The MSC design review team visited BxA Monday, 20 May, to review the design of the cask, the fuel capsule, and the integrated cask mount assembly, with particular emphasis being placed on safety.

Prepared By

W. Durrant

Approved By

M. Katz
The subjects presented by cognizant BxA engineers are noted in the following Meeting Agenda:

- **Introduction**  
  W. Durrant

- **Review analyses and tests pertaining to potential vacuum welding problems.**  
  W. Durrant

- **Review of integrated cask testing performed on prototype hardware.**  
  L. Wagman & J. McNaughton

- **Verification of on-pad installation and removal techniques for the cask capsule and associated G. E. furnished hardware.**  
  C. Ahlstrom

- **Review of integrated structural/thermal cask qualification test plans, including cask, capsule and support structure.**  
  C. Ahlstrom

- **Review of verification of crew compatibility with the integrated cask system. This review should include the functional and safety aspects.**  
  H. Grubbs

The minutes of the meeting are covered in the attached ALSEP 9712-864. These minutes document the subject material covered by each cognizant engineer, along with subsequent questions and answers.

Copies of the "viewgraphs" used to form the basis for presentation are also attached. The figure numbers corresponding to the Agenda subject are listed below:
Introduction

Analyses and test pertinent to potential vacuum welding problems

Prototype hardware integrated cask testing

Verification of on-pad installation and removal techniques

Integrated structural/thermal cask qualification test plans

Verification of crew compatibility with integrated cask system

Figures 1 & 2

Figures 3 thru 7

Figures 8 thru 57

(Film)

Figure 58

Figures 59 thru 63
ATTENDEES

Bendix
M. Katz
L. Wagman
E. Van Valkenburg
J. Maszatics
J. McNaughton
C. Ahlstrom
H. Grubbs
R. Redick
K. Wright
E. Rutz
D. Dewhirst
R. Hostettler
W. Durrant

NASA/ MSC
D. Medlock
D. Greenshields
R. Miller
R. Ferguson
T. Kerr
D. Lind
T. Herrington
J. Grayson

1.0 The meeting was opened and a welcome given to our visitors by E. Van Valkenburg.

2.0 W. Durrant reviewed the present mechanical design of the Cask Assembly and discussed in detail the analyses and test pertaining to possible vacuum welding phenomenon.

2.1 Question - Review of materials making up gearbox in particular the bearings.

Answer - All self aligning steel bearings. W. Durrant will check on specific material and respond to T. Herrington and J. Grayson.

2.2 Question - Temp and pressure at which gear box was tested?

Answer - 700°F @ 10⁻⁷ torr

2.3 Question - Have we run lab tests on cold welding of titanium to steel?

Answer - No, our component level tests did not indicate a need for such tests.

2.4 Question - What prevents pin and lever of upper trunnion release from coming loose as occurred at MSC?

Answer - Model at MSC is not representative of final design.
2.5 Question - What materials make up trunnion release pin? Interior Rod?
Answer - Rod should be microsealed. The balls are definitely microsealed.

2.6 Question - On-pad temp. of release pin?
Answer - 250 to 270°F.

2.7 Explanation given of new dome removal mechanism.

2.8 Question - Material from which springs are fabricated?
Answer - Inconel X

2.9 Question - Can direction of pin in dome release mechanism be changed to allow release of nut in one direction and dome removal in opposite direction.
Answer - Have new release in house and will demonstrate it.

2.10 Question - What are effects of radiation on cold welding?
Answer - Are not aware of any but BxA tests have not been made.

3.0 Vibration Test Program

Test item w/electric capsule subjected to sine sweep 1g magnitude
1. at 280°F
2. at 600°F.

Details of accelerometers - see handout.
Details of strain gages - see handout

2 element rosette type - temp compensated.

Band location of strain gages - see handout.

Slides of test shown
High temp accelerometers used - o.k. up to 700°F.
Film of Vibration run - full level.

