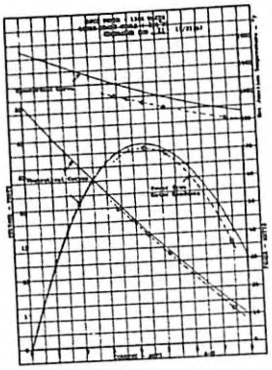


Figure 12-33. Mod 21 I-V Map - Lunar Night Cycle (EFCS Power 1505 Watts)

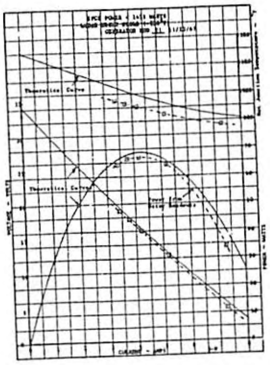


Figure 12-34. Mod 21 I-V Map - Lunar Night Cycle (EFCS Power 1455 Watts)

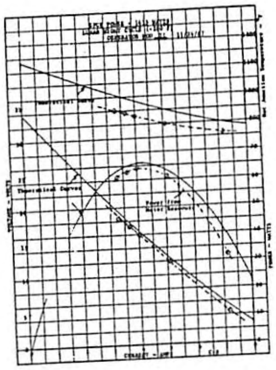


Figure 12-35. Mod 21 I-V Map - Lunar Night Cycle (EFCS Power 1415 Watts)

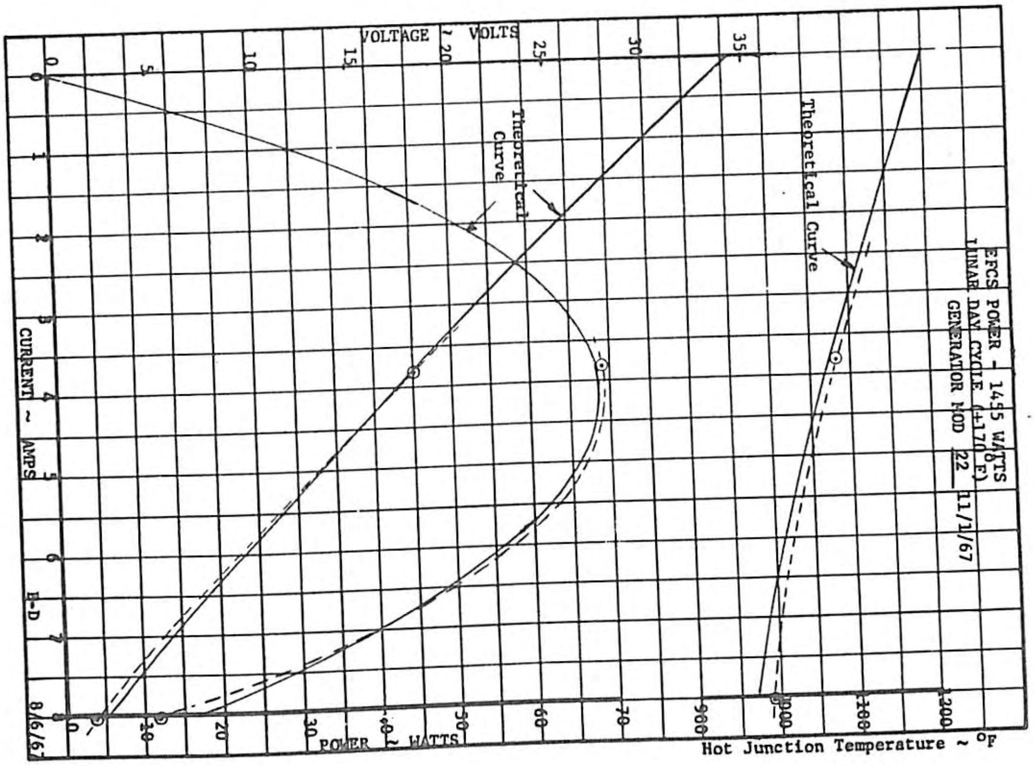


Figure 12-36. Mod 22 I-V Mapping in Air

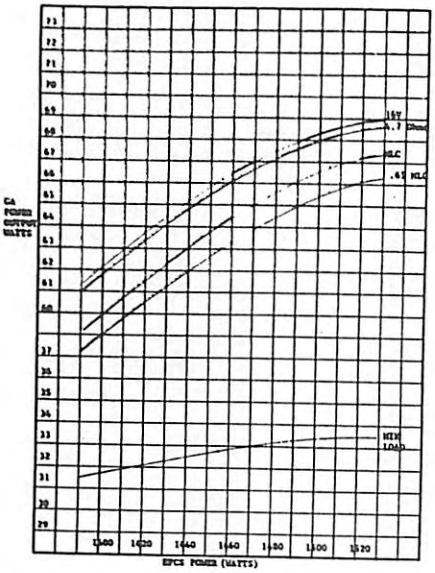


Figure 12-37. Mod 22 GA Output Power Versus EFCS Input at Lunar Day Conditions

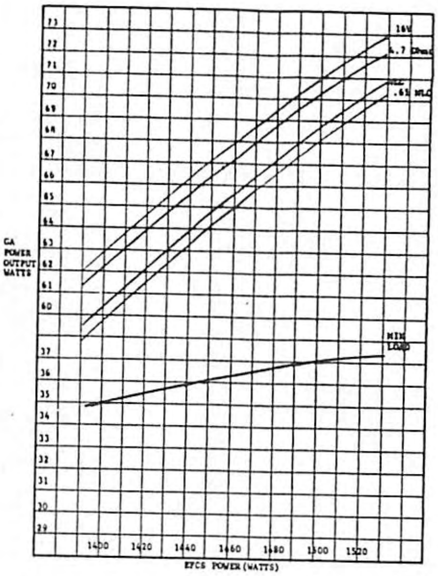


Figure 12-38. Mod 22 GA Output Power Versus EFCS Input at Lunar Night Conditions

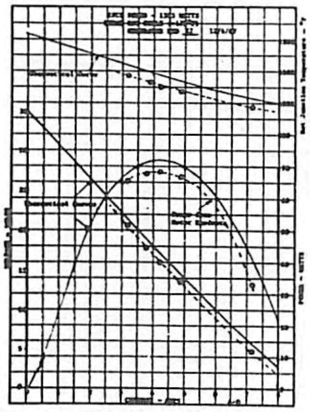


Figure 12-39. Mod 22 I-V Map - Lunar Day Cycle (EFCS Power 1505 Watts)

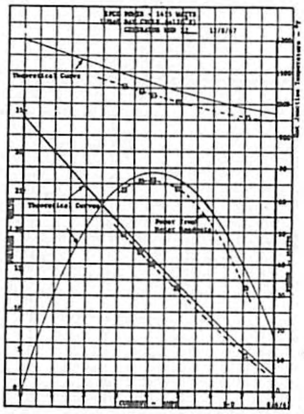


Figure 12-40. Mod 22 I-V Map - Lunar Day Cycle (EFCS Power 1455 Watts)

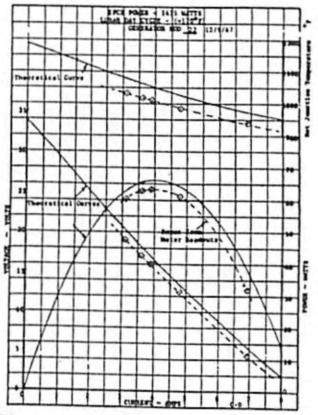


Figure 12-41. Mod 22 I-V Map - Lunar Day Cycle (EFCS Power 1415 Watts)

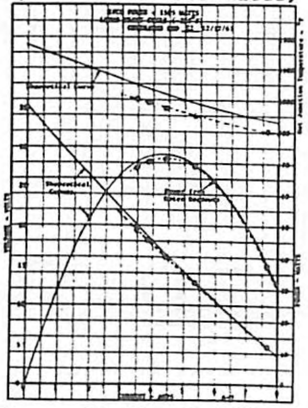


Figure 12-42. Mod 22 I-V Map - Lunar Night Cycle (EFCS Power 1505 Watts)

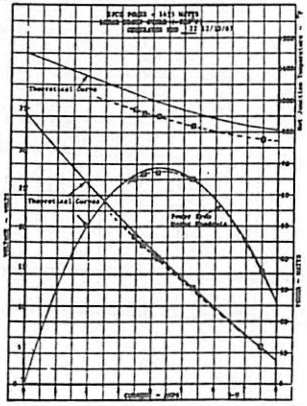


Figure 12-43. Mod 22 I-V Map - Lunar Night Cycle (EFCS Power 1455 Watts)

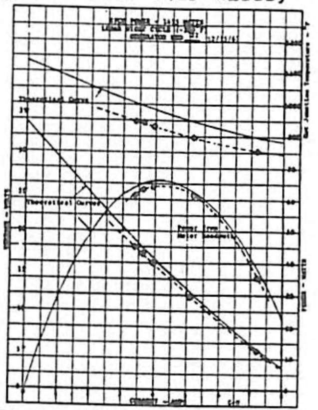


Figure 12-44. Mod 22 I-V Map - Lunar Night Cycle (EFCS Power 1415 Watts)

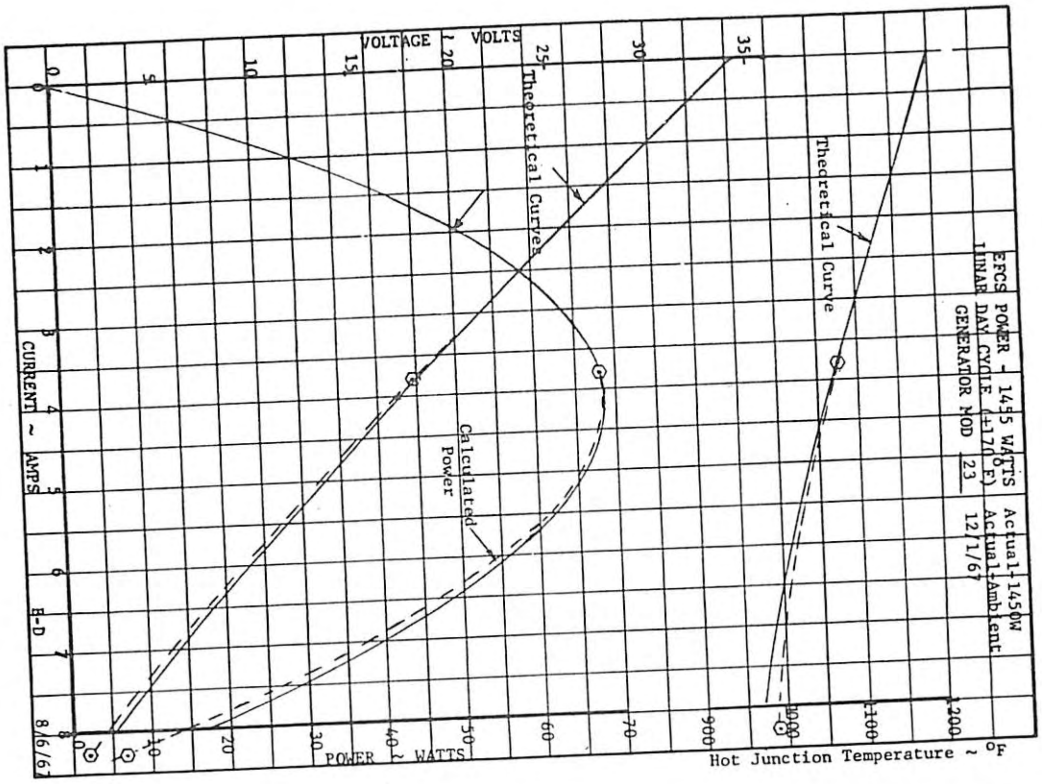


Figure 12-45. Mod 23 I-V Mapping in Air

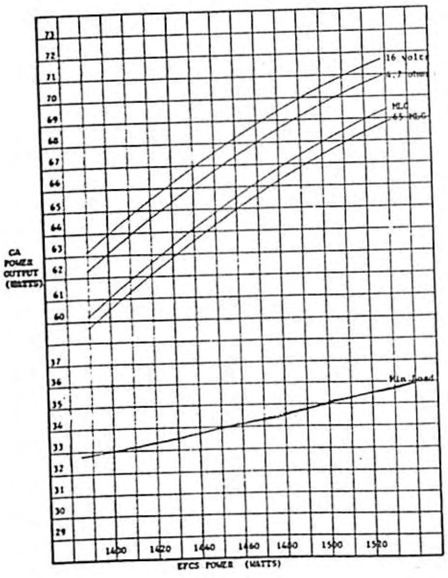


Figure 12-46. Mod 23 GA Power Output Versus EFCS Input at Lunar Day Conditions

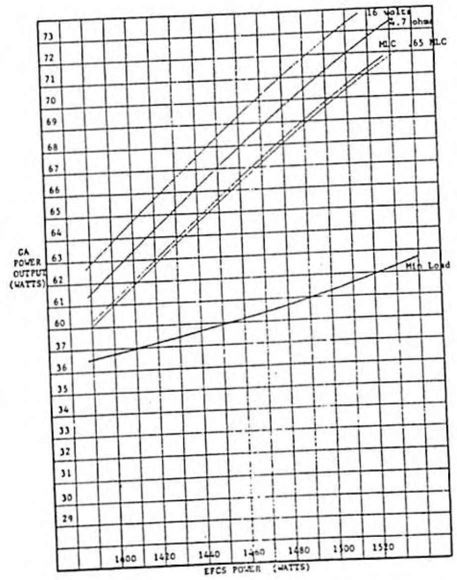


Figure 12-47. Mod 23 GA Power Output Versus EFCS Input at Lunar Night Conditions

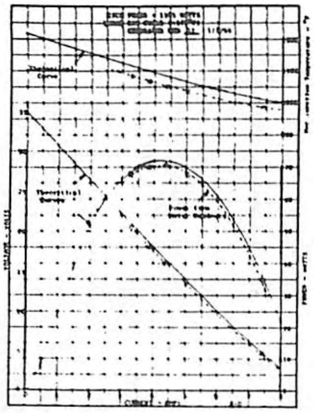


Figure 12-48. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1505 Watts)

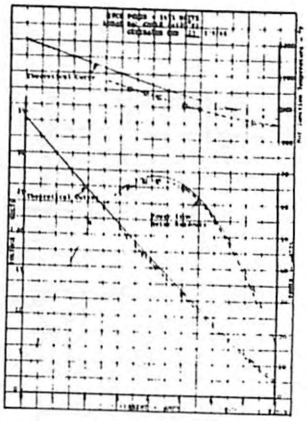


Figure 12-49. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1455 Watts)

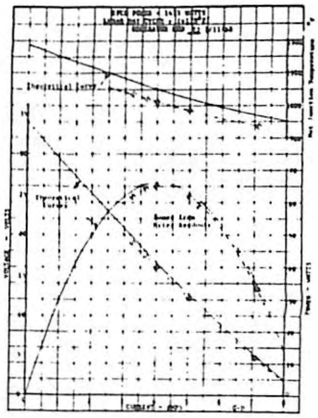


Figure 12-50. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1415 Watts)

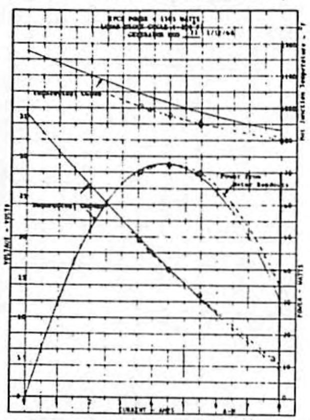


Figure 12-51. Mod 23 I-V Mapping - Lunar Night Cycle

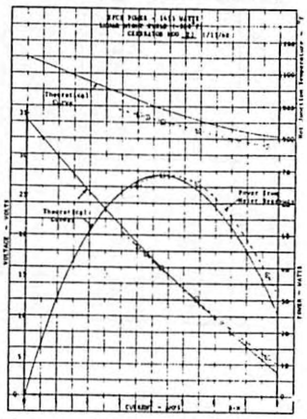


Figure 12-52. Mod 23 I-V Mapping - Lunar Night Cycle

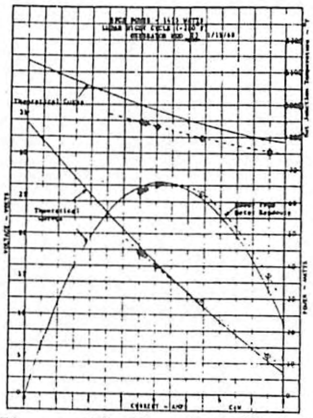


Figure 12-53. Mod 23 I-V Mapping - Lunar Night Cycle

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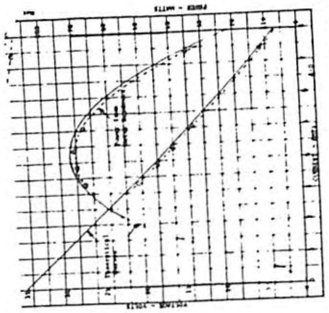

Figure 12-48. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1505 Watts)

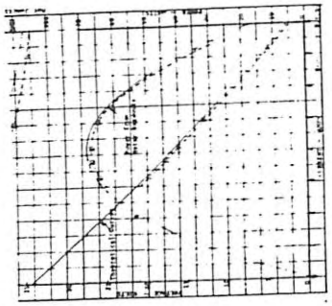

Figure 12-49. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1455 Watts)

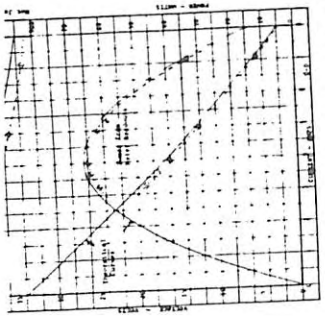

Figure 12-50. Mod 23 I-V Mapping - Lunar Day Cycle (EFCS Power 1415 Watts)

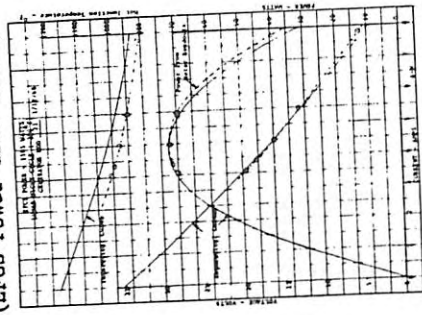

Figure 12-51. Mod 23 I-V Mapping - Lunar Night Cycle (EFCS Power 1505 Watts)

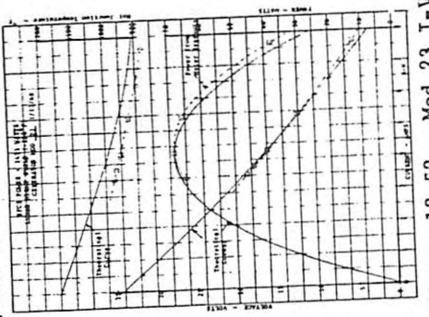

Figure 12-52. Mod 23 I-V Mapping - Lunar Night Cycle (EFCS Power 1455 Watts)

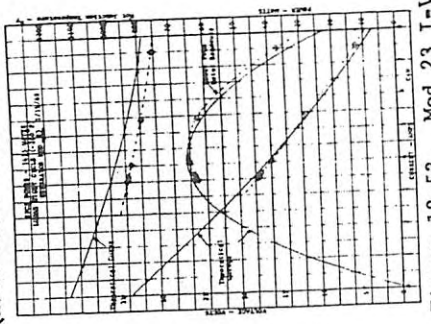

Figure 12-53. Mod 23 I-V Mapping - Lunar Night Cycle (EFCS Power 1415 Watts)

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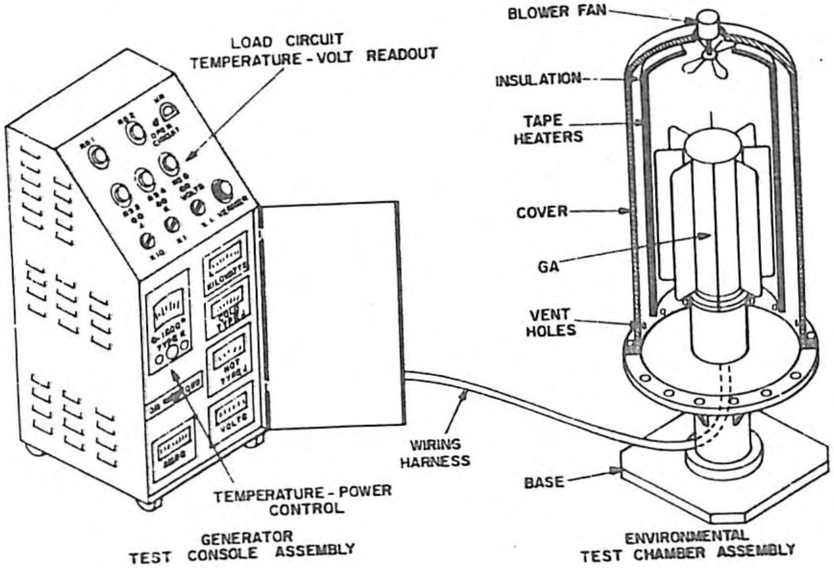


Figure 12-54. Test Setup for Generator Air Operation

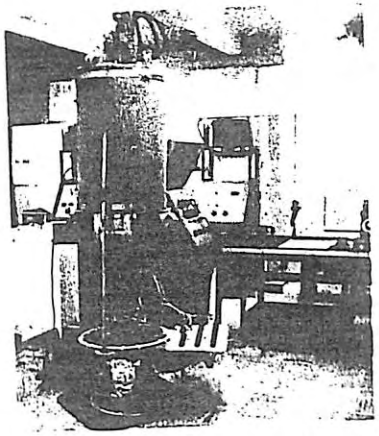


Figure 12-55. Environmental Shroud Showing Installed Generator

	RTD No.	Axial Leg Row	Circumferential Row
Hot Frame	R1-1	28	1
	R1-2	28	9
	R1-3	28	17
Outer Shell	R3-1	11	1
	R3-1	25	17
Fin No. 2 (top)	R3-2	--	--

The Bendix connector is installed at the end of the cable per Drawing 47D300952.

12.2.3 LEAK RATE TEST

The helium leak rate is determined in a bell jar at 4×10^{-6} torr and then corrected to that of an argon leak rate. The generator is non-operating during this check. (See Figure 12-56.)

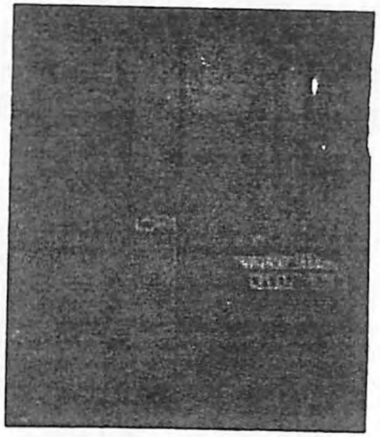


Figure 12-56. Mod 23 GA Installed in a Bell Jar

12.2.4 OPERABILITY ASSURANCE VIBRATION TEST

This low-level shake of the generator by itself consists of a five minute sweep in the generator's three orthoginal axis at a constant octave sweep rate.

Frequency	Vibration Level
5 to 10 Hz	0.4" double amptitude
10 to 2000 Hz	± 2g

The generator is nonoperating during this test; however, the thermocouple resistance is monitored for variations in resistance. (See Figure 12-57.)

12.2.5 THERMAL VACUUM TEST

Generator performance was parametrically evaluated while operating in a thermal vacuum chamber under simulated lunar day and night conditions of $+170 \pm 5^{\circ}$F and $-280 \pm 20^{\circ}$F, respectively, at a pressure of 5.5×10^{-6} torr, for electric fuel capsule power inputs of 1505 watts, 1455 watts and 1415 watts and for the following load conditions:

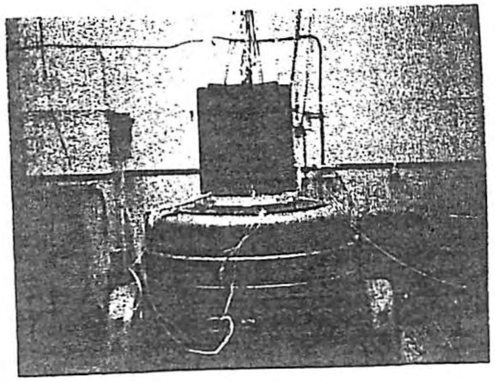
1. 4.7 ohms
2. Matched load current
3. Load for 16.0 volt generator output
4. Minimum load
5. 0.65 matched load current

Figure 12-58 depicts the Long Life Laboratory established for endurance testing of the generators. While operating under thermal vacuum conductions, the generators were also leak checked.

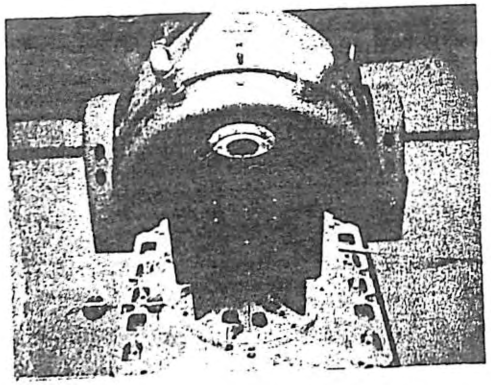
12.2.6 IPU TEST CONSOLE COMPATIBILITY TEST

This test is performed to demonstrate mechanical and electrical compatibility between each flight generator, its associated IPU test console, Type "A" EFCS, cables and connectors and the back-up console, EFCS, cables and connectors.

Under thermal vacuum conditions, the generator is operated with the back-up console. Both the flight and back-up EFCS's are powered by the



X Axis



Z and Y Axis

Figure 12-57. Typical Setup, Vibration Test

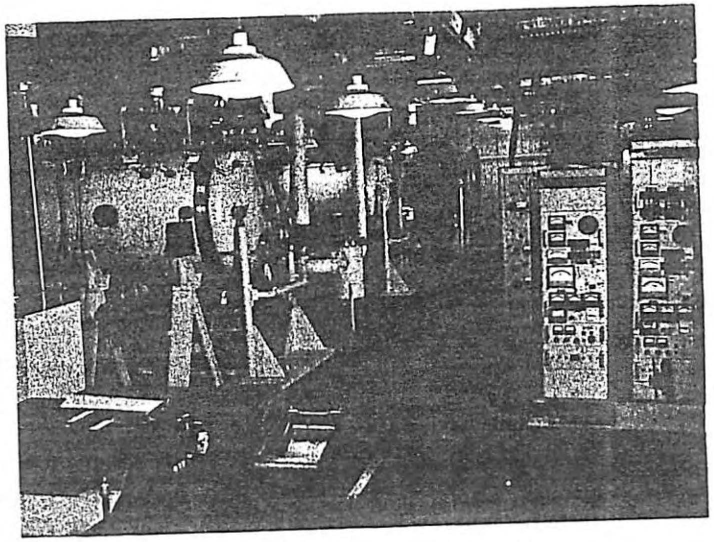


Figure 12-58. Long Life Test Laboratory

the other console. Interchangeability between connectors and EFCS's is also demonstrated.

12.2.7 THERMAL EVACUATION TEST

This test is performed to bake out any moisture from the generator cable which may have accumulated as a result of preceding thermal cycling. The generator is installed in a thermal vacuum chamber and maintained nonoperating at 7.0 x 10^{-7} torr at +175 ± 25°F for 168 hours. Insulation resistance is measured before and after this test. Test details for each generator can be found in References 12-1 through 12-5.

12.3 FUEL CAPSULE FLIGHT ACCEPTANCE TESTS

All capsules, including the qualification unit, S/N 6330004, were subjected to these tests. Figure 12-59 depicts the flow sequence. The flight acceptance vibration testing is performed as part of the ACA flight acceptance vibration.

12.3.1 RECEIVING INSPECTION

Each of the fuel capsules was shipped in its Ground Shipping Cask (GSC) from Mound Laboratory via GE-Vallecitos to GE-VFSTC by the AEC in a special AEC-ALO van equipped for transporting nuclear materials. Following its inspection by Health Physics and Quality Control, the GSC was stored and secured. The FCA remained in this storage area until required for the test program.

Receiving inspection of the GSC involved review of the FCA log books, an examination for shipping damage, cask and capsule presence of nickel shot bottles, presence of lead security seals, tool box contents and an examination for radioactive contamination or leakage.

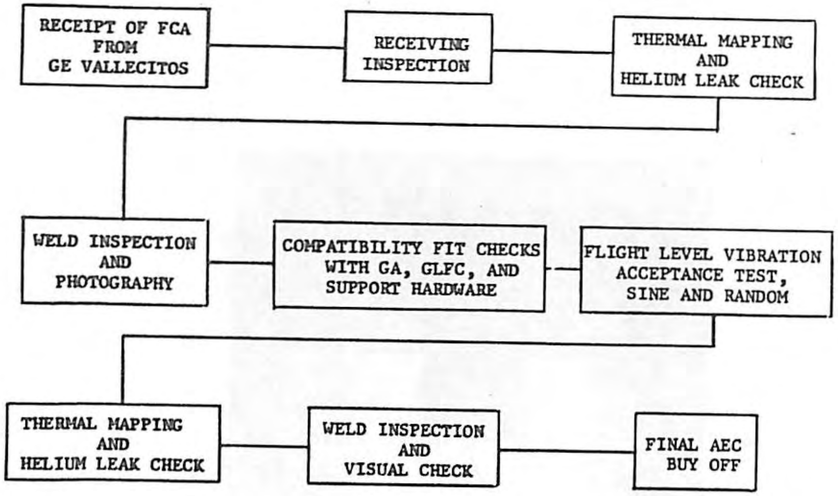


Figure 12-59. FCA Flow Sequence for Flight Hardware

12.3.2 THERMAL MAPPING, HELIUM LEAK CHECK AND FLANGE WELD INSPECTION

The thermal mapping and helium leak checks are performed under the following test conditions:

1. Chamber pressure - 10^{-5} torr or less
2. Chamber wall temperature - $70^{o}F \pm 20^{o}F$
3. Chamber emissivity - 0.9

The capsule is removed from its GSC with a Ground Handling Tool and positioned in the thermal mapping vacuum chamber, Figure 12-60, such that the zero degree reference mark is the first position mapped. This is a 16-inch diameter, 24-inch high cylindrical vacuum chamber which is utilized for both thermal mapping and leak checking the FCA's. The chamber has six axial located, barium fluoride, infrared transmission windows which permit viewing of the FCA surface by a Barnes radiometric microscope, model RM-2B. An internal latch fitting assembly remotely rotates the FCA 360 degrees into various radial positions for thermal mapping of its axial and radial temperatures utilizing the Barnes scope.

Also attached to this same vacuum chamber is a GE helium mass spectrometer, model LC-20. While the chamber is still evaculated, a FCA helium leak rate is determined by following standard leak checking techniques.

See Table 12-2 for thermal mapping data obtained before acceptance level vibration and following the vibration, and Table 12-3 for helium leak rate data.

12.3.3 FCA WELD INSPECTION FIXTURE

The FCA weld inspection fixture consists of a 55 gallon stainless steel drum with a cover. Installed into the cover is a 3-inch diameter cavity with a supporting latch mechanism. When the FCA is inserted into the fixture cavity, the latch mechanism positions the FCA so the flange weld seam extends above the cover (approximately 2 inches). The remainder of the capsule is within the cavity. The cavity, which is surrounded by water, is coated with a high emissivity coating to absorb the FCA radiated heat. The water also provides nuclear radiation shielding.

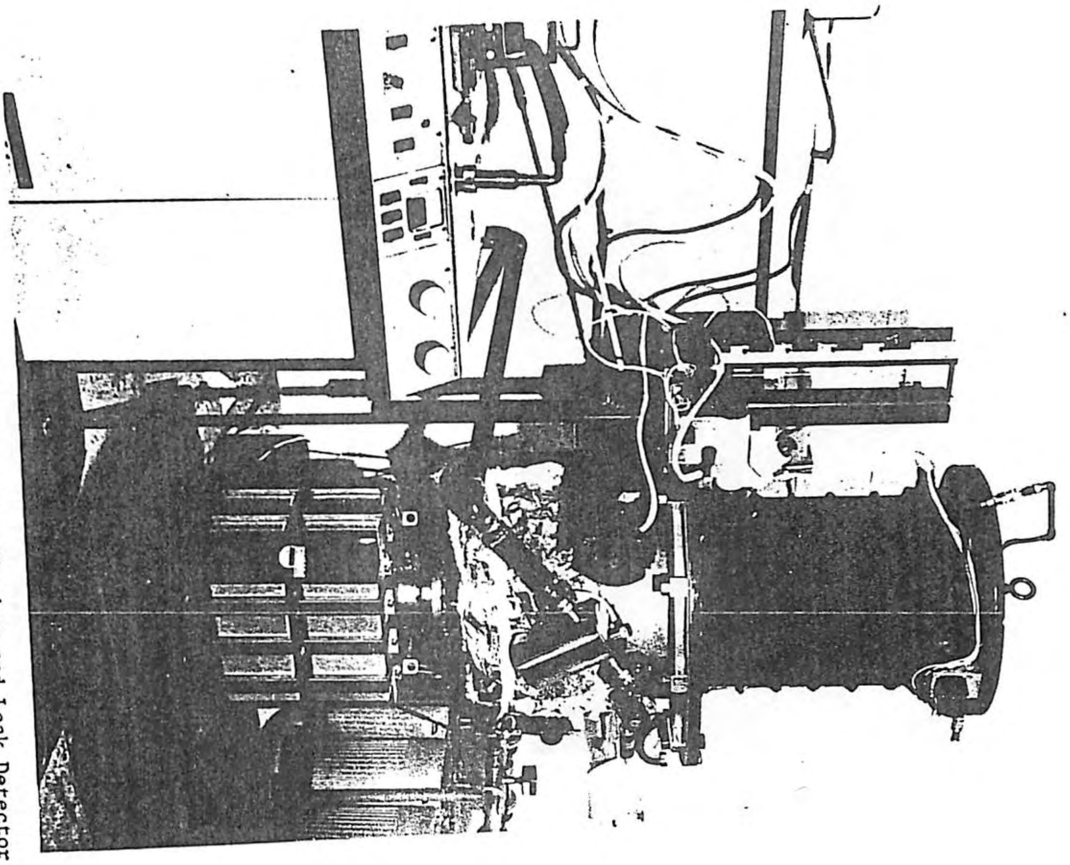


Figure 12-60. FCA Thermal Mapping Test Chamber and Leak Detector

TABLE 12-2. SNAP-27 FLIGHT FUEL CAPSULE ASSEMBLY AVERAGE THERMAL PROFILE DATA (^{o}F)

Distance From Dome (inches)	Serial No.				
	6330001	6330002	6330005	6330006	6330007
	Prior To Acceptance Level Vibration				
0.3	760	747	724	701	736
1.0	833	820	798	778	811
4.5	979	990	988	982	965
8.0	923	947	940	928	922
11.5	990	987	979	973	974
15.2	765	803	793	800	769
	Post Acceptance Level Vibration				
0.3	798	766	745	735	734
1.0	870	838	817	810	813
4.5	979	989	978	965	947
8.0	898	942	934	923	905
11.5	987	990	984	966	956
15.2	792	814	807	811	792

TABLE 12-3. FLIGHT FUEL CAPSULE ASSEMBLY HELIUM LEAK RATE DATA (SNAP-27)

	Serial No.				
	6330001	6330002	6330005	6330006	6330007
Prior To Vibration	2.0×10^{-8}	3.4×10^{-8}	4.6×10^{-8}	2.5×10^{-8}	4.1×10^{-8}
Post Vibration	2.4×10^{-8}	2.4×10^{-8}	7.2×10^{-8}	1.8×10^{-8}	3.0×10^{-8}

An inspection of the FCA flange weld is made utilizing a Questar telescope which has the capabilities to magnify to 40X, 60X and 80X power. The magnification factors are used for viewing and photographing the FCA flange weld from a distance to reduce radiation exposure of test personnel. The capsule is rotated in 120-degree segments and the flange weld joint photographed at each position until the entire weld joint has been viewed. This same weld fixture is utilized during the removal and assembly of FCA backplate assemblies. The complete operation requires less than 10 minutes to perform.

Upon completion of the thermal mapping, the capsule is removed from the thermal mapping vacuum chamber with the GHT and positioned in the weld inspection fixture (see Figure 12-61).

12.4 D2/M5 MOCKUP ASSEMBLY FLIGHT ACCEPTANCE TESTS

The mechanical mockup assembly designated for flight was subjected to acceptance tests consisting of weight/cg measurements and vibration in the same manner as the operational flight units. No vibration damage was experienced.

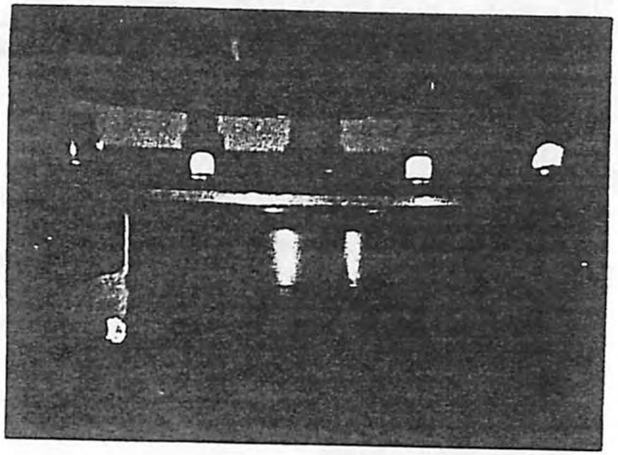


Figure 12-61. FCA Weld Joint (↙) as Viewed Through the Questar Telescope.

12.5 ALSEP CASK ASSEMBLY (ACA) FLIGHT ACCEPTANCE TESTS

Each of the six flight ACA assemblies was subjected to weight and cg measurements (see Table 12-4), acceptance vibration and a tilt test, in that order, as required by Procedures SU 249198, SI 249203 and SI 240206, respectively.

12.5.1 WEIGHT AND CG MEASUREMENT

(Figure 12-62 identifies the cg location.)

TABLE 12-4. WEIGHT AND CG DATA FOR ALL FLIGHT ACA'S

FLIGHT NO.	1	BACKUP	2	3	4
Weight (lb)	54.078	54.813	54.079	53.593	53.871
"A" Dimension (in.)	+.749	+.836	+.812	+.757	+.709
"B" Dimension (in.)	+.0736	+.0766	+.087	+.081	+.068
"C" Dimension (in.)	-.545	-.523	-.500	-.528	-.534

12.5.2 ACCEPTANCE LEVEL VIBRATION

Each flight ALSEP Cask Assembly (ACA), comprised of a Graphite LM Fuel Cask, a Fuel Capsule Assembly and Bendix Cask Mounting Hardware, was dynamically tested to the levels specified below.

Frequency	Amplitude
5 to 14 Hz	0.154 in. DA
14 to 75 Hz	1.54 g
75 to 100 Hz	2.3 g

The sinusoidal sweep was in the up-scale direction only, at a rate of 3 octaves/minute along each of the ACA's three orthogonal axes.

