FINAL REPORT

for the

VELOCITY CONTROL PROPULSION SUBSYSTEM

of the

RADIO ASTRONOMY EXPLORER SATELLITE

for

GODDARD SPACE FLIGHT CENTER

under

CONTRACT NO. NAS 5-11463

Prepared By:

W. Braught,
Senior Experimental Engineer

E. K. Moore,
RAE-B Engineering Manager

R. L. Steinberg,
RAE-B Program Manager
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1.0 INTRODUCTION

The Velocity Control Propulsion Subsystem (VCPS) was designed, manufactured and tested by Hamilton Standard under contract to Goddard Space Flight Center for use on the Radio Astronomical Explorer (RAE-B). The purpose of the VCPS is to provide the propulsion required for trajectory and lunar orbit corrections of the spacecraft. A GFE clamp assembly physically attaches the VCPS to the spacecraft and the unit is ejected after completing the required corrections. The VCPS is physically and functionally separated from the spacecraft except for the electrical and telemetry interfaces.

A GFE transtage provides the superstructure on which the VCPS is assembled. The subsystem consists of two 5 lb$_f$ rocket engine assemblies (REAs), 4 propellant tanks, 2 latching valves, 2 fill and drain valves, a system filter, pressure transducer, gas and propellant manifolds and electrical heaters and thermostats. Figures 1 and 2 provide schematics of the fluid and electrical systems respectively. A series of photographs of the VCPS are presented in Appendix A to provide a visual reference of the unit.

The RAE-B VCPS program covered the design, manufacture and qualification of one subsystem. This subsystem was to be manufactured, subjected to qualification tests; and refurbished, if necessary, prior to flight. The VCPS design and test program precluded the need for refurbishing the subsystem and the unit was delivered to GSFC at the conclusion of the program described herein.
2.0 SUMMARY

The VCPS was acceptance tested per Hamilton Standard Plan of Test SVHS 5618 and met all test requirements. The unit was released for qualification testing on 24 March 1972.

Qualification testing was performed in accordance with Hamilton Standard Plan of Test SVHS 5619. Testing was grouped into structural, environmental and firing performance tests. Appropriate base point and monitoring tests were included before and after each significant test sequence. All testing was conducted at Hamilton Standard with the exception of Mass Properties, Acceleration and Thermal Verification; these tests were performed at GSFC, D. T. Brown and General Electric, respectively.

The qualification testing was completed on 18 August 1972. Two hardware discrepancies were encountered and successfully resolved during qualification program. The first involved an REA heater and was detected during the first electrical test when the REA/tank heater circuit gave an incorrect resistance reading. An analysis of the REA heater malfunction was performed, reference GSFC malfunction report #D02908, and as a result, all flight and flight spare heaters were replaced with new equipment manufactured in accordance with more stringent procedures to prevent a recurrence of the malfunction.

The second anomaly occurred during the thermal verification test conducted at General Electric, Valley Forge, Pennsylvania in its solar simulation chamber. The VCPS thermal control subsystem was unable to maintain the propellant tanks and line temperatures to specification requirements. Hamilton Standard subsequently modified the tank thermal analysis by incorporating the test results and changed the tank coating pattern as required to maintain a 45°F min. fuel temperature. The propellant line insulation was redesigned and the heater power changed to provide the required line temperatures. A thermal vacuum test of the VCPS verified the acceptability of these modifications.

Subsequent to the delivery of the VCPS, a need for modification of the gas manifold was established; a copy of the report on that hardware change is included in Appendix E.
FIGURE 2. SUBSYSTEM ELECTRIC SCHEMATIC
NOTES:
1. HEATERS AND REDUNDANT TEMPERATURE CONTROLS ARE LOCATED ON COMPONENT MOUNTING BRACKET.
2. TANK HEATERS (4) CONTROLLED BY PARALLEL RELIABLE THERMOSTATS.
3. TEMPERATURE SENSORS ARE THERMISTOR TYPE.
4. LINE HEATERS CONTROLLED BY REDUNDANT THERMOSTATS.

FIGURE 1
3.0 ACCEPTANCE TEST

The VCPS acceptance test was designed to verify the proper assembly of the wiring harness, the operation of the electrical components and the leakage integrity of the manifold and the flow control valves. Testing was performed in accordance with Hamilton Standard Specification SVHS 5618.

After the VCPS was fully assembled and passivated, the acceptance test was started with a visual examination of the unit. The unit met all drawing requirements; some cosmetic defects were noted and repaired. The acceptance test was successfully completed on 3/18/72. Table 1 is a summarization of the Acceptance testing and shows the test sequence and provides a brief description of the test requirements and results.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>Test Name</th>
<th>Specification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Examination of Product</td>
<td>Visual Examination. Inspection of installation dimensions.</td>
</tr>
<tr>
<td>2</td>
<td>Electrical Check</td>
<td>Verify VCPS electrical interface.</td>
</tr>
<tr>
<td>3</td>
<td>Proof Pressure</td>
<td>Proof 450 psia min. Collapse 5 mm Hg max.</td>
</tr>
<tr>
<td>4</td>
<td>Internal Leakage</td>
<td>8 sec/hr GN for sum of latching valves or thrust control valves.</td>
</tr>
<tr>
<td>5</td>
<td>External Leakage</td>
<td>VCPS external leakage shall not exceed $1 \times 10^{-4}$ sec/sec He.</td>
</tr>
<tr>
<td>6</td>
<td>Dry Weight</td>
<td>VCPS dry weight less GFE shall not exceed 20.5 lbs</td>
</tr>
<tr>
<td>7</td>
<td>Post Test Inspection</td>
<td>Review tests for compliance to specification requirements. Visual Examination</td>
</tr>
</tbody>
</table>