Discussion of Data From Tests

See Handout Pictures.
Launch & Boost Sine  
Max Transmissibility  
Y-Axis  7.6 max  
Z-Axis  1.6 max  
X-Axis  3.8 max  

Launch & Boost Random:  Z-Axis input  
Launch & Boost Random:  Cross Axis (Y/Z)  

Fuel Cask sine input  
Cask & Support Random - X response  
Cask & Support Random - Y response  
Cask & Support Random - Z response  

Sine response X input/output  
Sine response Y input/output  
Sine response Z input/output  

1g sweep launch & boost (X axis)  280°F  
"       "       600°F  

Discussion Grayson/Maszatics on differences in transmissibilities predicted and those actually experienced in test. System is non-linear and transmiss, therefore varies with input level.  

J. Grayson asked if information from test has been included in rewritten ICS - answer is not yet.  

4.0 J. McNaughton - Discussion of On-pad cooling and Thermal/Vacuum Testing.  

Question - Dimensions and ΔP of nozzle.  

Answer - The design of the Qual cask cooling nozzle has been completed and copies transmitted to MSFC. The nozzle has a 5 inch diameter inlet, a 2 1/4 inch dia. exit and an overall length of 8 inches. The predicted performance of the nozzle is shown in the enclosed viewgraph for nozzle inlet pressure versus I, U, tapoff flowrate. The data is derived from the engineering tests conducted at MSFC combined with the results from the BxA Prototype cask cooling test program.  

The preliminary interface layout for the Bendix/MSC/MSFC cask cooling configuration is described in the viewgraphs. The interface locates the exit plane of the nozzle 2 ft below the cask. For this configuration, nozzle pressures are predicted to range from 0.3 to 0.6 psig with corresponding nozzle flow rates from 15 to 30 lb/min. Maximum cask surface temperatures for these conditions with a 130°F SIVB I, U, inlet temperature range from 230°F to 275°F.
5.0  C. Ahlstrom - On-pad Operations

Film shown on installation of cask assembly on LM.

6.0  C. Ahlstrom - Cask Qual Test

1. Distributed TM-157, Exhibit B - Qual Test Plan and described Qual Plan

2. QTRR will be after Acceptance according to Ahlstrom. Grayson stated that the rest of the ALSEP Program has been run such that the QTRR precedes acceptance. Timing of QTRR will be resolved by BxA - L. Wagman.

3. Qual Test start on 6/14/68 with D-2 Qual on 6/17/68.

Question - When will ICS be completed?

Answer - Will be completed before Qual according to M. Katz. At Grayson's request a date on which spec will be completed for NASA review. Date given by M. Katz is 31 May 1968. The ICD and ICS will be mailed on this date.

4. Concern was expressed over fact that T/V Test does not cover entire mission time. Time allocated according to McNaughton is for nominal mission and was dictated by economics.

5. Question raised on use of live capsules throughout Qual Program. Answer was that the capsule, cask, and BxA cask assembly will all be qualified. Qual is a system level test with no upper dome modification allowable on Qual or Flight hardware.

6. Data was requested on band strain. Copies of the ATM by Dr. D. Dewhirst on this subject will be obtained by C. Ahlstrom.

7.0  H. Grubbs - Mission & Crew Safety Features of Cask

1. Discussion of cask safety features.

2. Film on ALSEP unloading and cask unloading w/RTG fueling.

3. Protective device will withstand at least 30 lbs.
4. Question, D. Lind - Storage provisions for lanyard?
   Answer - 2 strips of Velcro tape.

5. BxA will deliver the 2 GFE casks as a part of the E-2 model. Hardware will be representative of the Qual/Ft design and delivered approximately 24 July 1968.

8.0 General

1. The following drawings were transmitted to J. Grayson of NASA/MSC. 2337960, 2338140, 2338141, 2338142, 2338143, 2338218, 2338219, 2338220, 2338221, 2338348, 2338349, 2338350, 2338351, 2338352, 2338353, 2338354, 2338355, BSX 7658 (Preliminary), Lanyard Hook (Preliminary), Astronaut Guard/Gearbox (Preliminary), and Center Plunger Dome (Preliminary). These drawings relate to the redesign of the cap removal lock and the one-piece lanyard.