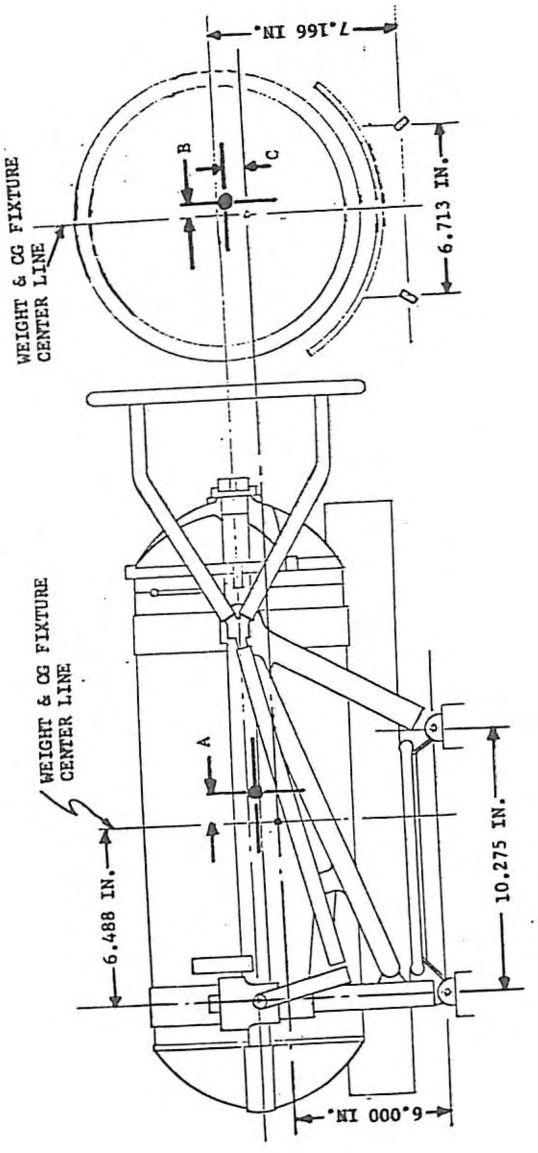


Figure 12-62. Flight ALSEP Cask Assembly CG Location

Frequency	Power Spectral Density
20 to 100 Hz	9 db/octave increase
100 to 500 Hz	0.089 g^2/cps
500 to 2000 Hz	6 db/octave decrease

The random vibration was for 2-1/2 minutes along each of three orthogonal axes.

12.5.3 TILT TEST

At the completion of the vibration testing, the ACA was positioned vertically and the force and torque required to execute the various steps relating to lunar cask deployment determined. Test data for all ACA's are summarized in Table 12-5.

12.6 COMPATIBILITY AND INTERCHANGEABILITY VERIFICATION TESTS (FIT CHECKS)

In compliance with the requirements of Specification NS 0080-05-28, "Test Requirements for Compatibility and Interchangeability of SNAP-27 Systems", tests were conducted on all deliverable SNAP-27 systems (as the hardware became available) to verify mechanical and functional compatibility between interfacing components. The demonstrations were carried out to specifically:

1. Verify that no incompatibility or malfunctioning would be experienced, both at the launch site or on the lunar surface during system deployment
2. Provide assurance that, in case of a failure or damage experienced by a component during pre-launch operations, a verified replacement could be immediately made available.

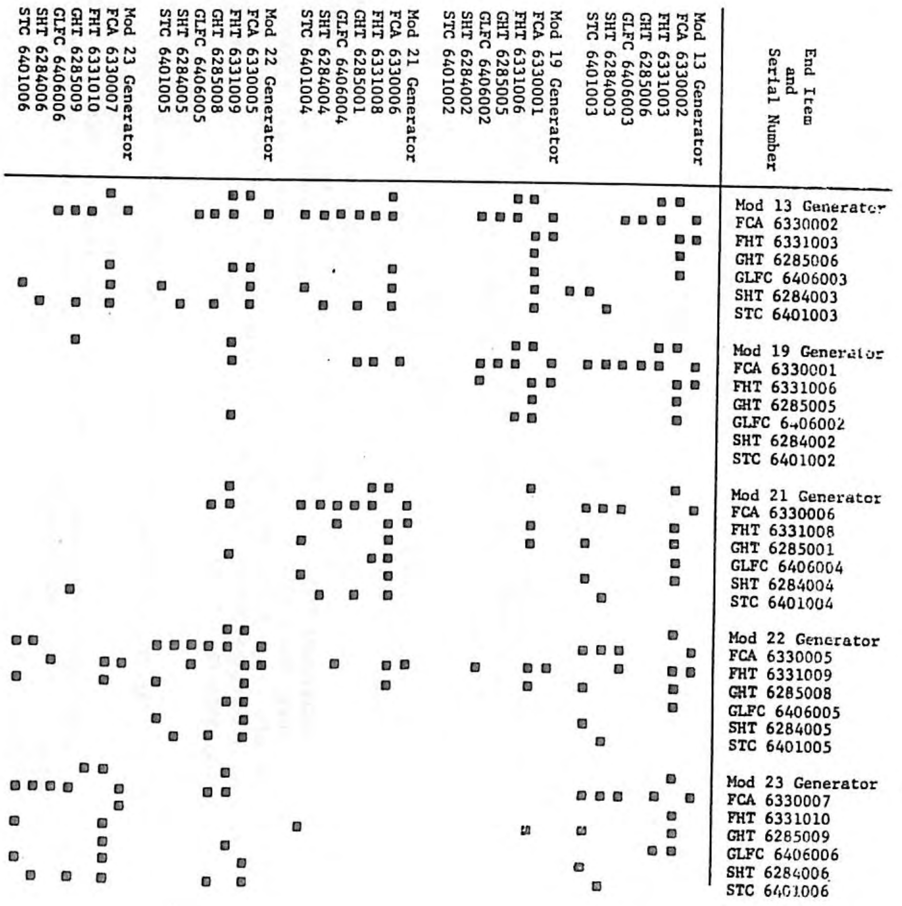
Figure 12-63 is a matrix summarizing the various combinations of SNAP-27 flight components which were fit-checked.

Because of the complexity of fit-checking each system with all of its interrelating end items, and cross fit-checking this system with its backup and all interrelating backup end items, the requirement for fit-checking SLA hardware was waived by authority of the customer.

TABLE 12-5. FLIGHT ALSEP CASK ASSEMBLY TILT TEST DATA

FLIGHT NO.	1 (A)	BACKUP (B)	2 (C)	3 (D)	4 (E)
Force to remove lanyard from left retaining clip (lb)	(F)	(F)	2.0	2.0	6.75
Force to remove lanyard from right retaining clip (lb)	(F)	(F)	2.0	3.5	4.5
Maximum force to shear right trunnion shear pin (lb)	24.0	20.0	23.25	20.5	19.25
Maximum force to shear left trunnion shear pin (lb)	22.0	22.0	29.0	17.0	13.0
Maximum force to remove dome spline lock (lb)	1.25	0.75	(G)	(G)	11.0
Maximum force to lower cask 120° (lb)	10.0	11.0	10.0	10.0	19.0
Maximum force to raise cask to FCA removal position (lb)	36.0	26.0	38.0	40.0	38.0
Maximum force to engage dome removal tool (lb)	20.0	19.0	11.0	12.0	18.0
Maximum force to depress plunger on dome (lb)	28.0	9.0	8.0	8.0	7.5
Maximum torque to rotate cask nut (in-lb)	10.0	19.0	39.0	39.0	18.0
Maximum torque to rotate dome 60° (in-lb)	7.0	9.0	12.0	25.0	24.0
Maximum torque to engage handling tool to FCA in three positions (in-lb)	10,8,10	5,3,3	6,4,3	11,11,14	6.5, 9,9

(A) Utilized Bendix supplied flight handling tool (GE S/N 6331006).
(B) Utilized GE flight handling tool, S/N 6331009.
(C) Utilized GE flight handling tool, S/N 6331009.
(D) Utilized Bendix-supplied flight handling tool (GE S/N 6331008).
(E) Utilized GE ground handling tool.
(F) Retaining clips not installed on these units before test.
(G) Spline was pulled loose during shearing of right trunnion shear pin.



Solid block indicates fit performed successfully

Figure 12-63. SNAP-27 Fit Checks

12.7 REFERENCES

12-1 Test Report SNAP-27 Generator Assembly Model 13, ANSO Document 6300-289.

12-2 Test Report SNAP-27 Generator Assembly Model 19, ANSO Document 6330-282.

12-3 Test Report SNAP-27 Generator Assembly Model 21, ANSO Document 6300-296.

12-4 Test Report SNAP-27 Generator Assembly Model 22, ANSO Document 6300-313.

12-5 Test Report SNAP-27 Generator Assembly Model 23, ANSO Document 6300-310.

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13. SNAP-27 AUXILIARY SUPPORT EQUIPMENT

13.1 GROUND HANDLING TOOL

This device, Figure 13-1, is the primary means for ground handling of the Fuel Capsule or the Electric Fuel Capsule Simulator. It is used to insert, lock, release and extract the capsule from the Ground Shipping Cask, SLA Transfer Cask, Generator Assembly and Graphite LM Fuel Cask, because the latching mechanism design for engaging the capsule backplate is common to each of these end items. The overall tool length is 25.4 inches and the weight is 3.6 pounds. The tool consists of a movable jaw assembly fabricated of titanium which employs three fingers which are moved radially inwards or outwards for engaging or releasing the three spring-loaded latches on the capsule backplate. Movement of the fingers is accomplished by rotation of the knob at the end of the tool. The number of complete 360 degrees turn between the full unlock position to the full lock position is 2 ± 1/4 turns. The inner knob shown on the tool is rotated to actuate a collet assembly which provides a friction lock on the shaft used to rotate the jaw mechanism. The friction force between the collet and control tube eliminates the hazard of accidentally disengaging the jaw assembly from the capsule backplate. All metal parts except the titanium jaw assembly are fabricated of corrosion resistant steel. The insulating handles are formed of glass melamine.

During use, the tool handles remain sufficiently cool for comfortable operation without the need for protective gloves.

13.2 SLA HANDLING TOOL

This device, Figure 13-2, will be used at the launch site for transferring the Fuel Capsule from the SLA Transfer Cask into the GLFC inside the SLA.

Functionally, it is identical to the Ground Handling Tool. It has been specifically designed for use in the close confines of the SLA where the length of the GHT precludes its being employed for loading due to mechanical interference. Its overall length is approximately 14.5 inches; its weight 2 pounds 14 ounces.

a 90-degree offset handle is provided for added stability and orientation while handling the capsule. A tethering ring is also attached to the base of the offset handle. The temperature rise which is experienced in the handles will be negligible when engaging the capsule, particularly since the loading procedure will be accomplished in approximately one minute.

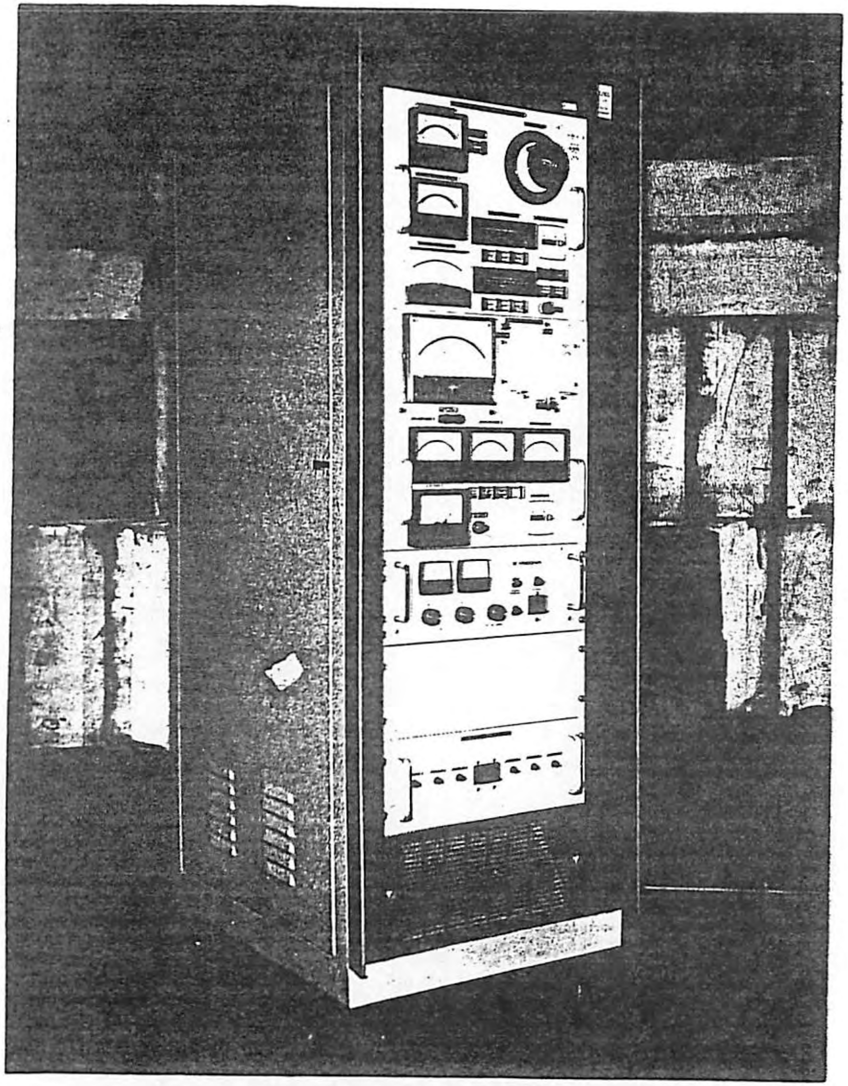
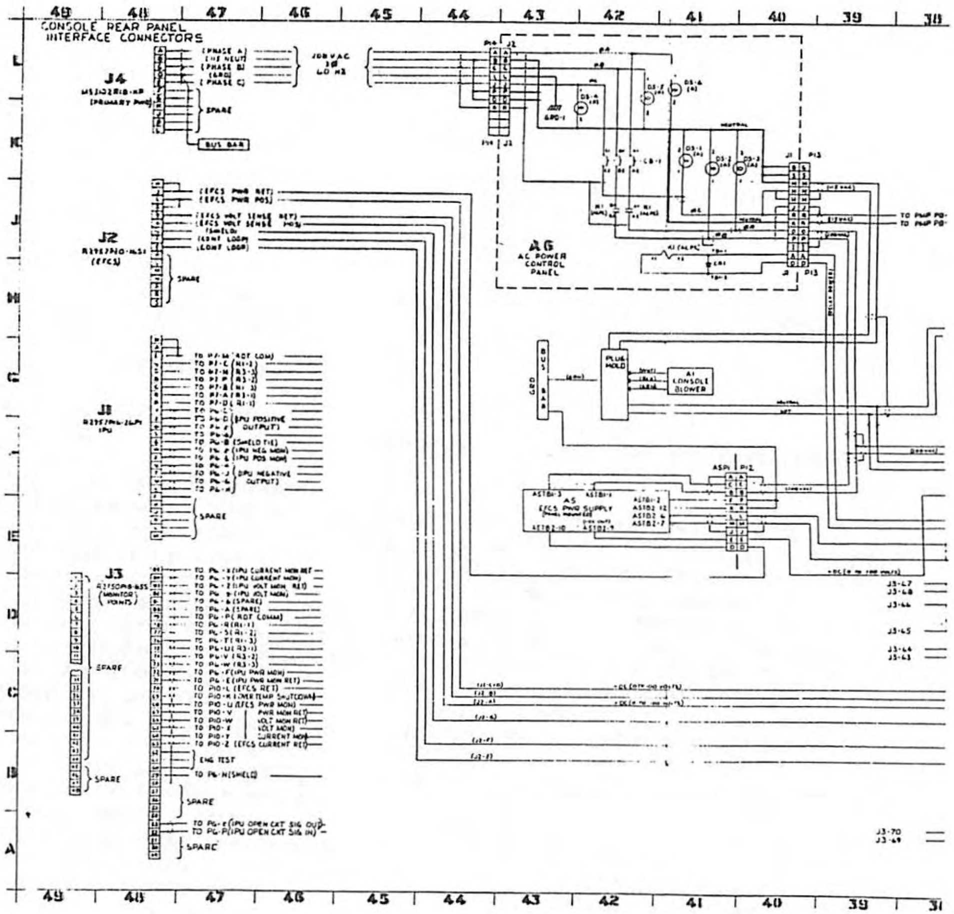
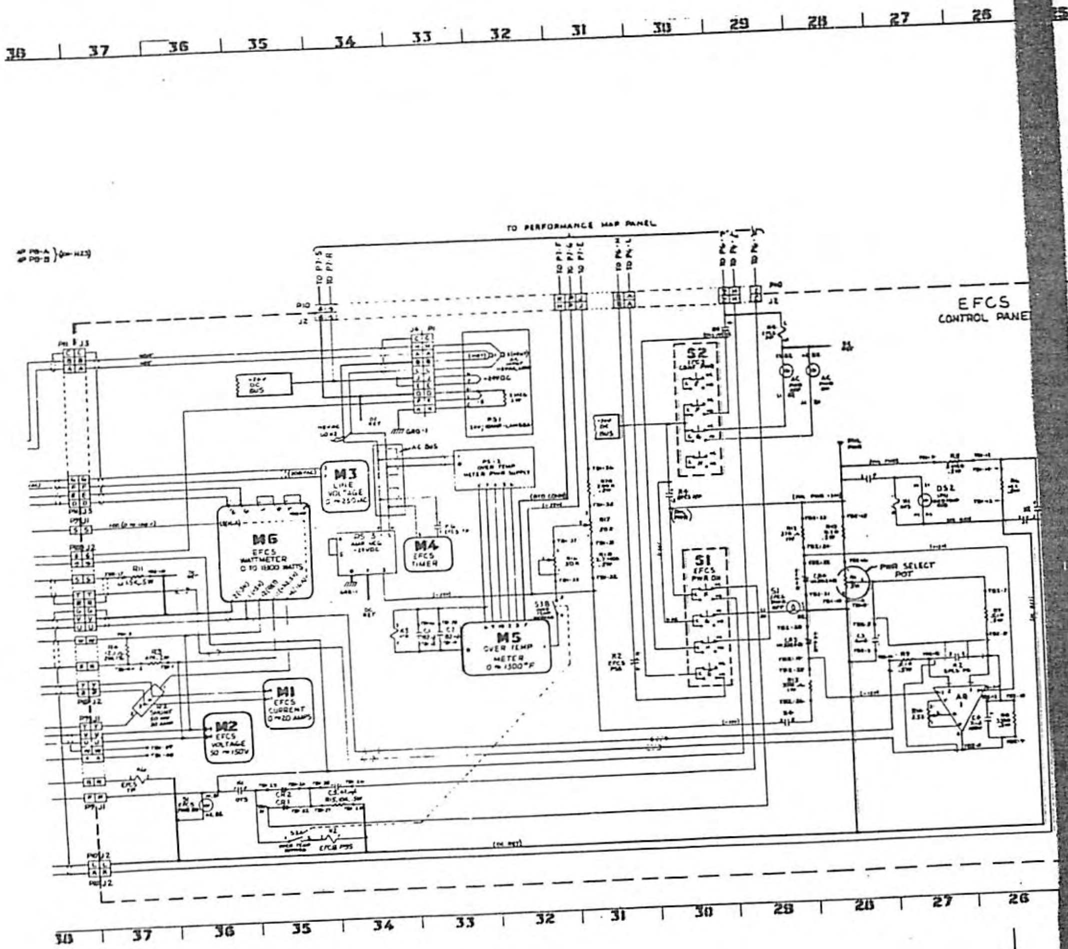


Figure 13-6. Integrated Power Unit Test Console

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TO PERFORMANCE MAP PANEL
TO P7-S
TO P7-R
TO P7-F
TO P7-G
TO P7-E
P10
J2
J6
P1
P11
J3
+28V DC BUS
PS1
+28VDC
AC BUS
GRD-1
DC REF
M3
LINE VOLTAGE 0 ~ 250 VAC
PS-2 OVER TEMP METER PWR SUPPLY
M6
EFCS WATTMETER 0 TO 1800 WATTS
PS 3
+28VDC
M4
EFCS TIMER
R11
M5
OVER TEMP METER 0 ~ 1300°F
S1B
M1
EFCS CURRENT 0 ~ 20 AMPS
M2
EFCS VOLTAGE 50 ~ 150V
CR2
CR1
EFCS PWS
(DC RET)
EFCS
CONTROL PANEL
S2
+28V DC BUS
S1
EFCS PWR ON
K2
EFCS PWR
DS2
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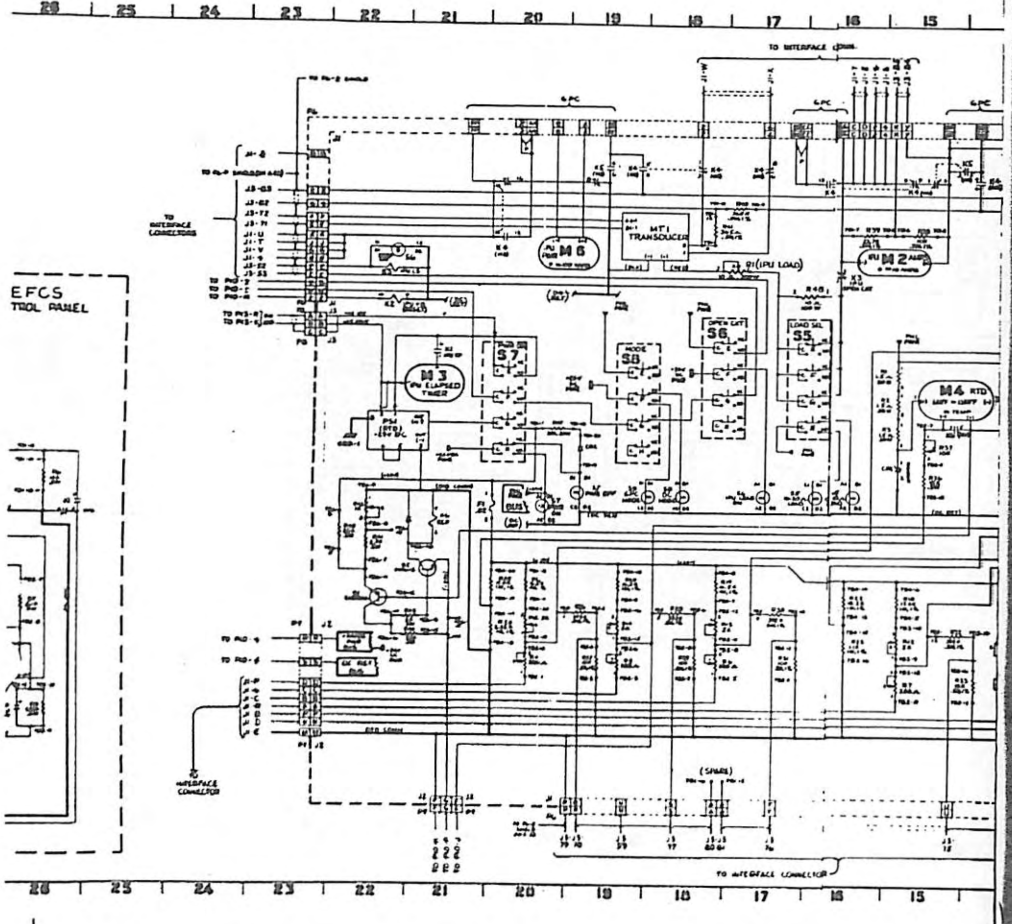

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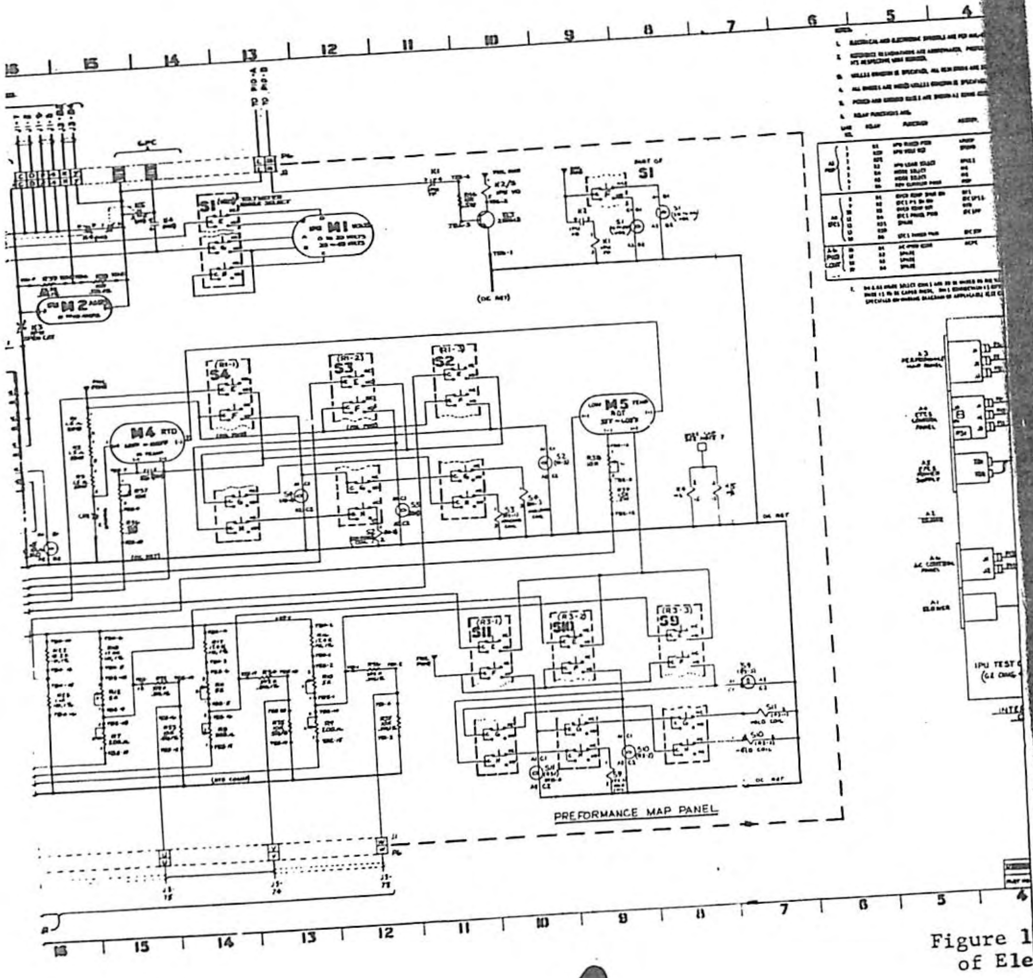

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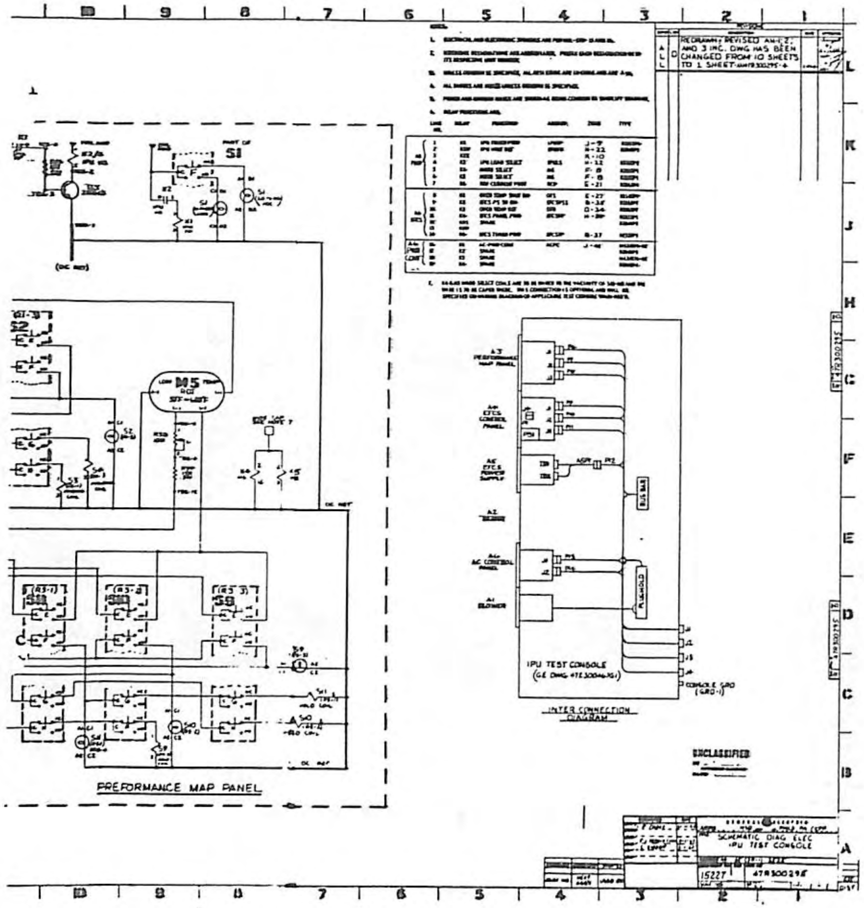

Figure 13-7. Schematic Diagram of Electric IPU Test Console

A reverse current detector circuit is provided to protect the hot frame meter from experiencing reverse current while temperatures are below 600°F during warmup. The reverse current detector activates a relay which shorts out the hot frame meter terminals at temperatures below 600°F.

13.4.1.2 Performance Map Section

This section provides the means for monitoring and visually displaying the potential in volts dc, current in amperes, power in watts, variable load resistance in ohms, and also measures the elapsed time of the monitored functions which follow:

a. The voltage monitor/display section monitors generator output voltage over the ranges of 0 to 40 vdc in two ranges (0 to 20 and 20 to 40 volts) and provides analog display of the voltage to an accuracy of ± 1 percent of full scale.

b. The current monitor/display section monitors generator output current over the range of 0 to 10 amperes and provides analog display of the current to an accuracy of ± 1 percent of full scale.

c. The power monitor/display section monitors generator dc power in watts over the range of 0 to 100 watts, and provides analog display of the power to an accuracy of ± 2 watts. A load resistor is provided with a variable resistance between 0 and 20 ohms with a step to open circuit.

d. The elapsed time indicator and display measures elapsed time in hours and tenths of hours.

13.4.1.3 Variable Load Resistor

This resistor is provided for the generator output; it is rated 0 to 10 ohms, 300 watts. There is a 10 ohm series resistor which is normally shorted out by relay contacts. Upon actuation of the relay, load resistance is then adjustable between 10 to 20 ohms. Open circuit mode is achieved by energizing a switch which disconnects the load resistor from the generator output for as long as the switch remains activated.

13.4.1.4 Test Data Interface Signals

These signals are provided at the Real Panel Interface Connector. Signals are as follows:

c. The circuit breaker (a three-pole breaker) interrupts all power to the console.

d. The large power relay switches 208 vac (phase-to-phase) to the EFCS power supply upon properly energizing a sequential series of switches located on both the Performance Map Control and EFCS Control panels.

13.4.5 BLOWER PANEL

This panel, which is used during console operations, is actuated when the main power circuit breaker is energized. The blower capacity is sufficient to keep internal console temperatures below 110°F during normal operation.

13.5 FUEL CAPSULE GROUND SHIPPING CASK

The Ground Shipping Cask (see Figures 13-8 and 13-9) was designed to contain a single SNAP-27 Fuel Capsule Assembly (FCA) for purposes of common carrier transportation and for storage for a period of up to two years. The GSC was designed to meet the performance and design requirements of GE Specification NS 0110-07-02-B, AEC Regulations 10 CFR 71 and 10 CFR 72, and ICC Regulations 47CRF71-81

The contract was awarded to Battelle Memorial Institute to design, develop, manufacture and qualify the SNAP-27 GSC. The basic requirements for the GSC were:

a. Radiation attenuation

b. Thermal attenuation

c. Passive operation

d. Reliability

e. Safety

f. Minimum handling requirements

The cylindrical cask body is a 20-inch diameter, 36-inch long stainless steel (Type 304) shell, and is designed as a pressure vessel to withstand a maximum internal pressure of 75 psi. An inner type 304 stainless cylinder forms a cavity which is used to contain the SNAP-27 FCA. This cylinder is positioned and held in place by 24 internal copper fins which attach also to the cask shell. The neutron shield

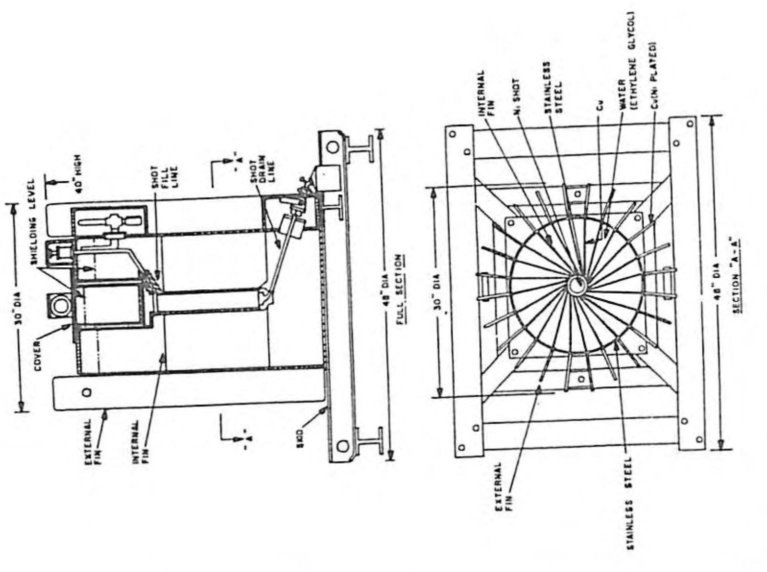

Figure 13-9. Fuel Capsule Ground Shipping Cask Internal Structure

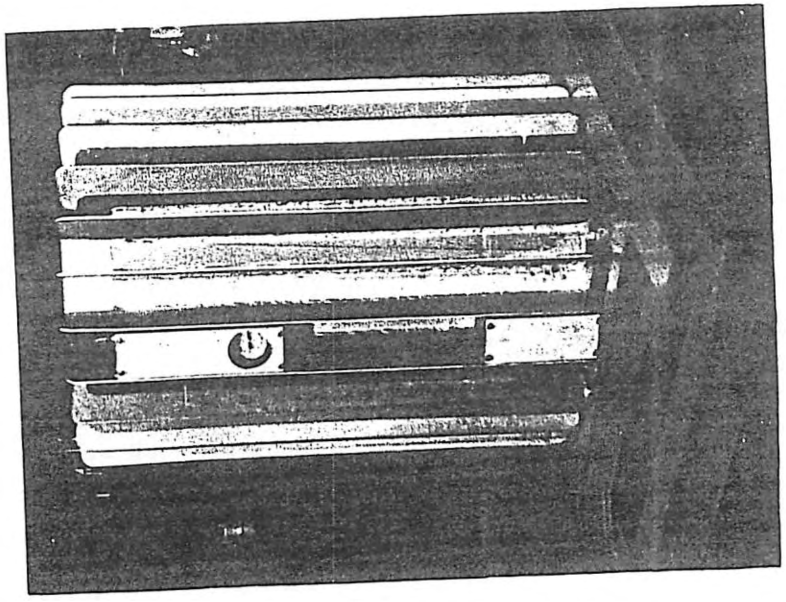

Figure 13-8. Fuel Capsule Ground Shipping Cask

material, a mixture of water-ethylene glycol solution, fills the annulus formed by the inner cavity and the cask shell. Two openings penetrate the outer shell; a side penetration has connections for a pressure gage and shield water pressure-relief valve (75 psi maximum), and a top penetration (which is normally plugged) is utilized to introduce the shield material into the cask.

There are 24 external copper fins for heat dissipation purposes; these external fins also provide a measure of crash protection to the cask.

The top cover assembly, which is secured to the cask by studs and nuts, consists of a flat circular plate welded atop a canister plug filled with the same water-ethylene glycol solution for shielding purposes. The cover plug has a diameter sufficient to accommodate the removable backplate of the fuel capsule with allowance being made for the handling tool. Installation and latching of the fuel capsule into the GSC by its backplate is accomplished in the same manner as it is in the GLFC or the Generator Assembly.

Heat is transferred from the fuel capsule to the internal copper fins by means of small spherical particles (nickel shot) used to fill the annulus space between the capsule and cavity wall. Access to the inner cavity for filling and draining the shot after the capsule is inserted is through tubing attached at the cask top and lower side. Nickel particle fill access is by a simple pipe plug; drain access is through a ball valve. Gas sampling capability is achieved by additional sampling connections at the fill and drain points. The GSC is bolted to a shipping skid made of 48-inch and 36-inch long structural steel beams. A pair of trunnions is attached to the external fins for lifting the cask, and eight holes are drilled into the skid beams for securing the unit to the transport vehicle. Three sealed charges of nickel shot, a funnel, the gas sampling apparatus, and a shot collection container are normally provided in two steel boxes attached to the shipping skid.

During storage, with approximately 1500 watts $^{238}PuO_2$, the measured radiation is less than ten milliroentgens (mr) per hour at one meter from the cask, and the cask surface temperature will not exceed 135 to 145°F.

A complete evaluation of the safety aspects of this cask has been made by Battelle Memorial Institute, the cask designer and fabricator. The results of that evaluation, which proved the adequacy of the cask, are given in "Safety Analysis Report on the SNAP-27 Ground Shipping Cask", dated February 3, 1967, by Battelle.

For the SNAP-27 program, the FCA's were transported on public roads in an AEC courier van. This was accomplished by obtaining a Certificate of

Approval for the shipping container from AEC/ALO in accordance with AEC Manual chapter 0529, in addition to the Department of Transportation Permit (Special Permit No. 5229).

BMI manufactured a total of seven units, one qualification and six flights. The acceptance testing of these units was performed at BMI with the qualification testing being conducted primarily at Dayton T. Brown Testing laboratories with portions being done at both BMI and GE. The acceptance and qualification test plans were written by BMI and approved by GE.

During the development, acceptance and qualification testing a number of problems were encountered which led to several design changes and product improvements. These items are:

a. The nickel shot particles did not pack to as great a bed density as was expected and even though this could be improved by "tapping" the GSC during particle loading, the maximum capsule surface temperature had to be increased.

b. Humidity testing showed that the nickel particles, packed around the capsule, agglomerate readily in the presence of moisture and did not drain readily from the GSC during unloading. This prompted:

   1. An improved nickel particle preparation procedure to ensure cleaner and drier nickel particles initially

   2. The incorporation of a new shot drain valve and stainless steel fittings to improve leak tightness and integrity

   3. The addition of a drain-bulb between the shot collection container and the air monitor to induce shot draining.

c. Vibration testing failures made necessary the addition of gussets to the shipping skid portion of the GSC and the use of higher strength bolts for bolting the skid to the basic structure of the GSC.

With the incorporation of the aforementioned changes, all testing was successfully completed, the GSC qualified, and all flight units delivered for use.

13.6 GENERATOR ASSEMBLY SHIPPING CONTAINER

The generator assembly shipping container (see Figure 13-10) is a reuseable shipping container which provides support and environmental rotection for the generator assembly during transportation, handling, nd storage. It is a hermetic enclosure fabricated of 6061-T6 aluminum lloy consisting of top and lower sections of an integral shipping skid. nternally, the shipping container contains a base plate, with a bolt pattern identical to the generator feet configuration and sufficient rea for tie-down of the RTG cable. Tie-down for the cable is provided by velcore hook and pile straps. The baseplate is supported in the hipping container structurally by elastomeric damping rods which ffectively isolate the base from shipping container vibrations and hocks. Attached to the baseplate is a three-axis shock indicator of sufficient accuracy and resolution to ensure that any excessive accel- ration environments during shipping are detected. In addition, the hipping container contains an external gage for direct readout of internal pressure.

imensionally the container can be viewed as a 40-inch cube. Its eight, when empty, is approximately 255 pounds.

he shipping container provides an internal dry argon atmosphere with minimum pressure of 15.5 psia for the shipping and storage period. It an be easily transported with provisions for lifting hooks and a skid onfiguration for fork lift manipulation.

3.7 SLA TRANSFER CASK

his device (see Figures 13-11 and 13-12) has been designed for use at he launch site and is employed for transportation and temporary stor- ge of the fuel capsule during the pre-launch operational sequences. he overall weight of the cask with capsule installed is approximately 1 pounds, the cask weight being approximately 26 pounds. All major omponents of the cask are made from 6061-T6 aluminum, chosen for trength, lightness, and corrosion resistance. The wheels are rubber. verall height to the top of the handles is 27 inches; overall cask idth is 18 inches. Heat rejection is achieved by free convection and adiation to the ambient environment and is accomplished by fifty 5- nch by 10-inch by 0.032-inch aluminum fins brazed to a 3-inch aluminum ylinder in which the capsule is inserted. A wire mesh barrier sur- ounds the fins to prevent damage by snagging on objects when being oved along as well as to act as a thermal barrier to prevent contact ith the fins. The top plate, bottom plate, and inside of the capsule ousing are plated with a high emissivity coating to enhance heat rejection. A latching mechanism similar to that employed in the GSC is rovided for engagement and securing of the fuel capsule assembly after ts insertion into the cask.

ortability is provided by four handles, two on top and two on each ide, and by three wheels, one of which contains a brake. This

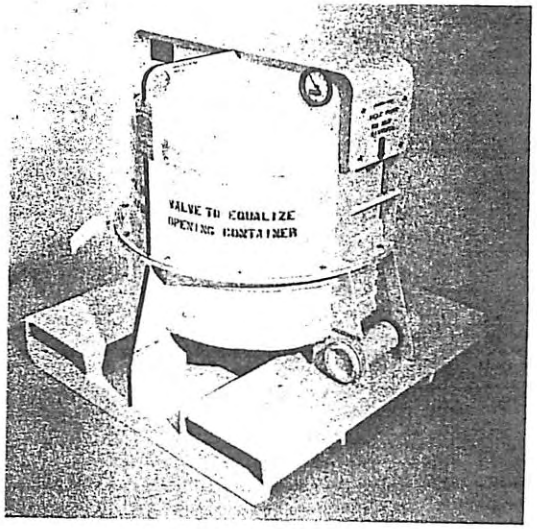

Figure 13-10. Generator Assembly Shipping Container

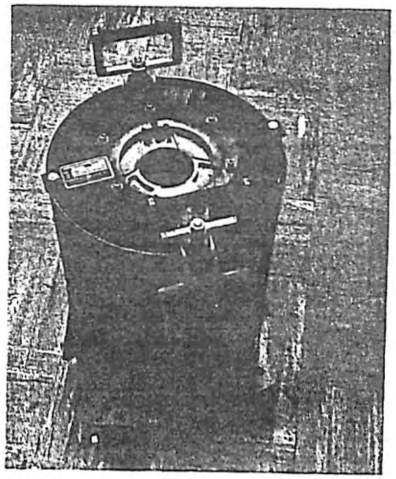

Figure 13-11. SLA Transfer Cask

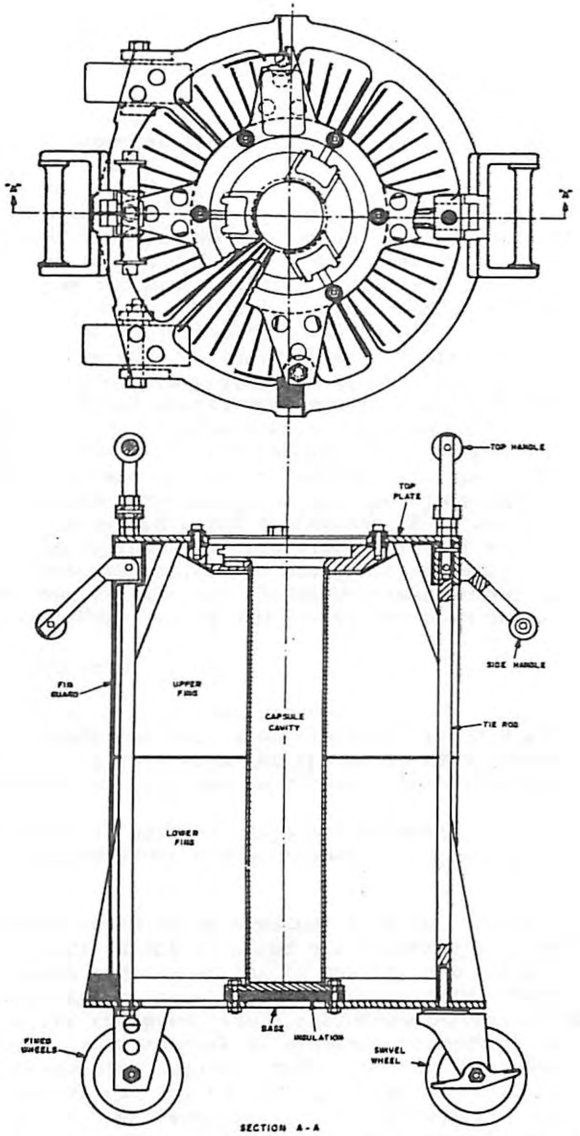

Figure 13-12. SLA Transfer Cask Internal Structure

arrangement provides for flexibility relative to the method of transporting and handling to allow it to be pushed, pulled and lifted.

Representative stabilized room temperatures recorded on different parts of the SLA Transfer Cask when containing an electric fuel capsule energized to 1500 watts are given below:

LOCATION	TEMPERATURE °F
Fuel Capsule Surface	925
Fuel Capsule Backplate	275
Top Handle	100
Side Handle	100
Bottom Center	98
Fin Root	275
Fin Edge (top)	190
Screening over fins	100

13.8 CAPSULE SEATING CHECK TOOL

The tool, depicted in Figure 13-13, is used at the launch site to verify that the fuel capsule assembly is securely latched in the GLFC before flight. This is accomplished by individually checking each of the three spring-loaded tabs of the capsule backplate. The design consists of an outside housing and spring-loaded plunger. The outside housing is designed to fit the slot in the capsule backplate and the ring in the GLFC. The plunger can be fully depressed only when the spring-loaded latching tabs in the capsule backplate are fully engaged in the GLFC latching ring.

13.9 PORT ENTRY TROUGH

This device, Figure 13-14, is employed at the launch site for moving the fuel capsule into or out of the interior of the SLA through one of the SLA's 10-inch fueling ports. The trough is basically a half cylinder formed of 6061-T6 aluminum, except for the cradle which is of

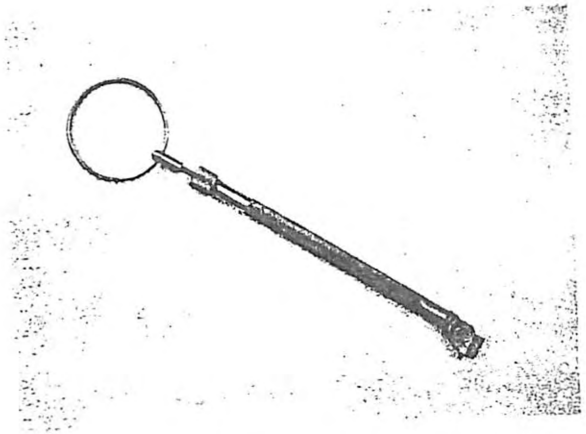

Figure 13-13. Capsule Seating Check Tool

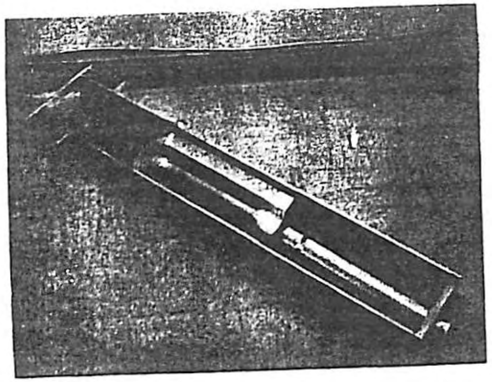

Figure 13-14. Port Entry Trough

stainless steel. It is 4 feet long by 6.5 inches wide and weighs 11 pounds. The cradle in the center supports the capsule. Handles are provided on both ends to facilitate handling. Stops are provided on the bottom to prevent its being pushed or pulled too far into, or out of, the port during the capsule loading activities.

14. NUCLEAR SAFETY

The SNAP-27 Safety Program covered five major categories of activity:

a. Safety Design

b. Safety Analysis

c. SNAP-27 Safety Documentation

d. Safety Tests

e. Operational Safety

Performed as an adjunct to the program was a finned body re-entry study (for possible application of the SNAP-27 RTG to future missions in which separate shipment of the fuel capsule was not feasible) to evaluate requirements for survivability to assure radioisotope fuel containment. This is briefly discussed in Section 14.6.

Also included (Section 14.7) is a summation of the radiation data and measurements made on the SNAP-27 fuel capsules by Mound Laboratory.

14.1 SAFETY DESIGN

14.1.1 DESIGN CRITERIA

Approval to use SNAP-27 in the ALSEP application is contingent upon providing assurance that the general populace will not be subjected to undue radiation hazards resulting from the use of plutonium-238 dioxide fuel, including all plausible accidents which might occur during any phase of the mission. A safety specification (Reference 14-1) was prepared to provide the safety design objectives and fuel capsule requirements for the SNAP-27 program. The system design requirement was for intact re-entry to localize containment of the fuel material on earth. In those low probability situations where containment might not be achievable, the intact philosophy was modified to permit fuel dispersal where such dispersal does not subject the populace to an undue radiobiological hazard.

14.1.2 DESIGN OBJECTIVES

Safety design objectives used in the SNAP-27 Program were:

a. Complete containment of the fuel for all launch environments

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including terminal free-fall impact against a rigid medium

b. Containment in the near-shore ocean environment for a time to permit shallow water recovery effort

c. In the event of deep ocean impact, either containment will be assured or the fuel (if released) will not constitute a significant radiological hazard

d. In the event of land impact, in cases where containment cannot be assured, the fuel (if released) will not constitute a significant radiological hazard.

14.1.3 FUEL CAPSULE REQUIREMENTS

The fuel capsule is required to meet the following anticipated mechanical, thermal, chemical and nuclear effects:

a. Shock overpressure caused by missile explosion on the launch pad

b. Internal pressure caused by the helium gas, if any, due to alpha decay of the fuel

c. Internal pressure caused by the helium gas, if any, due to alpha decay of the fuel and subsequent subjection of the system to fire or re-entry environments

d. Thermal environment of a missile fire on the launch pad

e. Corrosive action of missile fuels on the launch pad

f. Chemical action of the nuclear fuel on the capsule materials

g. Self-radiation damage during system life or one year after launch, whichever is longer.

14.1.4 GRAPHITE LM FUEL CASK REQUIREMENTS

The normal and abort mission performance requirements utilized in the design of the Graphite LM Fuel Cask are summarized in Reference 14-2.

14.2 SAFETY ANALYSIS

The SNAP-27 safety evaluation determined if any accidents could occur that would result in release of fuel to the biosphere. The approach taken in performing this safety analysis was as follows:

a. Thoroughly define the mission, the associated equipment, and the RTG design to be used as the baseline system that can significantly affect the safety analysis.

b. Identify all potential accidents involving the fuel capsule (directly or indirectly) that could occur during transportation and ground handling, during on-pad pre-launch operations, or during the actual mission.

c. Characterize the environments associated with each of the aforementioned accidents or mission aborts.

d. Analyze the consequences of these environments on the fuel capsule to determine if fuel release to the biosphere can occur. Where fuel release is possible, determine the amount, chemical and physical state, location, and probability of release.

e. Determine the radiological consequences for those cases where release to the biosphere is possible. The number of people affected, the geographical location, the dose levels received, and the probability of occurrence will be included.

Booster, spacecraft, mission, and abort information was obtained from published reports, from vendors, and from the NASA centers for preparing accident or abort logic diagrams, identifying accidents, and determining abort environments.

Environmental factors such as meteorology, hydrology, geology, ecology, and population distribution were used to determine the magnitude of the hazards, given the condition of released fuel. Accordingly, the following models were employed, and the effect on the general populace was evaluated:

a. Atmospheric Dispersion

b. Water Dissolution and Release

c. Radiation Exposure

d. Population Distribution

e. Human Food Crop Areas

14.3 SNAP-27 SAFETY REPORT

The SNAP-27 Safety Report describes the nuclear safety analysis of the

Apollo-ALSEP mission with the primary purpose of providing the basis for assessment of the SNAP-27 system adequacy in minimizing any nuclear hazard associated with the mission. The Safety Report is comprised of three documents: Volume I, "Reference Design Document" (Reference 14-3); Volume II, "Accident Model Document" (Reference 14-4); and Volume III, "Safety Analysis Report" (Reference 14-5). In addition, two supplements have been prepared for the AMD: Supplement No. 1 (Reference 14-6) presents Appendix P which gives the detailed re-entry evaluation of the Graphite LM Fuel Cask (GLFC) and the LM; Supplement No. 2 (Reference 14-7) presents revisions and completion of sections and other appendixes that were incomplete at the time of publication of the AMD.

14.3.1 REFERENCE DESIGN DOCUMENT

The Reference Design Document (RDD) establishes the description of all safety-related systems, the mission, the launch site, and normal operations necessary for the accident and safety analyses. Thus, it serves as a common body of data, nomenclature, and units on which are based all analyses and tests pertaining to the safety evaluation. Included in this document are the following topics:

a. Apollo Lunar Surface Experimental Package (ALSEP)

b. SNAP-27 Power System

   1. Generator Assembly

   2. Fuel Capsule Assembly

   3. Isotopic Fuel

   4. Graphite LM Fuel Cask (GLFC)

   5. GLFC Support System

   6. Tools and Ground Support Equipment

c. Apollo/Saturn V Space Vehicle

d. Mission Operations and Description

e. Merritt Island Launch Area (MILA)

14.3.2 ACCIDENT MODEL DOCUMENT

The Accident Model Document (AMD) serves the following purposes:

a. It identifies potential modes of failure in the ground handling, pre-launch, and flight phases of the mission which can affect the SNAP-27 Fuel Capsule.

b. It assesses factors affecting the probability of occurrence of the identified failures.

c. It describes the environments to which the fuel capsule is subjected following the various failures.

d. It evaluates the effects of failure environments on the fuel capsule and determines the instances of fuel release if it occurs.

For purposes of evaluating the potential accidents during the pre-launch and mission operations, the lunar bound portion of the Apollo mission has been divided into a total of nine subphases representing specific intervals of time and defining discrete mission events. The subphases represent changes in launch vehicle/spacecraft configurations and/or changes in other aspects of the mission that could affect or change the potential safety consequences. The subphases are:

a. Pre-launch

b. S-IC Boost

c. S-II Boost I (Prior to LET jettison)

d. S-IV B Boost

e. Earth Orbit

f. Translunar Injection

g. Translunar Coast

h. Lunar Orbit Insertion

i. Coast

Although the actual Apollo mission includes the return of the astronauts to Earth, the mission for purposes of the AMD is terminated at the end of the lunar orbit coast period when the descent to the lunar surface is initiated. This period of the overall mission (commencing with loading of the fuel capsule aboard the launch vehicle at the start of the pre-launch subphase) corresponds to that portion in which there is a hazard potential to the Earth's population that can be realized by release of radioactive fuel.

Abort and failure sequence trees have been constructed for each of the nine subphases to present the sequence of events that follow mission failures and aborts and the manner in which these events with their conditional probabilities affect potential fuel release. These sequence trees identify any instances of fuel release on a probability basis. Thus, they are instrumental in arriving at the source terms for fuel release; the source terms define the location, quantity, condition and probability of release of fuel and become the inputs for the diffusion, dispersion and uptake calculations pertaining to biological exposure that are included in the Safety Analysis Report (SAR) or third volume of the SNAP-27 Safety Report.

With the various aborts and accidents having been defined, the identification and characterization of the associated induced environments is effected to perform analyses and/or to define tests to determine the response of the GLFC and fuel capsule. The results of these response analyses and tests are then used to complete the abort and failure sequence trees. Table 14-1 lists the various environments that have been presented in the AMD and against which the GLFC and fuel capsule have been evaluated.

The AMD as given in Reference 14-4 was published while both analytical and experimental work was continuing on the Graphite LM Fuel Cask (GLFC) program. This work being incomplete necessitated that several sections of the AMD be reported in later supplements. However, the results of the following analyses and tests pertaining to the response of the GLFC and fuel capsule to the abort induced environments are reported in Reference 14-7.

14.3.3 SAFETY ANALYSIS REPORT

The Safety Analysis Report (SAR) analyses the potential consequences of the release of radioactive material for those instances of fuel capsule failure resulting from the abort induced environments as determined in the AMD. This is effected by developing the utilizing analytical models for dissemination and uptake of the radioactive material. The various models and data used in the analyses include:

a. Atmospheric Dispersion Models
    1. High Altitude Release
    2. Low Altitude Release

TABLE 14-1. ACCIDENT INDUCED ENVIRONMENTS IN SNAP-27 ACCIDENT MODEL DOCUMENT

1. Ground Handling, Transportation, and Storage
    a. Shipping/Storage Fire
    b. Dropping and Crushing

2. Launch Pad (Including Immediate Post-Launch)
    a. Explosion
    b. Fireball/Afterfire
    c. Firestream
    d. Fragmentation
    e. Chemical

3. Re-entry
    a. Ballistic
    b. Earth Orbital
    c. Superorbital or Elliptic Dynamic Loads
    d. Heating Rates
    e. Integrated Heating

4. Impact
    a. Surfaces
    b. Velocities

5. Burial and Post-Impact
    a. Soil Characteristics
    b. Water Characteristics
    c. Pad Abort Effects
        (1) GLFC Responses to Fireball/Afterfire
    d. Launch Through Lunar Orbit Coast
        (1) Re-entry of GLFC and LM (Reference cases only)
            (a) Thermal Response
            (b) Structural Response
    e. Earth Impact of GLFC and Fuel Capsule
        (1) Impact Structural Response
        (2) Burial Evaluation
            (a) Burial Depths
            (b) Thermal Response

b. Release to Water

   1. Open Oceans
   2. Coastal Waters
   3. Large Lakes
   4. Small Lakes, Reservoirs and Streams

c. Radiation Exposure Models

   1. Inhalation
   2. Ingestion
   3. External Radiation

d. Population Distribution

e. Human Food Crop Areas

The output of the SAR is a set of parametric curves and tables as follows:

a. Isopleth areas for standard man lung doses associated with the release of PuO_2 vapor in a fireball at Cape Kennedy.

b. Parametric probabilities for affecting more than N people to lung doses greater than selected values for release to a fireball at Cape Kennedy.

c. Isopleth areas for standard man lung doses associated with the release of fine particulates at ground level.

d. Total (Curie) lung burdens for release of crushed fuel in several population density areas for unstable, neutral, stable, and very stable weather conditions.

e. Total man-rem lung doses for release of crushed fuel in several population density areas for unstable and very stable weather conditions.

f. Estimated probabilities for the number of people with lung doses greater than selected values.

g. Areas (water) within which various concentrations are exceeded for several potential release locations.

h. Fresh water areas within which 50-year integrated bone doses are exceeded for an initial release rate.

i. Sea water areas within which bone doses are exceeded for an initial release rate.

14.3.4 SUPPLEMENT NO. 1 - APPENDIX P: RE-ENTRY EVALUATION OF GLFC AND LM

Because of the importance and magnitude of the effort involved in the re-entry evaluation of the GLFC with fuel capsule, the description of the work performed along with the results have been reported in a separate supplement to the SNAP-27 Safety Report. Also, the GLFC design, evaluation, and test program was still in progress at the time of publication of the AMD, requiring that the re-entry work be reported later.

Appendix P presents a comprehensive discussion of the analytical, thermal and structural techniques used in the re-entry safety evaluation of the GLFC. Results of the calculations are included in the form of tables and figures. This appendix is subdivided into the following sections:

- Introduction
- Configurations
- Re-entry Trajectories
- Re-entry Heating Environment
- GLFC Thermal Analysis
- Graphite Structural Analysis
- LM/GLFC Separation
- Plasma Jet Testing of Graphite Heat Shield
- Re-entry Capability of the GLFC Without the Graphite Shell
- References and Glossary

A matrix of cases was developed for the analytical program and was subdivided into case groups including reference cases, maximum total heating cases, thermal shock cases, and mission abort cases. The reference cases were used as the initial design point for the GLFC. Limiting conditions of re-entry represented by the maximum total heating and thermal shock cases were analyzed to determine the capability of the cask under extreme conditions. Because these conditions were ıown to be within the capability of the GLFC, there was no necessity ır design iterations. Finally, the mission abort cases, being the ɔst realistic and credible, were analyzed for purposes of completing ıe abort and failure sequence trees of the AMD.

ncluded in the matrix of cases were such factors as the re-entry mode r orientation of the free GLFC, the flight path angle, the separation ltitude of the GLFC from the LM, the trajectory type, and the assumed low field. A summary of the re-entry cases analyzed, together with he more significant assumptions, is given in Table P-1 of Appendix P [.e., Supplement No. 1), and is included here (Table 14-2) for reference.

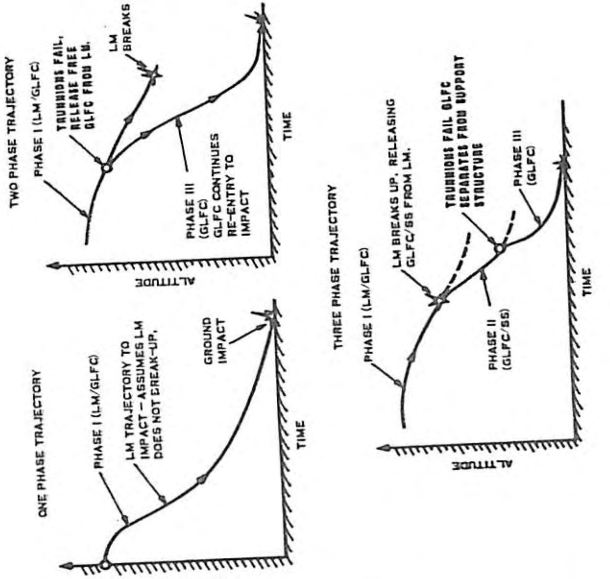
.4.3.5 SUPPLEMENT NO. 2 - REVISION AND COMPLETION OF (AMD) REPORT SECTIONS AND APPENDIXES

he purpose of Supplement No. 2 was to present the completed work for hose sections and appendixes of the AMD that were lacking at its ublication. At that time, a detailed reassessment of the GLFC capa- ility to survive the various abort environments was in progress, as ecessitated by a major design change to the GLFC secondary heat shield SHS) earlier in the program, and the analyses were not finished. The ections of the AMD that were affected were concerned mainly with the esponse of the cask to the blast and fragment environment associated ith an explosive abort (launch pad) and with the re-entry capability ollowing an abort in flight. Shortly after the interim AMD was pub- ished, the re-entry analysis and capability study was completed, and upplement No. 1 was then published.

upplement No. 2 contains the following sections:

- GLFC Response to Blast Pressure
- GLFC Response to Shrapnel
- Response of GLFC to Booster Explosion (Postlaunch)
- Fuel Release Source Terms
- GLFC Response to Blast Pressure (Appendix D)
- GLFC Response to Fragments (Appendix D)
- Experimental Data (GLFC Drop Test)
- Helium Retention Capability of SNAP-27 Fuel Capsule under Various Abort Situations (Appendix J)

TABLE 14-2. SUMMARY OF RE-ENTRY CASES EVALUATED



	GLFC MODE	γ_I	SEPARATION ALTITUDES (KFT)		TRAJECTORY TYPE	ASSUMED FLOW FIELD
			GLFC FROM LM	GLFC FROM SS		
REFERENCE CASES	LS	EO	300		TWO PHASE	GLFC FLOW FIELD
		6.25	330			
		20				
		30				
	PT SIDE HEATING	6.25	330			
		20				
		30				
	PT END HEATING	6.25	330			
		20				
		30				
	SOS	EO	300			
		6.25	330			
		20				
		30				
MAXIMUM TOTAL HEATING	SOS	EO	GLFC NOT RELEASED FROM LM		ONE PHASE	GLFC FLOW FIELD
		6.25				
		20				
		30				
THERMAL SHOCK	SOS	6.25				
		20				
		30				
MISSION ABORT CASES	SOS	EO	332	330	THREE PHASE	LM FLOW FIELD WHILE ON LM, GLFC FLOW FIELD AFTER SEPARATION, AUGMENTATION FACTOR INCLUDED
			217	215		
			272	250		
		6.25	250 210		TWO PHASE	
		20	200			
		30	228 183			

ONE PHASE TRAJECTORY: LM GLFC
TWO PHASE TRAJECTORY: LM GLFC → GLFC
THREE PHASE TRAJECTORY: LM GLFC → GLFC SS GLFC

- Crushed Fuel Particle Size (Appendix M)

These sections correspond to and replace those sections of the AMD having the same designations. The sections corresponding to the response of the GLFC to blast pressure and fragments include the analytical evaluations plus the description and results of test programs pertaining to the same topics. Appendixes J and M were revised and expanded in Supplement No. 2 to reflect additional test data and analyses.

14.4 SAFETY TESTS

A SNAP-27 Safety Test Plan was prepared to identify tests required to obtain data for designing the system safety features, for analyzing the responses of the system to contain the fuel and for evaluating the potential of the fuel for creating a hazard under those circumstances where fuel containment cannot be ensured. After customer review of the Safety Test Plan (Reference 14-11), test descriptions were prepared and are incorporated in References 14-12 and 14-13

A brief discussion of the objectives, test description and results of the Safety Test Program, as originally planned, is presented in the following sections:

a. Evaluation of Fuel Simulant - This test was performed to evaluate fuel simulants having mechanical and chemical properties similar to those of the $^{238}PuO_2$ SNAP-27 fuel. Fuel simulants were used for the performance of some of the safety tests because of the radiological problems associated with utilizing the actual fuel, as well as the question of its availability.

b. Capsule Vibration - In evaluating the safety of the SNAP-27 fuel capsule, the response of the fuel to vibration loads was required. Generation of fuel fines by vibration may be hazardous if those fines are released due to loss of fuel capsule containment. Uncertainties in predicting the production of fines by mathematical analysis indicates that the fines produced by vibration must be determined experimentally.

A vibration capsule shown in Figure 14-1 was loaded with 12.5 grams of $^{238}PuO_2$ microspheres. The loaded capsule was preheated to 1000°F and randomly vibrated at g^2/cps from 20 to 2000 cps for 30 minutes. (This vibration level was the limit of the equipment used for the test and exceeded that specified for SNAP-27 (0.075 g^2/cps from 30 to 1200 cps). The

vibration capsule was opened and fuel analyzed to determine the amount of fines and the particle size distribution. It was determined that no essential change occurred in the fuel fines content or in the particle size distribution as a result of vibration (Reference 14-14).

c. Capsule Impact - The response of the $^{238}PuO_2$ fuel particles in an abort environment in which the SNAP-27 fuel capsule is mechanically deformed and/or shocked is of importance in determining the source term in the event of fuel release from a ruptured capsule. The fuel particles may be crushed to sizes in the respirable range by the blast wave or shrapnel in a booster explosion or by earth impact following re-entry from an abort at altitude. Small quantities of fuel (tests conducted with 5.5 and 15 grams of $^{238}PuO_2$ microspheres) encapsulated in a rigid capsule (see Figure 14-2) were impacted at Sandia into targets which included granite, Ottawa sand, graphite mounted on granite and on concrete. Fuel capsules were preheated to about 1000°F to simulate SNAP-27 fuel capsule impact temperatures. Impact velocities ranged from 101.7 to 456 feet per second.

The results of the fuel impact tests conducted by Sandia Corporation are presented and discussed in Reference 14-15. The impacted fuel particle size distribution for all tests conducted in the Sandia fuel impact program is shown in Table 14-3.

d. Capsule Burial Tests - The primary purpose of the tests was to determine the temperatures attained when a SNAP-27 capsule is buried in representative soils. This information was needed to:

1. Determine the temperature at which fuel will be exposed to soil on loss of capsule integrity due to melting and the temperature of possible fuel-soil-clad reactions.

2. Verify the validity of validity of analytical techniques for predicting the maximum capsule temperatures from known soil thermal properties.

Three burial tests of electrically heated SNAP-27 capsules were performed. Each capsule was buried at a depth of 33 inches and energized to a power level of 1500 watts. The results of the tests are presented in Reference 14-16 and 14-17. In the first test in which the capsule was buried in

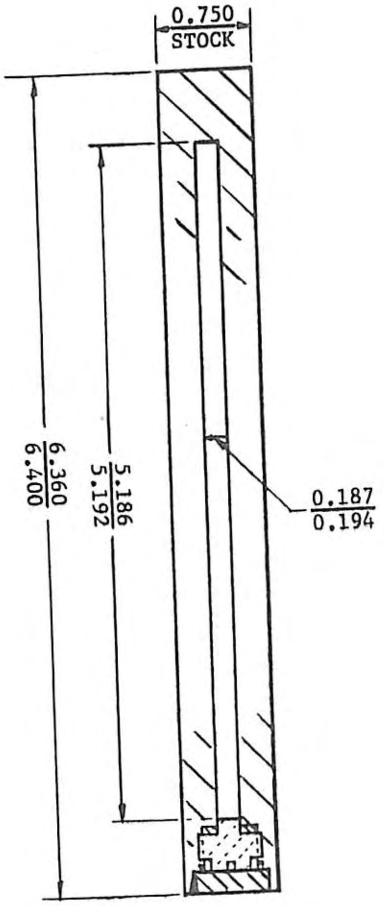


Figure 14-2. Fuel Impact Capsule

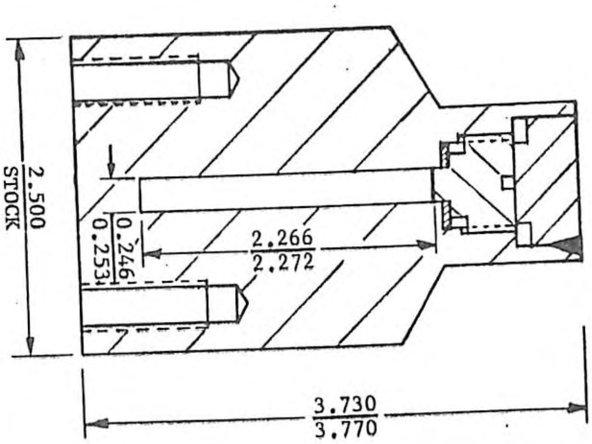


Figure 14-1 Fuel Vibration Capsule

TABLE 14-3. WEIGHT PERCENT $^{238}PuO_2$ PARTICLE SIZE DISTRIBUTION FOLLOWING IMPACT

Particle Size μ	Test 1 377 FPS Granite	Test 2 247 FPS Granite	Test 3 107 FPS Granite	Particle Size μ	Test 4 101,7 FPS Granite	Test 5 105,9 FPS Granite	Test 6 105,8 FPS Granite	Test 7 116 FPS Con-crete	Test 9 102,7 FPS Ottawa Sand	Test 10 104,3 FPS Granite	Test 11 102,5 FPS Granite	Test 12 317,3 FPS Granite	Test 13 442 FPS Granite & 3/4" Super-temp Graphite.	Test 14 456 FPS Concrete & 3/4" Bitco Graphite
> 105	28	32,72		177-210 < 177	7,68	9,4	5,68	24,1	8,8	13,0	12,8	5,4	5.5	6,24
< 105	72	66.40		149-177	18.30	25.2	14,8	15,9	16,5	16,5	14,5	7,0	5.9	6.52
< 53	51	30.66		125-149	15,85	18.1	12,1	18,7	22,1	17,8	17,8	7,1	7,7	8,87
< 37	16	17.22		105-125	14,05	12.6	14.2	13,6	18,6	15,5	14,5	5,2	5,8	5,70
20-44			10,4	77-105	24,34	19,8	24,6	11,9	19,1	23,2	25,1	13,9	14,2	9.78
< 20				44- 77	16,90	10,4	23,1	14,4	13,2	7,5	7.2	8,5	5,4	13,18
< 10		0,03		20- 44	0,73	3,02	3,80	4,6		2,5	3,1	24,9	34,0	21,41
				10- 20	0,08	0,26	0,19	0,72		0,35	0,50	9,8	6,5	15,60
				< 10	0,06	0,025	0,18	0,007		0,15	0,15	4,8	6,4	12,72
				Totals	97,99	98,805	98,55	103,927	98,3	96,50	96,65	86,6	91,4	100.02

Note 1: Fuel For Tests 1, 2, and 3 Not Available.
Fuel For Tests 4, 5, and 6 From Mound Fuel Batch 116 Produced 6/20/67.
Fuel For Tests 7, 9, 12, and 14 From Mound Fuel Batch 126 Produced 8/10/67.
Fuel For Tests 10, 11, and 13 aged (~2 years) and thermally cycled (5 min. at 1200°C).

Note 2: Test 8 was encapsulate Fuel From Mound Fuel Batch 126, heated to 1000°F and then returned to Mound for Analysis.
See Batch 126 on Table M-1.

Note 3: Analyses by Mound Laboratory.

bentonite (a low thermal conductivity soil), the capsule melted through in the center region as shown in Figure 14-3. Bentonite near the capsule was vitrified and a soil mass was formed around the capsule. A void area was formed between the capsule and the soil. In the second test which had the capsule buried in Ottawa sand (a high thermal conductivity soil), the capsule was highly oxidized with no apparent melting of the cladding (Figure 14-4). The third capsule, which was buried in a mixture of equal parts of Bentonite, Ottawa sand, and feldspar (a low melt point material), experienced some melting of the Haynes-25 in the thin section below the flange. The burial capsule from this test was encased in a sintered soil mass that had an 8 to 12-inch diameter at the center of the capsule as shown in Figure 14-5. The burial tests provided data which confirmed the results obtained by analysis.

e. Fuel-Clad-Soil Reaction Tests - The purpose of the test was to determine if any changes occur in the physical and chemical properties of the fuel when in contact with soil and the capsule material under earth burial conditions at elevated temperatures. The soils investigated by Mound Laboratory were attapulgite, bentonite, chernozem soil, diatomaceous earth, feldspar, hematite, kaoline, montmorillonite, Ottawa sand and Yellowstone limestone. The information was needed to determine if any possible changes in the fuel would increase its release capability. In Reference 14-18, it was concluded that no observable effect on the tested fuel was created by heating the fuel with the specified soils and capsule cladding material up to 1000°C in air. This conclusion is based on microscopic examination, apparent density, crush strength, and X-ray diffraction analysis of the tested fuel.

f. Thermal Shock Test - The purpose of this test was to determine whether the thermal shock will cause failure of the hot fuel capsule if it were to impact into a body of water. This test was deleted from the Safety Test Program when a new fuel cask design was required due to changes made in fuel cask requirements to incorporate superorbital re-entry capability.

g. Capsule Immersion in Ocean - The objective of this test was to determine any changes in fuel capsule integrity during long term exposure of electrically heated reference design SNAP-27 fuel capsule in the ocean at various locations, i.e., suspended near the ocean bottom, lying on the bottom, and

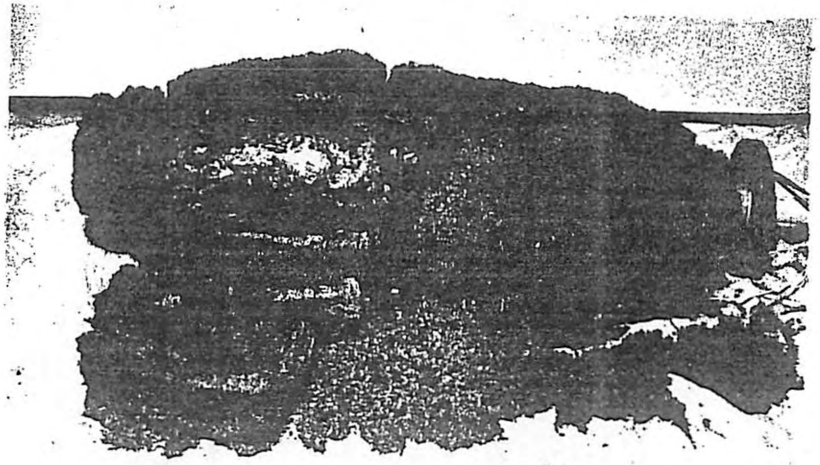


Figure 14-3. Test No. 1, Capsule Buried in Bentonite

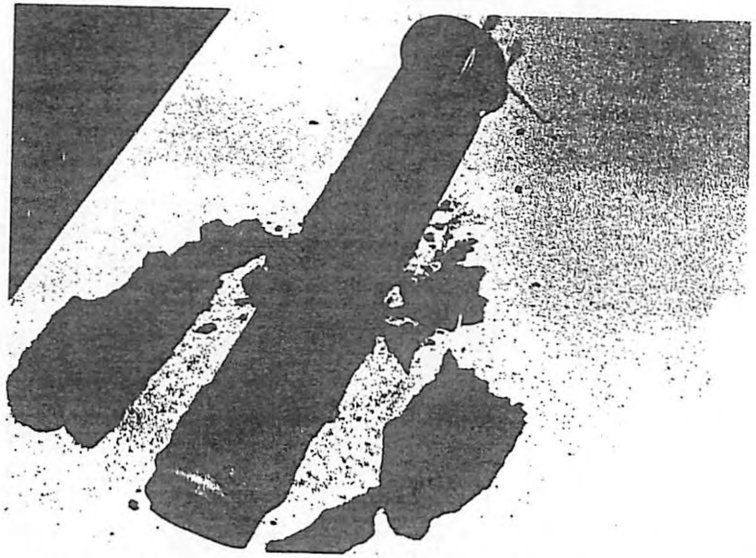


Figure 14-4. Test No. 2, Capsule Buried in Ottawa Sand

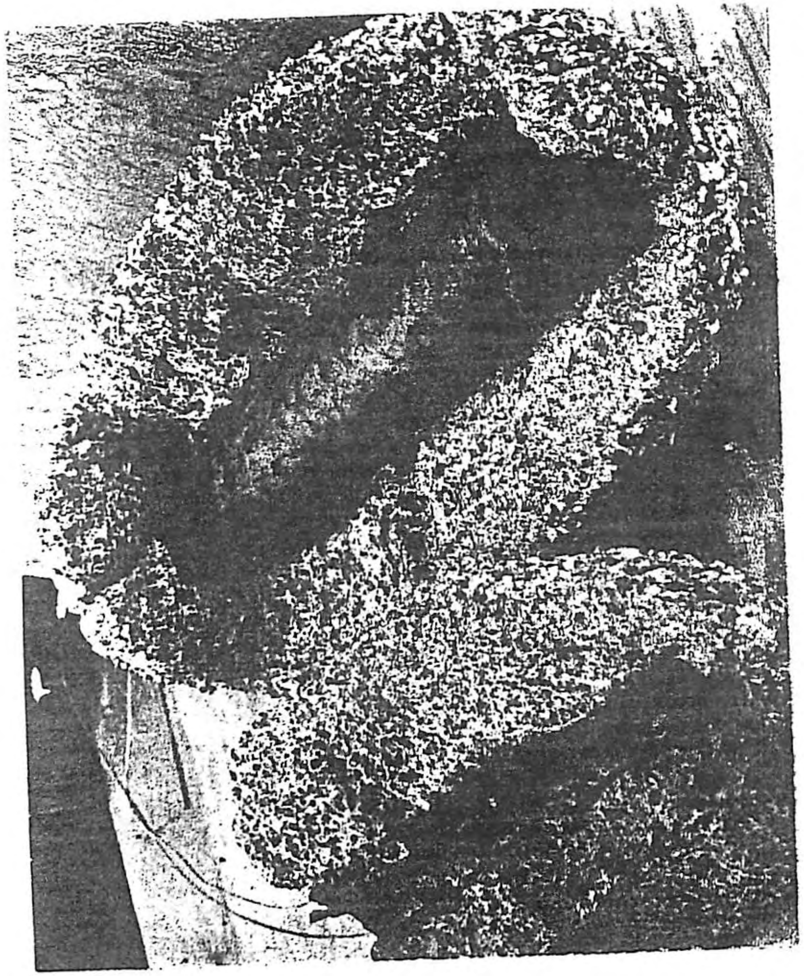


Figure 14-5. Test No. 3, Capsule Buried in 1/3 Bentonite, 1/3 Ottawa Sand and 1/3 Feldspar

buried under the bottom sediment. This test was terminated in accordance with instructions from AEC/SAO. Results from SNAP-19 capsules exposed to a similar ocean test and fuel solubility data were used in the safety analysis where applicable.

h. Fuel-Water Reaction - To determine the release rate of fuel to the sea water environment, the solubility rates of $^{238}PuO_2$ microspheres in sea-water were investigated by the U.S. Naval Radiological Defense Laboratory (Reference 14-19). The observed long-term rates at room temperature, 120°C and 190°C were 4 x 10^{-3}, 1.3 x 10^{-4} and 6 x 10^{-4}, ug/mg/day, re- spectively. The lower rates at 120°C and 190°C were attri- buted to the formation of a coating of calcium sulfate on the plutonium dioxide microsphere.

i. Exposure to Explosion and Fireball - A test specimen which was an analogue of the original beryllium LM Fuel Cask and fuel capsule was exposed to a Project Pyro test at the Air Force Rocket Propulsion Laboratory test site. The objective of the test was to determine the thermal and blast response of the analogue fuel capsule and cask to a liquid propellant explosion fireball. The test specimen was mounted about 23 feet from the propellant tanks, 25,000 pounds of liquid hy- drogen and oxygen, in a launch vehicle configuration. The test produced a fireball encompassing the test specimen, how- ever, neither blast pressure or fragmentation caused damage. Because the test had a very low yield (0.1% weight TNT equiv- alent), as related to peak pressure gage readings, the test data was not applicable to SNAP-27 safety analysis.

j. Radiant Heat Testing of the SNAP-27 Fuel Capsule - Two re- ference design SNAP-27 Fuel Capsules containing a tungsten- molybdenum powder to simulate the $^{238}PuO_2$ fuel were pres- surized with helium to simulate initial helium loading and were then subjected to radiant heating. The heat input to the capsule was continuously varied in order to produce a clad temperature transient identical to that predicted for the earth orbital decay, reference case, re-entry. Two con- ditions were tested: (1) lateral spin and (2) side-on stag- nated. A third reference design, full scale SNAP-27 fuel capsule was subjected to a thermal pulse simulating a fire- ball/afterfire which may result from a launch pad abort. This fuel capsule was not pressurized with helium. The tests were performed at Sandia Corporation's Radiant Heat Facility (References 14-20 and 14-21).