2. Differences between Proto and Qual:
   (a) Change in dome release to center plunger.
   (b) Gear box swivel change.
   (c) Adjustment on axial band.
   (d) 1 piece lanyard.
   (e) Increase in axial band thickness, from .017 to .030.
   (f) Cut-off thermal shield - analysis indicates that input to LM is within spec.
   (g) Addition of astronaut guard.
   (h) Increase in surface area of trunnion pads.

3. Question on T/C instrumentation of LM skin. New Grumman blankets were used on Proto T/V. How representative is this blanket? LM Panel is now made of 4 mil? Inconel. Behind this is aluminized Kapton and Mylar.
4. T/C on rear face of shield is not included in final design. Will be mounted upon final approval. According to Grayson T/C is still shown on BxA/GAEC ICD.

Grayson asked for look at ICD location of T/C. Interface problem should be resolved by MSC. Signal conditioning components for this T/C have already been included in the LM.

T/C instrumentation on LM Panel was bonded to Inconel foil and used for steady state conditions only.
Figure 1

INSTALLATION IN LUNAR MODULE

Fuel Cask
Figure 2

FUEL CASK SUPPORT ASSEMBLY

CASK SPLINE

CASK/BAND ASSY

HEAT SHIELD ASSY

SUPPORT STRUCTURE ASSY
Figure 3
CASK ROTATION DETAILS

TRUNNION RELEASE

TRUNNION RELEASE CORD

GEARBOX

GEARBOX OPERATING CORD
Figure 4

TILT GEARBOX ASSEMBLY

- SPROCKET HOUSING
- WORM
- WORM WHEEL BEARING
- CHAIN SPROCKET
Figure 5

UPPER TRUNNION RELEASE MECHANISM

- Ball-lock pin
- BXA 2335009 nut - Spherical End
- AN 545-C-416 nut
- Top of upper cradle member
- Pull to release
- Travel
- Lever Assy
- Upper trunnion
Figure 6

DOME RELEASE DETAILS

AXIAL BAND UPPER SECTION

LEVER

BODY, RELEASE

LOCKING PLUNGER

DOME ATTACHMENT BOLT
Figure 7

DOME REMOVAL TOOL

SPLINE REMOVAL CLAW

DOME ATTACHMENT LOCK

4422-8
Figure 8

PROTOTYPE FUEL CASK VIBRATION TEST

1 g SINUSOIDAL SURVEY - 280°F (LAUNCH AND BOOST)

- 600°F (LUNAR DESCENT)

3 g SINUSOIDAL - 280°F (LAUNCH AND BOOST)

FULL LEVEL RANDOM - 280°F (LAUNCH AND BOOST)
NOTE: Location 2 and 3 will be used if the accelerometer blocks at locations 5 and 6 come off during vibration.

1 Response Accelerometer in direction of vibration
4 Response Accelerometer in direction of vibration
5 Triaxial Response Accelerometer
6 Triaxial Response Accelerometer

Figure 9
ACCELEROMETER LOCATIONS

VIBRATION TEST SETUP
Figure 10

STRAIN GAGE LOCATIONS ON SUPPORT STRUCTURE

NO. S INDICATE STRAIN GAGE IDENTIFICATION

SECTION A-A

SECTION B-B
Figure 11

STRAIN GAGE LOCATIONS ON BAND ASSEMBLY

* FULL-BRIDGE STRAIN GAGES:
(ALL OTHERS, HALF-BRIDGE STRAIN GAGES)
LAUNCH AND BOOST SINE

MAXIMUM TRANSMISSIBILITY - X AXIS

Figure 12
Figure 13

MAXIMUM TRANSMISSIBILITY - Y AXIS

LAUNCH AND BOOST SINE

\( Y_0/Y_1 \)
Figure 14

LAUNCH AND BOOST SINE
MAXIMUM TRANSMISSIBILITY - Z AXIS

[Graph with axes labeled as TR vs. cps, and Z0/Z1 in the top right corner]
Figure 15