The radiant heat lamp array was programmed to simulate the fuel capsule clad temperature for the earth orbital reference cast trajectories. Peak capsule clad temperatures experienced during the transients were 2000°F for the lateral spin case, and 2200°F for the side-on stagnated case. The fuel capsules were pressurized with helium to represent the buildup of helium during 2-1/2 years of fuel decay. The pressure used was compatible with 72 and 83 percent release of the amount of helium theoretically generated in 2-1/2 years for the lateral spin and side-on stagnated case, respectively.

During the lateral spin test the capsule helium pressure increased from 100 psia to 345 psia. No fuel capsule damage was observed as a result of the lateral spin temperature and pressure transient. The emissivity coating spilled off most of the cladding surface during the cooldown period.

During the side-on stagnated earth orbital re-entry test, the helium pressure increased from 116 psia to 412 psia when rupture occurred in the pressurizing system. Due to the low flow rate of the filter assemblies and the short time remaining in the temperature transient, it was concluded that the forward capsule half pressure reached about 463 psia at the time of the rupture. The forward half capsule ruptured axially along the peak temperature stagnation line and circumfrentially at the cladding closure weld on both sides of the axial failure (see Figures 14-6 and 14-7). Close visual inspection of the capsule midsection weld indicated a circumferential hairline crack. Emissivity coating spalled off during cooldown. It was concluded that:

1. The capsule midsection and half-capsule cladding ruptured at approximately the temperature, pressure and time predicted by analysis.

2. Although capsule cladding rupture occurred, the liner remained intact and thus contained the fuel simulant.

3. The forward capsule cladding half and midsection ruptures were not particularly violent and thus capsule damage was not severe.

The fireball/afterfire pad abort test resulted in no fuel capsule damage. It was estimated that the fuel capsule internal helium pressure increased from 14.7 to about 70 psia during the temperature transient. The emissivity coating flaked off.

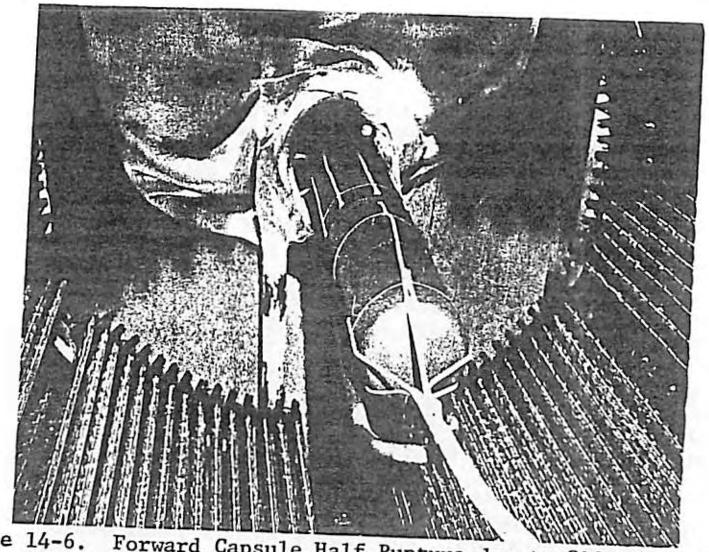


Figure 14-6. Forward Capsule Half Rupture due to Side-on Stabilized Re-entry Test.

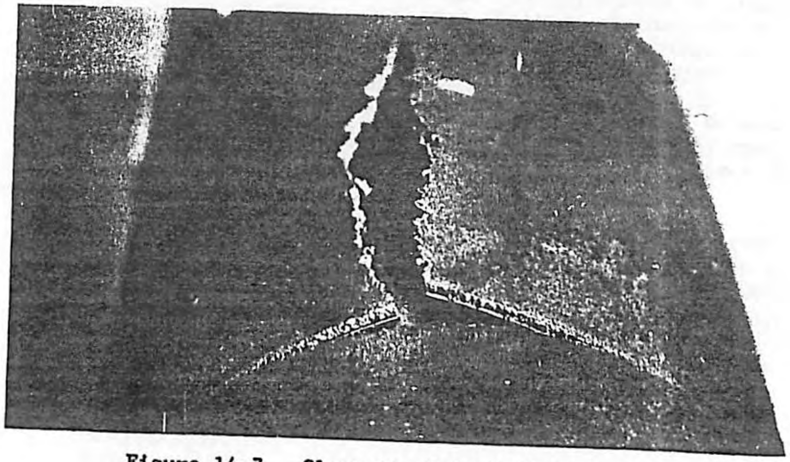


Figure 14-7. Close-up of RG-2 Cladding Failure

k. Fuel Particle Re-entry and Particle Heating - Although the SNAP-27 fuel capsule is designed for intact re-entry, there is a remote possibility that the fuel capsule may fail and release fuel particles during re-entry at high velocity to the atmosphere. The response of $^{238}PuO_2$ microspheres during re-entry from orbit involves heating, melting, and possible size degradation. Experiments were performed on $^{238}PuO_2$ microspheres to determine their response to the re-entry environment in a 40 kw hyperthermal arc tunnel (References 14-22 and 14-23). Results of these tests verified analyses which defined the conditions of altitude and velocity for which the microspheres begin to melt.

When changes were subsequently made in the fuel cask requirements to incorporate superorbital re-entry capability, a new fuel cask design (Graphite LM Fuel Cask - GLFC) was required. The Safety Test Program of Reference 14-13 was extended to provide additional test data to determine the response of the GLFC to blast and fragmentation from a launch vehicle explosion and that of earth impact following abort re-entry.

14.4.1 GLFC RESPONSE TO BLAST

A GLFC blast test was conducted at Sandia Corporation to determine the response of the GLFC to a launch vehicle explosion. The test specimen consisted of an as-built Bendix mounting structure and thermal shield. An electrical heater inserted into the fuel capsule from the backplate end was used to preheat the capsule and GLFC/to about 1200 and 400°F, respectively, before the blast. Twenty-nine pounds of C-4 explosive were loaded into one end of a schedule 80, two-foot diameters, 50-foot long, shock tube. At the other end of the shock tube, the GLFC was mounted at an angle of 13 degrees with the axis of the shock tube to represent the orientation for a launch vehicle explosion. Test details are given in Reference 14-33.

The blast static pressure near the forward end of the GLFC was measured to be 680 psig with an impulse of 2.7 psi-sec. The stagnation pressure gage indicated a pressure of about 2900 psi with an impulse of 4.4 psi-sec. Complete demolition of the graphite barrel of the GLFC occurred as evidenced by the small fragments found. The GLFC secondary heat shield (SHS) containing the fuel capsule assembly (FCA) was found at a distance of 750 feet from the end of the shock tube (Figure 14-8). The test demonstrated that the SHS and FCA as a unit can withstand the overpressure and impulse associated with a probable maximum yield (30 percent TNT equivalent) explosion of the S-IVB stage. Although slight damage was sustained by the SHS/FCA structure, it was not sufficient to cause loss of integrity of the fuel capsule.

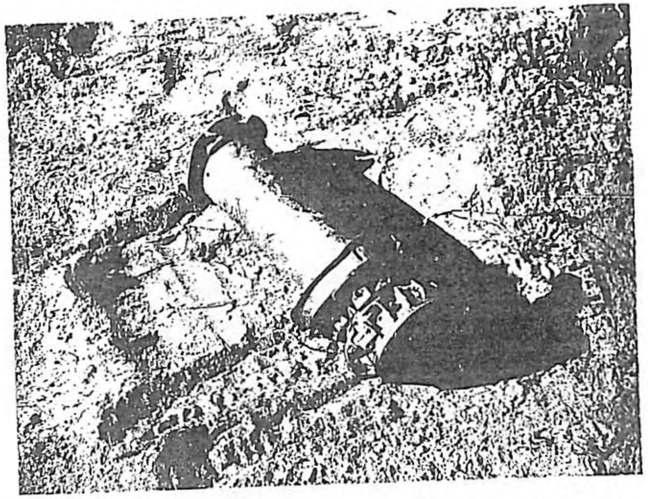


Figure 14-8. Alternate View of SHS/Capsule After Test

Even if the latch ring were to come loose as observed in the test (this event would not be expected), exposure of the SHS/FCA assembly to the fireball would not result in loss of fuel from the capsule. The fuel liner does not extend into the portion of the capsule that would be exposed. In addition, the liner is protected by other internal parts of the capsule. The fireball would have lifted before these parts could all be melted to expose the liners.

14.4.2 GLFC RESPONSE TO FRAGMENTS

The purpose of the fragmentation test program was to produce perforation definition as a function of fragment velocity and size. The objectives of the tests included the determination of perforation velocity for fragments impacting the titanium heat shield and the Haynes-25 capsule representative of hits on the end of the cask and for fragments impacting the beryllium heat shield and Haynes-25 capsule representative of hits on the side of the cask. All tests were conducted with the materials at temperatures equivalent to those in the GLFC while mounted on the launch vehicle. Test details are given in Reference 14-34.

The tests were conducted using the sled test facility at Sandia

Corporation (see Figure 14-9). Test specimens representative of the end of the SHS and FCA were rigidly mounted on a sled and propelled into fragments loosely suspended over the sled track and oriented both edge-on and flat-on to the direction of travel of the specimens.

Table 14-4 presents a brief summary of the test results. As observed, only at the highest velocity tested is there damage to the capsule (from an end-on impact) severe enough to cause fuel leakage, and then only from edge-on fragments. Lower velocities with both edge-on and flat-on fragments results in damage to the secondary thermal shield (titanium thermal cover, end-on impacts), but these are not considered to be severe enough to result in release of fuel from secondary effects such as a fireball or firestream environment. Damage to the beryllium cylinder of the SHS can occur at lower velocities as evidenced by the results of Test No. 5 for flat fragments directed at the side of the GLFC. Unless the GLFC gest knocked off the mount by the shock wave and turned so that its side is toward the direction of travel of the fragments, there will be no direct side-on hits.

14.4.3 GLFC DROP TEST

Five SNAP-27 dummy GLFC's and one as-built GLFC with fuel capsule were drop-tested at the AEC Tonapah Test Site. The primary test objective was to determine whether the GLFC/FCA will be damaged to the extent that the fuel capsule will be breached and fuel will be released as a result of the impact. The secondary objectives were to determine if the subsonic flight characteristics were such that the assembly would assume a particular orientation. Test details are reported in Reference 14-35 and 14-36.

Before the drop, the GLFC/FCA were preheated to simulate re-entry heating conditions (fuel capsule at 1890°F at time of release). The GLFC/FCA was dropped at an altitude of 16,300 feet with an impact point elevation of 5,300 feet. The GLFC impacted on a dry lake bed surface at a velocity of 295 fps. Post impact examination of the test assembly revealed delamination of the graphite cylinder and cracking of the beryllium SHS with no breaching of the fuel liners. Figures 14-10 and 14-11 indicate the GLFC components after the earth impact test. There was a crack at the midsection weld and the thined down collar between aft half capsule and the backplate flange. There was no release of the fuel simulant. The test demonstrated that the fuel capsule can maintain its integrity on impact with a relatively hard surface following re-entry.

The drop tests of the dummy GLFC's indicated that the impact velocities were in the range of 300 to 350 fps at the test range altitude (5300 feet). The test assemblies did not assume any particular orientation, but enter a planar tubling mode. Thus, the GLFC/FCA has an equal probability of impacting at any impact angle.

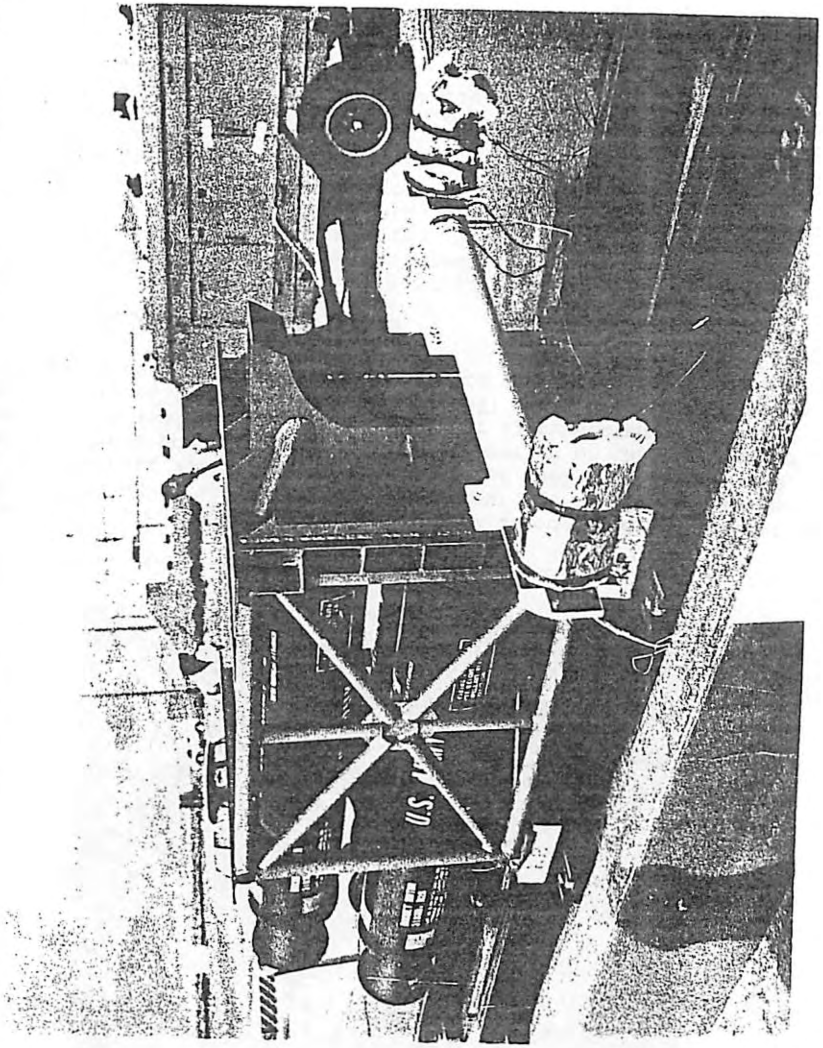


Figure 14-9. Sled Test Facility

TABLE 14-4. SUMMARY OF TEST RESULTS

TEST NO.	TEST UNIT	SPECIMEN	FRAGMENT ORIENTATION	VELOCITY FPS	RESULTS
1	A	End-on	Edge-on	1045	Ti cover and capsule end dented.
	B	End-on	Flat-on	1045	Slight depression of Ti cover.
2	A	End-on	Edge-on	1900	Ti cover cut; hairline cracks in capsule clad and liner; no fuel leakage.
	B	End-on	Flat-on	1900	Ti cover sprung slightly.
3	-	End-on w/graphite and Bx plate	Edge-on	1830	Ti cover and capsule dented; hairline crack in clad; no fuel leakage.
4	-	Side-on	Edge-on	975	No damage.
5	-	Side-on	Flat-on	1040	Be cylinder cracked in several places; no capsule damage
6	-	End-on	Flat-on	3200	Sled and specimen demolished; Ti cover apparently intact.
7	-	End-on w/graphite	Edge-on	1815	Ti cover dented but not cut; capsule dented but not breached.
8	-	End-on w/graphite	Edge-on	2800	Capsule clad and liner severely cut; excessive fuel leakage.
9	-	End-on w/graphite and 2.5 inch Bx plate	Flat-on	2800	Ti cover dented and sprung; capsule slightly dented, but not breached.

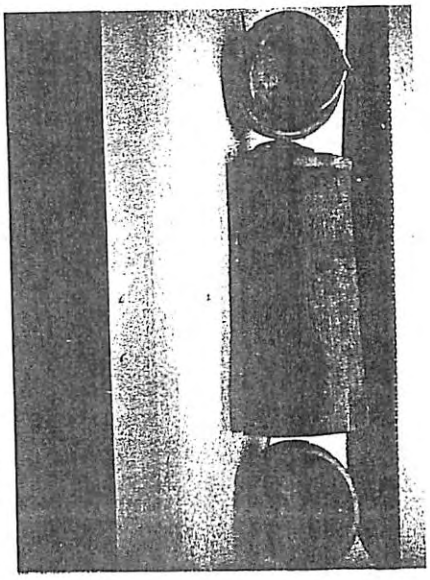


Figure 14-10. Graphite Parts of GLFC After Test

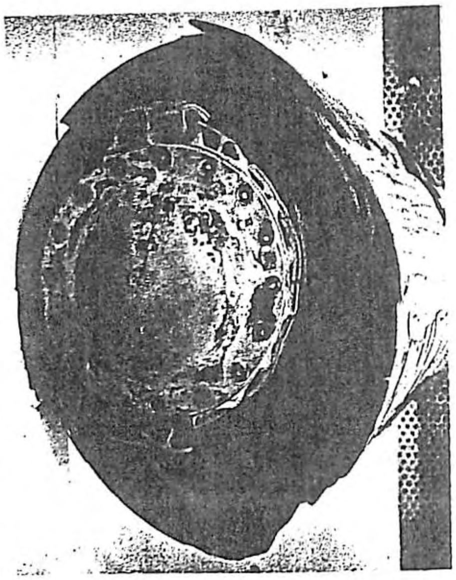


Figure 14-11. View of Forward End of SHS Before Disassembly

14.5 OPERATIONAL SAFETY

In order to receive and test SNAP-27 fuel capsules at GE/VFSTC, a comprehensive nuclear safety capability was established which involved specially trained personnel, complete health physics coverage, approved detailed test procedures, and facilities and equipment to ensure maximum radiological safety. The operational safety program complied with all safety requirements specified by the AEC/ALO Operational Safety Division. Pursuant to the provisions contained in AEC regulations (Reference 14-8), the AEC General Manager exempted SNAP-27 operations at GE/VFSTC from Special Nuclear Material licensing and instead designated that AEC/ALO Operational Safety Division radiation safety requirements be enforced during the contract (Reference 14-9). The essential facets of the operational safety program are briefly described as follows:

14.5.1 RADIOLOGICAL PROTECTION PROGRAM

The Radiological Protection Program was established to minimize radiation exposure to personnel involved with handling and conducting measurements in the vicinity of the SNAP-27 fuel capsule. This program (Reference 14-10) was utilized to inform test personnel concerning radiological safety. An important section of this document presents detailed emergency procedures, to indicate the action to be taken in the event of an accident and to provide guidance for emergency exposure and contamination conditions.

14.5.2 TEST PROCEDURES

Detailed test procedures were prepared to carefully control and implement test operations utilizing a SNAP-27 fuel capsule. Safety review and approval of these procedures was by GE Nuclear Safety and Health Physics before submittal to AEC/ALO for safety approval.

14.5.3 TRAINING

The most significant factor responsible for safe testing with SNAP-27 fuel capsules was proper training of all personnel involved in the rest operations. Two essential parts of the training program were a radiological safety course and on-the-job training. The Health Physicist presented lectures on basic radiation physics, health physics concepts and instrumentation, plutonium radiological properties, biological effects of radiation, and radiation protection program (normal and emergency procedures).

The on-the-job training consisted of conducting dry-runs of each test before handling of a SNAP-27 FCA. All test personnel participated in an actual step-by-step walkthrough of the procedures utilizing all test

hardware to be used in the actual test with the exception of a dummy fuel capsule being substituted for the FCA.

14.5.4 FACILITIES AND EQUIPMENT

New test facilities were provided and existing facilities modified to ensure maximum radiological safety during the SNAP-27 fuel capsule test program at GE. Safeguards were required to prevent the occurrence of an accident and to minimize the consequence of an accident should it occur. All test facilities and safety equipment were reviewed and approved by the AEC/ALO Operational Safety Division.

14.5.5 HEALTH PHYSICS

During receipt, storage, handling and shipping of all SNAP-27 fuel capsules, the GE health physics organization maintained surveillance over all operations of a radiological nature in accordance with the requirements of AEC/ALO Operational Safety Division. The SNAP-27 fuel capsule integrity was checked at appropriate times by airborne alpha and plutonium activity monitoring and by alpha counting of surface wipe samples obtained from surfaces in contact or in the vicinity of a fuel capsule.

14.6 FINNED BODY RE-ENTRY STUDIES

Because the SNAP-27 system was designed for separate shipment of the fuel capsule in the ALSEP mission, the generator assembly itself was not required to function as a fuel capsule re-entry vehicle. For possible applications of the SNAP-27 RTG to future missions where separate fuel capsule shipment is not feasible, a finned body re-entry study was performed. A detailed task description is reported in Reference 14-37. This study included analytical and experimental work required to develop design tools for treatment of the complex aerodynamic heating and stability problems inherent with finned body re-entry.

An accurate analysis of the response of fueled intact radioisotope generators during atmospheric entry was required in order to provide high reliability assurance for safety purposes. For the control of thermal waste heat, the design of these generators generally takes the form of a finned cylinder. The flow phenomena for a finned cylinder are generically defined as protuberance interaction and corner flow phenomena. Their importance stems from the generation of a secondary flow field about the cylindrical centerbody with a resultant shock-boundary layer interaction which induces a localized, high heat transfer rate on the centerbody. In addition, corner flow phenomena (the merging of the boundary layer formed on the fin and body) occur which gives rise to aggravated local heating effects.

Additional phenomena which are of greater significance to those configurations, are those associated with the large portion of the trajectory which is spent at high attitude in low density flow, and the random, high effective angle of attack attitude associated with a non-directed entry. Because of configuration complexity, semi-empirical techniques, (data correlations), are most frequently used to predict the aerothermodynamic environment. However, these required extensive testing over a very wide range of angle of attack, Reynolds number, and Mach number, because one does not usually obtain the type information which will sufficiently general to apply to new configurations design, in which design optimization techniques are utilized, the latter type of approach should be reserved for prototype testing. Consequently, because the past effort devoted to this new type geometry has been very small, a program of applied research was carried out, which was specifically directed at developing an understanding of the very complex local flow fields associated with finned-cylindrical geometries in a hypersonic re-entry environment. The research program performed was based upon the following essential phases:

a. Theoretical Studies

   1. Supersonic Laminar Separation on a Forward Facing Wall

   2. Study of Hypersonic Flows Associated with Leading Edges

   3. Hypersonic Boundary Layer Corner Flow

   4. Material Response - A Study of Condensed Phase Behavior

   5. Shock Wave - Boundary Layer Interaction

b. Correlation of Theoretical Studies and Experimental Data

c. Experimental Studies

   1. Arc Wind Tunnel Experiments

   2. Shock Tunnel Experiments

The finned body re-entry program was initiated on April 1, 1966, and was completed in September 1967. The results of the study are reported in References 14-38, 14-39, 14-40 and 14-41.

14.7 SNAP-27 FUEL CAPSULES RADIATION MEASUREMENTS BY MOUND LABORATORIES

The dose rates for both the neutron and gamma emission on all SNAP-27 fuel capsules were measured by Mound Laboratory before shipment to GE

Vallecitos Laboratory for application of emissive coating and ultrasonic testing of the closure welds. One of the capsules, SN 633002, was subsequently returned to Mound Laboratory for additional radiation measurements when installed in a SNAP-27 generator.

14.7.1 DOSE RATE DATA

Detailed neutron and gamma dose rate measurements from the side, forward end and flanged end of the first three fuel capsule assemblies are presented in Table 14-5. Dose rates are shown as a function of distance from the center of the fuel capsule assembly. The dose rate for all seven SNAP-27 fuel capsule assemblies at 1 meter from the center are summarized in Table 14-6. The higher neutron dose rate for Fuel Capsule No. 7 is not explained. The fuel used in this capsule was essentially all recovered from the Fuel Capsule No. 3.

Additional data on dose rates from Capsule No. 2 in the SNAP-27 generator are given in Table 14-7 and are compared there with the dose rates from the bare capsule. The values for the neutron dose rates reported for the side-on view of the assembly are consistent with expected values. The neutron dose rates reported for the two end views of the assembly are anomalous since they exceed the rates reported for the same views with the capsule bare. No explanation for this anomaly has been determined. It should be noted, however, that the values reported are given in mrem and thus include the RBE factor of ten (10). This translates into a measurement of a very low total neutron flux in which counting statistics can easily bias the results.

14.7.2 NEUTRON SPECTRA

The neutron energy spectra for SNAP-27 Fuel Capsule Assemblies No. 1 and 2 are presented in Figures 14-12 and 14-13, respectively. The more complete resolution of the spectrum below 2 Mev shown in Figure 14-13 is accounted for by Mound Laboratory's use of a revised computer program applied to the measurements on Fuel Capsule Assembly No.2.

The effect of the SNAP-27 Generator Assembly on the neutron spectrum (fueled with Fuel Capsule Assembly No. 2) is shown in Figure 14-14. The most notable aspect of this curve being a flattening of the $(\alpha, n)^{18}O$ reaction peak at 2.3 Mev.

14.7.3 GAMMA SPECTRUM

The gamma spectrum has been measured for SNAP-27 Fuel Capsule Assembly No. 1 only and the results are shown in Figures 14-15 and 14-16. The 67 Kev peak is probably Am^{241} (60 Kev) produced by the beta decay of Pu^{241}. The remaining peaks at 100, 150, 205, 506 and 765 Kev are

TABLE 14-5. SNAP-27 FUEL CAPSULE ASSEMBLY DOSE RATE MEASUREMENTS

(SNAP-27 Fuel Capsule Assembly Dose Rates - mrem/hr)									
Distance from Center of Fuel Capsule to Center of Detector-cm	Fuel Capsule No. 1 (Ref. 14-25)			Fuel Capsule No. 2 (Ref. 14-26)			Fuel Capsule No. 3 (Ref. 14-27)		
	neutron	gamma	total	neutron	gamma	total	neutron	gamma	total
SIDE									
20	1,604	150	1,754	1,688	165	1,853	1,800	160	1,960
25	1,089	115	1,204	1,132	120	1,252	1,237	120	1,357
40	476	48	524	490	52	542	536	36	572
50	306	29	335	319	33	352	358	23	381
100	86	6	92	93	8	101	101	5.3	106
200	27	2	29	29	2	31	31	1.5	33
FORWARD END									
40	364	20	384	346	15	361	480	15.0	495
50	194	8.5	202	189	7.1	196	250	8.0	258
60	125	4	129	120	4.1	124	157	4.1	161
100	45	1	46	42	1.4	43	52	1.3	53
120	32	0.8	33	31	1.2	32	37	0.9	38
200	12	0.4	12	15	0.5	16	17	0.4	17
FLANGED END									
40	250	9	259	334	15	349	305	8.0	313
50	132	4.5	137	172	6.6	179	164	3.5	168
60	85	2.5	88	109	4.4	113	105	2.3	107
100	32	0.9	33	38	1.6	40	37	0.8	38
120	23	0.6	24	29	1	30	28	0.5	29
200	10	0.3	10	14	0.6	15	14	0.3	14

TABLE 14-6. SNAP-27 FUEL CAPSULE DOSE RATE DATA

CAPSULE DESIGNATION (NO.)	REF.	DOSE RATE AT 1 METER FROM CENTER		
		neutron/mrem/hr	gamma-mrem/hr	total mrem/hr
1 - First Flight	25	86	6	92
2 - First Flight Backup	26	93	8	101
3 - Cut apart - fuel re-used in Capsule 7	27	101	5.3	106
4 - Qualification	28	99	7.1	106
5 - Fourth Flight	29	82	4.7	87
6 - Third Flight	30	81	5.5	87
7 - Second Flight	31	130	7.5	138

TABLE 14-7. COMPARISON OF DOSE RATE MEASUREMENTS FROM FUEL CAPSULE NO. 2 AND FUELED GENERATOR ASSEMBLY (REFERENCE 32)

Distance from Center of Generator/Source to Center of Detector - Centimeters	Neutron Mrem/Hr		Gamma Mrem/Hr		Total Mrem/Hr	
	Bare	In Gen	Bare	In Gen	Bare	In Gen
SIDE						
40	490	497	52	23	542	520
50	319	319	33	14	352	333
100	93	90	8	3	101	93
200	29	28	2	0.8	31	28.8
FORWARD END						
40	346	450	15	11	361	461
50	189	245	7.1	5.2	196.1	250.2
60	120	115.7	4.1	3.1	124.1	160.1
100	42	52	1.4	1.0	43.3	53.0
120	31	38	1.2	0.6	32.2	38.6
200	15	15.9	0.5	0.3	15.5	16.2
FLANGED END						
40	334	432	15	12	349	444
50	172	244	6.6	5.5	178.6	249.5
60	109	158	4.4	3.5	113.4	161.5
100	38	52	1.6	1.0	39.6	53.6
120	29	38	1.0	0.7	30.0	38.7
200	14	16	0.6	0.3	14.6	16.3

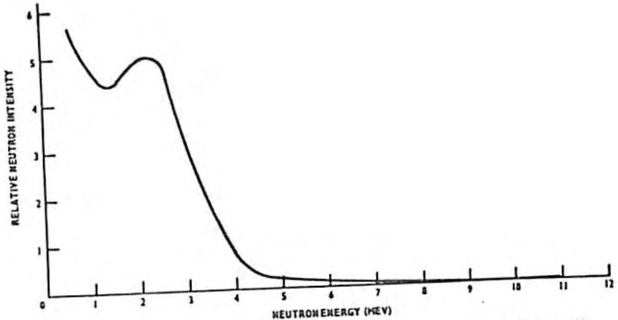


Figure 14-12. Neutron Energy Spectrum SNAP-27 Fuel Capsule No. 1 (Reference 25)

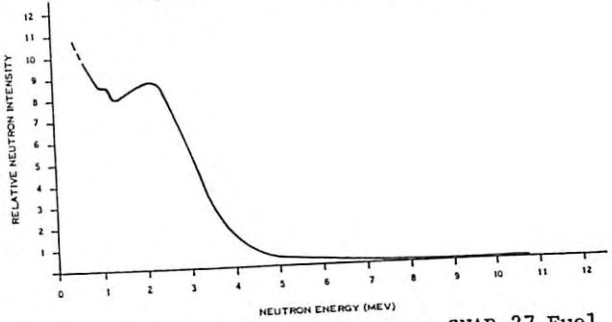


Figure 14-13. Neutron Energy Spectrum SNAP-27 Fuel Capsule No. 2 (Reference 32)

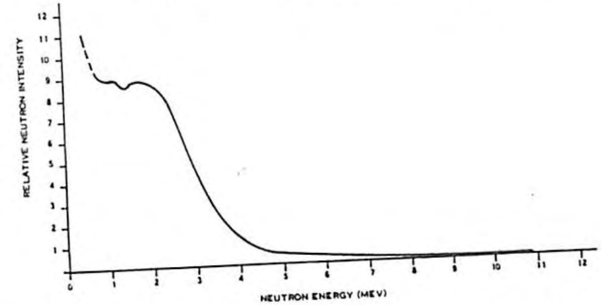


Figure 14-14. Neutron Energy Spectrum SNAP-27 Fuel Capsule No. 2 in Generator Assembly (Reference 32)

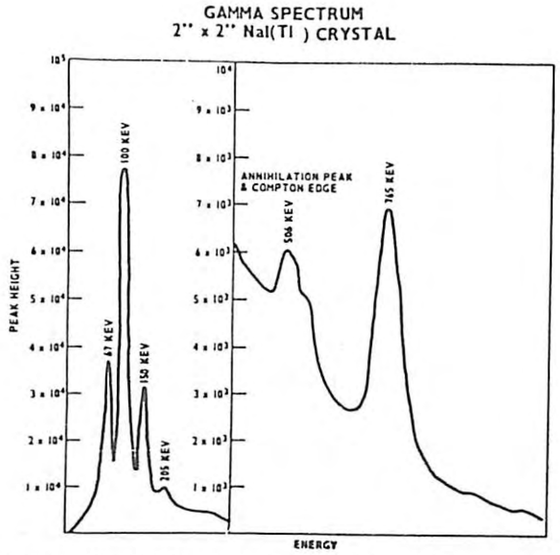


Figure 14-15. SNAP-27 Fuel Capsule No. 1 Gamma Spectrum, Low Energy (Reference 25)

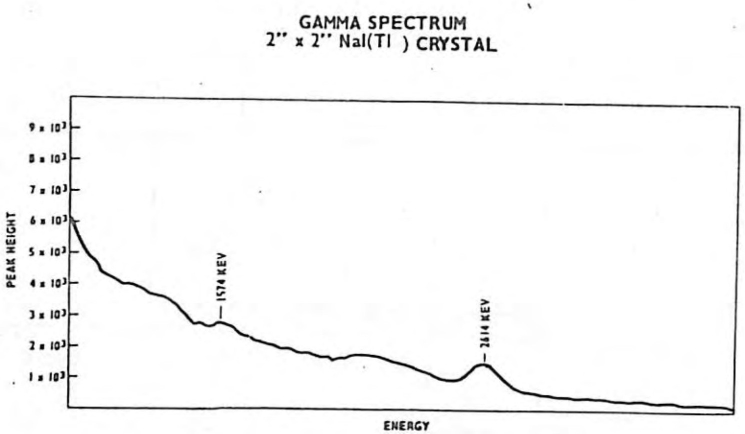


Figure 14-16. SNAP-27 Fuel Capsule No. 1 Gamma Spectrum, High Energy (Reference 25)

associated with the various alpha energies of Pu^{238} decay. The peaks of 1.574 Mev and 2.6.4 Mev are ascribed to the Bi^{212} and Tl^{208} decay products of Pu^{236}, respectively.

14.7.4 DOSE RATE INSTRUMENTATION

14.7.4.1 Gamma

A Victoreen Radector II beta/gamma survey meter was used for measuring the gamma dose rate. Note: the manufacturer stated that the instrument was linear in response for gamma ray energies from 80 Kev to 1.2 Mev. The majority of the gamma dose is expected to be contributed by the 765 Kev gamma rays generated by the fuel. Because this energy is close to the effective energy of the Radium-226 source used for calibrating the meter, the gamma dose rates were therefore measured with an accuracy of at least ± 20 percent with this meter.

14.7.4.2 Neutron

The neutron dose rate was measured with a Texas Nuclear Spherical Nemo Dosimeter, Series 9145. This instrument was calibrated with a $^{238}PuO_2$ neutron source and is expected to have an accuracy of ± 20 percent for neutrons ranging from the thermal energy up to 7 Mev. The gamma and neutron dose rates are added to give the total dose rate.

14.7.4.3 Neutron Emission Rate

The neutron emission rate was measured using a precision long counter as described in Reference 14-24. All neutrons above the thermal level escaping from the bare capsule or whatever enclosure it may be in are seen. The percentage of neutrons produced by SNAP-27 fuel with energies above 6 Mev is small. However, all energies above thermal are measured. The accuracy of the neutron emission rate measurement is expected to be ± 7 percent.

14.7.5 SPECTRA INSTRUMENTATION

14.7.5.1 Gamma

The gamma spectrum is determined using either a 3-inch diameter by 3-inch high or 2-inch diameter by 3-inch high NaI(TI) scintillation detector. The signal is fed to a multichannel analyzer. The spectrum is measured in two separate energy ranges. One range covers energies from about 50 to 900 Kev and the other from about 50 Kev to 3 Mev. The system is energy calibrated with a series of sources having well known gamma-ray energies. The accuracy of the measurement is expected to be ± 10 - 15 Kev and the energy resolution to be about eight percent on the C_s^{137} 0.661 Kev line. Neutrons from the source are not expected to interfere with the accuracy of the measurements.

14.7.5.2 Neutron

The neutron spectrum is determined in an energy range from 0.75 to 10 Mev. A single stilbene crystal fast neutron spectrometer incorporates space charge limitation at the 14th dynode of the photomultiplier tube to discriminate against gamma pulses resulting from gamma interactions in the crystal. The data from the spectrometer is recorded by a 400 channel analyzer.

The energy accuracy of the measurements is about $\pm$ 0.1 Mev at the 1 Mev level and progressively changes to about $\pm$ 0.25 Mev at the 10 Mev level. The relative intensity accuracy varies from about $\pm$ 10 percent in the 1-4 Mev range to about $\pm$ 25 percent at the 10 Mev level.

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15. LAUNCH OPERATIONS PLANNING

eneral Electric's involvement in launch planning began with the ALSEP
SC working group meeting on September 8, 1966, at which time GE was
equested to provide design and performance information relating to
uel capsule handling. As a result of the October 3-4, 1966, KSC meet-
ng, it became evident that special fuel capsule handling equipment
ould be required for bringing the fuel capsule on board the space
ehicle and for its installation into the graphite LM fuel cask.

In addition, the subject of a more active role for GE with regard to planning, checkout and actual loading of the fuel capsule on board the space vehicle had been suggested by AEC/Sandia, but never officially imposed upon GE as a requirement. At the ALSEP working group meeting on October 3-4, 1967, the AEC officially committed GE to the role of a participant in KSC operations which related directly to the fuel capsule handling and checkout of the SNAP-27 hardware.

15.1 KSC PRELAUNCH SUPPORT (TASK 12.0)

Under supplementary Task 12.0 to the SNAP-27 Program, GE was directed to:

a. Provide technical support for:

   1. Planning, preparation, conduct and on-site data analysis of prelaunch inspections and tests on SNAP-27 end-items (on an individual basis and as part of the ALSEP system).

   2. Planning and preparation for the operational phase of the Apollo Program

   3. Review of all operational procedures applicable to SNAP-27 end-items from a technical and safety standpoint

   4. Preparation of procedures covering practice loadings of the fuel capsule and GLFC and the surveillance of these loadings

b. Prepare a comprehensive SNAP-27 operating manual covering all end items.

As a part of the support effort, General Electric participated in a number of walk-throughs at KSC using the Grumman SLA/LM mock-up to wring out the loading and unloading procedures which were prepared by GE, and to uncover any unanticipated problem areas.

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As a result of a request from KSC Operational Safety, a test was run by GE to demonstrate that no potentially hazardous conditions would exist in the SLA as a result of the fuel capsule accidentally coming into brief contact with different materials which are present in the SLA during the capsule prelaunch loading operation. The materials specimens tested consisted of samples of the following:

a. Inconel sheet
b. Kapton insulation (gold side)
c. Kapton insulation (silver side)
d. Gloves worn by capsule loader
e. Coveralls worn by capsule loader.