LAUNCH AND BOOST RANDOM VIBRATION SPECTRUM-Z AXIS INPUT
Figure 16

LAUNCH AND BOOST RANDOM VIBRATION SPECTRUM - CROSS AXIS RESPONSE

POWER SPECTRAL DENSITY $-g^2/\text{cps}$

FREQUENCY - cps

$y_o/z_i$
FUEL CASK SINUSOIDAL
LAUNCH AND BOOST INPUT SPECIFICATION

x-axis : 5-23 cps 0.5 in. d.a.
        23-100 cps 13 g - peak
y-axis : 5-30 cps 0.5 in. d.a.
        30-100 cps 23 g - peak
z-axis : 5-18 cps 0.3 in. d.a.
        18-100 cps 5.0 g - peak
Figure 18

CASK AND SUPPORT LAUNCH AND BOOST

FROM MIL-STD-810:

GRMS = 16.9
Figure 19

CASK AND SUPPORT LAUNCH AND BOOST

y - RESPONSE

GRMS = 13.3
Figure 20

CASK AND SUPPORT LAUNCH AND BOOST

z - RESPONSE

$\frac{g^2}{\text{cps}}$

0 100 0.4 1500

10 100 1000

GRMS = 26.3
Figure 21

ANALYSIS VS. TEST DATA

x - INPUT
x - OUTPUT

cps

TR

10

3.9

2.9

1

.1

10

100

220

380

1000

ANALYSIS

TEST
Figure 22

ANALYSIS VS. TEST DATA

y - INPUT
y - OUTPUT

TEST

ANALYSIS

y

10
100
1000
cps
Figure 23

ANALYSIS VS. TEST DATA

z - INPUT
z - OUTPUT

TR
10
3.2
1

ANALYSIS

TEST

cps
10
43
100
1000

1

.1

.1

5607-5
Figure 24

1G SWEEP LAUNCH AND BOOST

![Graph showing 1G sweep launch and boost](image)
Figure 25

1G SWEEP LUNAR DESCENT

![Graph showing 1G sweep lunar descent with Xo/Xi on the y-axis and cps on the x-axis.](image)
1G SWEEP LAUNCH AND BOOST
Figure 27

1G SWEEP LUNAR DESCENT

\[ \frac{Y_0}{Y_i} \]

\[ \text{TR} \]

\[ \text{cps} \]

10.0

1.0

0.1

10

100

1000
Figure 28

1G SWEEP LAUNCH AND BOOST

\[ \frac{Z_0}{Z_i} \]

\[ TR \]

\[ cps \]

\[ 10, 100, 1000 \]
Figure 29

1G SWEEP LUNAR DESCENT
PURPOSE: VERIFY THE THERMAL INTEGRATION OF THE ALSEP/GLFC/LM CONFIGURATION FOR THE PRELAUNCH AND FLIGHT ENVIRONMENT

TESTS: TEST SERIES INCLUDED THE FOLLOWING SIMULATED FLIGHT ENVIRONMENTS:

1. PRELAUNCH AMBIENT ENVIRONMENT (FREE CONVECTION CASE)
2. PRELAUNCH CASK COOLING WITH FORCED CONVECTION (35 RUNS)
3. LAUNCH AND BOOST TRANSIENT TESTS
4. EARTH ORBIT WITH AND WITHOUT SOLAR HEATING
5. TRANSLUNAR WITH AND WITHOUT SOLAR HEATING
INTERFACE AND DESIGN REQUIREMENTS USED FOR INPUT CRITERIA FOR BxA THERMAL MODEL OF ALSEP/CASK/LM INTERFACE CONFIGURATION

- **Bendix**
  1) Prototype structural design configuration
  2) Prototype thermal shield design
    
    A. Circumferential angle of shield with cask is 135°
    
    B. Total hemispherical emittance ≈ 0.10

  3) 800°F maximum temperature with 150°F circumferential gradient around cask

- **G.E.**
  1) -19D cask design configuration
  2) Material properties per CCP #29
  3) Graphite coatings for total emittance ≈ 0.80 per -19D and CCP #29
  4) 1530 watts maximum power
  5) Fuel Capsule design per ICS 314119