The test was performed by briefly placing in contact with each of these specimens an electric fuel capsule simulator energized with 1500 watts, following its removal from a simulated GLFC. Stabilization within this container increased the surface temperature of the EFCS to that representative of a fueled capsule removed from the GLFC in an emergency during pre-launch. Smoking and melting were found to be the most extreme effects. No flaming was experienced.

Due to the protracted and uncertain schedule for the Apollo flights, the support task was subsequently terminated by the AEC on July 1968. Sandia was given responsibility for loading the fuel capsules.

15.2 FUEL CAPSULE SUPPORT EQUIPMENT (TASK 13.0)

Under supplementary Task 13.0 to the SNAP-27 Program, GE was directed o design, develop and provide the following end-items to be used at SC for handling and loading of the fuel capsule in the space vehicle:

a. SLA Transfer Cask
b. SLA Handling Tool
c. Port Entry Trough
d. Inspection Tool
e. Wrist Tether

Descriptions of these items appear in preceding Section 13. All required end-items were subsequently developed, tested and delivered to the AEC.

15.3 ASTRONAUT LUNAR DEPLOYMENT SIMULATION

An astronaut lunar deployment demonstration was performed at the General Electric Company by two Apollo astronauts at the completion of SNAP-27/ALSEP integrated testing. This demonstration was intended to permit the astronauts to go through a simulated lunar deployment sequence and to condition them phychologically to handling a real capsule, since their previous training was with mockups.

A LM mockup was fabricated and a GLFC/ALSEP Support Structure Assembly mounted into position on it. A counter balance system was utilized to provide the 1/6-g lunar gravity. The FCA was loaded into the cask and allowed to thermally stabilize. Astronauts Alan Bean and Don Lind both demonstrated their ability to transfer a nuclear fuel capsule from a GLFC into the generator assembly while wearing space suits similar to those used in lunar excursions. Operations were recorded on 35 mm film. The sequence is depicted in Figures 15-1 through 15-10.

15.4 GLFC SUPPORT SYSTEM (ALSEP SUPPLIED)

Listed below are the ALSEP elements which comprise the GLFC support system:

a. Support Structure
b. Thermal Shield
c. Astronaut guard
d. Cask release/rotation lanyard
e. Fuel Transfer Assembly Tool
f. Equipment compartment lanyard and astronaut door.

15.4.1 SUPPORT STRUCTURE

15.4.1.1 Description

This assembly supports the GLFC to the outside surface of the LM vehicle. It basically consists of:

a. Tension bands which contact the GLFC and provide attachment points

b. A truss to which the bands are attached and which transfers loads to the LM vehicle structure

c. A trunnion release mechanism and a tilt mechanism used to position the GLFC for capsule removal.

The structural support concept involves positive constraint through all axes using flexible metallic bands which are designed to apply positive pressure against the cask throughout the entire flight. The bands and support structure are made of titanium (6Al-4V alloy) except for the stainless steel rivets and bolts used in the band assembly.

Because the coefficient of thermal expansion for titanium is considerably greater than for the graphite shell of the GLFC, the bands are pretensioned to apply a compressive load when the assembly is at room temperature. Thus, the initial load is such that a positive pressure is maintained after the assembly comes up to normal operating temperatures and throughout the entire mission. Figure 15-11 shows the installation of the ALSEP Cask Assembly for the Astronaut Deployment Demonstration conducted at General Electric-Valley Forge on May 13, 1969.

Basically the mode of operation of the support structure is such that a trunnion release mechanism can be actuated on the upper cradle, thus allowing the entire ALSEP Cask Assembly (ACA) to pivot about the lower cradle mount. The pivoting of the ACA about the lower cradle mount is controlled by means of a gear box which is operated by the astronaut pulling on the lanyard.

The trunnion release mechanism on the upper cradle is a guillotine-type device which is actuated by the astronaut pulling a lever by means of the lanyard which allows a cutter to sever a pre-tensioned pin, thus freeing the trunnion. There is one of these release mechanism on each side of the upper cradle (total of 2) and these mechanisms are actuated in series by the astronaut continuing to pull the lanyard.

5.4.1.2 Bendix Support Structure Design Requirements

Design of the cask support structure reflects an interface with both the Grumman LM Structure (LID 360-2809) and the GE cask (ICS 314121 and ICD 2334552). The specifications used by Bendix were:

a. The weight of the cask and support structure shall not exceed 60 pounds. (The cask/fuel capsule weight was considered to be 40 pounds nominal.)

b. Equipment used by the astronaut during fuel transfer operations shall not exceed 250°F.

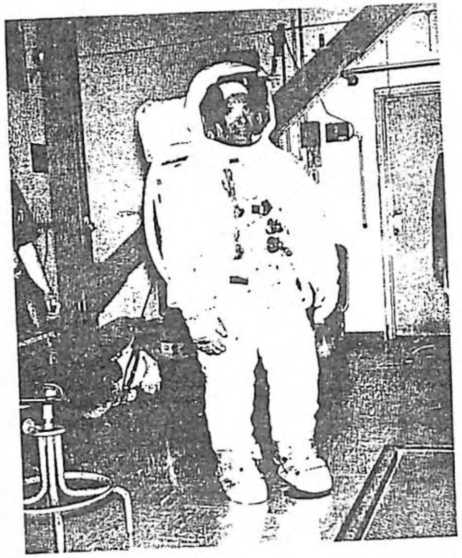

Figure 15-1. Astronaut Alan Bean Fully Suited and Ready to Begin Deployment Exercise

Figure 15-2. Astronaut Don Lind Fully Suited and Ready to Begin Deployment Exercise

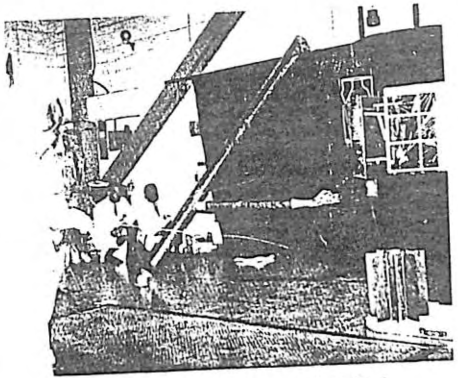

Figure 15-6. Astronaut Lind Pulling Lanyard to Lower ALSEP Cask Assembly

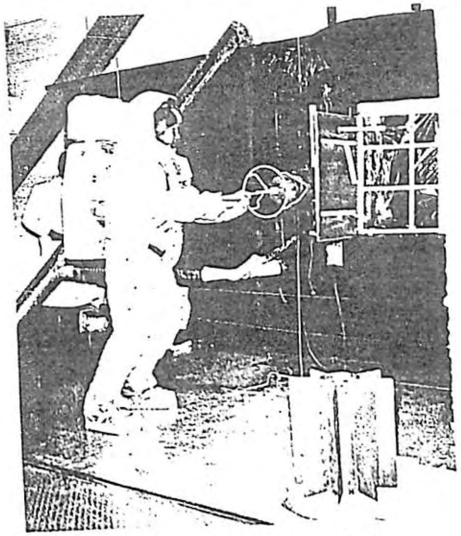

Figure 15-7. Astronaut Lind Removing Dome from Graphite Cask

Figure 15-3. Insertion of SNAP-27 Fuel Capsule into Graphite Cask in Preparation for Deployment

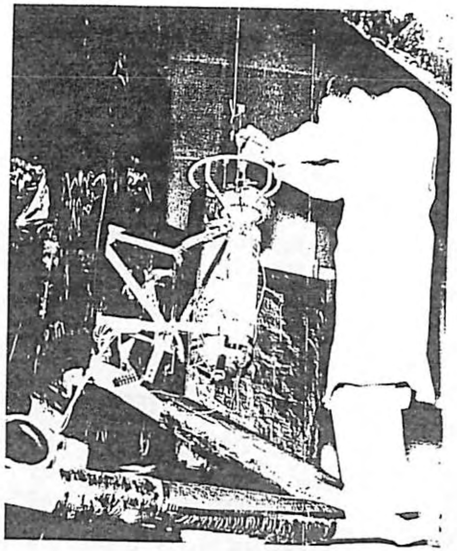

Figure 15-4. Installation of Graphite Dome after Insertion of Fuel Capsule

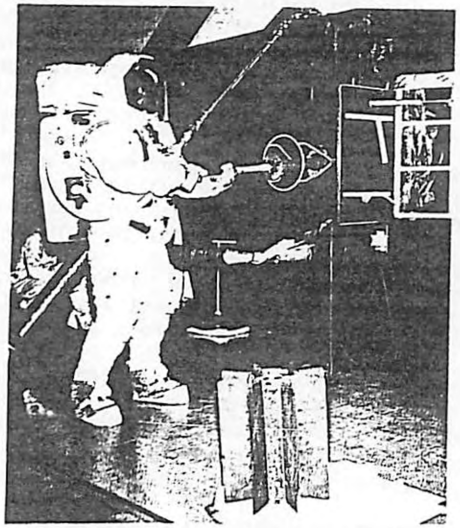

Figure 15-8. Astronaut Lind Removing Fuel Capsule from Graphite Cask

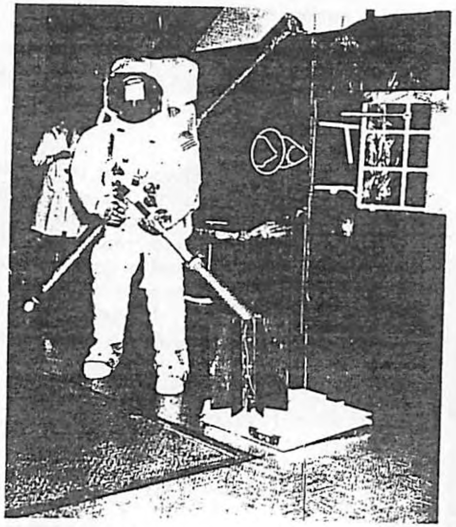

Figure 15-9. Astronaut Lind Begins Insertion of Fuel Capsule into SNAP-27 Generator

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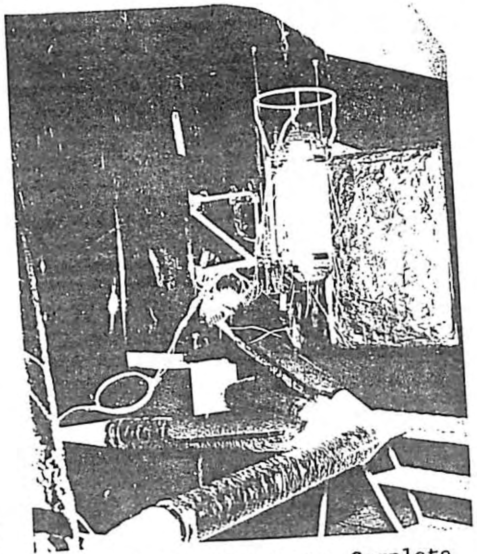

Figure 15-5. Test Setup Complete Showing Simulated LM Section with Grumman Struts, Bendix Structure Assembly and GE Graphite Cask

naut Lind Begins
Capsule into

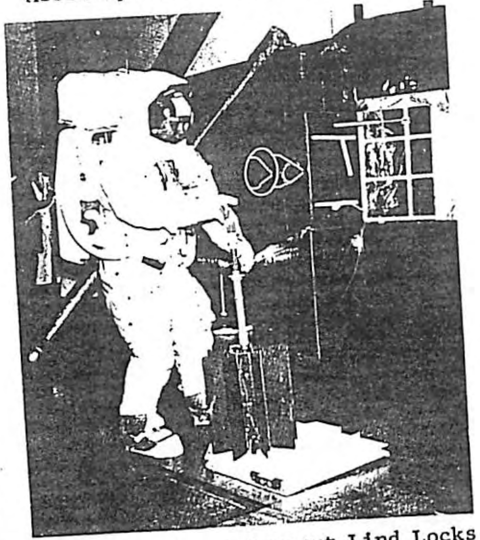

Figure 15-10. Astronaut Lind Locks Fuel Capsule into Position in the SNAP-27 Generator

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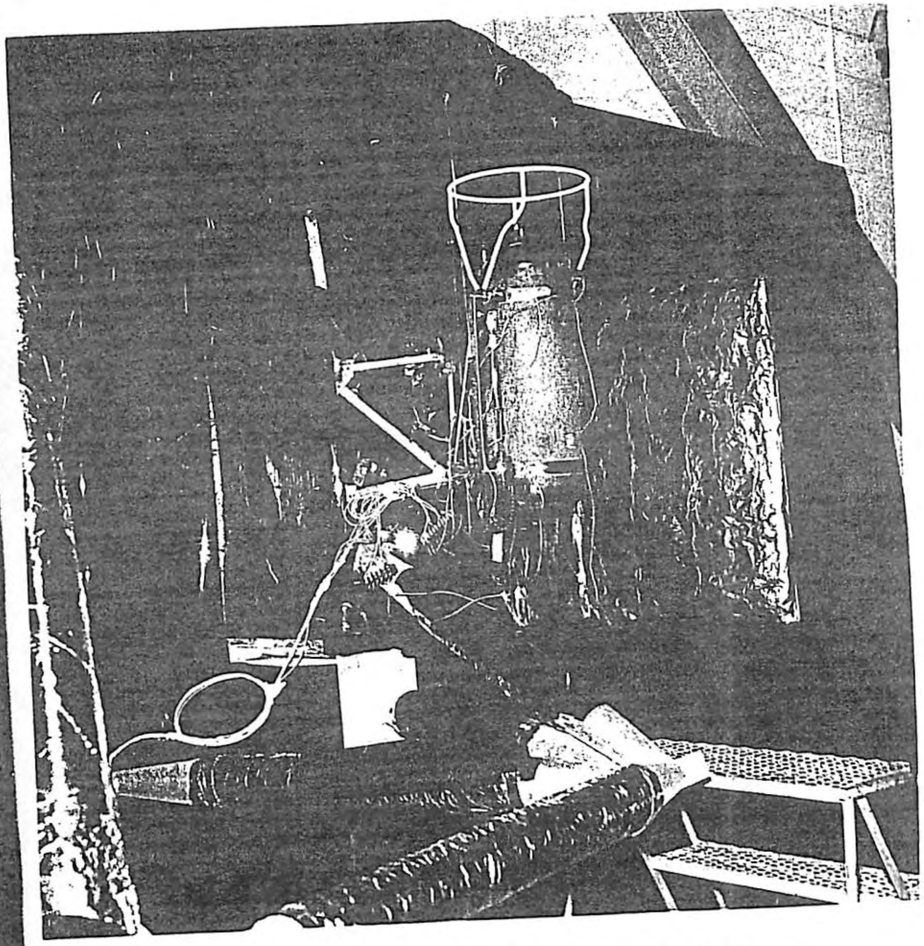


Figure 15-11. ALSEP Cask Assembly Installation on Simulated LM

c. Tools required by the astronaut for fuel transfer, apart from the FHT (less handle), will be designed and manufactured. The weight for such tools will not be included in the 60 pounds.

d. The maximum temperature on the surface of the cask shall not exceed 800°F, and circumferential gradients around the cask shall not exceed 150°F.

e. The principal dimensions of the cask shall be in accordance with ICD 2334552, and internal details will be as on GE drawing 47E301134 dated February 9, 1968. The provisions of the ICS 314121 shall apply. The center of gravity of the cask shall be 11.25 inches from the lower end of the cask and shall be on the x axis.

f. The maximum torque and force that the astronaut can apply are 80-inch-pound and 20 pounds, respectively.

g. The quasi-steady-state design load factor, in all three principal axes, is 60 g.

15.4.2 THERMAL SHIELD

The thermal shield protects sensitive portions of the LM against direct thermal radiation from the hot GLFC. It is composed of a curved 15-mil sheet of titanium (6Al-4V alloy) and a 1/2-inch thick insulation blanket. The installation blanket is fabricated of 1/2 mil Kapton sheets (aluminized on one side) which are attached to the reverse side of the titanium sheet. Titanium stiffeners are used in the insulation blanket and the support structure discussion cover the description of the thermal shield.

15.4.3 ASTRONAUT GUARD

The purpose of this guard is to prevent the astronaut from contacting the hot cask surface if he stumbles in a head-on approach. The maximum surface temperature of the exposed guard surfaces is less than 250°F, which is within the safety limitations of the suit and gloves. The guard is put in place (mounted to the support structure trunnions) during pre-launch operations, thus eliminating the need for the astronaut to mount the device on the lunar surface.

The top ring of the guard is made of aluminum. The remainder of the guard is made of 3/8-inch titanium tubing (wall thickness, 35 mil). The entire guard assembly weighs 16 ounces. This guard is shown in Figure 15-11.

15.4.4 CASK RELEASE AND ROTATION LANYARD

When the astronaut door is opened, another lanyard assembly is retrived by the astronaut to begin the fuel transfer operation. Through use of this lanyard assembly, the following operations can be performed remotely (from a distance ten feet in front of the cask):

a. Release of the cask for rotation by actuating the release mechanism on the upper cradle

b. Pulling the cask dome locking spline

c. Rotating the cask to the desired attitude.

The release pins and spline pulled in the aforementioned operations are permanently affixed to the lanyard to preclude unnecessary handling by the astronaut.

15.4.5 DOME REMOVAL TOOL

The Dome Removal Tool is used to release the axial band tension, unlock (rotate) the dome from cask body, remove the dome from cask, and carry the dome to a safe distance from the scene of operations where it is discarded.

Once engaged by the astronaut, the tool cannot be removed from the dome release mechanism. The overall length of 21-1/2 inches is intended to enable the astronaut to operate the mechanism at a safe distance from the hot cask.

15.4.6 FUEL TRANSFER ASSEMBLY TOOL

This tool is used by the astronaut on the lunar surface to remove the fuel capsule from the GLFC for insertion into the Generator Assembly which will be resting on the lunar surface. The Fuel Transfer Assembly Tool (FTAT) is an assembly comprised of the Tie Down Release Tool (TDRT), the Flight Handling Tool (FHT) supplied by SNAP-27 and a handle. The FHT is attached at the end of the hollow handle and the TDRT is then secured inside the handle. The handle includes a locking device to lock the FHT in the engaged position ensuring attachment to the fuel capsule during astronaut handling.

15.4.7 EQUIPMENT COMPARTMENT LANYARD AND ASTRONAUT DOOR

A remote lanyard arrangement is available for opening the experiment compartments and lowering the experiment packages to the lunar surface.

This arrangement eliminates the need for the astronaut to approach the cask area until he is ready to perform cask operations. When the experiment compartment door is opened, the astronaut protection door swings open, thereby protecting the astronaut from touching the cask from the right hand or experiment bay side. (The LM landing gear prohibits the astronaut from approaching the cask from the opposite side.)

15.5 GLFC AND FUEL CAPSULE OPERATIONAL DATA

15.5.1 TEMPERATURE DISTRIBUTIONS

Figure 15-12 and Table 15-1 show the locations and maximum temperature distributions on the GLFC and the fuel capsule during the two critical operational mission phases:

a. On the pad with cooling

b. In a vacuum representative of Earth orbit and translunar environment.

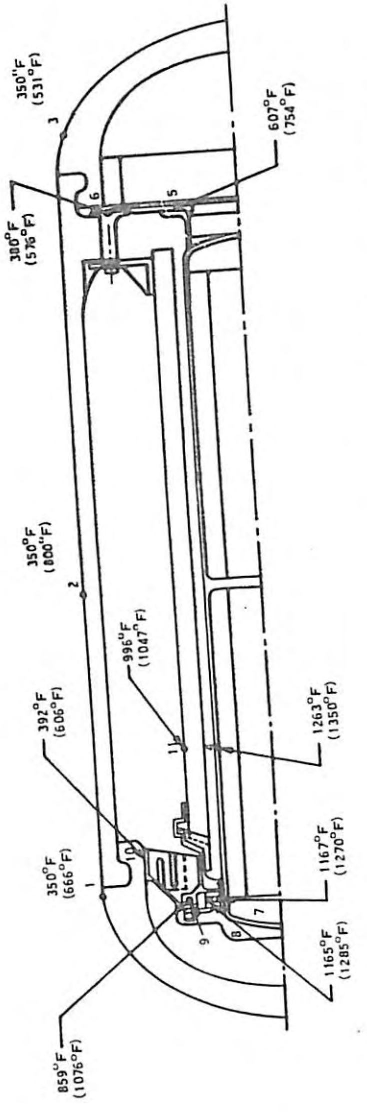
In the latter case, the GLFC is inside the spacecraft LM adaptor (SLA) which is the worst heating case.

Figure 15-13 shows the GLFC components temperature response after fuel capsule insertion in air without external cooling. No thermal shock is indicated in the analysis. Under normal conditions, cooling would be "on" before capsule insertion.

Table 15-2 summarizes the test results versus pretest predictions for the free convection cooling case obtained as part of the Bendix On-Pad Cask Cooling Test Program. For this ambient baseline test without active cooling, the maximum cask surface temperature recorded was 651°F with a 1309°F maximum EFCS temperature.

Table 15-3 shows test results for a nominal cask cooling flow rate (17.5 lb/min). Figure 15-14 shows the cask surface temperature rise after forced convection cooling is eliminated. The latter case simulates the temperature transient for the cask during launch.

As shown in Tables 15-4 and 15-5, cask surface temperatures were predicted to be approximately 725 ± 50° for all flight and lunar phases.



NOTE: UPPER VALUE IS MAXIMUM TEMPERATURE FOR ON-PAD COOLING CASE WHILE LOWER VALUE, I.E., NUMBERS IN PARENTHESES ( ), ARE MAXIMUM TEMPERATURES IN THE SLA, IN VACUUM.

Figure 15-12. GLFC Maximum Operational Temperatures

TABLE 15-1. GLFC MAXIMUM OPERATIONAL TEMPERATURES

LOCATION (See Figure 15-13)	MAXIMUM TEMPERATURE (°F)	
	AT AMBIENT COOLED ON THE PAD	INSIDE SLA IN VACUUM
1. Primary Shield Outer Surface Forware Cup	350	666
2. Cylinder	350	800
3. Aft Cap	350	531
4. Fuel Capsule Outer Cladding Near Forward Support	1263	1350
5. Backplate		
Capsule attach point	607	754
Latch Fitting attach point	502	638
6. Latch Fitting Body	380	576
Forward Capsule Support Guide Ring		
7. Inner Radius	1167	1270
8. Outer Radius	1165	1285
Forward Capsule Support Housing		
9. Inner Radius	859	1076
10. Outer Radius	392	606
11. Secondary Thermal Shield	996	1047

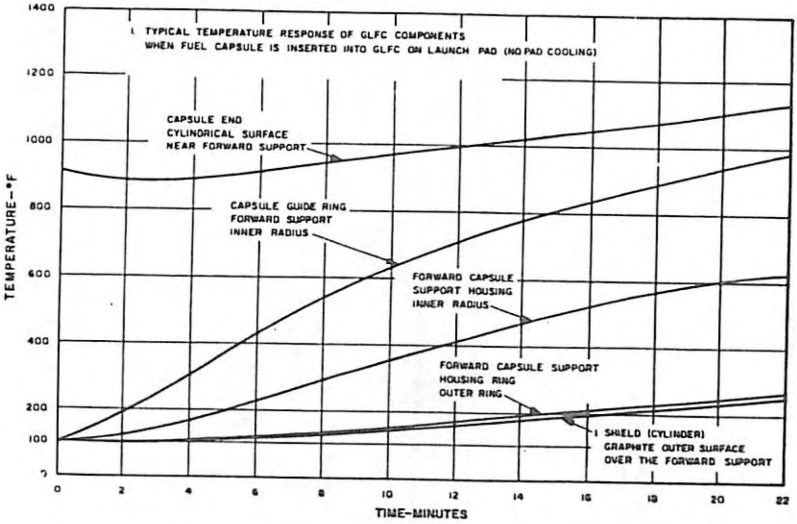


Figure 15-13. Typical Temperature Response of GLFC Components When Capsule is Inserted into GLFC in Air (No Cooling Applied)

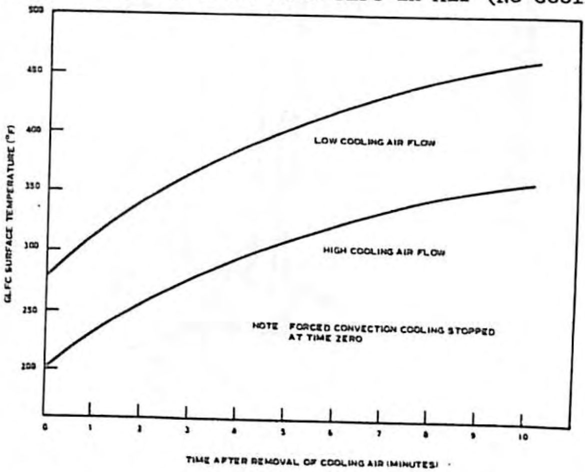


Figure 15-14. GLFC Surface Temperature Warmup

TABLE 15-2. FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS ON-PAD WITH FREE CONNECTION

SURFACE DESCRIPTION	TEST RESULTS (°F)		PRE-TEST PREDICTIONS (°F)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Capsule Surface	1182	1309	1146	1232
Cask Exterior Surface				
1. Center	527	609	518	580
2. Ends	506	545	464	519
Cask Domes	385	397	364	137
Thermal Shield	93	135	90	121
LM Panel	75	94	77	85
Astronaut Door	91	154	85	170
SLA	71	77	70	

TABLE 15-3. FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS ON-PAD FORCED COOLING WITH 17.5 LB/MIN OF AMBIENT AIR TEMPERATURES FOR IN-LINE NOZZLE

SURFACE DESCRIPTION	TEST RESULTS (°F)		PRE-TEST PREDICTIONS (°F)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Capsule Surface	1094	1357	1110	1245
Cask Exterior Surface				
1. Center	179	222	175	230
2. Ends	157	206	153	194
Cask Domes	115	444	121	166
Thermal Shield	75	92	70	85
LM Panel	72	109	70	100
SLA	70		70	

NOTE: Variations shown are for 2-inch nozzle offset

TABLE 15-4. FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS TRANS-LUNAR (SLA OFF) - MAXIMUM AND MINIMUM SOLAR HEATING

SURFACE DESCRIPTION	TEST RESULTS (°F)		PRE-TEST PREDICTIONS (°F)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Capsule Surface	1212	1311	1281	1290
Cask External Surface				
1. Center	640	795	634	770
2. Ends	612	712	590	690
Cask Domes	453	521	435	541
Thermal Shield	283	604	270	494
LM Panel	-214	217	-131	273
Astronaut Door	- 12	337	1	380

TABLE 15-5. FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS - EARTH ORBIT WITH SLA ON - MAXIMUM AND MINIMUM SOLAR HEATING

SURFACE DESCRIPTION	TEST RESULTS (°F)		PRE-TEST PREDICTIONS (°F)	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Capsule Surface	1210	1315	1293	1302
Cask External Surface				
1. Center	635	798	643	775
2. Ends	627	718	617	687
Cask Domes	482	519	447	559
Thermal Shield	310	588	350	550
LM Panel	0	240	28	215
Astronaut Door	118	383	219	400

15.6 KSC PRELAUNCH OPERATIONS

All flight SNAP-27 hardware, except the fuel capsules, are stored at KSC together with the ALSEP hardware. The flight and backup fuel capsules are maintained in their shipping containers beside the Sandia Corporation facility, Building No. 1428, located at Cape Kennedy Air Force Station, in a special trailer provided by Sandia for that purpose.

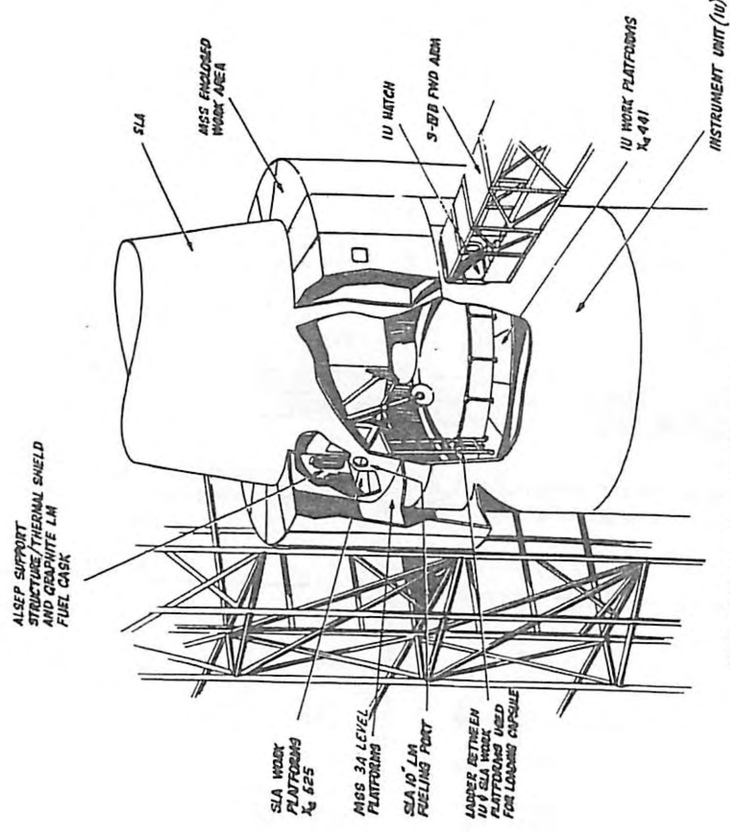
Approximately T-84 days, the two ALSEP subpackages are installed in the SEQ bay of the LM. The SNAP-27 generator and flight handling tool is included on one of these subpackages (No. 2).

Fuel capsule loading operations in the SLA are presently scheduled for T-15 hours, primarily because of the thermal and radiological safety considerations associated with capsule loading. The primary concern is accidental ignition of fluids or gases carried on the spacecraft should a leak develop in any of the propellant and/or storage tanks. On-board loading of the fuel capsule follows completion of the CSM and LM final fluid servicing, specifically at the completion of the LM gaseous oxygen and the descent stage super-critical liquid helium servicing activities, as well as the topping of the CSM fuel cells with LH_2 and LO_2. Servicing lines from the SLA will have been removed and the systems and the area adequately checked for leakage or vapors.

All temporary work platforms within the SLA and IU will have been taken out and stored at the time of fuel capsule loading, except those essential for installation of the GLFC and fuel capsule assembly. The LM ascent stage platforms and the descent stage SLA platforms which are not used during the loading will have been removed before this time. All 441 level work platforms in the Instrument Unit (IU) which are not required to provide access from the IU hatch to the ladder leading up to the SLA 525 level work platforms (required for installing the capsule) will be removed as will hand railings not considered essential.

At approximately T-16 hours, the flight and spare fuel capsules in their GSC's and handling equipment are transported to the vehicle park area of Pad A, Launch Complex 39, to await loading instructions. The ground shipping cask is rechecked for indications of radioactive contamination by the KSC Radiation Safety Officer while still in the pad parking area. The fuel capsule assembly is removed from the GSC and inserted into the SLA transfer cask using the ground handling tool.

Two possible access points for bringing the fuel capsule assembly into the SLA during the loading activities, as well as removing it, are depicted in Figure 15-15.



VIEW DEPICTING ALTERNATE POINTS OF ENTRY INTO SLA FOR LOADING SNAP-27 FUEL CAPSULE ON LUNAR MODULE

·VIA MSS AND SLA 10" LM FUELING PORT
OR
·VIA S-IVB FWD ARM AND ML HATCH

Figure 15-15. Access Points for Bringing Fuel Capsule into SLA and IU

15.6.1 PRIMARY LOADING METHOD

The method which will actually be employed for loading requires that
the fuel capsule assembly be brought up to platform 3A of the Mobile
Service Structure (MSS) and then passed into the interior of the SLA
through one of the SLA 10-inch LM fueling ports. Figure 15-16 de-
picts the sequence.

At approximately T-15 hours, the capsule transport vehicle is driven
to the MSS elevator door. The SLA transfer cask is lowered to the
ground, moved into the MSS elevator and transported up to the MSS 3A
level by two men. The port entry trough and SLA handling tool are
also carried along. The SLA transfer cask is carried to the desig-
nated SLA 10-inch fueling port. One man partially inserts the port
entry trough into the SLA 10-inch port while at the same time stabi-
lizing it horizontally by its handle. The fuel capsule is removed
from the SLA transfer cask by another member of the team using the SLA
handling tool and placed horizontal in the cradle of the port entry
trough, with the SLA handling tool engaged and facing toward the port
and the offset handle of the tool facing up. The port entry trough is
slid, SLA handling tool first, into the interior of the SLA. The SLA
handling tool (with the capsule attached) is lifted up from the port
entry trough inside the SLA and carried over to the LM-mounted GLFC.
The capsule is inserted into the GLFC and latched and the SLA handling
tool removed. Proper engagement of the capsule with the GLFC latch
fitting is then verified using the SLA inspection tool. The GLFC dome
is installed, all bands torqued and the spline lock inserted.

A cooling duct installed below the GLFC directs cooling air tapped
from the main IU cooling system upwards and axially over the surface
of the GLFC to maintain its surface temperature continuously below
350°F. At T-4 hours, the cooling medium is switched over from air to
gaseous nitrogen and maintained until launch. In the event of a hold,
the cooling system remains in operation.

15.6.2 ALTERNATE LOADING METHOD

Following removal of the fuel capsule from the trailer, the SLA trans-
fer cask with fuel capsule is moved up to the S-IVB forward arm (via
the ML elevator) and across the arm to the IU hatch. After being hand-
ed in through the IU hatch, the SLA transfer cask is placed directly
below the edge of the 525 platform. The ladder separating the 441 and
525 platforms will have been previously disassembled and moved out of
the way. The SLA transfer cask with capsule installed is then lifted
up by two men standing on the IU 441 platform (grasping the handles of
the cask) so that the surface of the cask is approximately level with
the surface of the 525 platform. The man on the 525 platform then

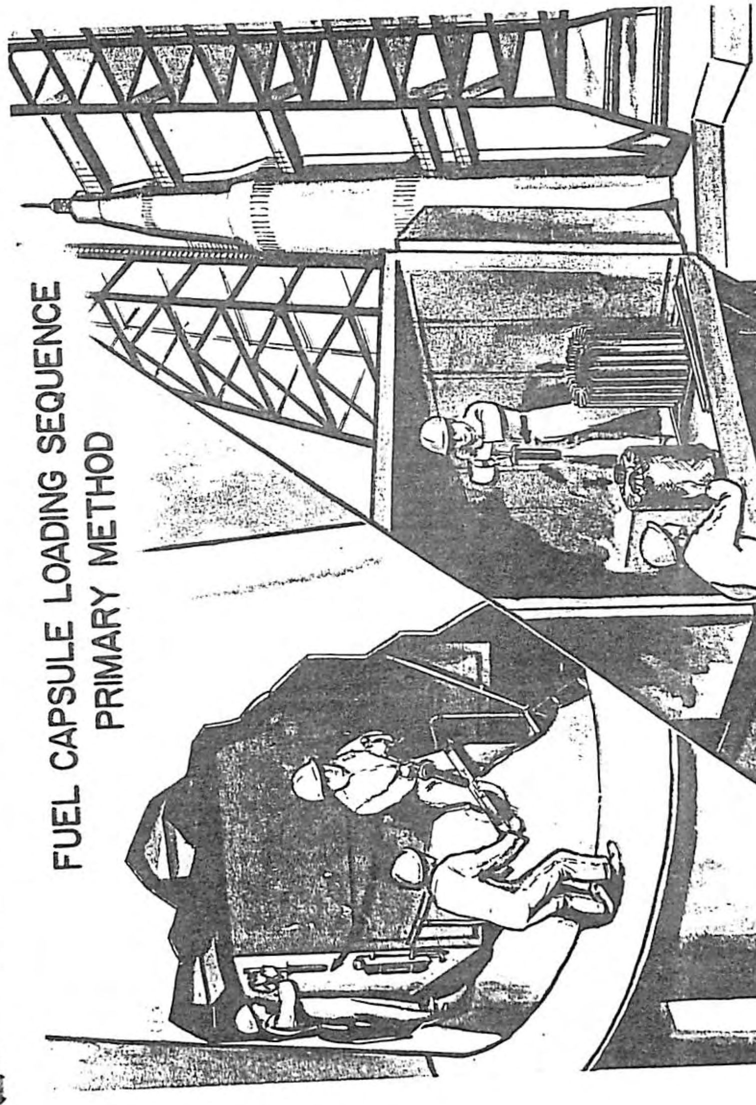


Figure 15-16. Fuel Capsule Loading Sequence, Primary Method

extracts the capsule from the SLA transfer cask using the tethered SLA handling tool and carries it over to the location of the (previously mounted) Graphite LM Fuel Cask. Following installation and latching of the fuel capsule into the GLFC cavity, the GLFC dome will be installed, the support bands tightened and the spline lock inserted. This method is depicted by Figure 15-17.

15.6.3 PRIMARY UNLOADING METHOD

The primary method of fuel capsule removal is the reverse of the primary loading procedure; i.e., the fuel capsule is passed through the SLA 10-inch LM access port by means of the port entry trough to personnel standing on MSS platform 3A, the capsule is placed in the SLA transfer cask and then moved down via the MSS elevators to the AEC storage trailer parked adjacent to the MSS.

15.6.4 ALTERNATE UNLOADING METHOD

This is the reverse of the alternate approach for bringing in the capsule. The capsule is extracted from the GLFC, installed in the SLA transfer cask and the cask handed out through the IU hatch for removal via the S-IVB forward arm to the AEC storage trailer parked along side the LM.

15.7 LUNAR SURFACE OPERATIONS

Described herein are the lunar surface operations involved with removal of the fuel capsule from the GLFC in preparation for generator fueling (see Figures 15-18 and 15-19). A single lanyard (25) is used to sequentially pull the left-hand release mechanism lever (22), the dome locking spline (31) and the right-hand release mechanism lever (22). The cask is then free to rotate. Rotation about the lower trunnion points is accomplished through activating the gearbox (24) by continuing to pull on the same lanyard. The lanyard is connected to the dome locking spline by a low melting point material (Bronze-Aluminum D) to ensure that the locking spline is not inadvertently pulled during reentry.

The astronaut then retrieves the dome removal tool and approaches the cask from the forward end. He engages the tool to the body release mechanism (26), depressing a spring lock, and rotates a cam lock 90 degrees clockwise to release the axial band tension by tripping two locking levers (27) which restrain the upper dome band. He then rotates the assembly 60 degrees counterclockwise, until bracket stop (29) is reached. The dome and dome cap assembly are then withdrawn exposing the fuel capsule backplate. The dome, body release assembly, and dome removal tool are then disposed of as a unit to preclude

FUEL CAPSULE LOADING SEQUENCE
ALTERNATE METHOD

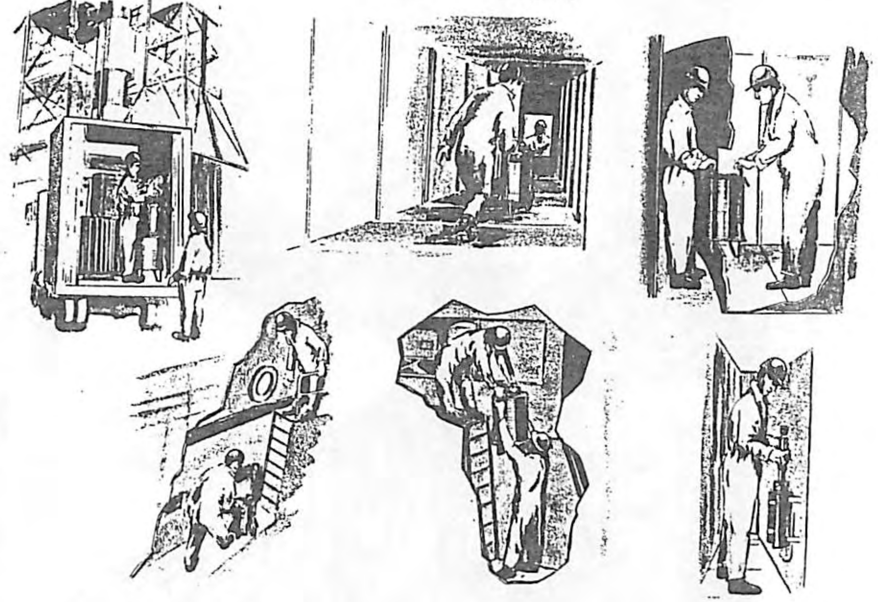


Figure 15-17. Fuel Capsule Loading Sequence, Alternate Method

unnecessary handling of the hot dome by the astronaut. The astronaut
is now ready for the actual fuel transfer operation. After assembling
the ALSEP fuel transfer assembly tool, he approaches the cask from the
forward end, engages the tool to the capsule backplate (which, simul-
taneously unlocks the capsule from the aft capsule support and posi-
tively engages). The fuel capsule is then withdrawn from the cask,
lowered into the SNAP-27 generator, and locked into place by dis-
engaging the tool jaws. The generator, in the ALSEP subpackage, is
then carried to a site, bar-bell fashion, about 300 feet from the LM,
and the experiments are deployed.