- **GAEC**
  1) 100 Btu/hr maximum heat leak into LM due to direct cask radiation and conduction
  2) 270°F maximum temperature on LM (not including new astronaut thermal door)
  3) Mechanical interface per LID 360-22809
  4) Environmental interface per ICS LIS 360-22402 and LED 520-IF

- **MSC**
  1) NAA SLA internal and external thermal coatings per MSC transmittal dated June 1966
  2) LM vehicle thermal coating per LM-3 and on report by J. Smith, of MSC, dated January 1967
  3) LM vehicle mission profile per MSC June 1966 transmittal and LD-520-F
  4) Apollo Program environment specification per M-DE 8020.008B dated April 1965
  5) BxA/MSC contract 9-5829, Exhibit B
Computer Programs Used in Thermal Model of ALSEP/Cask/LM Interface
DESCRIPTION OF BxA DIGITAL COMPUTER PROGRAMS UTILIZED FOR THERMAL ANALYSIS OF ALSEP/CASK/LM INTERFACE

- 15 node, 3 dimensional thermal model for ALSEP/cask/LM configuration defined by CCP #29, reference Figure 1
- 25 node, 3 dimensional thermal model of ALSEP/LM vehicle interface to evaluated GAEC temperatures on thermal door and landing gear, reference Figure 2
- 22 node, 3 dimensional thermal model of BxA/GAEC support structure interface for conduction heat leak evaluation
- 20 node, 3 dimensional thermal model of ALSEP/cask interface to evaluate axial and circumferencial gradients for on pad cooling temperature and thermal stresses
- 35 node, 2 dimensional model of Saturn SIVB Instrumentation Unit (I.U.) manifold to determine flow distribution and pressure gradients in I.U. manifold for on pad cooling requirements
Figure 34

BENDIX THERMAL MODEL NODES

FUEL CASK SUPPORT ASSEMBLY

Note: Node 13 is Saturn Vehicle & I.U.
Figure 35

Begin Translunar Injection $T = 6000$ secs

T = 600 secs.

Launch $T = 0$

Sun Oriented

Leave Earth
Shadow $T = 2820$ secs.

ALSEP/cask/LM/SLA Earth Orbit Case
With and Without Solar Heating
TABLE 3-1
ALSEP/CASK/LM INTERFACE SPECIFICATION REQUIREMENTS
VERSUS PROTOTYPE TEST RESULTS AND
PRETEST PREDICTED VALUES

<table>
<thead>
<tr>
<th></th>
<th>Interface Specification</th>
<th>Specification Requirement</th>
<th>Test Results</th>
<th>Pretest Predicted Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM FUEL CASK SURFACE</td>
<td>BxA/GE</td>
<td>800°F</td>
<td>615°F-798°F</td>
<td>672°F-785°F</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAXIMUM FUEL CASK CIRCUMFERENTIAL</td>
<td>BxA/GE</td>
<td>150°F</td>
<td>130°F</td>
<td>140°F</td>
</tr>
<tr>
<td>TEMP. GRADIENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAXIMUM FUEL CAPSULE SURFACE</td>
<td>BxA/GE</td>
<td>1400°F</td>
<td>1210°F-1320°F</td>
<td>1220°F-1302°F</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAXIMUM HEAT LEAK TO LM</td>
<td>BxA/GE</td>
<td>100 BTU/HR</td>
<td>50 BTU/HR</td>
<td>75 BTU/HR</td>
</tr>
<tr>
<td>MAXIMUM LM SKIN SURFACE</td>
<td>BxA/GE</td>
<td>270°F</td>
<td>238°F</td>
<td>240°F</td>
</tr>
<tr>
<td>TEMPERATURE (EXCEPT ASTRONAUT</td>
<td>BxA/GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THERMAL DOOR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTRONAUT THERMAL DOOR</td>
<td>BxA/GE</td>
<td>400°F</td>
<td>388°F</td>
<td>400°F</td>
</tr>
<tr>
<td>MAXIMUM CASK THERMAL SHIELD</td>
<td>BxA</td>
<td>600°F</td>
<td>588°F</td>
<td>558°F</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 37

GRAPHITE FUEL CASK
Figure 38

SLA/LM Canister Used for Proto Cask Cooling and T/V Test
Prototype Conical Nozzle Configuration Inside SLA/LM Canister
PHYSICAL CONFIGURATION OF CSM/LEM/SLA - BLOCK II

100 lb/ min

SPS He TANK

SM/RCS

SM/H/SPS PROPELLANT TANKS (Typ.)