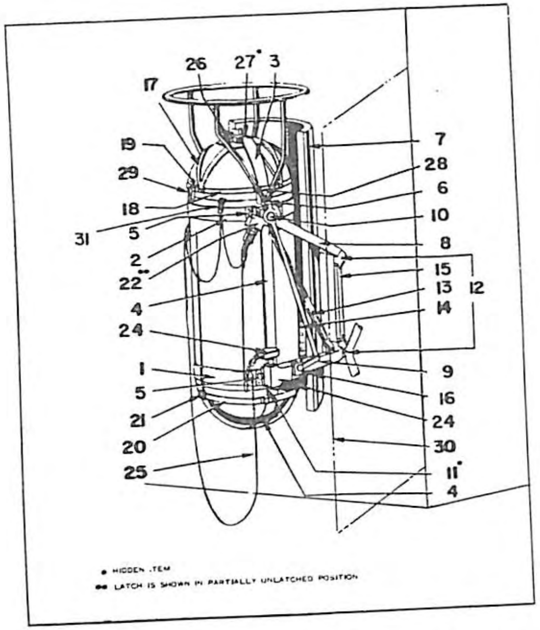


Figure 15-18. GLFC Support Structure Details

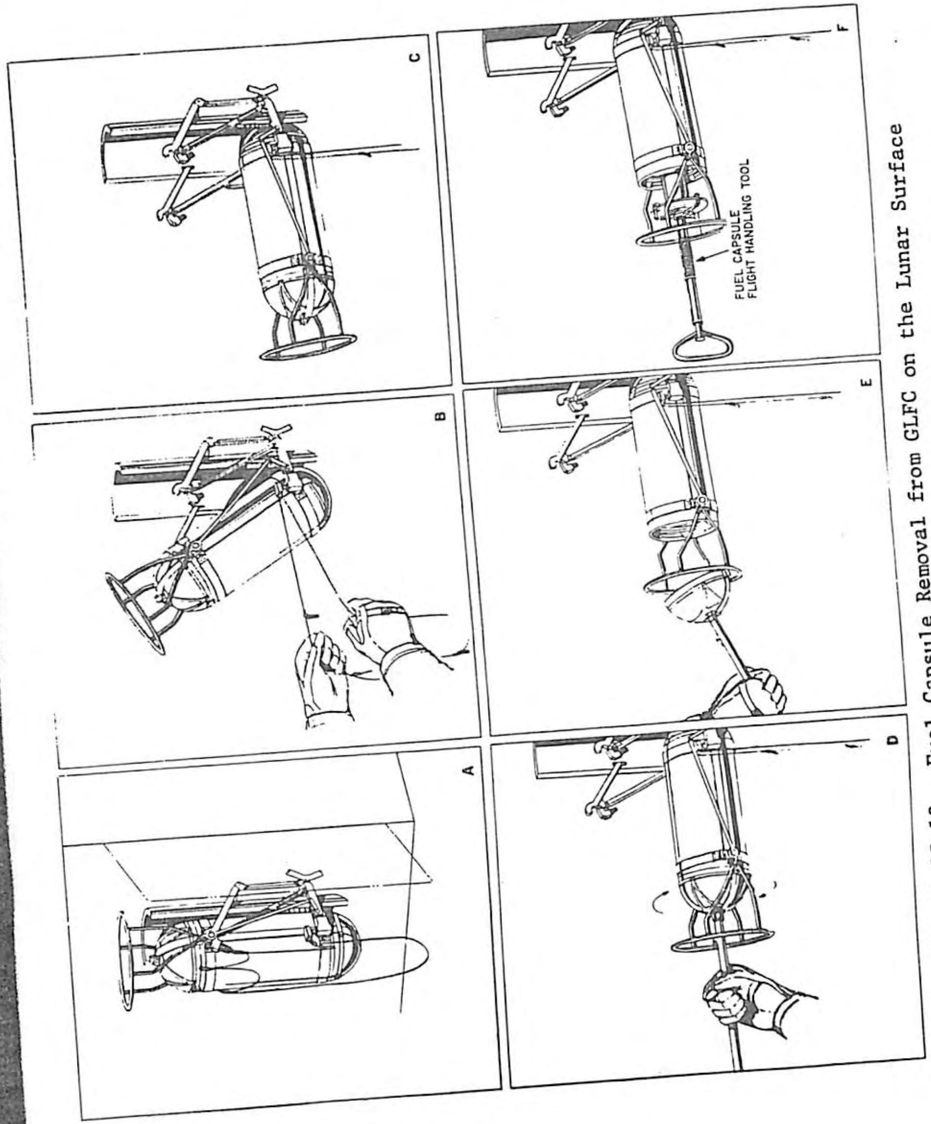


Figure 15-19. Fuel Capsule Removal from GLFC on the Lunar Surface

APPENDIX A
SNAP-27 BIBLIOGRAPHY

A. PROGRAMMING DOCUMENTATION

TITLE	DOC. NO.	DATE
SNAP-27 Phase II Program Plan	65SD4535A	7/19/66
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SNAP-27 Phase III Program Plan Volume 1, Technical Program Plan	66SD2021	11/17/66
SNAP-27 Phase III Program Plan Volume II Cost Breakdown	66SD2023	6/4/66
SNAP-27 Phase IV Program Plan Volume 1, Program Plan	66SD2022	6/4/66
SNAP-27 Phase IV Program Plan Volume II Cost Breakdown	66SD2024	6/4/66
SNAP-27 Safety Test Program	66SD4399	6/30/66
SNAP-27 Integrated Test Program	NS0080-05-01	11/3/66
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SNAP-27 Documentation Plan Phase II Program	6300-005	2/15/66
SNAP-27 Quality Assurance Plan	6300-006	2/15/66
Reliability Estimate Analysis of SNAP-27 Generator Assembly (U)	6300-012	2/18/66
SNAP-27 Reliability Plan	6300-013	2/28/66
SNAP-27 Reliability Measurement Plan	6300-014	4/25/66
SNAP-27 Program Manufacturing Plan	6300-023	7/19/66
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Performance and Design Requirements for the Mechanical Flight Mock-up (MFM) Systems M5, SNAP-27 Program	NS 0220-02-08	1/13/67

Performance and Design Requirements for the M5 Graphite LM Fuel Cask Mock-up, SNAP-27 Program	NS 0220-02-15	1/23/68
Performance and Design Requirements for the M5 Fuel Capsule Assembly Mock-up, SNAP-27 Program	NS 0220-02-16	2/23/68
Performance and Design Requirements for the EFCS Power Controller, M4, M5 and M6, SNAP-27 Program	NS 4935-01-16	11/18/66
Performance and Design Requirements for Training Mock-up M6, SNAP-27 Program	NS 0220-02-09	10/12/67
Performance and Design Requirements for the 1G Final Training Mock-up, M8, SNAP-27 Program	NS 0220-02-13	1/5/68

C. GENERATOR ASSEMBLY TESTPLANS AND PROCEDURES

Thermal-Vacuum Test Plan Practice Shrink Fit Model #2	NS-0080-05-02	8/10/66
"SNAP-27 Radioisotope Thermoelectric Generator Thermal Development Test for a Lunar Environment"	NS-0080-04-02	2/5-11/66
Test Plan for Proof Model Tests of the SNAP-27 Radioisotope Thermoelectric Generator #1	NS 0080-04-05	4/1/66
Test Plan for SNAP-27 Radioisotope Thermoelectric Generator Magnetic Field Test	NS 0080-04-01	12/10/65
Thermal Insulation Stability Test Plan (3M Co.)	MMM8406-0043	5/17/66
Test Plan for Follower Performance Tests	NS 0080-04-11	4/4/66
Test Plan for 104-Couple Module Development Tests	NS 0080-04-13	9/1/66

104-Couple Module Acceptance (3M Co.)	MMM8406-0485	8/31/66
10-Couple Composite Test Plan (3M Co.) SNAP-27 Program, Phase III (U)	MMM8406-1254	5/1/67
Test Plan for Engineering Model #5 Environmental Tests	NS 0080-04-15	10/31/66
Test Plan for SNAP-27 Engineering Model #6 Life Test	NS 0080-04-16	11/14/66
Test Plan for SNAP-27 Engineering Model #7 Performance Tests	NS 0080-04-17	11/18/66
Test Plan for SNAP-27 Engineering Model #8 Simulated Mission Tests	NS 0080-04-18	1/24/67
Test Plan for the Engineering Generator MOD 8B Magnetic Evaluation Tests	SI 249167	4/24/67
Test Plan for SNAP-27 MOD 10 Qualification Tests	NS 0080-04-20	2/2/67
Qualification Test Plan for the Generator Assembly Model #10 SNAP-27 Program	S.I. 249155	3/21/67
Test Plan for the Formal Magnetic Evaluation Testing of the Model #10 SNAP-27 Integrated Power Unit	SI 249172	2/1/68
Test Plan for System Qualification Test Unit MOD 15	NS 0220-02-11	1/9/67
Qualification Test Plan for the Integrated Power Unit Model #13 SNAP-27 Program	S.I. 249163	6/26/67
Test Plan for SNAP-27 Model #14 Acceptance Test	NS 0080-04-19	1/5/67
Plan for SNAP-27 Generator Assembly Model #15 Acceptance Tests	S.I. 249156	3/15/67

Flight Acceptance Test Plan for Generator Assemblies 19,20, 21,22 and 23 SNAP-27 Program	SI-249168	6/20/67
Test Plan for Weight, CG of Generators M5, M6 and M7	SI 249157	3/9/67
Acceptance Test Instructions for the MOD #5-Mechanical Flight Mock-up Generator Assembly-SNAP-27 Program	SI 249158	3/9/67
Acceptance Test Instructions for the Model #6 Training Mock-up Generator Assembly for SNAP-27 Program	SI 249160	3/22/67

D. FUEL CAPSULE ASSEMBLY TEST PLANS AND PROCEDURES

Test Plan for Liner Rupture Disc	NS 0080-04-07	4/1/66
Test Plan for Capsule Burst Disc	NS 0080-04-08	4/1/66
Test Plan for Filter Development Tests	NS 0080-04-06	4/1/66
Test Plan for SNAP-27 Verification Capsules	NS 0080-03-05	12/1/67
Test Plan for SNAP-27 Fuel Capsule Terminal Velocity Drop Test	NS 0080-04-03	1/12/66
Test Plan for Vented Capsule Impact Test	NS 0080-04-10	6/9/66
Test Plan for Series I Fuel Capsules Impact Test Program	NS 0080-04-04	3/2/66
Test Plan for Series II of SNAP-27 Fuel Capsule Impact Test Program	NS 0080-04-09	5/17/66
Test Plan for the S-27 Fuel Capsule Materials Compatibility Test Program	NS 0080-03-02	3/31/66

Acceptance Test Plan for Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly	SI 249178	10/30/67
Thermal mapping, Leak Testing and Visual Inspection of the Fuel Capsule Assembly	SI 249162	4/25/67
Total Hemispherical Emittance Fuel Capsule	NS 0060-02-25	5/16/69
Acceptance Test Procedure for the Fuel Capsule Assembly	SI 249171	4/28/67
Fuel Capsule Installation into the Ground Shipping Cask	6300-211	4/28/68
Fuel Capsule Removal from the Ground Shipping Cask	6300-212	4/25/68

D. GRAPHITE LM FUEL CASK AND LM FUEL CASK (LFC) TEST PLANS

Test Plan for LEM Fuel Casks Models #1 and 2 Environmental Proofing and LFC/ALSEP-Thermal/Mechanical System Interfaces Evaluation	NS 0080-04-14	9/2/66
Engineering Development Test Plan for Graphite LM Fuel Cask	S.I. 249177	10/30/67
Test Plan for the Graphite LM Fuel Cask Operational Test	SI 249193	3/21/68
Procedure for Receiving Inspection of SNAP-27 GLFC	SI 249185	6/27/68
Astronaut Training Test	SI 249214	4/21/69
GLFC Operational Test	NS 0080-04-27	12/15/67
Engineering GLFC Dynamic Testing #11	SI 249209	5/20/68
Engineering GLFC Thermal Testing	SI 249170	4/29/68

E. ALSEP CASK ASSEMBLY (ACA) INTEGRATED TEST PROCEDURES

Test Plan for the ACA Integrated Test Program	(Bendix) TM-157	
ALSEP Cask Assembly Handling Procedure	SI 249208	6/27/68
ALSEP Cask Assembly Receiving Inspection Procedure	SI 249197	6/24/68
ALSEP Cask Assembly Instrumentation Procedure	SI 249199	6/26/68
ALSEP Cask Assembly Weight and CG Measurement Procedure	SI 249198	10/3/68
ALSEP Cask Assembly Vibration Test Procedure, D2/M5 Hardware	SI 249200	10/10/68
ALSEP Cask Assembly Post Test Inspection Procedure	SI 249201	7/19/68
ALSEP Cask Assembly LM-SLA Simulator Instrumentation Procedure	SI 249202	8/29/68
ALSEP Cask Assembly Dynamic Test Procedure	SI 249203	12/1/68
ALSEP Cask Assembly Air Soak Procedure	SI 249204	8/19/68
ALSEP Cask Assembly Thermal Vacuum Test Procedure	SI 249205	10/10/68
ALSEP Cask Assembly Tilt Test Procedure	SI 249206	2/19/69
ALSEP Cask Assembly Final Inspection	SI 249207	7/25/68

F. AUXILIARY SUPPORT EQUIPMENT TEST PLANS AND PROCEDURES

Acceptance Test Procedure for the SNAP-27 IPU Test Console	SI 237049	1/12/67

Calibration Procedure for the SNAP-27 IPU Test Console	SI 237050	1/11/67
Electromagnetic Interference for IPU Test Console	SI 249164	8/14/67
Acceptance Test Instructions for SLA Transfer Cask	SI 249179	1/9/68
Qualification Test Plan for SNAP-27 Flight Handling Tool, Ground Handling Tool and SLA Handling Tool	SI 249159	7/20/67
Acceptance Test for Flight Handling Tool	SI 249151	1/25/67
Qualification Test Plan for the SLA Transfer Cask	SI 249181	2/21/68
Test Instructions for Ground Shipping Cask	SI 249154	3/3/67
SNAP-27 IPU Test Console Retrofit Procedures	6300-248	7/20/67
Nickel Particle Coolant Cleaning and Drying Procedure (For use in the SNAP-27 Ground Shipping Cask)	6300-279	11/7/67
Qualification Test Instructions for Generator Assembly Shipping Container	SI 249165	4/3/67
Acceptance Test for the Ground Handling Tool and SLA Handling Tool	SI 249161	4/17/67

G. SYSTEM TEST PLANS AND PROCEDURES

Test Requirements for Compatibility and Interchangeability of SNAP-27 IPU Systems	NS 0080-05-28	4/4/68
IPU System Mechanical and Functional Compatibility Phase II	SI 249195	7/2/68

H. GENERATOR ASSEMBLY TEST REPORTS

Follower Performance Test for SNAP-27 Radioisotope Thermoelectric Generator	6300-103	9/30/66
Test Report SNAP-27 Radioisotope Thermoelectric Generator Magnetic Considerations	NS 0080-04-01 (RPT.)	4/21/66
Test Report Breakaway Friction of Boron Nitride Against in-102 Alloy in Argon Atmosphere At Elevated Temperatures	6300-095	9/23/66
"SNAP-27 Radioisotope Thermoelectric Generator Thermal Development Test for a Lunar Environment"	NS-0080-04-02 (RPT)	3/30/66
Performance Test Report for 10-Couple Modules (3M Co.)	ST10B-1 and ST10C-3	6/30/67
Compatibility and Performance Testing of the ALSEP Power Conditioning Unit (PCU) with the SNAP-27 Integrated Power Unit (IPU) Summary Report-1/15/68	6300-307	1/15/68
Phase I Test Report for Flight Acceptance Testing Performed on Qualification Model Generator Assembly MOD 10	6300-281	10/67
Phase II Test Report for Qualification Testing Performed on Generator Assembly MOD 10	6300-288	1/5/68
Qualification Test Report for the Model #10 Integrated Power Unit Magnetic Evaluation Test	6300-318	3/28/68
Final Report for Magnetic Field Measurement and Analysis Part I SNAP-27 Program	6300-237	6/15/67

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Final Report for Magnetic Field Measurement and Analysis Part 2 SNAP-27 Program	6300-285	11/30/67
Final Report for Magnetic Field Measurement and Analysis Part 3 SNAP-27 Program	GEMS-401	7/10/68
Test Report SNAP-27 Generator Assembly Model 13 Flight Acceptance Tests	6300-289	1/8/68
SNAP-27 Generator Assembly Model #15 Acceptance Tests Revision A Test Report	6300-258	9/67
Test Report SNAP-27 Generator Assembly Model #19 Flight Acceptance Tests	6300-282	10/67
Test Report SNAP-27 Generator Assembly Model 21 Flight Acceptance Tests	6300-296	3/1/68
Test Report SNAP-27 Generator Assembly Model 22 Flight Acceptance Tests	6300-313	4/10/68
Test Report SNAP-27 Generator Assembly Model 23 Flight Acceptance Tests	6300-310	3/15/68
"Generator Functional Performance and Acceptance Test Report, Model 13" (3M Co.)	MMM8406-1614	7/67

I. FUEL CAPSULE TEST REPORTS

Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330001	6300-326	6/17/68

Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330001	6300-348	2/13/69
Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330002	6300-323	2/10/69
Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330002	6300-350	3/10/69
Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330004	6300-N550A Addendum I	2/10/69
Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330004	6300-349	2/10/69
Post Qualification Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 63330004	6300-351	4/2/69
Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330005	TM-68-12-301	12/30/68
Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330005	6300-355	4/29/69

Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330006	TM-68-12-304	12/30/68
Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330006	6300-354	4/28/69
Acceptance Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330007	6300-342	2/18/69
Post Acceptance Level Vibration Test Report for the Thermal Mapping, Helium Leak Check and Flange Weld Inspection of the SNAP-27 Fuel Capsule Assembly S/N 6330007	6300-352	4/14/69

J. GRAPHITE LM FUEL CASK AND LM FUEL CASK TEST REPORTS

Test Report Graphite LM Fuel Cask Operational Test	GESP-7004	7/3/68
Functional Acceptance Test Report for the BSTA Graphite LM Fuel Cask (SI 249180)	6300-302	1/8/68

K. ALSEP CASK ASSEMBLY (ACA) INTEGRATED TEST REPORTS

"Results of Engineering Vibration Tests of GLFC/ALSEP structural Assembly at GE", C.V. Stahle, IK75 SNAP-27-20		8/68
"Vibration Response of ALSEP/GLFC during fine Sweep Tests", C.V. Stahle		8/68
"Test Report for the Weight and CG Measurement of the ALSEP Cask Assembly", Flight No. 3 System, SI 249198 (RPT)		5/69

"Test Report for the ALSEP Cask Assembly Flight Qualification Acceptance Level Vibration and Tilt Test",		3/69
Test Report for the Weight and CG Measurement of the ALSEP Cask Assembly Flight Qualification System	249198	12/9/68
Test Report for the Air Soak Test of the ALSEP Cask Assembly Flight Qualification System	249204	2/24/69
Test Report for the Weight and CG Measurement of the ALSEP Cask Assembly Flight Backup System	249198	2/28/69
Test Report for the ALSEP Cask Assembly Flight No. 1 Acceptance Level Vibration and Tilt Test and Post Test Inspection	249203, 249206, 249201	2/24/69
Test Report for the Thermal Vacuum Test of the ALSEP Cask Assembly Flight Qualification System	249205	3/5/69
Test Report for the ALSEP Cask Assembly Flight Backup Acceptance Level Vibration and Tilt Test and Post Test Inspection	249203, 249206, 249201	3/12/69
Test Report for the ALSEP Cask Assembly Flight Qualification Acceptance Level Vibration and Tilt Test	249203, 249206, 249201	3/7/69
Test Report for the Weight and CG Measurements of the ALSEP Cask Assembly Flight No. 2 System	249198	4/16/69
Test Report for the ALSEP Cask Assembly Flight No. 2 Acceptance Level Vibration and Tilt Test and Post Test Inspection	249203, 249206, 249201	4/15/69

Test Report for the ALSEP Cask Assembly Flight No. 3 Acceptance Level Vibration and Tilt Test and Post Test Inspection	249203, 249206, 249201	4/21/69
Test Report for the Weight and CG Measurement of the ALSEP Cask Assembly Flight No. 3 System	249198	5/1/69
Test Report for the ALSEP Cask Assembly Flight No. 4 Acceptance Level Vibration and Tilt Test and Post Test Inspection	249203, 249206, 249201	4/28/69
Test Report for the Weight and CG Measurement of the ALSEP Cask Assembly Flight No. 4 System	249198	5/9/69
Test Report for the Qualification Level Vibration and Tilt Test of the ALSEP Cask Assembly Flight Qualification System	249203, 249206, 249207	4/14/69

L. AUXILIARY SUPPORT EQUIPMENT TEST REPORTS

Qualification Test Report SNAP-27 Ground Handling Tool	6300-253	7/24/67
Qualification Test Report for the SNAP-27 Flight Handling Tool	6300-254	8/1/67
Qualification Test Report for Generator Assembly Shipping Container (GASC) 47E300754G1 SNAP-27	6300-265	7/27/67
Engineering Test Report for the SNAP-27 SLA Handling Tool	6300-276	10/31/67
Test Report for Qualification Humidity, Vibration and Post Qualification Acceptance Tests on the SNAP-27 Ground Shipping Cask (GSC) S/N 6317001	6300-303	1/22/68

Test Report for Qualification Tests of the SLA Transfer Cask S/N 6401001	6300-338	9/10/68
Test Report for Qualification Tests of SLA Transfer Cask	SI 249181	2/21/68
Report on Results of Acceptance and Qualification Tests of SNAP-27 Ground Shipping Cask (Battelle Memorial Institute)		
Qualification Tests SNAP-27 Fuel Capsule Simulater (TEECO)		

M. MISCELLANEOUS TOPICAL REPORTS

Electrical Properties of Thermoelectric Legs-Statistical Correlation Studies	67SD336	11/67
Thermoelectric Leg Product Specification (Telps) Midterm Technical Report	6300-235	6/13/67
Thermoelectric Leg Product Specification (TELPS) Final Technical Report Volume 1-Technical Results Part 2	6300-262	10/15/67
SNAP-27 Generator Outer Case Failure Presentation AEC Headquarters	6300-158	12/15/66
Cask Separation Study SNAP-27 Program 11/1 to 12/1/66	6300-160	1/3/67
SNAP-27 Integrated Power Unit Familiarization Manual	6300-188	3/1/67
SNAP-27 Beryllium Case Presentation	6300-190	2/8/67
Failure Analysis of SNAP-27 Outer Shell Assembly	6300-221	3/67

Fatigue Testing of Haynes-25 Alloy Tubular Weld Test Specimens	TM 68-12-303	12/68
MOD 15, Type a EFCS Failure Analysis	TR 1E14-073	4/23/68
Report on Beryllium Metallurgical Analysis of Failed Outer Cases PSF-1 and PSF-2	6300-192	3/3/67
Report on Thermal Tests of SLA Materials	SI 249211	7/17/68
Report on Materials Compatibility SNAP-27 GLFC Re-Entry Capsule Part 1	GESP-7002	7/19/68
Classified Supplement Report on Materials Compatibility SNAP-27 GLFC Re-Entry Capsule (U) Part II	GESP-7003	7/19/68

N: OPERATIONAL PROCEDURES FOR KENNEDY SPACE CENTER

"Procedure for Installation of SNAP-27 Fuel Capsule into Ground Shipping Cask"	SI 249189	4/9/68
"Procedure for Receiving and Inspection of SNAP-27 Fuel Capsules at Kennedy Space Center"	SI 249187	4/9/68
"Procedure for Removal of SNAP-27 Fuel Capsule from the Ground Shipping Cask"	SI 249190	4/9/68
"Procedure for SNAP-27 Fuel Capsule Assembly Prelaunch Unloading from the Lunar Module"	SI 249191	4/8/68
"Procedure for SNAP-27 Fuel Capsule Assembly Prelaunch Loading on the Lunar Module"	SI 249192	4/8/68
"Procedure for SNAP-27 Fuel Capsule Fit Checks at Kennedy Space Center"	SI 249186	6/5/68

"Procedure for SNAP-27 Fuel Capsule Ground Support Equipment Receiving and Inspection"	SI 249184	6/27/68
"Procedure for Storage of SNAP-27 Fuel Capsule at Kennedy Space Center"	SI 249188	4/9/68

O. <u>NUCLEAR SAFETY DOCUMENTATION</u>

SNAP-27 Safety Review (Preliminary Report) (U)	6300-018	1/19/66
SNAP-27 Reference Design Document (U) (Rough Draft)	6300-138	11/28/66
SNAP-27 Accident Model Document (U) (Rough Draft)	6300-139	11/28/66
SNAP-27 Safety Analysis Report (U) (Rough Draft)	6300-140	11/28/66
Addendum to SNAP-27 Phase II Program Plan Task 3.9 Safety Testing	6300-141	11/14/66
SNAP-27 Radiological Protection Program	6300-206	3/31/67
Supplement No. 1 to SNAP-27 Safety Report Volume III Safety Analysis Report	6300-299 R I	1/31/69
Supplement No. 1 to SNAP-27 Safety Report Volume II Accident Model Document, Appendix P Re-Entry Evaluation of GLFC and LM	6300-300PRI	9/16/68
Supplement No. 2 to SNAP-27 Safety Report Volume II Accident Model Document (U), Revision and Completion of Report Sections and Appendices	6300-300R2	1/24/69
SNAP-27 Safety Report Volume I Reference Design Document (U) (Preliminary)	6300-325	7/24/68

SNAP-27 Safety Report Volume II Accident Model Document	6300-300	7/24/68
SNAP-27 Safety Report Volume III Safety Analysis Report	6300-299	7/24/68
SNAP-27 Safety Test Plan Preliminary Draft	NS 0080-06-01	2/17/66
Burial of Fuel Capsules (U)	6300-007	1/24/66
SS Material Control Manual	PROP.67-1	
Criticality Evaluations (U)	6300-008	1/24/66

P. <u>MATERIALS AND PROCESS SPECIFICATIONS</u>

Selected Materials List	NE 0060-07-03	
Selected Parts List - SNAP-27 AVE/AGE	NS 0060-03-10	8/3/66
Non-Nuclear Materials (U)	6300-010	1/24/66
Process Specification High Emissivity Grit Blast Surface Preparation Coatings	NS 0060-02-14	12/29/66
Chemical Milling of Beryllium	NS 0060-02-21	12/9/66
Cherry Blind Rivet Insulation Process Spec.	NS 0060-02-19	12/14/66
Coating, High Emissivity, High Temperature (1200°F), Stable, Type Radifrax - RC 161	NS 0060-02-16	
Coating, High Emissivity, Radifrax RC-100 Series	NS 0060-05-17	6/20/68
Coating, High Emissivity Radifrax RC-166	NS 0060-05-10	1/9/67
Coating, High Emissivity Radifrax RC-168	NS 0060-05-11	1/9/67

Coating, Radifrax RC-356	NS 0060-05-03	10/31/66
Weldability Study of Haynes Stellite 25 Alloy (Mitron)	8426	1/19/67
Welding, Columbium and Columbium Alloys	NS 0060-02-37	3/4/68
Welding Fusion, Edge and Pin Joints	NS 0060-02-27	4/14/67
RTU 560, Potting of Power Headers	NS 0060-02-26	8/3/67
Silicon Dioxide	NS 0060-02-031	
Plasma-ARC Spray, High Emissivity Coating, Radifrax	NS 0060-02-13	5/20/66
Plasma-Arc Spray, High Emissivity Coating, Radifrax RC-356	NS 0060-02-35	11/7/67
Niobium C129Y Alloy	NS 0060-02-30	2/7/68
Process Specification for High Emissivity Coating SNAP-27 Fuel Capsule	NS 0060-02-18	12/23/66
High Emissivity Coating, Lithoid Type	NS 0060-05-12	12/7/67
Inconnel - 718 Alloy	NS 0060-07-07	8/28/67
Corrosion Resistant Cleaning and Packaging	NS 0060-02-20	12/9/66
Insulation, Rop, Thermal, Refractory Fiber, Flexible	NS 0060-01-01	12/14/66
Electron Beam Certification Welding Machine-High Voltage (150 KV)	NS 0030-11-02	5/12/66
Electron Beam Certification of Welding Machine Operator for 150 KV Machine	NS 0031-11-01	12/3/66

Electron Beam Welds	NS 0060-02-17	2/6/68
Fatigue Testing of Haynes-25 Alloy Tubular Weld Test Specimans	TM 68-12-303	12/68
Fiberfrax T-30LR	NS 0060-02-33	9/22/67
Foam Spacer, Cobalt Alloy	NS 0060-07-06	8/8/67
Calorimetric Determination-Hemispherical Emittance	NS 0060-02-24	1/12/67
Center Section Assembly	NS 0060-02-28	8/14/67
Back Plate Removal Operations, Fuel Capsule Assembly S/N 6330001	SI 249196	4/12/68
Beryllium, Block & Sheet, for Structural Applications	NS 0060-07-04	12/22/66
Beryllium, Cleaning and Packaging	NS 0060-02-22	12/9/66
Beryllium Fabrication Development Phase 11A - SNAP-27 Program Plan for the Period Sept. 29, 1965 to April 21, 1966	RDR 1499-1	12/1/65
Burst Testing Procedures of Center Section Assemblies	SI 249175	8/3/67
Application of Aluminide Protective Coating to Metal Surfaces	NS 0060-02-38	12/6/67
Application of Aluminum Oxide Coatings by Plasma Arc Spray	NS 0060-02-44	6/20/68
Application of Aluminum Oxide Coatings by Thermal Spray	NS 0060-02-45	6/28/68
Applications of High Temperature, High Emissivity Coatings	NS 0060-02-15	6/20/68
Application of Protective Coatings to Beryllium	NS 0060-02-14	12/30/66
Acceptance Specification for Pyrocarb 406	NS 0060-02-32	11/27/68

Q. SUBCONTRACT WORK STATEMENTS

Application of Protective Coatings to the Secondary Heat Shield for the SNAP-27 GLFC	NW 9999-10-29	5/13/68
Fuel Capsule NDT and Emissive Coating Activities	NW 9999-10-08	8/7/67
Materials Testing Program Creep Rupture and Materials Compatibility	NW 9999-10-06	2/8/66
Phase IV - SNAP-27 Capsule	NW 9999-10-25	8/7/67
SNAP-27 Astronaut Test	NW 9999-10-26	11/13/67
GLFC Operational Test	NW 9999-10-27	12/11/67
Electrically Heated Burial Capsule	NW 9999-10-13	1/20/67
Electric Fuel Capsule Simulator	NW 9999-10-03	7/14/66
Generator Components, Phase IV	NW 9999-10-12	6/30/67
Generator and LM Shipping Cask Components	NW 9999-10-05	10/12/66
Thermopile Assembly, Phase III	NW 9999-10-17	5/1/67
Thermopile Assembly, Phase IV	NW 9999-10-18	5/23/67

APPENDIX A. SNAP-27 CHRONOLOGY

1. GENERAL PROGRAM HIGHLIGHTS

SNAP-27 Phase IIA Contract Award	March 1965
Phase IIA Go Ahead	August 1965
Phase IIA Award to Y-12 (ORNL)	September 1965
Phase IIA Award to Solar	September 1965
Phase IIA Award to 3M	September 1965
Phase IIB Technical Presentation to AEC (H. Finger)	October 1965
Formal Phase IIB Quote Submitted by GE	October 1965
NASA-Directed Change to "Separate Shipment"	November 1965
Phase IIB Go Ahead	November 1965
Phase IIB Go Ahead to 3M	December 1965
Design of EFCS Started at TEECO	January 1966
Solar Selected as Beryllium Fabricator	January 1966
PCU Responsibility Transferred from GE to Bendix	January 1966
First Prototype EFCS Fabricated	April 1966
SNAP-27 Technical and Administrative Responsibility Transferred from NYOO to ALOO AEC	May 1966
TEECO Subcontract Program Appraisal Review	July 1966
3M Subcontract Program Appraisal Review	August 1966
Solar Subcontract Program Appraisal Review	August, September 1966
Task 13.0 Added to Program	October 1966

Task 12.0 Added to Program	October 1967
Completion of GSC Qual Transferred to GE	October 1967
First Two GSC's Shipped to Mound	November 1967
SNAP-27 Orientation Briefing and Hot EFCS Demonstration Performed for KSC Management	August 1968
Forwarded (Rough Draft) SNAP-27 Technical Manual to Sandia	September 1968
Shipped Disassembled SLA/LM Mock-Up to Sandia	September 1968

2. GENERATOR CHRONOLOGY

2.1 DESIGN AND DEVELOPMENT

Be Billets Ordered for Engineering Model Generators	January 1966
1G and 1/6G Mechanical Integration Mock-ups Delivered	Jaunary 1966
Thermal Model Tests Completed	February 1966
Engineering Model Design Completed	February 1966
Instrumentation Requirements for Engineering Generators Defined	February 1966
Design Release for 10-Couple Test Module	February 1966
Fabrication of First T/E Legs	February 1966
Fabricated First T/E Couple Assemblies	March 1966
Initiated Testing of Isothermal Compatibility Modules	April 1966

Completed Tests on BeO and Coated Be Followers	June 1966
Completed Generator MOD 1 Thermal/Mechanical Tests	June 1966
Completed Hermetic Closure Tests on Phase IIA Units	June 1966
Completed Fabrication of Phase IIB Hermetic Closure Units	June 1966
Completed Leg Fabrication of MODs 5-8 Generators	June 1966
Five Operating Generators Deleted from Program (6, 7, 11, 12, 13)	August 1966
MOD 6 Outer Case Failed (Cracked) at 3M During Processing	October 1966
Generator Outer Case Redesigned to Eliminate Cracking	October 1966
Generator Life Testing Terminated (By AEC Direction) on MODs 5, 8B and 10	July 1968
MOD 10 Shipped to Bendix for use in ALSEP Thermal Vacuum Test	October 1968
Completed Manned Test at Litton	June 1968

2.1.1 ENGINEERING GENERATOR MOD-5 VERIFICATION TESTS

Visual Examination and Resistance Test	November 1, 1966
Leak Rate Test (Non-Operating)	November 7, 1966
I-V Mapping in Air	November 17, 1966
Acceptance Level Vibration Test	November 21, 1966
Installation of RTD's and Connector	December 12, 1966
I-V Mapping in Vacuum	January 13, 1967
Leak Rate (Operating)	January 13, 1967

Sinusoidal Vibration Test, Qual Levels	January 30, 1967
Random Vibration Test, Qual Levels	February 6, 1967
Operational Life Test	July 10, 1968
Testing Discontinued	July 10, 1968

2.1.2 ENGINEERING GENERATOR MOD 6 VERIFICATION TESTS

Visual Examination and Resistance Test	January 11, 1967
I-V Mapping in Air	January 20, 1967
Installation of RTD's and Connector	January 22, 1967
Leak Rate Test (Non-Operating)	January 23, 1967
Acceptance Vibration Test	January 26, 1967
Outer Case Cracked During Air Operation; Testing Discontinued	February 4, 1967

2.3 ENGINEERING GENERATOR MOD 8B VERIFICATION TESTS

Visual Examination and Resistance Tests	March 22, 1967
Installation of RTD's and Connector	April 1, 1967
Leak Rate Test (Non-Operating)	April 8, 1967
I-V Mapping in Air	April 11, 1967
Acceptance Vibration Tests	April 13, 1967
Magnetic Evaluation Test (NASA-Goddard)	April 28, 1967
Hot EFCS Insertion Test	May 15, 1967
Thermal Vacuum Test	May 29, 1967
Operational Life Test (Start)	May 29, 1967
Life Test Halted	July 11, 1967
Acceleration Test	July 12, 1967

Post-Acceleration I-V Mapping in Vacuum/Leak Rate	July 17, 1967
Shock Test	July 18, 1967
Post-Acceleration I-V Mapping in Vacuum/Leak Rate	August 1, 1967
Sinousidal and Random Vibration Test, Qual Level	August 3, 1967
Post-Vibration I-V Mapping in Vacuum/Leak Rate	August 9, 1967
Life Test Resumed	August 17, 1967
Life Test Interrupted; Changed Test Chambers	September 6, 1967
Generator/ALSEP PCU Integrated Performance Test	November 13, 1967
Life Test Resumed	November 14, 1967
Life Test Halted	February 15, 1968
Magnetic Fixture Evaluation Test (with FCA)	February 17, 1968
Baffle Evaluation Test (with EFCS)	March 15, 1968
Life Test Resumed	March 16, 1968
Operational Life Test Terminated	July 9, 1968

2.2.1 PRIME GENERATOR MOD 10, S/N 6320005

Visual Examination and Resistance Test	June 9, 1967
I-V Mapping in Air	June 13, 1967
Installation of RTD's and Connector	June 27, 1967
Leak Rate Test (non-operating)	June 28, 1967
Acceptance Vibration Test	June 28, 1967
Thermal Vacuum Test	July 18, 1967
Sinusoidal and Random Vibration Test, Qual Levels	July 19, 1967

Shock Test	July 27, 1967
Acceleration Test	August 1, 1967
Operational Life Test Started	August 4, 1967
Operational Life Test Halted	February 19, 1968
Magnetic Test (NASA-Goddard)	February 26, 1968
Life Test Resumed	March 4, 1968
Life Test Discontinued	July 15, 1968

2.3 ALSEP TEST GENERATORS ACCEPTANCE TESTS

2.3.1 GENERATOR MOD 14, S/N 6320007

Visual Examination and Resistance Test	December 21, 1966
I-V Mapping in Air	December 27, 1966
Installation of RTD's and Connector	December 28, 1966
Leak Rate Test (non-operating)	December 29, 1966
Acceptance Vibration Test	December 29, 1966
I-V Mapping in Vacuum	January 3, 1967
Leak Rate Test (operating)	January 3, 1967
Ship to Bendix Corporation	January 5, 1967

2.3.2 GENERATOR MOD 15, S/N 6320008

Visual Examination and Resistance Test	March 31, 1967
I-V Mapping in Air	April 1, 1967
Installation of RTD's and Connector	April 4, 1967
Leak Rate Test (non-operating)	April 5, 1967
Acceptance Vibration Test	April 5, 1967
I-V Mapping in Vacuum	April 16, 1967

I-V Mapping in Air	April 18, 1967
Ship to Bendix Corporation	April 21, 1967

2.4 FLIGHT GENERATORS ACCEPTANCE TESTS

2.4.1 GENERATOR MOD 13, S/N 6320006

Visual Examination and Resistance Test	July 6, 1967
I-V Mapping in Air	July 17, 1967
Installation of RTD's and Connector	October 12, 1967
Leak Rate Test (non-operating)	October 12, 1967
Thermal Evacuation Test (cable)	October 21, 1967
Acceptance Vibration Test	October 23, 1967
Thermal Vacuum Test	November 3, 1967
Ship to Bendix Corporation	February 5, 1968
Return to General Electric	April 8, 1968
Fit Check with FCA's S/N -001, -002	April 9, 1968
Ship to Bendix Corporation	April 15, 1968
Return to General Electric	August 13, 1968
Retrofit RTD and Spacer Blocks Nuts and Bolts	October 15, 1968
Fit Check with FCA's S/N -005, -006, -007	October 17, 1968
Ship to Bendix Corporation	October 23, 1968
Return to General Electric	January 7, 1969
Fit Check with FCA's S/N -001 and -002	January 8, 1969
Ship to Bendix Corporation	January 9, 1969

2.4.2 GENERATOR MOD 19, S/N 6320009

Visual Examination and Resistance Test	June 22, 1967

I-V Mapping in Air	June 27, 1967
Installation of RTD's and Connector	September 27, 1967
Leak Rate Test (non operating)	September 27, 1967
Operability Assurance Vibration Test	September 29, 1967
Thermal Vacuum Test	October 10, 1967
Thermal Evacuation Test (cable)	October 21, 1967
Ship to Bendix Corporation	February 6, 1968
Return to General Electric	April 8, 1968
Fit Checks with FCA's S/N -001, -002	April 9, 1968
Ship to Bendix Corporation	April 15, 1968
Return to General Electric	August 13, 1968
Minor Rework	September 24, 1968
Replace RTD and Spacer Blocks Nuts and Bolds	October 1, 1968
Ship to Bendix Corporation	October 20, 1968
Return to General Electric	January 7, 1969
Fit Checks with FCA's S/N -001 and -002	January 8, 1969
Ship to Bendix Corporation	January 9, 1969

2.4.3 GENERATOR MOD 21, S/N 6320011

Visual Examination and Resistance Test	October 30, 1967
I-V Mapping in Air	November 1, 1967
Installation of RTD's and Connector	November 14, 1967
Leak Rate Test (non-operating)	November 15, 1967
Acceptance Vibration Test	November 15, 1967
Thermal Vacuum Test	November 27, 1967

Thermal Evacuation Test (cable)	December 5, 1967
Ship to Bendix Corporation	February 5, 1968
Return to General Electric	June 20, 1968
Fit Check with FCA's -001, -002, -004	June 21, 1968
Repeat Fit Checks with FCA -004	June 24, 1968
Changed Spacer Blocks	June 27, 1968
Ship to Bendix Corporation	June 28, 1968
Return to General Electric	August 13, 1968
Retrofit RTD and Spacer Blocks Nuts and Bolts	October 1, 1968
Fit Check with FCA's S/N -002, -006	October 24, 1968
Ship to Bendix Corporation	October 28, 1968
Return to General Electric	March 14, 1969
Fit Check with FCA S/N -002	March 20, 1969
Reship to Bendix Corporation	March 21, 1969

2.4.4 GENERATOR MOD 22, S/N 6320012

Visual Examination and Resistance Test	October 30, 1967
I-V Mapping in Air	November 2, 1967
Installation of RTD's and Connector	November 18, 1967
Leak Rate Test (non-operating)	November 20, 1967
Acceptance Vibration Test	November 21, 1967
Thermal Evacuation Test (cable)	December 5, 1967
Fit Check with FCA S/N -002	December 16, 1967
Thermal Vacuum	December 18, 1967
Ship to Bendix Corporation	February 26, 1968

Return to General Electric	July 30, 1968
Fit Check with FCA S/N -005	July 31, 1968
Elimination of Short in Cable at Connector End with Replacement of Connector	December 9, 1968
Fit Check with FCA S/N -002	December 16, 1968
Ship to Bendix Corporation	December 19, 1968

2.4.5 GENERATOR MOD 23, S/N 6320013

Visual Examination and Resistance Test	December 1, 1967
I-V Mapping in Air	December 3, 1967
Installation of RTD's and Connector	December 26, 1967
Operability Assurance Vibration Test	December 28, 1967
Leak Rate Test (non-operating)	December 29, 1967
Thermal Evacuation Test (cable)	January 6, 1968
Ship to Bendix Corporation	February 26, 1968
Return to General Electric	May 20, 1968
Fit Check with FCA S/N -002	May 21, 1968
Cable Connect X-Ray for Short Replaced Cable Connector	June 14, 1968
Replace Cable Connector	June 21, 1968
Ship to Bendix Corporation	June 25, 1968
Return to General Electric	November 15, 1968
Replaced RTD Nuts and Bolts	November 22, 1968
Fit Check with FCA's S/N -002, -007	December 4, 1968
Fit Check Replaced with FCA S/N -002	December 16, 1968
Ship to Bendix Corporation	December 19, 1968

3. FUEL CAPSULE

3.1 DESIGN AND DEVELOPMENT

Microsphere Fuel Form Selection by AEC for SNAP-27	November 1965
Initiated Fuel Capsule Testing	January 1966
Fuel Capsule Drop Tests Completed at Sandia	February 1966
Delivered Liner Assembly to Mound for Fuel Tests	February 1966
GE Decision to use Dual Liner Design	March 1966
Radiation Dose Rates Determined for Natural and Depleted Oxygen in Fuel	March 1966
Delivered Fuel Capsule Liners to Mound	March 1966
AEC Directed GE to Prepare Fuel Performance Specification; Mound Laboratory, Fuel Characteristics Specification	March 1966
Vented Capsule Rupture Disc and Burst Section Tests	April 1966
Reviewed Vented Capsule Design with Mound	April 1966
First Prototype EFCS Fabricated	April 1966
Completed Series I Impact Test Program	June 1966
Initiated Series II Impact Tests	June 1966
Thermal Diffusivity/Conductivity of PuO_2 Determined by BMI	June 1966
Effective Thermal Conductivity of PuO_2 Microspheres in Helium and Argon Established by Mound Tests and GE Calculations	August 1966
Capsule NDT, Emissive Coat and Backplate Attachment Subcontracted to GE-VAL	August 1966

Effective PuO_2 Power Density (2.6 ± 0.2 W - CM^{-3}) Established by Mound	September 1966
Need for Four Liner Sizes Established Based on Variations in Power Densities	September 1966
AEC Authorization for Direct Liaison Between GE-MSD and Mound	October 1966
Final Review and Drawing Release of Series III Fuel Capsule Design	October 1966
Final Review Completed for Series III Capsule and Drawing Released	October 1966
Series III Impact Test Program Cancelled by AEC	Feburary 1967
Sea Water Corrosion Test Cancelled by AEC	February 1967
First Fuel Capsule Completed	October 1967
Mound Lab Requested to do Radiation Spectrum Analysis on Capsule 2	October 1967
Completed Capsule 2 Fueling at Mound	October 1967
Bare Capsule Dose Rate and Spectrum Measurements Completed by Mound	November 1967

3.2 QUALIFICATION TESTING

CAPSULE S/N 6330004

Arrival at GE-MSC	June 17, 1968
FCA-IPU Compatibility Test - MOD 21	June 21, 1968
FCA-IPU Compatibility Test - MOD 21	June 24, 1968
FCA Thermal Mapping, Helium Leak Check, Flange Weld Inspection	June 24, 1968
FCA-Qual GLFC Fit Check	June 25, 1968
FCA-Qual GLFC Fit Check	November 6, 1968

FCA Thermal Mapping, Helium Leak Check, Flange Weld Inspection	January 9, 1969
FCA-GLFC Vibration Test	January 15, 1969
FCA Thermal Mapping, Helium Leak Check, Flange Weld Inspection	January 23, 1969
FCA-GLFC Air Soak Test	January 28, 1969
FCA-GLFC Thermal Vacuum Test	January 29, 1969
FCA-GLFC Vibration Test	March 24, 1969
FCA Thermal Mapping, Helium Leak Check, Flange Weld Inspection	April 1, 1969
Shipped Via AEC van from GE-MSC	April 10, 1969

3.3 FLIGHT ACCEPTANCE TESTS

FUEL CAPSULE, S/N 6330001

Arrival at GE-VFSTC	February 6, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	February 9, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection (Repeat)	February 16, 1968
FCA-MOD 8B IPU Operations	February 17, 1968
FCA-MOD 10 IPU Operations (Magnetic Evaluation Test)	February 27, 1968
FCA-MOD 13, MOD 19 IPU Compatibility Test	April 9, 1968
FCA-MIN-K Removal Operation	April 16, 1968
FCA Returned to GE-Val for Recoating	April 18, 1968
FCA Returned to GE-MSD for Test	June 5, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	June 7, 1968

Thermal Mapping, Helium Leak Check and Flange Weld Inspection	June 10, 1968
FCA-MOD 21 IPU Compatibility Test	June 21, 1968
FCA-SLA Compatibility Test	August 2, 1968
FCA-GLFC 2, GLFC 3 Compatibility Test	November 6, 1968
FCA-GLFC 2 Compatibility Test	December 11, 1968
FCA-GLFC 4, MOD 13, MOD 14 Compatibility Test	January 8, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	January 10, 1969
FCA-GLFC 2 Compatibility Test	January 20, 1969
FCA-GLFC Vibration Test	February 5, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	February 12, 1969
Shipped from GE-VFSTC	March 3, 1969

FUEL CAPSULE, S/N 6330002

Arrival at GE-VFSTC	March 26, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	April 1, 1968
FCA-MOD 13, MOD 19 IPU Compatibility Test	April 9, 1968
FCA-MOD 23 IPU Compatibility Test	May 21, 1968
FCA-MOD 21 IPU Compatibility Test	June 21, 1968
FCA-SLA Compatibility Test	July 29, 1968
FCA-MOD 21 IPU Compatibility Test	October 24, 1968
FCA-GLFC 3, GLFC 2 Compatibility Test	November 6, 1968
FCA-GLFC 1, GLFC 6 Compatibility Test	November 15, 1968
FCA Backplate Exchange	December 4, 1968

FCA-MOD 23 IPU, GLFC 6 Compatibility Test	December 4, 1968
FCA-GLFC 3 Compatibility Test	December 6, 1968
FCA-GLFC 2 Compatibility Test	December 11, 1968
FCA-MOD 22, MOD 23 IPU Compatibility Test	December 16, 1968
FCA-MOD 13, MOD 19 IPU Compatibility Test	January 8, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	January 10, 1969
FCA-GLFC 2 Compatibility Test	January 20, 1969
FCA-GFLC 4 Compatibility Test	January 23, 1969
FCA-GLFC 5 Compatibility Test	February 12, 1969
Thermal Mapping, Helium Leak Rate and Flange Weld Inspection	March 7, 1969
FCA-MOD 21 IPU Compatibility Test	March 20, 1969
Shipped from GE-VFSTC	April 10, 1969

FUEL CAPSULE, S/N 6330005

Arrival at GE-VFSTC	July 23, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	July 29, 1968
FCA-MOD 22 IPU Compatibility Testing	July 30, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	September 18, 1968
FCA-SLA Compatibility Testing	October 17, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	October 30, 1968
FCA-GLFC 3 Compatibility Test	December 6, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	December 6, 1968

FCA-GLFC 5 Compatibility Test	February 12,1969
FCA-GLFC Vibration Test	April 24, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	April 28, 1969
FCA-MOD 6 IPU Compatibility Test	May 12, 1969
Astronaut Deployment Test	May 13, 1969
Shipped from GE-VFSTC	May 19, 1969
<u>FUEL CAPSULE, S/N 6330006</u>	
Arrivat at GE-VFSTC	September 16, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	September 19, 1968
FCA-SLA Compatibility Test	October 17, 1968
FCA-MOD 21 IPU Compatibility Test	October 24, 1968
FCA-GLFC 3 Compatibility Test	December 6, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	December 11, 1968
FCA-GLFC 4 Compatibility Test	December 16, 1968
FCA-GLFC 4 Compatibility Test	January 23, 1969
FCA-GFLC Vibration Test	April 14, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	April 23, 1969
Shipped from GE-VFSTC	April 29, 1969
<u>FUEL CAPSULE, S/N 6330007</u>	
Arrival at GE-VFSTC	October 14, 1968
FCA-MOD 13 IPU Compatibility Test	October 17, 1968
FCA-SLA Compatibility Test	October 17, 1968

FCA-MOD 21 IPU Compatibility Test	October 24, 1968
FCA-GLFC 3 Compatibility Test	December 6, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	December 11, 1968
FCA-GLFC 4 Compatibility Test	December 16, 1968
FCA-GLFC 4 Compatibility Test	January 23, 1969
FCA-GLFC Vibration Test	April 14, 1969
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	April 23, 1969
Shipped from GE-VFSTC	April 29, 1969
<u>FUEL CAPSULE, S/N 6330007</u>	
Arrival at GE-VFSTC	October 14, 1968
FCA-MOD 13 IPU Compatibility Test	October 17, 1968
FCA-SLA Compatibility Test	October 17, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	October 29, 1968
FCA-GLFC 3 and GLFC 6 Compatibility Test	November 6, 1968
FCA-MOD 23 IPU Compatibility Test	December 4, 1968
Thermal Mapping, Helium Leak Check and Flange Weld Inspection	February 17, 1969
FCA-GLFC Vibration Test	April 17, 1969
Thermal Mapping,Helium Leak Check and Flange Weld Inspection	April 11, 1969
FCA-GLFC 6 Compatibility Test	April 22, 1969
Shipped from GE-VFSTC	April 29, 1969

4. LM FUEL CASK (LFC) AND GRAPHITE LM FUEL CASK (GLFC)

4.1 DESIGN AND DEVELOPMENT

LFC Stage II Design Release	February 1966
LTV Aero-Stability Tests Completed	February 1966
LFC Backward Stability Problem Resolved	
Aero-Thermo Testing Completed	
Superorbital Compatibility Study Completed	
Transulnar Abort Trajectory Study Initiated	April 1966
LFC Static Stability Test at Mach 10 Completed	April 1966
LFC Modification to Eliminate Backward Stability Problem Initiated	April 1966
Backward Stability Problem Resolved thru Addition of Aero-Flap	June 1966
LFC Aero and Thermal Testing Completed	June 1966
AEC Direction for LFC Separation Study	October 1966
LFC/ALSEP Thermal Integration Test Started	October 1966
Bendix Directed by NASA to Provide Release Design by December 1, 1966	October 1966
LFC/ALSEP Integrated Dynamic Tests Deleted	October 1966
GLFC Program Go-Ahead	January 1967
GLFC Hardware Shipped to Bendix for Cooling Test	October 1967
Final GLFC Drawings Released	October 1967
GLFC Critical Design Review (CDR)	November 1967
M6 and M7 Mockups Shipped to NASA	November 1967
Engineering Development Cask Assembled	January 1968
Thermal Test of Engineering GLFC and Thermal Test of Barrier Completed	January 1968
Second Fansteel Barrier for Engineering Tests Received	January 1968
BSTA GLFC Delivered to Bendix	January 1968
AMES and JPL on Record that GLFC Cannot Survive Re-entry Due to Re-entry Stabilization	February 1968
NASA-Bendix Presented New Dynamic Loads of Excessive Levels	February 1968
Graphite Characterization Program Completed	February 1968
Decision to Use M5 Hardware for Litton Test	February 1968
Qual-Type Radiation Barrier Successfully Brazed	March 1968
First Qual Graphite Hardware Received	March 1968
Vibration Test on GLFC Using Original Loads Defined	March 1968
Beryllium Radiation Barrier Defined	March 1968
Proposal Submitted to Bendix for Integrated ACA Testing	March 1968
Radiation Barrier Redesign Completed	April 1968
Bendix Prototype ACA Tests Completed	April 1968
ACA Program Redefined by Bendix	April 1968
Bendix's ACA Subcontract Received	May 1968
Engineering Be Cylinder Received	May 1968
Litton Manned Test Completed	May 1968
GLFC ICS 314121 (Rev. A) Recieved from Bendix; Dynamic Loads Revised Upwards	June 1968
Engineering Unit Assembled with Be SHS	June 1968

Engineering Tests on GLFC (Hot, Dynamic) Completed	June 1968
Spline Pull Test Completed	July 1968
Engineering ACA Vibration Test Completed	August 1968

.2 QUALIFICATION TESTING

QUAL M5 MOCKUP ASSEMBLY, S/N 6405001

Weight and CG Measurements	July 18, 1968
Inspect and Assemble into ACA	October 29, 1968
Acceptance Vibration	October 31, 1968
Inspection	November 4, 1968
Qual Shock and Vibration	November 7, 1968
Final Inspection	November 14, 1968
Ship to Bendix Corporation	November 18, 1968

GLFC, S/N 6406001

Receive, Inspect and Assemble into ACA	July 2, 1968
Weight and CG Measurement	July 3, 1968
Engineering Tests	August 29, 1968
Weight and CG Measurements (repeat) Due to Redesign	December 5, 1968
Instrument	December 16, 1968
Operability Assurance Vibration (set-up test)	January 6, 1969
Post Vibration Tilt Test	January 16, 1969
Inspection	January 17, 1969
Thermal Air Soak Test	January 29, 1969
Thermal Vacuum Test	February 4, 1969

Inspection	February 5, 1969
Qual Shock and Vibration	March 29, 1969
Post Vibration Tilt Test	March 29, 1969
Final Inspection	April 3, 1969
Ship to Bendix Corporation	April 4, 1969

4.3 FLIGHT ACCEPTANCE TESTING*

FLIGHT M5 MOCKUP ASSEMBLY, S/N 6405002

Receive, Inspect and Assemble into ACA	November 13, 1968
Weight and CG Measurements	November 15, 1968
Acceptance Vibration	November 18, 1968
Final Inspection	November 19, 1968
Ship to Bendix Corporation	December 8, 1968

GLFC, S/N 6406002 (FLIGHT 1)

Receive, Inspect and Assemble into ACA	January 21, 1969
Weight and CG Measurements	February 4, 1969
Acceptance Vibration	February 6, 1969
Tilt Test	February 7, 1969
Final Inspection	February 10, 1969
Ship to Bendix Corporation	February 11, 1969

GLFC, S/N 6406003 (BACK-UP)

Receive, Inspect and Assemble into ACA	February 24, 1969
Weight and CG Measurements	February 27, 1969
Acceptance Vibration	March 5, 1969

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* As part of the ACA assembly

DECLASSIFIED

APPENDIX C

GENERATOR DATA

DECLASSIFIED

DECLASSIFIED

ENGINEERING GENERATOR

MOD 5 DATA

DECLASSIFIED

FIRST GENERATOR I-V MAPPING IN AIR SUMMARY SHEET - MOD 5

GENERATOR ASSEMBLY NO. 5

START DATE 11/16/66 TIME 3:40 P.M.

AVERAGE CHAMBER PRESSURE AMBIENT AIR

EFCS POWER INPUT 1445 WATTS

MAP POINT	T_C (°F)	T_H (°F)	E_x (VOLTS)	E_L (VOLTS)	I_L (OHMS)	$R_L = E_L/I_L$ (AMPS)	POWER OUT $(E_L \times I_L)$ (WATTS)	POWER IN (EFCS) (WATTS)	INT. RES. $(E_X - E_L)/I_L$ (OHMS)	ELAPSED TIME (HOURS)
4.7 Ω	522	1080	25.4	17.96	3.81	4.7	68.4	1445	2.9	4
MLC	523	1048	27.0	13.52	4.92	2.75	66.4	1450	2.74	4
1.25 MLC	529	1023	25.31	8.92	6.14	1.45	57.74	1445	2.68	4
1.50 MLC	533	998	23.69	4.07	7.37	0.552	30.06	1445	2.66	4
Minimum Load	536	991	23.18	3.06	7.61	0.402	23.26	1445	2.64	4
0.75 MLC	520	1078	28.16	18.18	3.69	4.923	67.14	1445	2.82	4
0.50 MLC	521	1118	30.67	23.43	2.45	9.582	57.40	1445	2.96	4

NOTE: Elapsed time is defined as: The beginning of- to the end of steady state conditions. All of the above values shall be averaged over the elapsed time period.

FIRST GENERATOR I-V MAPPING IN VACUUM SUMMARY SHEET - MOD 5

GENERATOR ASSEMBLY NO. 5

START DATE 1/10/67 TIME 6.00 P.M.

AVERAGE SINK TEMPERATURE 172°F

AVERAGE CHAMBER PRESSURE 10^{-6} TORR

EFCS POWER INPUT 1496 WATTS

MAP POINT	T_C (°F)	T_H (°F)	E_x (VOLTS)	E_L (VOLTS)	I_L (OHMS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT $(E_L \times I_L)$ (WATTS)	POWER IN (EFCS) (WATTS)	INT. RES. $(E_x - E_L)$ (OHMS)	ELAPSED TIME (HOURS)
4.7 Ω	525	1092	29.20	18.36	3.87	4.74	71.08	1496	2.80	4
MLC	526.5	1060	27.4	13.7	5.01	2.736	68.74	1496	2.735	4
1.25 MLC	530	1034	25.9	9.00	6.20	1.476	55.80	1498	2.735	4
4.2 Ω	524	1082	28.7	17.2	4.15	4.14	71.38	1496	2.77	4
Minimum Load	534	1018.5	24.8	5.6	7.1	0.789	39.76	1501	2.704	4
0.65 MLC	523.7	1110.7	30.24	21.00	3.25	6.46	68.25	1498	2.84	4

NOTE: Elapsed time is defined as: The beginning of- to the end of steady state conditions. All of the above values shall be averaged over the elapsed time period.

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GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 5
START DATE 7/9/68 TIME 2400
TECHNICIAN I. Maimon
ENGINEER
APPROVED DATE 9/3/68

AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 9.0×10^{-6} torr
EFCS POWER UNIT 1500 WATTS
ELAPSED HOURS 12,116 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	523	1097	17.5	3.72	29.5	4.70	67.5	3.23	1500	4
MLC	525	1080	14.3	4.48	28.5	3.18	65.6	3.18	1500	4
16.0 VOLT LOAD	526	1092	16.0	4.09	29.0	3.91	67.2	3.18	1500	4
MINIMUM LOAD	536	1037	4.9	6.50	25.8	0.75	32.4	3.22	1500	4
0.63 MLC	NOT PERFORMED DUE TO HIGH TEMPERATURES.									

CA LEAK RATE -- 4.43×10^{-6} std cc/sec or Argon

Final Generator I-V Mapping Summary Sheet - Mod 5
(Lunar Day Conditions)

GENERATOR I-V MAPPING SUMMARY SHEET
Final Mapping Prior to Termination of Testing

GENERATOR ASSEMBLY NO. MOD 5
START DATE 7/8/68 TIME 0930
TECHNICIAN E. Streup, B. Schmall
ENGINEER
APPROVED DATE 9/3/68

AVERAGE SINK TEMPERATURE -240 °F
AVERAGE CHAMBER PRESSURE 1.2×10^{-6} TORR
EFCS POWER UNIT 1500 WATTS
ELAPSED HOURS 12,101 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	665	1066	17.9	3.79	29.0	4.71	69.7	2.92	1500	4
MLC	670	1018	13.6	4.81	27.5	2.83	66.8	2.89	1500	4
16.0 VOLT LOAD	669	1034	16.0	4.23	28.3	3.78	69.7	2.91	1500	4
MINIMUM LOAD	679	985	5.0	6.80	25.2	0.73	33.8	2.98	1500	4
0.63 MLC	NOT PERFORMED DUE TO HIGH TEMPERATURES.									

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

Final Generator I-V Mapping Summary Sheet - Mod 5
(Lunar Night Conditions)

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ENGINEERING GENERATOR

MOD 8B DATA

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I-V Mapping in Air Summary Sheet - Mod 8B

MAP POINT	(CALC) T_C (^oF)	T_H (^oF)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7Ω	529	1089	17.92	3.80	28.89	4.71	68.13	2.88	1450	4
MINIMUM LOAD	546	1008	1.58	7.56	23.80	0.208	11.93	2.94	1446	4.5

Note: Elapsed time is from the beginning to the end of steady-state conditions. All of the above values were averaged over the elapsed time period.

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I-V Mapping in Air Summary Sheet - Mod 8B (Lunar Day Conditions)

GENERATOR I-V MAPPING SUMMARY SHEET
7500 HOUR I-V MAPPING

GENERATOR ASSEMBLY NO. 8 B
START DATE 6/18/68 TIME 0:830
TECHNICIAN B. Schmell
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE + 170 °F
AVERAGE CHAMBER PRESSURE 6.5×10^{-8} TORR
EFCS POWER UNIT 1505 WATTS
ELAPSED HOURS 7851 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	513	1023	17.9	3.79	28.6	4.71	67.9	2.84	1505	4
MLC	515	1046	13.6	4.81	27.1	2.83	65.0	2.81	1505	4
16.0 VOLT LOAD	513	1062	16.0	4.21	28.0	3.80	67.2	2.85	1505	4
MINIMUM LOAD	519	1008	5.9	6.61	24.8	0.89	37.8	2.87	1505	4
0.65 MLC	513	1093	20.5	3.13	29.7	6.55	65.8	2.94	1505	4

GENERATOR I-V MAPPING SUMMARY SHEET
7500 Hour I - V Mapping

GENERATOR ASSEMBLY NO. 8 B
START DATE 6/16/68 TIME 0000
TECHNICIAN B. Schmell
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 7.8×10^{-8} TORR
EFCS POWER UNIT 1455 WATTS
ELAPSED TIME 7815 HOURS

MAP POINT	(CALC) T_C (F)	T_H (F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	505	1047	17.3	3.70	27.5	4.70	64.8	2.75	1455	4
MLC	506	1019	13.0	4.81	26.0	2.69	61.9	2.71	1455	4
16.0 VOLT LOAD	505	1039	16.0	4.01	27.1	3.98	64.8	2.77	1455	4
MINIMUM LOAD	511	986	5.8	6.45	23.9	0.89	36.1	2.81	1455	4
0.65 MLC	505	1065	19.8	3.12	28.5	6.35	63.0	2.79	1455	4

GENERATOR I-V MAPPING SUMMARY SHEET
7500 HOUR I-V MAPPING

GENERATOR ASSEMBLY NO. MOD 8B
START DATE 6/15/68 TIME 1600
TECHNICIAN R. Martin, E. Straup, B. Schmell
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE 171 °F
AVERAGE CHAMBER PRESSURE 8×10^{-8} TORR
EFCS POWER UNIT 1415 WATTS
ELAPSED HOURS 7759 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	500	1030	17.0	3.61	26.8	4.70	62.1	2.71	1415	4 hrs
MLC	501	1001	12.6	4.70	25.2	2.68	58.5	2.68	1415	4 hrs
16.0 VOLT LOAD	500	1022	16.1	3.81	26.4	4.23	62.0	2.70	1415	4 hrs.
MINIMUM LOAD	503	983	5.8	6.60	23.0	0.88	35.3	2.72	1415	4 hrs
0.65 MLC	500	1044	19.4	3.06	27.6	6.34	60.2	2.68	1415	4 hrs

NOTE: ELAPSED TIME IS DEFINED AS THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS.
ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping in Air Summary Sheet - Mod 8B (Lunar Night Conditions)

GENERATOR I-V MAPPING SUMMARY SHEET
7500 HOUR I-V MAPPINGS

GENERATOR ASSEMBLY NO. 8B
START DATE 6/20/68 TIME 1700
TECHNICIAN E. Straup
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 4.8×10^{-8} TORR
EFCS POWER UNIT 1505 WATTS
ELAPSED TIME 7915 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	440	1004	18.1	3.84	27.9	4.71	69.5	2.55	1505	4
MLC	440	969	13.0	5.19	25.9	2.50	66.2	2.49	1505	4
16.0 VOLT LOAD	439	986	16.0	4.40	27.0	3.64	69.8	2.50	1505	4
MINIMUM LOAD	446	930	6.2	7.01	23.7	0.88	41.9	2.50	1505	4
0.65 MLC	439	1014	19.9	3.37	28.5	5.88	67.2	2.56	1505	4

GENERATOR I-V MAPPING SUMMARY SHEET
7500 HOUR I-V MAPPING

GENERATOR ASSEMBLY NO. 8B
START DATE 6/22/68 TIME 1500
TECHNICIAN B. Schmell, J. Nieman
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 4.9×10^{-8} TORR
EFCS POWER UNIT 1455 WATTS
ELAPSED TIME 7952 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	430	973	17.5	3.71	26.6	4.72	65.4	2.45	1455	4
MLC	431	935	12.3	5.16	24.6	2.37	62.2	2.39	1455	4
16.0 VOLT LOAD	430	961	16.0	4.10	26.0	3.90	66.0	2.44	1455	4
MINIMUM LOAD	436	899	6.1	6.88	22.5	0.88	40.0	2.39	1455	4
0.65 MLC	430	984	18.9	3.35	27.2	5.64	64.1	2.48	1455	4

GENERATOR I-V MAPPING SUMMARY SHEET
7500 HOUR I-V MAPPING

GENERATOR ASSEMBLY NO. MOD 8B
START DATE 6/23/68 TIME 2300
TECHNICIAN S. D'Abbene, B. Schmell, E. Straup
ENGINEER
APPROVED DATE 6/26/68

AVERAGE SINK TEMPERATURE -269 °F
AVERAGE CHAMBER PRESSURE 7.7×10^{-7} TORR
EFCS POWER UNIT 1415 WATTS
ELAPSED TIME 7985 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	423	950	17.1	3.62	25.7	4.71	62.2	2.39	1415	4
MLC	424	911	11.6	5.15	23.6	2.25	58.9	2.33	1415	4
16.0 VOLT LOAD	423	942	16.0	3.90	25.3	4.10	62.0	2.38	1415	4
MINIMUM LOAD	428	828	6.0	6.75	21.7	0.88	39.0	2.33	1415	4
0.65 MLC	423	936	17.9	3.32	26.0	5.27	61.2	2.40	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS.
ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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QUALIFICATION GENERATOR

MOD 10 DATA

DECLASSIFIED

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First I-V Mapping in Air Summary Sheet - Mod 10

GENERATOR ASSEMBLY NO. 10

AVERAGE SINK TEMPERATURE ---

START DATE 6/12/67 TIME 1110

AVERAGE CHAMBER PRESSURE Ambient

TECHNICIAN R. Schmidt/F. Hibbs

EFCS POWER UNIT 1450 WATTS

ENGINEER R. Schoneker

APPROVED Neil R. [illegible] DATE 13 June 1967

MAP POINT	(CALC) T_C (^oF)	T_H (^oF)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT ($E_L \times I_L$) (WATTS)	INT. RES. ($E_O - E_L/I_L$) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ohms	517	1085	18.34	3.90	29.11	4.70	71.5	2.76	1450	4
Minimum Load	533	986	.96	8.21	23.12	0.12	7.9	2.70	1450	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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Initial I-V Mapping Summary Sheet (Lunar Day Cycle) Mod 10

GENERATOR ASSEMBLY NO. MOD #10
START DATE 7/7/67 TIME 0400
TECHNICIAN J. Neiman/S. D'Abbene
ENGINEER G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE +170°F
AVERAGE CHAMBER PRESSURE 1.1 x 10^{-9} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC.) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	496	1070	18.41	3.89	29.2	4.74	70.3	2.77	1505	4
MLC	501	1055	14.10	5.13	28.2	2.74	71.3	2.75	1505	4
16.0 VOLTS	500	1066	16.03	4.60	28.8	3.49	72.7	2.78	1505	4
MINIMUM LOAD	510	1000	4.65	7.54	24.9	0.62	34.3	2.68	1505	4
0.65 MLC	493	1077	20.50	3.33	29.7	6.13	67.2	2.76	1505	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

GENERATOR ASSEMBLY NO. MOD #10
START DATE 7/9/67 TIME 0730
TECHNICIAN P. O'Donnell/J. Banesh
ENGINEER G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE +170°F
AVERAGE CHAMBER PRESSURE 9 x 10^{-10} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (VOLTS)	E_O (AMPS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	484	1034	17.80	3.78	27.7	4.71	66.0	2.63	1455	4
MLC	486	1000	12.89	5.00	25.8	2.58	63.4	2.58	1455	4
16.0 VOLTS	485	1021	16.10	4.20	27.0	3.83	66.6	2.60	1455	4
MINIMUM LOAD	492	951	4.39	7.26	22.9	0.60	31.2	2.55	1455	4
0.65 MLC	485	1051	19.82	3.24	28.6	6.11	63.2	2.71	1455	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

GENERATOR ASSEMBLY NO. MOD #10
START DATE 7/10/67 TIME 2400
TECHNICIAN S. D'Abbene/B. Schmell
ENGINEER G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE +169°F
AVERAGE CHAMBER PRESSURE 9.8 x 10^{-10} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	480	1018	17.50	3.70	27.0	4.73	63.8	2.57	1420	4
MLC	482	983	12.62	4.93	25.1	2.56	61.6	2.53	1418	4
16.0 VOLTS	483	1007	15.99	4.02	26.3	3.96	64.0	2.55	1417	4
MINIMUM LOAD	486	933	4.22	7.11	22.2	0.59	30.1	2.53	1415	4
0.65 MLC	478	1029	19.30	3.20	27.7	6.03	60.8	2.63	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

Initial I-V Mapping Summary Sheet (Lunar Night Cycle) Mod 10

GENERATOR ASSEMBLY NO. 10
START DATE 7/12/67 TIME 1600
TECHNICIAN B. Borell/J. Neiman
ENGINEER A. Caruvana G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE -280°F
AVERAGE CHAMBER PRESSURE 1.3 x 10^{-9} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	421	988	18.36	3.90	27.8	4.71	70.2	2.43	1505	4
MLC	422	945	12.79	5.48	25.5	2.33	68.8	2.32	1505	4
16.0 VOLTS	422	971	16.00	4.52	26.8	3.54	71.6	2.40	1505	4
MINIMUM LOAD	431	897	4.71	7.84	22.6	0.60	35.9	2.28	1505	4
0.65 MLC	422	1000	19.58	3.56	28.4	5.50	68.5	2.47	1505	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/14/67 TIME 0700
TECHNICIAN B. Borell/J. Neiman
ENGINEER G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE -280°F
AVERAGE CHAMBER PRESSURE 1.6 x 10^{-9} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	417	963	17.85	3.79	26.6	4.71	66.3	2.32	1455	4
MLC	418	918	11.99	5.45	24.2	2.20	64.4	2.24	1455	4
16.0 VOLTS	412	941	15.99	4.30	25.7	3.72	67.8	2.26	1455	4
MINIMUM LOAD	424	873	4.60	7.65	21.6	0.60	34.9	2.22	1455	4
0.65 MLC	414	967	18.62	3.52	27.0	5.28	65.0	2.36	1455	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

GENERATOR ASSEMBLY NO. MOD #10
START DATE 7/15/67 TIME 1600
TECHNICIAN S. D'Abbene/J. Neiman
ENGINEER A. Caruvana G. Caruvana 7/17/67
APPROVED Neil K. Yerger DATE 7/18/67

AVERAGE SINK TEMPERATURE -270°F
AVERAGE CHAMBER PRESSURE 1.5 x 10^{-9} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT.RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	405	936	17.40	3.69	25.7	4.71	63.0	2.25	1415	4
MLC	406	894	11.70	5.30	23.4	2.21	61.5	2.21	1415	4
16.0 VOLTS	405	925	16.00	4.00	25.1	3.99	64.0	2.27	1415	4
MINIMUM LOAD	413	848	4.58	7.52	20.8	0.61	33.4	2.16	1415	4
0.65 MLC	406	942	18.17	3.44	26.0	5.28	61.5	2.28	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

GENERATOR ASSEMBLY NO. MOD 10
START DATE 10/2/67 TIME 1100
TECHNICIAN J. Banesh/J. Neiman
ENGINEER 10/4/67
APPROVED DATE 10/5/67

AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 2.8×10^{-7} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 1351

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	508	1073	18.3	3.88	28.8	4.72	71.5	2.71	1505	4
MLC	511	1038	13.4	5.04	26.8	2.66	68.0	2.66	1505	4
16.0 VOLT LOAD	510	1056	16.0	4.40	27.8	3.64	71.1	2.68	1505	4
MINIMUM LOAD	517	990	4.54	7.30	23.9	0.62	31.1	2.66	1505	4
0.65 MLC	508	1089	20.6	3.28	29.6	6.28	68.8	2.74	1505	4

I-V Mapping After 1000 Hours (Lunar Day Cycle) Summary Sheet - Mod 10

GENERATOR ASSEMBLY NO. MOD 10
START DATE 10/4/67 TIME 1730
TECHNICIAN E. Straup/B. Schnell
ENGINEER 10/9/67
APPROVED DATE 10-9-67

AVERAGE SINK TEMPERATURE -280 °F
AVERAGE CHAMBER PRESSURE 3.2×10^{-6} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 1385

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	Meter POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	436	998	18.4	3.91	27.7	4.71	72.9	2.33	1505	4
MLC	438	956	12.6	5.45	25.4	2.32	68.9	2.34	1505	4
16.0 VOLT LOAD	436	978	16.0	4.52	26.7	3.55	73.2	2.36	1505	4
MINIMUM LOAD	444	909	4.9	7.72	22.6	0.64	35.4	2.29	1505	4
0.65 MLC	436	1009	19.7	3.54	28.3	5.58	71.0	2.42	1505	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping After 1,000 Hours (Lunar Night Cycle) Summary Sheet - Mod 10

GENERATOR ASSEMBLY NO. MOD 10
START DATE 12/26/67 TIME 0830
TECHNICIAN J. Banesh/J. Neiman
ENGINEER 12/28/67
APPROVED DATE 1-3-68

AVERAGE SINK TEMPERATURE 169 °F
AVERAGE CHAMBER PRESSURE 7.0×10^{-8} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 3308

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	512	1070	18.3	3.90	28.5	4.69	72.0	2.62	1505	4
MLC	513	1038	13.4	5.09	26.7	2.63	68.5	2.61	1505	4
16.0 VOLT LOAD	512	1055	16.0	4.42	27.7	3.63	71.9	2.64	1505	4
MINIMUM LOAD	521	990	4.8	7.21	23.8	0.67	33.1	2.63	1505	4
0.65 MLC	514	1091	20.5	3.31	29.5	6.19	69.3	2.72	1505	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping After 3,000 Hours (Lunar Day Cycle) Summary Sheet Mod 10

GENERATOR ASSEMBLY NO. MOD 10
START DATE 1/2/68 TIME 0900
TECHNICIAN J. P. O'Donnell/J. Neiman
ENGINEER 1/4/68
APPROVED DATE 1-4-68

AVERAGE SINK TEMPERATURE -271 °F
AVERAGE CHAMBER PRESSURE 4.3×10^{-8} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 3476

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	440	999	18.4	3.90	27.6	4.71	72.4	2.37	1505	4
MLC	441	956	12.7	5.42	25.3	2.34	69.0	2.32	1505	4
16.0 VOLT LOAD	440	981	16.0	4.55	26.7	3.52	73.1	2.35	1505	4
MINIMUM LOAD	448	910	5.2	7.6	22.6	0.68	36.9	2.30	1505	4
0.65 MLC	441	1011	19.9	3.51	28.2	5.66	70.9	2.38	1505	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping After 3,000 Hours (Lunar Night Cycle) Summary Sheet Mod 10

Final I-V Mapping Summary Sheet (Lunar Day Cycle) Mod 10

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/11/68 TIME 1630
TECHNICIAN R. Schmall
ENGINEER 9-4-68
APPROVED DATE 9/4/68
AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 6.0 X 10^{-6} torr
EFCS POWER UNIT 1505 WATTS
ELAPSED HOURS 7677 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	515	1072	18.1	3.85	28.5	4.70	71.9	2.70	1505	4
MLC	516	1040	13.3	5.02	26.7	2.64	68.0	2.68	1505	4
16.0 VOLT LOAD	515	1058	15.9	4.40	27.7	3.61	71.5	2.68	1505	4
MINIMUM LOAD	522	982	4.9	7.10	23.8	0.68	33.2	2.68	1505	4
0.68 MLC	515	1080	20.5	3.26	29.5	6.29	69.0	2.76	1505	4

GA LEAK RATE IS LESS THAN 5.21X 10^{-9} STD CC/SEC OF ARGON.