RCS FUEL TANK (Typ.)

SPS ENGINE

SLA

LEM

LEM/RCS PROPELLANT TANKS

8 lb/ min

ASCENT ENGINE (LEM/AE)

DESCENT ENGINE (LEM/DE)

150 lb/ min

8 exit slots TANK

VENT SLOT (Typ. B)

S-IVB
Figure 42

PROPOSED RTG CASK COOLING INTERFACE CONFIGURATION
Figure 43

RTG CASK COOLING NOZZLE LOCATIONS FOR
BxA PROTOTYPE TEST PROGRAM
Figure 44

Nozzle Pressure and Flow Rate for Maximum Cask Surface Temperature Versus Predicted I.U. Flow Conditions (From MSFC)
Nozzle 2 ft. Below Cask
Figure 45

FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS
ON PAD FORCED COOLING WITH 17.5 LB/MIN OF AMBIENT AIR
TEMPERATURES FOR IN-LINE NOZZLE
VARIATIONS SHOWN FOR NOZZLE OFFSET 2 INCHES

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Test Results, °F</th>
<th>Pre-Test Predictions, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capsule Surface</td>
<td>1094-1257</td>
<td>1110-1245</td>
</tr>
<tr>
<td>2. Cask Exterior Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Center</td>
<td>179-222</td>
<td>175-230</td>
</tr>
<tr>
<td>b. Ends</td>
<td>157-206</td>
<td>153-194</td>
</tr>
<tr>
<td>3. Cask Domes</td>
<td>115-144</td>
<td>121-166</td>
</tr>
<tr>
<td>4. Thermal Shield</td>
<td>75-92</td>
<td>70-85</td>
</tr>
<tr>
<td>5. LM Panel</td>
<td>72-109</td>
<td>70-100</td>
</tr>
<tr>
<td>6. SLA</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>
Figure 46

GLFC Surface Transient Warmup
Forced Convection Off at Time = 0

GLFC Surface Temperature - °F

Time After Removal of Cooling Air - Minutes
Prototype Cask and Support Structure
Attached to Simulated LM
Fuel Cask and Support Assembly for Prototype Thermal Tests
Figure 49

FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS ON PAD WITH FREE CONVECTION

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Test Results, °F</th>
<th>Pre-Test Predictions, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capsule Surface</td>
<td>1182-1309</td>
<td>1146-1232</td>
</tr>
<tr>
<td>2. Cask External Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Center</td>
<td>527-609</td>
<td>548-580</td>
</tr>
<tr>
<td>b. Ends</td>
<td>506-545</td>
<td>461-519</td>
</tr>
<tr>
<td>3. Cask Domes</td>
<td>385-397</td>
<td>364-437</td>
</tr>
<tr>
<td>4. Thermal Shield</td>
<td>93-135</td>
<td>90-121</td>
</tr>
<tr>
<td>5. LM Panel</td>
<td>75-91</td>
<td>77-85</td>
</tr>
<tr>
<td>6. Astronaut Door</td>
<td>91-154</td>
<td>85-170</td>
</tr>
<tr>
<td>7. SLA</td>
<td>71-77</td>
<td>70</td>
</tr>
</tbody>
</table>

Surface Temperatures:
- Capsule Surface: 1182-1309°F
- Cask External Surface: 527-609°F (Center) 506-545°F (Ends)
- Cask Domes: 385-397°F
- Thermal Shield: 93-135°F
- LM Panel: 75-91°F
- Astronaut Door: 91-154°F
- SLA: 71-77°F

Pre-Test Predictions:
- Capsule Surface: 1146-1232°F
- Cask External Surface: 548-580°F (Center) 461-519°F (Ends)
- Cask Domes: 364-437°F
- Thermal Shield: 90-121°F
- LM Panel: 77-85°F
- Astronaut Door: 85-170°F
- SLA: 70°F
Figure 50

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

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Test Results, °F</th>
<th>Pre-Test Predictions, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capsule Surface</td>
<td>1210-1315</td>
<td>1293-1302</td>
</tr>
<tr>
<td>2. Cask External Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Center</td>
<td>635-798</td>
<td>643-775</td>
</tr>
<tr>
<td>b. Ends</td>
<td>627-718</td>
<td>617-687</td>
</tr>
<tr>
<td>3. Cask Domes</td>
<td>482-519</td>
<td>447-559</td>
</tr>
<tr>
<td>4. Thermal Shield</td>
<td>310-588</td>
<td>350-550</td>
</tr>
<tr>
<td>5. LM Panel</td>
<td>0-240</td>
<td>28-215</td>
</tr>
<tr>
<td>6. Astronaut Door</td>
<td>118-383</td>
<td>219-400</td>
</tr>
<tr>
<td>7. SLA</td>
<td>210-261</td>
<td>250</td>
</tr>
</tbody>
</table>
Figure 51

FUEL CAPSULE AND CASK SURFACE TEMPERATURE RESULTS TRANSLUNAR (SLA OFF) - MAXIMUM AND MINIMUM SOLAR HEATING

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Test Results, °F</th>
<th>Pre-Test Predictions, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Capsule Surface</td>
<td>1212-1311</td>
<td>1281-1290</td>
</tr>
<tr>
<td>2. Cask External Surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Center</td>
<td>640-795</td>
<td>634-770</td>
</tr>
<tr>
<td>b. Ends</td>
<td>612-712</td>
<td>590-690</td>
</tr>
<tr>
<td>3. Cask Domes</td>
<td>453-521</td>
<td>435-541</td>
</tr>
<tr>
<td>4. Thermal Shield</td>
<td>283-604</td>
<td>270-494</td>
</tr>
<tr>
<td>6. Astronaut Door</td>
<td>-12-+337</td>
<td>1-380</td>
</tr>
<tr>
<td>7. SLA</td>
<td>-300</td>
<td>-300</td>
</tr>
</tbody>
</table>

Surface Description Test Results, °F Pre-Test Predictions, °F
1. Capsule Surface 1212-1311 1281-1290
2. Cask External Surface
   a. Center 640-795 634-770
   b. Ends 612-712 590-690
3. Cask Domes 453-521 435-541
4. Thermal Shield 283-604 270-494
6. Astronaut Door -12-+337 1-380
7. SLA -300 -300

5607-33
Figure 53

STRUCTURE ASSY. FUEL CASK

MAXIMUM AND MINIMUM THERMAL VACUUM TEMPERATURES
Figure 54
PREDICTED CASK STRUCTURE AND ASTRONAUT THERMAL GUARD TEMPERATURES DURING LUNAR SURFACE DEPLOYMENT
GAEC STRUT TEMPERATURE RESULTS

TEMPERATURES SHOWN IN FOLLOWING ORDER:

- SLA On W/Sun
- SLA On W/O Sun
- SLA Off W/Sun
- SLA Off W/O Sun

Temperatures are shown in the following order:

- SLA On W/Sun
  - 146°F
  - 97°F
  - 120°F
  - 73°F

- SLA On W/O Sun
  - 209°F
  - 125°F
  - 175°F
  - 77°F

- SLA Off W/Sun
  - 192°F
  - 127°F
  - 156°F
  - 93°F

- SLA Off W/O Sun
  - 256°F
  - 148°F
  - 200°F
  - 83°F

- 236°F
  - 151°F
  - 67°F
  - 86°F
  - 30°F

- 202°F
  - 78°F
  - 104°F
  - 15°F

- 231°F
  - 110°F
  - 194°F
  - 42°F

- 181°F
  - 90°F
  - 166°F
  - 42°F

- 201°F
  - 80°F

- 122°F
  - 149°F
  - 63°F

- 125°F
  - 67°F
  - 87°F
  - 44°F

- 208°F
  - 73°F
  - 101°F
  - 7°F
LEM THERMAL BLANKET TEMPERATURE RESULTS
EARTH ORBIT WITH SLA ON, WITH AND WITHOUT SOLAR HEATING
Figure 57