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/13/68 TIME 0100
TECHNICIAN L. Heiman
ENGINEER 9-4-68
APPROVED DATE 9/3/68
AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 1.8 X 10^{-6} torr
EFCS POWER UNIT 1455 WATTS
ELAPSED HOURS 7726 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	506	1066	17.7	3.76	27.5	4.71	68.1	2.61	1455	4
MLC	—	—	—	—	—	—	—	—	—	—
16.0 VOLT LOAD	—	—	—	—	—	—	—	—	—	—
MINIMUM LOAD	516	970	4.8	6.85	23.0	0.69	31.7	2.66	1455	4
0.68 MLC	—	—	—	—	—	—	—	—	—	—

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/13/68 TIME 1345
TECHNICIAN R. Straup
ENGINEER 9-4-68
APPROVED DATE 9/6/68
AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 1.4 X 10^{-6} torr
EFCS POWER UNIT 1415 WATTS
ELAPSED HOURS 7739 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	508	1026	17.4	3.69	26.6	4.71	64.0	2.51	1415	4
MLC	503	986	12.4	4.82	24.0	2.55	61.8	2.55	1415	4
16.0 VOLT LOAD	508	1016	16.0	3.99	26.1	4.01	64.1	2.53	1415	4
MINIMUM LOAD	502	953	4.8	6.77	22.6	0.71	30.6	2.60	1415	4
0.68 MLC	509	1042	19.6	3.16	27.5	6.16	62.1	2.50	1415	4

NOTE: ELAPSED TIME IS DEFINED AS THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

Final I-V Mapping Summary Sheet (Lunar Night Cycle) Mod 10

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/8/68 TIME 1100
TECHNICIAN R. Straup
ENGINEER 9-4-68
APPROVED DATE 9/3/68
AVERAGE SINK TEMPERATURE -280 °F
AVERAGE CHAMBER PRESSURE 1.4 X 10^{-5} torr
EFCS POWER UNIT 1505 WATTS
ELAPSED HOURS 7614 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	439	990	18.2	3.87	27.6	4.70	72.3	2.43	1505	4
MLC	460	958	12.7	5.36	[illegible]	2.36	68.9	2.38	1505	4
16.0 VOLT LOAD	439	981	16.1	4.42	26.7	3.64	73.0	2.40	1505	4
MINIMUM LOAD	447	917	5.2	7.42	22.9	0.70	36.3	2.39	1505	4
0.68 MLC	439	1009	19.8	3.49	28.2	5.66	70.3	2.42	1505	4

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/9/68 TIME 1800
TECHNICIAN S. F. D'Abbene
ENGINEER 9-4-68
APPROVED DATE 9/3/68
AVERAGE SINK TEMPERATURE -280 °F
AVERAGE CHAMBER PRESSURE 2.2 X 10^{-5} torr
EFCS POWER UNIT 1455 WATTS
ELAPSED HOURS 7645 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	430	969	17.7	3.76	26.4	4.71	67.9	2.31	1455	4
MLC	—	—	—	—	—	—	—	—	—	—
16.0 VOLT LOAD	—	—	—	—	—	—	—	—	—	—
MINIMUM LOAD	437	887	5.0	7.3	21.8	0.68	36.9	2.30	1455	4
0.68 MLC	—	—	—	—	—	—	—	—	—	—

GENERATOR I-V MAPPING SUMMARY SHEET
FINAL MAPPING PRIOR TO TERMINATION OF TESTING

GENERATOR ASSEMBLY NO. MOD 10
START DATE 7/10/68 TIME 0530
TECHNICIAN R. Straup
ENGINEER 9-4-68
APPROVED DATE 9/6/68
AVERAGE SINK TEMPERATURE -280 °F
AVERAGE CHAMBER PRESSURE 2.3 X 10^{-5} torr
EFCS POWER UNIT 1415 WATTS
ELAPSED HOURS 7656 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	423	944	17.4	3.63	25.4	4.71	64.5	2.21	1415	4
MLC	423	903	11.4	5.31	23.2	2.23	61.2	2.23	1415	4
16.0 VOLT LOAD	422	936	16.0	3.99	26.0	4.01	63.2	2.23	1415	4
MINIMUM LOAD	429	883	5.0	7.13	21.0	0.70	36.0	2.24	1415	4
0.68 MLC	422	951	18.2	3.39	25.8	5.37	61.7	2.24	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

ALSEP PROTOTYPE TEST GENERATOR

MOD 14 DATA

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First Generator I-V Mapping in Air Summary Sheet - Mod 14

GENERATOR ASSEMBLY NO. 14

START DATE 12/26/66 TIME 0030 AVERAGE CHAMBER PRESSURE AIR

EFCS POWER INPUT 1445 WATTS

MAP POINT	T_C (°F)	T_H (°F)	E_x (VOLTS)	E_L (VOLTS)	I_L (AMPS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT ($E_L \times I_L$) (WATTS)	POWER IN (EFCS) (WATTS)	INT. RES. ($E_x - E_L$) (OHMS)	ELAPSED TIME (HOURS)
4.7 Ω	525	1079	28.45	18.02	3.85	4.67	69.5	1447.5	2.70	4
1.50 MLC	532	1008	24.31	4.408	7.35	0.6	32.4	1445	2.71	4

Second Generator I-V Mapping in Vacuum Summary Sheet - Mod 14

GENERATOR ASSEMBLY NO. 14 AVERAGE SINK TEMPERATURE 170° F

START DATE 1/1/67 TIME 11:00 A.M. AVERAGE CHAMBER PRESSURE 3.3×10^{-6} TORR

EFCS POWER INPUT 1445 WATTS

MAP POINT	T_C (°F)	T_H (°F)	E_x (VOLTS)	E_L (VOLTS)	I_L (OHMS)	$R_L = E_L/I_L$ (AMPS)	POWER OUT ($E_L \times I_L$) (WATTS)	POWER IN (EFCS) (WATTS)	INT. RES. ($E_x - E_L$) (OHMS)	ELAPSED TIME (HOURS)
4.7 Ω			27.65	17.7	3.76	4.72	66.44	1445	2.65	4
MLC			25.9	12.95	4.95	2.62	63.8	1445	2.62	4
Minimum Load			23.62	5.376	6.857	.783	26.86	1445	2.66	4
0.65 MLC			28.52	19.98	3.22	6.189	64.25	1450	2.66	4

NOTE: Elapsed time is defined as: the beginning of- to the end of steady state conditions. All of the above values shall be averaged over the elapsed time period.

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ALSEP QUALIFICATION TEST GENERATOR

MOD 15 DATA

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I-V MAPPING IN AIR - GENERATOR ASSEMBLY MOD 15 (PRESSURE = AMBIENT)

INITIAL MAPPING (3/31/67)

MAP POINT	(CALC) T_C (^oF)	T_H (^oF)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT ($E_L x I_L$) (WATTS)	INT. RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ohms	525	1083	17.75	3.79	28.74	4.69	67.27	2.90	1445	4
Minimum load	538	1002	1.19	7.65	23.8	0.16	9.10	2.96	1445	4

FINAL MAPPING (4/17/67)

MAP POINT	(CALC) T_C (^oF)	T_H (^oF)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT ($E_L x I_L$) (WATTS)	INT. RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ohms	529	1085	18.0	3.80	28.7	4.73	68.4	2.81	1435	4
Minimum load	549	1010	2.0	7.44	23.7	0.27	15.0	2.92	1435	4

Note: Elapsed time is from the beginning to the end of steady-state conditions. All of the above values were averaged over the elapsed time period.

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I-V MAPPING IN VACUUM - GENERATOR ASSEMBLY NO. 15
(SINK TEMP = 170°F; PRESSURE = 4 X 10^{-7} TORR)

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. E_O-E_L/I_L (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
FIRST MAPPING (4/6/67)										
4.7 Ohms	499	1072	18.18	3.84	29.1	4.73	71.72	2.86	1502	4
MLC	499	1039	13.74	4.96	27.3	2.76	69.6	2.74	1500	4
1.25 MLC	502	1010	8.45	6.20	25.7	1.35	53.8	2.76	1500	4
Minimum Load	507	991	4.55	7.31	24.5	0.622	33.3	2.73	1500	4
0.65 MLC	499	1086	20.51	3.25	29.9	6.31	68.6	2.89	1500	4
SECOND MAPPING (4/11/67)										
4.7 Ohms	500	1071	18.18	3.86	29.0	4.70	72.5	2.82	1500	4
MLC	501	1042	13.66	5.02	27.5	2.71	70.4	2.75	1500	4
1.25 MLC	505	1016	8.75	6.27	25.9	1.40	55.7	2.73	1500	4
Minimum Load	508	994	4.57	7.39	24.6	0.62	33.45	2.71	1500	4
0.65 MLC	500	1089	20.67	3.26	30.0	6.33	69.6	2.83	1500	4
THIRD MAPPING (4/15/67)										
4.7 Ohms	501	1070	18.31	3.87	29.0	4.73	73.0	2.76	1500	4
MLC	502	1041	13.70	5.07	27.4	2.70	71.0	2.70	1500	4
1.25 MLC	504	1011	8.84	6.34	25.7	1.39	56.7	2.66	1500	4
Minimum Load	508	996	4.62	7.38	24.7	0.63	33.8	2.71	1500	4
0.65 MLC	501	1088	20.73	3.29	29.9	6.30	70.0	2.80	1500	4

Note: Elapsed time is from the beginning to the end of steady-state conditions. All of the above values were averaged over the elapsed time period.

16-Volt Generator Performance in Vacuum - Mod 15

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT ($E_L x I_L$) (WATTS)	INT. RES. (E_O-E_L/I_L) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
SINK TEMPERATURE (+170°F)										
16.0V Output	501	1058	16.11	4.43	28.3	3.64	73.1	2.75	1500	4
SINK TEMPERATURE -280°F										
16.0V Output	427	984	16.04	4.58	27.4	3.50	75.2	2.48	1500	4

Generator Mod 13 I-V Mapping in Air Summary Sheet

GENERATOR ASSEMBLY NO. 13
AVERAGE SINK TEMPERATURE -------
START DATE 7/13/67 TIME 0730
AVERAGE CHAMBER PRESSURE Air
TECHNICIAN R. Schmidt/F. Hibbs
EFCS POWER UNIT 1450 WATTS
ENGINEER A. Caruvana 7/21/67
ACCUMULATED HOURS 295
APPROVED DATE 7/25/67

MAP POINT	T_C (°F)	(CALC) T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L=E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT.RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	521	1083	18.12	3.84	28.92	4.70	69.6	2.84	1450	4
MINIMUM LOAD	538	999	1.22	7.82	23.5	0.16	9.54	2.86	1450	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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Generator Mod 13 I-V Map - Lunar Day Cycle Summary Sheet

GENERATOR ASSEMBLY NO. MOD 13
START DATE 10/24/67 TIME 2330
TECHNICIAN B. Schmell/E. Straup
ENGINEER R. T. 10/27/67
APPROVED DATE 10/27/67
AVERAGE SINK TEMPERATURE 169 °F
AVERAGE CHAMBER PRESSURE 5.2 x 10⁻⁷ torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 330

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	508	1082	18.0	3.86	29.3	4.67	69.1	2.92	1505	4
MLC	510	1056	13.9	4.88	27.8	2.85	67.5	2.85	1505	4
16.0 VOLT LOAD	510	1069	16.0	4.36	28.5	3.65	69.8	2.87	1505	4
MINIMUM LOAD	517	1006	4.7	7.1	24.8	0.66	33.1	2.83	1505	4
0.65 MLC	510	1104	21.2	3.17	30.4	6.69	66.2	2.90	1505	4

GENERATOR ASSEMBLY NO. MOD 13
START DATE 10/26/67 TIME 1000
TECHNICIAN S. D'Abbene/P. O'Donnell
ENGINEER 10/31/67
APPROVED DATE 10/31/67
AVERAGE SINK TEMPERATURE 169 °F
AVERAGE CHAMBER PRESSURE 5.7 x 10⁻⁸ torr
EFCS POWER UNIT 1455 WATTS
ACCUMULATED HOURS 366

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	502	1057	17.8	3.78	28.2	4.71	66.9	2.75	1455	4
MLC	503	1028	13.3	4.87	26.6	2.73	64.9	2.73	1455	4
16.0 VOLT LOAD	502	1043	16.0	4.21	27.5	3.8	67.1	2.73	1455	4
MINIMUM LOAD	511	983	4.6	6.92	23.9	0.66	31.9	2.79	1455	4
0.65 MLC	503	1076	20.4	3.18	29.2	6.42	64.0	2.78	1455	4

GENERATOR ASSEMBLY NO. MOD 13
START DATE 10/27/67 TIME 1830
TECHNICIAN B. Schmell, E. Straup
ENGINEER 10/31/67
APPROVED DATE 11-2-67
AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 4.7 x 10⁻⁸ torr
EFCS POWER UNIT 1415 WATTS
ACCUMULATED HOURS 398

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	497	1037	17.4	3.70	27.3	4.70	64.0	2.68	1415	4
MLC	499	1007	12.8	4.83	25.6	2.65	61.5	2.65	1415	4
16.0 VOLT LOAD	497	1027	16.0	4.0	26.8	4.0	64.3	2.70	1415	4
MINIMUM LOAD	505	963	4.6	6.81	23.0	0.67	30.9	2.71	1415	4
0.65 MLC	496	1051	19.4	3.15	28.2	6.18	61.1	2.77	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

Generator Mod 13 I-V Map - Lunar Night Cycle Summary Sheet

GENERATOR ASSEMBLY NO. MOD 13
START DATE 10/29/67 TIME 0500
TECHNICIAN J. Banesh, S. D'Abbene
ENGINEER 10/31/67
APPROVED DATE 11-2-67
AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 3.0 x 10⁻⁸ torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 433

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	436	1011	18.4	3.90	28.4	4.71	71.4	2.58	1505	4
MLC	438	971	13.1	5.38	26.2	2.43	69.6	2.44	1505	4
16.0 VOLT LOAD	436	992	16.0	4.54	27.4	3.53	72.5	2.51	1505	4
MINIMUM LOAD	445	927	4.9	7.59	23.6	0.64	36.2	2.47	1505	4
0.65 MLC	436	1021	19.9	3.50	29.0	5.67	69.6	2.61	1505	4

GENERATOR ASSEMBLY NO. MOD 13
START DATE 10/30/67 TIME 1900
TECHNICIAN J. Heiman/P. O'Donnell
ENGINEER 11/1/67
APPROVED DATE 11-2-67
AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 4.8 x 10⁻⁸ torr
EFCS POWER UNIT 1455 WATTS
ACCUMULATED HOURS 467

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	428	954	17.9	3.80	27.3	4.72	67.8	2.46	1455	4
MLC	428	940	12.5	5.30	25.0	2.36	65.8	2.36	1455	4
16.0 VOLT LOAD	428	968	16.0	4.32	26.4	3.70	68.8	2.41	1455	4
MINIMUM LOAD	435	900	4.8	7.38	22.6	0.66	35.2	2.40	1455	4
0.65 MLC	427	992	19.2	3.45	27.8	5.56	66.0	2.48	1455	4

GENERATOR ASSEMBLY NO. MOD 13
START DATE 11/1/67 TIME
TECHNICIAN J. Banesh/B. Schmell
ENGINEER 11/2/67
APPROVED DATE 11/6/67
AVERAGE SINK TEMPERATURE -276 °F
AVERAGE CHAMBER PRESSURE 2.4 x 10⁻⁸ torr
EFCS POWER UNIT 1415 WATTS
ACCUMULATED HOURS 503

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	419	936	17.4	3.70	26.2	4.70	64.1	2.38	1415	4
MLC	421	916	12.0	5.22	24.0	2.30	62.0	2.30	1415	4
16.0 VOLT LOAD	419	945	16.0	4.11	25.6	2.89	65.3	2.34	1415	4
MINIMUM LOAD	427	879	4.8	7.23	21.7	0.66	34.3	2.33	1415	4
0.65 MLC	419	966	18.6	3.39	26.7	5.49	62.6	2.39	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

FLIGHT GENERATOR

MOD 19 DATA

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Generator Mod 19 I-V Mapping in Air Summary Sheet

GENERATOR ASSEMBLY NO. MOD 19

START DATE 6/26/67 TIME 1000

TECHNICIAN W. Klimiuk, R. Schoneker

ENGINEER 7/5/67

APPROVED DATE 7-5-67

AVERAGE SINK TEMPERATURE -------

AVERAGE CHAMBER PRESSURE Ambient

EFCS POWER UNIT 1440 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT ($E_L \times I_L$) (WATTS)	INT. RES. ($E_O - E_L/I_L$) (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 OHMS	524	1089	18.01	3.87	29.07	4.65	69.7	2.86	1440	4
MININUM LOAD	535	996	1.26	7.81	23.63	0.16	10.0	2.86	1440	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS.
ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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Thermal Vacuum Test - Lunar Day Cycle Summary Sheet - Mod 19

GENERATOR ASSEMBLY NO. MOD 19
START DATE 9/30/67 TIME 2100
TECHNICIAN E. Straup/J. Neiman
ENGINEER 10/3/67
APPROVED DATE 10-4-67
AVERAGE SINK TEMPERATURE 169 °F
AVERAGE CHAMBER PRESSURE 1.5×10^{-6} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	502	1081	18.0	3.84	29.5	4.69	68.7	3.0	1505	4
MLC	503	1054	14.0	4.86	28.0	2.88	67.1	2.88	1505	4
16.0 VOLT LOAD	503	1069	16.0	4.38	28.8	3.65	69.1	2.92	1505	4
MINIMUM LOAD	511	1004	4.55	7.15	24.9	0.64	31.9	2.85	1505	4
0.65 MLC	505	1104	21.38	3.16	30.6	6.77	66.8	2.92	1505	4

GENERATOR ASSEMBLY NO. MOD 19
START DATE 10/2/67 TIME 2100
TECHNICIAN E. Straup/B. Schmell
ENGINEER 10/4/67
APPROVED DATE 10/5/67
AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 3.6×10^{-6} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	496	1058	17.9	3.79	28.5	4.72	67.3	2.80	1455	4
MLC	499	1028	13.4	4.85	26.8	2.76	65.0	2.76	1455	4
16.0 VOLT LOAD	499	1045	16.0	4.22	27.7	3.79	67.5	2.77	1455	4
MINIMUM LOAD	506	984	4.4	6.90	24.1	0.64	30.8	2.86	1455	4
0.65 MLC	499	1077	20.6	3.15	29.4	6.54	64.0	2.80	1455	4

GENERATOR I-V MAPPING SUMMARY SHEET
THERMAL VACUUM TEST

GENERATOR ASSEMBLY NO. MOD 19
START DATE 10/4/67 TIME 0330
TECHNICIAN S. D'Abbene/J.P. O'Donnell
ENGINEER 10/6/67
APPROVED DATE 10-9-67
AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 3.9×10^{-7} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	492	1034	17.4	3.70	27.5	4.70	64.3	2.72	1415	4
MLC	494	1009	12.9	4.80	25.9	2.69	62.1	2.69	1415	4
16.0 VOLT LOAD	492	1022	16.0	4.05	26.9	3.95	64.7	2.69	1415	4
MINIMUM LOAD	509	964	4.3	8.81	23.2	0.43	29.5	2.78	1415	4
0.65 MLC	492	1052	19.7	3.12	28.6	6.31	61.6	2.79	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS.
ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

Thermal Vacuum Test - Lunar Night Cycle Summary Sheet - Mod 19

GENERATOR ASSEMBLY NO. MOD 19
START DATE 10/5/67 TIME 1830
TECHNICIAN J. Banesh/J. Neiman
ENGINEER 10/9/67
APPROVED DATE 10-9-67
AVERAGE SINK TEMPERATURE -280 °F
AVERAGE CHAMBER PRESSURE 3.1×10^{-7} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	Meter POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	433	1012	18.5	3.93	28.6	4.71	72.1	2.58	1505	4
MLC	434	975	13.3	5.30	26.6	2.51	70.0	2.51	1505	4
16.0 VOLT LOAD	433	993	16.0	4.57	27.6	3.51	72.9	2.55	1505	4
MINIMUM LOAD	442	932	4.8	7.52	24.0	0.64	35.8	2.55	1505	4
0.65 MLC	433	1027	20.4	3.45	29.4	5.91	69.6	2.61	1505	4

GENERATOR ASSEMBLY NO. MOD 19
START DATE 10/6/67 TIME 2300
TECHNICIAN B. Schmell/E. Straup
ENGINEER 10/9/67
APPROVED DATE 10-9-67
AVERAGE SINK TEMPERATURE -275 °F
AVERAGE CHAMBER PRESSURE 2.9×10^{-7} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	Meter POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	424	984	18.0	3.82	27.5	4.71	68.1	2.47	1455	4
MLC	425	946	12.7	5.19	25.4	2.45	65.9	2.44	1455	4
16.0 VOLT LOAD	423	967	16.0	4.32	26.6	3.70	68.8	2.45	1455	4
MINIMUM LOAD	433	906	4.8	7.31	23.0	0.66	34.8	2.48	1455	4
0.65 MLC	424	997	19.6	3.37	28.2	5.81	65.6	2.56	1455	4

GENERATOR ASSEMBLY NO. MOD 19
START DATE 10/8/67 TIME 0700
TECHNICIAN J. Banesh/S. D'Abbene
ENGINEER 10/8/67
APPROVED DATE 10-9-67
AVERAGE SINK TEMPERATURE -276 °F
AVERAGE CHAMBER PRESSURE 2.8×10^{-7} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	Meter POWER OUT (WATTS)	INT. RES. $(E_O-E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	416	961	17.6	3.71	26.5	4.74	64.8	2.40	1415	4
MLC	417	920	12.2	5.16	24.4	2.36	62.1	2.36	1415	4
16.0 VOLT LOAD	416	944	16.0	4.10	25.8	3.90	65.3	2.39	1415	4
MINIMUM LOAD	424	882	4.7	7.15	22.1	0.66	33.4	2.43	1415	4
0.65 MLC	416	969	18.8	3.35	27.0	5.61	62.7	2.45	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS.
ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

FLIGHT GENERATOR

MOD 21 DATA

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I-V Mapping in Air Summary Sheet - Mod 21

GENERATOR ASSEMBLY NO. MOD 21
START DATE 10/31/67 TIME 1000
TECHNICIAN R. Schmidt/J.Brown
ENGINEER 11/1/67
APPROVED DATE 11/2/67

AVERAGE SINK TEMPERATURE ____ °F
AVERAGE CHAMBER PRESSURE Ambient
EFCS POWER UNIT 1450 WATTS
ACCUMULATED HOURS 316

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L / I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L) / I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	521	1082	17.86	3.80	28.8	4.70	67.9	2.87	1451	4
MLC										
16.0 VOLT LOAD										
MINIMUM LOAD	539	998	1.30	7.9	23.5	0.16	10.3	2.81	1455	4
0.65 MLC										

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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FLIGHT GENERATOR
MOD 22 DATA

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I-V Map - Lunar Day Cycle Summary Sheet - Mod 21

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/17/67 TIME 0430
TECHNICIAN P. O'Donnell/J. Heiman
ENGINEER 11/20/67
APPROVED DATE 11-21-67

AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 1.0 x 10^{-8} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 335

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	489	1067	17.8	3.80	29.3	4.7	67.7	3.02	1505	4
MLC	491	1038	13.9	4.84	27.7	2.86	66.8	2.85	1505	4
16.0 VOLT LOAD	490	1054	16.0	4.29	28.6	3.73	68.2	2.94	1505	4
MINIMUM LOAD	497	988	4.61	7.08	24.7	0.65	32.7	2.84	1505	4
0.65 MLC	490	1085	20.9	3.15	30.2	6.64	65.3	2.95	1505	4

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/18/67 TIME 2330
TECHNICIAN J. Banesh/J. Heiman
ENGINEER 11/20/67
APPROVED DATE 11-21-67

AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 2.6 x 10^{-9} torr
EFCS POWER UNIT 1455 WATTS
ACCUMULATED HOURS 380

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	484	1042	17.6	3.74	28.2	4.71	65.8	2.84	1455	4
MLC	485	1015	13.3	4.80	26.6	2.77	64.0	2.77	1455	4
16.0 VOLT LOAD	484	1030	16.0	4.12	27.5	3.88	66.0	2.79	1455	4
MINIMUM LOAD	491	967	4.5	6.95	23.8	0.65	31.5	2.78	1455	4
0.65 MLC	484	1061	19.8	3.12	29.0	6.35	62.8	2.97	1455	4

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/20/67 TIME 0730
TECHNICIAN E. Straup/ S. D'Abbene
ENGINEER
APPROVED DATE 11/30/67

AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 1.9 x 10^{-9} torr
EFCS POWER UNIT 1415 WATTS
ACCUMULATED HOURS 405

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	477	1019	17.1	3.65	27.2	4.70	63.0	2.75	1415	4
MLC	479	991	12.8	4.76	25.6	2.68	60.9	2.68	1415	4
16.0 VOLT LOAD	477	1012	16.0	3.93	26.8	4.07	63.2	2.74	1415	4
MINIMUM LOAD	484	946	4.6	6.77	23.0	0.68	31.0	2.71	1415	4
0.65 MLC	477	1036	19.4	3.08	28.1	6.28	59.8	2.84	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Map - Lunar Night Cycle Summary Sheet - Mod 21

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/22/67 TIME 0500
TECHNICIAN E. Straup/S. D'Abbene
ENGINEER
APPROVED DATE 11/30/67

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 1.8 x 10^{-7} torr
EFCS POWER UNIT 1505 WATTS
ACCUMULATED HOURS 457

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	417	994	18.2	3.89	28.3	4.70	70.6	2.58	1505	4
MLC	418	957	13.1	5.21	26.3	2.52	69.0	2.52	1505	4
16.0 VOLT LOAD	417	978	16.0	4.44	27.4	3.60	71.3	2.58	1505	4
MINIMUM LOAD	425	912	4.9	7.46	23.6	0.66	36.1	2.50	1505	4
0.65 MLC	417	1006	19.8	3.40	28.9	5.84	67.9	2.66	1505	4

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/23/67 TIME 1100
TECHNICIAN J. Banesh/B. Schmell
ENGINEER
APPROVED DATE 11/30/67

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 2.0 x 10^{-7} torr
EFCS POWER UNIT 1455 WATTS
ACCUMULATED HOURS 486

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	409	966	17.7	3.76	27.1	4.71	66.5	2.50	1455	4
MLC	410	926	12.5	5.20	25.0	2.40	64.6	2.41	1455	4
16.0 VOLT LOAD	409	954	16.0	4.19	26.5	3.82	66.7	2.50	1455	4
MINIMUM LOAD	416	885	4.7	7.31	22.6	0.65	34.1	2.44	1455	4
0.65 MLC	409	977	19.0	3.38	27.7	5.62	64.3	2.57	1455	4

GENERATOR ASSEMBLY NO. MOD 21
START DATE 11/24/67 TIME 1630
TECHNICIAN P. O'Donnell/J. Heiman
ENGINEER
APPROVED DATE 11/30/67

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 1.8 x 10^{-7} torr
EFCS POWER UNIT 1415 WATTS
ACCUMULATED HOURS 515

MAP POINT	T_C (CALC) (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	402	941	17.2	3.66	26.1	4.70	63.0	2.43	1415	4
MLC	402	900	12.0	5.10	24.0	2.35	61.2	2.35	1415	4
16.0 VOLT LOAD	402	931	16.0	4.00	25.6	4.0	64.0	2.40	1415	4
MINIMUM LOAD	409	863	4.6	7.15	21.8	0.64	32.2	2.41	1415	4
0.65 MLC	402	932	18.4	3.30	26.7	5.58	61.0	2.52	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping in Air Summary Sheet - Mod 22

GENERATOR ASSEMBLY NO. MOD 22
START DATE 11/1/67 TIME 1700
TECHNICIAN J. Brown/R. Schmidt
ENGINEER 11/6/67
APPROVED DATE 11/6/67

AVERAGE SINK TEMPERATURE --- °F
AVERAGE CHAMBER PRESSURE Ambient
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L / I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	528	1082	18.06	3.83	28.51	4.72	69.1	2.74	1455	4
MLC	—	—								
16.0 VOLT LOAD	—	—								
MINIMUM LOAD	545	993	1.48	8.05	23.0	0.18	11.9	2.67	1457	4
0.65 MLC	—	—								

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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I-V Map - Lunar Day Cycle Summary Sheet - Mod 22

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/6/67 TIME 0400
TECHNICIAN B. Schmell/P. O'Donnell
ENGINEER 12/13/67
APPROVED DATE 12-13-67

AVERAGE SINK TEMPERATURE 171 °F
AVERAGE CHAMBER PRESSURE 5.5×10^{-9} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	498	1065	17.8	3.80	28.8	4.68	67.9	2.89	1505	4
MLC	499	1036	13.6	4.89	27.2	2.78	66.8	2.78	1505	4
16.0 VOLT LOAD	498	1052	16.0	4.23	28.1	3.78	68.3	2.86	1505	4
MINIMUM LOAD	507	985	4.7	7.17	24.1	0.65	33.4	2.70	1505	4
0.65 MLC	500	1085	20.6	3.18	29.8	6.48	65.5	2.89	1505	4

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/8/67 TIME 1830
TECHNICIAN B. Schmell/E. Straup
ENGINEER 12/12/67
APPROVED DATE 12/13/67

AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 2.9×10^{-9} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	491	1039	17.5	3.73	27.7	4.69	65.9	2.72	1455	4
MLC	492	1009	13.0	4.89	26.0	2.66	63.6	2.66	1455	4
16.0 VOLT LOAD	492	1029	16.0	4.11	27.1	3.89	66.2	2.70	1455	4
MINIMUM LOAD	499	960	4.6	7.06	23.1	0.65	32.8	2.62	1455	4
0.65 MLC	492	1055	19.6	3.19	28.6	6.15	63.0	2.80	1455	4

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/9/67 TIME 0130
TECHNICIAN J. Banesh/J. Beiman
ENGINEER 12/13/67
APPROVED DATE 12/13/67

AVERAGE SINK TEMPERATURE 171 °F
AVERAGE CHAMBER PRESSURE 2.4×10^{-9} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	485	1018	17.1	3.63	26.8	4.70	62.8	2.69	1415	4
MLC	486	986	12.6	4.80	25.0	2.61	61.1	2.59	1415	4
16.0 VOLT LOAD	486	1012	16.0	3.9	26.4	4.10	63.2	2.67	1415	4
MINIMUM LOAD	493	941	4.6	6.91	22.3	0.67	32.0	2.57	1415	4
0.65 MLC	485	1032	19.0	3.12	27.6	6.09	60.2	2.76	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Map - Lunar Night Cycle Summary Sheet - Mod 22

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/12/67 TIME 0030
TECHNICIAN J. Banesh/B. Schmell
ENGINEER 12/14/67
APPROVED DATE 12/14/67

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 1.2×10^{-7} torr
EFCS POWER UNIT 1505 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	426	991	18.2	3.87	27.8	4.69	70.5	2.49	1505	4
MLC	426	950	12.9	5.35	25.6	2.40	69.1	2.38	1505	4
16.0 VOLT LOAD	426	975	16.0	4.42	26.9	3.62	71.3	2.47	1505	4
MINIMUM LOAD	434	904	4.9	7.66	22.9	0.64	37.4	2.35	1505	4
0.65 MLC	426	1003	19.5	3.49	28.4	5.59	68.5	2.55	1505	4

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/13/67 TIME 1030
TECHNICIAN S. D'Abbene/E. Straup
ENGINEER 12/20/67
APPROVED DATE 1-3-68

AVERAGE SINK TEMPERATURE -272 °F
AVERAGE CHAMBER PRESSURE 1.5×10^{-9} torr
EFCS POWER UNIT 1455 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	417	962	17.6	3.72	26.7	4.73	66.8	2.44	1455	4
MLC	418	923	12.3	5.30	24.5	2.31	65.1	2.31	1455	4
16.0 VOLT LOAD	417	951	16.0	4.19	26.0	3.82	67.3	2.39	1455	4
MINIMUM LOAD	423	878	4.8	7.49	21.9	0.64	35.9	2.28	1455	4
0.65 MLC	417	973	18.7	3.45	27.2	5.42	65.1	2.46	1455	4

GENERATOR ASSEMBLY NO. MOD 22
START DATE 12/15/67 TIME 0400
TECHNICIAN S. D'Abbene/E. Straup
ENGINEER 12/20/67
APPROVED DATE 1-3-67

AVERAGE SINK TEMPERATURE -276 °F
AVERAGE CHAMBER PRESSURE 1.4×10^{-7} torr
EFCS POWER UNIT 1415 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	411	944	17.2	3.63	25.8	4.74	63.3	2.38	1415	4
MLC	411	899	11.8	5.21	23.6	2.26	61.6	2.26	1415	4
16.0 VOLT LOAD	410	930	16.0	3.95	25.2	4.05	64.1	2.33	1415	4
MINIMUM LOAD	417	855	5.0	7.22	21.0	0.69	35.7	2.22	1415	4
0.65 MLC	410	948	18.0	3.39	26.1	5.31	61.5	2.39	1415	4

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

FLIGHT GENERATOR
MOD 23 DATA

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I-V Mapping - Lunar Day Cycle Summary Sheet - Mod 23

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/7/68 TIME 2400
TECHNICIAN E. Straup/J. Neiman
ENGINEER
APPROVED DATE 1-16-68

AVERAGE SINK TEMPERATURE +170 °F
AVERAGE CHAMBER PRESSURE 1.6×10^{-7} torr
EFCS POWER UNIT 1505 WATTS
Accum. Hours 373 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	506	1069	18.1	3.85	28.7	4.70	70.0	2.75	1505	4
MLC	507	1035	13.4	5.07	26.8	2.65	68.2	2.65	1505	4
16.0 VOLT LOAD	506	1053	16.0	4.38	27.8	3.65	70.7	2.69	1505	4
MINIMUM LOAD	513	984	4.8	7.40	23.8	0.64	35.1	2.57	1505	4
0.65 MLC	506	1085	20.5	3.30	29.5	6.21	67.5	2.73	1505	4

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/9/68 TIME 1400
TECHNICIAN B. Schmell/P. O'Donnell
ENGINEER
APPROVED DATE 1-16-68

AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 8.6×10^{-8} torr
EFCS POWER UNIT 1455 WATTS
Accum. Hours. 413 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	METER POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	500	1044	17.6	3.78	27.6	4.67	67.1	2.63	1458	4
MLC	500	1008	12.8	5.03	25.6	2.54	65.0	2.55	1455	4
16.0 VOLT LOAD	500	1031	16.0	4.20	26.9	3.80	67.9	2.60	1458	4
MINIMUM LOAD	507	963	4.7	7.23	22.9	0.65	34.0	2.52	1455	4
0.65 MLC	498	1057	19.7	3.27	28.4	6.02	64.6	2.66	1455	4

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/11/68 TIME 2400
TECHNICIAN S. D'Abbene/J. Banesh
ENGINEER
APPROVED DATE

AVERAGE SINK TEMPERATURE 170 °F
AVERAGE CHAMBER PRESSURE 1.2×10^{-7} torr
EFCS POWER UNIT 1415 WATTS
Accum. Hours 444 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	492	1021	17.3	3.68	26.7	4.70	64.3	2.55	1415	4
MLC	494	988	12.4	4.98	24.8	2.49	62.2	2.49	1415	4
16.0 VOLT LOAD	492	1013	16.0	4.02	26.2	3.98	65.0	2.54	1415	4
MINIMUM LOAD	497	936	4.7	7.11	22.0	0.66	33.5	2.47	1415	4
0.65 MLC	492	1034	19.0	3.24	27.4	5.86	61.9	2.59	1415	4

NOTE: ELAPSED TIME IS DEFINED AS THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping - Lunar Night Cycle Summary Sheet - Mod 23

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/12/68 TIME 0500
TECHNICIAN S. D'Abbene/B. Schmell
ENGINEER
APPROVED DATE 1/16/68

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 5.8×10^{-8} torr
EFCS POWER UNIT 1505 WATTS
Accum. Hours 470 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	433	995	18.3	3.89	27.7	4.70	71.6	2.42	1505	4
MLC	436	954	12.8	5.69	25.5	2.32	70.0	2.32	1505	4
16.0 VOLT LOAD	433	970	16.0	4.51	26.8	3.55	72.9	2.39	1505	4
MINIMUM LOAD	461	909	5.1	7.80	22.8	0.66	39.6	2.27	1505	4
0.65 MLC	433	1005	19.6	3.57	28.2	5.48	70.0	2.42	1505	4

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/13/68 TIME 1700
TECHNICIAN J. Banesh/P. O'Donnell
ENGINEER
APPROVED DATE

AVERAGE SINK TEMPERATURE -268 °F
AVERAGE CHAMBER PRESSURE 5.8×10^{-8} torr
EFCS POWER UNIT 1455 WATTS
Accum. Hours 508 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	424	967	17.7	3.79	26.5	4.69	67.4	2.32	1455	4
MLC	426	926	12.2	5.41	24.3	2.25	66.1	2.24	1455	4
16.0 VOLT LOAD	424	952	16.0	4.29	25.8	3.73	68.9	2.28	1455	4
MINIMUM LOAD	432	879	5.0	7.66	21.6	0.65	38.0	2.17	1455	4
0.65 MLC	424	971	18.6	3.52	26.8	5.27	66.0	2.34	1455	4

GENERATOR ASSEMBLY NO. MOD 23
START DATE 1/15/68 TIME 0030
TECHNICIAN E. Straup, J. Neiman
ENGINEER
APPROVED DATE

AVERAGE SINK TEMPERATURE -270 °F
AVERAGE CHAMBER PRESSURE 5.3×10^{-8}
EFCS POWER UNIT 1415 WATTS
Accumulated Hours 536 HOURS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L/I_L$ (OHMS)	POWER OUT (WATTS)	INT. RES. $(E_O - E_L)/I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	417	943	17.3	3.67	25.6	4.71	63.9	2.26	1415	4
MLC	418	899	11.6	5.41	23.2	2.14	62.8	2.14	1415	4
16.0 VOLT LOAD	417	932	16.0	4.05	25.0	3.95	65.1	2.22	1415	4
MINIMUM LOAD	423	856	5.0	7.50	20.8	0.67	37.2	2.11	1415	4
0.65 MLC	417	948	17.7	3.52	25.8	5.03	63.0	2.30	1415	4

NOTE: ELAPSED TIME IS DEFINED AS THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

I-V Mapping in Air Summary Sheet - Mod 23

GENERATOR ASSEMBLY NO. MOD 23
START DATE 12/1/67 TIME 2030
TECHNICIAN R. Swaim, R. Martin, B. Borell
ENGINEER 12/4/67
APPROVED DATE 1-3-68

AVERAGE ROOM TEMPERATURE 28.3°C
AVERAGE CHAMBER PRESSURE Ambient
EFCS POWER UNIT 1450 WATTS

MAP POINT	(CALC) T_C (°F)	T_H (°F)	E_L (VOLTS)	I_L (AMPS)	E_O (VOLTS)	$R_L = E_L\ I_L$ (OHMS)	(CALL) POWER OUT (WATTS)	INT. RES. $(E_O - E_L)\ I_L$ (OHMS)	POWER IN (EFCS) (WATTS)	ELAPSED TIME (HOURS)
4.7 Ω	530	1079	17.9	3.80	28.2	4.7	68.0	2.71	1450	4
MLC										
16.0 VOLT LOAD										
MINIMUM LOAD	550	988	.79	8.30	22.5	0.10	6.6	2.61	1449	4
0.65 MLC										

NOTE: I-V mapping in air was completed. The temporary voltage leads, which measure GA voltage at the power headers, were removed prior to testing due to frayed insulation. The corrected power output equivalent to that measured at 3M is

Power Line Loss = $I^2 R_{Power\ Cable} = (3.8)^2\ (0.15) = 2.16$ watts

$P_{corrected} = P_{measured} + P_{line\ loss} = 68.0 + 2.16 = 70.16$ watts

NOTE: ELAPSED TIME IS DEFINED AS: THE BEGINNING OF - TO THE END OF STEADY STATE CONDITIONS. ALL OF THE ABOVE VALUES SHALL BE AVERAGED OVER THE ELAPSED TIME PERIOD.

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