LEM THERMAL BLANKET TEMPERATURE RESULTS
TRANS LUNAR WITH SLA OFF, WITH AND WITHOUT SOLAR HEATING

-205/151
-172/176
-214/158
-183/164
-200/5
-10/81
-181/140
-2/201
-136/136
-173/128
381/185
-171/120
-121/135
-12/185
-162/-24
-114/13
-116/6
-42/149
-167/-5
-22/130

5607-37
## ACCEPTANCE AND QUALIFICATION TEST PROGRAM

### OUTLINE AND TASK NUMBERS

<table>
<thead>
<tr>
<th>ACCEPTANCE</th>
<th>PRIME QUALIFICATION</th>
<th>FLIGHT 1 BACK-UP</th>
<th>FLIGHT 2</th>
<th>FLIGHT 3</th>
<th>D-2/M-5 QUALIFICATION</th>
<th>D-2/M-5 FLIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ASSEMBLY &amp; INSTRUMENTATION</td>
<td>A0</td>
<td>C0</td>
<td>D0</td>
<td>E0</td>
<td>F0</td>
<td>G0</td>
</tr>
<tr>
<td>1 WEIGHT AND CG MEASUREMENT</td>
<td>A1</td>
<td>C1</td>
<td>D1</td>
<td>E1</td>
<td>F1</td>
<td>G1</td>
</tr>
<tr>
<td>2 LAUNCH VIBRATION</td>
<td>A2</td>
<td>C2</td>
<td>D2</td>
<td>E2</td>
<td>F2</td>
<td>G2</td>
</tr>
<tr>
<td>3 FUNCTIONAL TILT TEST</td>
<td>A3</td>
<td>C3</td>
<td>D3</td>
<td>E3</td>
<td>F3</td>
<td>G3</td>
</tr>
<tr>
<td>4 INSPECTION</td>
<td>A4</td>
<td>C4</td>
<td>D4</td>
<td>E4</td>
<td>F4</td>
<td>G4</td>
</tr>
</tbody>
</table>

### QUALIFICATION

<table>
<thead>
<tr>
<th></th>
<th>PRIME QUALIFICATION</th>
<th>FLIGHT 1 BACK-UP</th>
<th>FLIGHT 2</th>
<th>FLIGHT 3</th>
<th>D-2/M-5 QUALIFICATION</th>
<th>D-2/M-5 FLIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 INSTRUMENTATION INSTALLATION</td>
<td>B0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 AIR SOAK</td>
<td>B1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 THERMAL VACUUM</td>
<td>B2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 INSPECTION</td>
<td>B3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 LAUNCH VIBRATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td></td>
<td></td>
<td></td>
<td>H5*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 FUNCTIONAL TILT TEST</td>
<td>B7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 INSPECTION</td>
<td>B8</td>
<td></td>
<td></td>
<td></td>
<td>H8</td>
<td></td>
</tr>
<tr>
<td>9 TEST REPORTS</td>
<td>B9</td>
<td></td>
<td></td>
<td></td>
<td>H9</td>
<td></td>
</tr>
</tbody>
</table>

* TASK H-5 INCLUDES ONLY LAUNCH VIBRATION
IN-FLIGHT STOWED POSITION OF ASTRONAUT PROTECTIVE DEVICE
CLOSE UP VIEW OF STOWED ASTRONAUT PROTECTIVE DEVICE
HEAD ON VIEW OF PROTECTIVE DEVICE
ILLUSTRATIONS OF CLEARANCE BETWEEN LANYARD AND CAGE ATTACHMENT ARM
SIDE VIEW ILLUSTRATING ATTACHMENT ARM/LANYARD INTERFACE