### Reference Table

<table>
<thead>
<tr>
<th>Test No.</th>
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<tr>
<td>7</td>
<td>Post Test Inspection</td>
<td>Review tests for compliance to specification requirements. Visual Examination</td>
</tr>
</tbody>
</table>

### Test Results

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination of Product</td>
<td>Unit passed visual examination. All dimensions within drawing requirements.</td>
</tr>
<tr>
<td>Electrical Check</td>
<td>All circuits demonstrated proper continuity and pin usage.</td>
</tr>
<tr>
<td>Proof Pressure</td>
<td>Unit met all acceptance test requirements. Unit passed visual examination.</td>
</tr>
<tr>
<td>Internal Leakage</td>
<td>The VCPS fluid manifold and tanks suffered no permanent deformation after being subjected to 452 psia proof and 1.8 mm Hg collapse pressure.</td>
</tr>
<tr>
<td>External Leakage</td>
<td>Latching Valves 1.25 sec/hr  Thrust Control Valves 0.4 sec/hr  Actual: 4.7 x 10^{-6} sec/sec He  Actual: 19.257 lbs</td>
</tr>
<tr>
<td>Dry Weight</td>
<td>Unit met all acceptance test requirements. Unit passed visual examination.</td>
</tr>
</tbody>
</table>
QUALIFICATION TEST

Qualification testing was conducted in accordance with Hamilton Standard specification SVHS5619 and appropriate operation sheets. An additional thermal vacuum test was run after the completion of the original sequence due to the out of specification conditions which occurred in the thermal verification test sequence 19. A sequential tabulation of the qualification test program is given in Table II. Each of the test sequences is summarized in Table III and a more detailed description of each test is provided in the following paragraphs.
# TABLE II

**RAE-B VCPS QUALIFICATION TEST SEQUENCE**

<table>
<thead>
<tr>
<th>Test</th>
<th>Completion Date</th>
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</thead>
<tbody>
<tr>
<td>1. System Firing Base Point</td>
<td>3/25/72</td>
</tr>
<tr>
<td>2. Decontamination and Contamination Check</td>
<td>3/25/72</td>
</tr>
<tr>
<td>3. Internal Leakage</td>
<td>3/26/72</td>
</tr>
<tr>
<td>External Leakage</td>
<td>3/27/72</td>
</tr>
<tr>
<td>4. Electrical Check</td>
<td>3/28/72</td>
</tr>
<tr>
<td>5. Mass Properties</td>
<td>4/6/72</td>
</tr>
<tr>
<td>6. Contamination Check</td>
<td>4/6/72</td>
</tr>
<tr>
<td>7. Acceleration</td>
<td>4/11/72</td>
</tr>
<tr>
<td>8. Contamination Check</td>
<td>4/12/72</td>
</tr>
<tr>
<td>9. Internal Leakage</td>
<td>4/13/72</td>
</tr>
<tr>
<td>External Leakage</td>
<td>4/13/72</td>
</tr>
<tr>
<td>10. Electrical Check</td>
<td>4/14/72</td>
</tr>
<tr>
<td>11. Vibration</td>
<td>4/19/72</td>
</tr>
<tr>
<td>12. Contamination Check</td>
<td>4/19/72</td>
</tr>
<tr>
<td>13. Proof Pressure</td>
<td>4/20/72</td>
</tr>
<tr>
<td>14. Internal Leakage</td>
<td>4/20/72</td>
</tr>
<tr>
<td>15. Alignment</td>
<td>4/20/72</td>
</tr>
<tr>
<td>16. Electrical</td>
<td>4/21/72</td>
</tr>
<tr>
<td>17. External Leakage</td>
<td>4/22/72</td>
</tr>
<tr>
<td>18. Visual Examination</td>
<td>4/22/72</td>
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<td>19. Thermal Verification</td>
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<td>20. Contamination Check</td>
<td>5/11/72</td>
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<tr>
<td>21. Thermal Vacuum</td>
<td>5/19/72</td>
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<td>22. Contamination Check</td>
<td>6/1/72</td>
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<tr>
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<td>6/2/72</td>
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<tr>
<td>24. Electrical Check</td>
<td>6/3/72</td>
</tr>
<tr>
<td>25. Spin Firing</td>
<td>6/7/72</td>
</tr>
<tr>
<td>26. System Firing Base Point</td>
<td>6/9/72</td>
</tr>
<tr>
<td>27. Wet Weight</td>
<td>6/9/72</td>
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<td>28. Mission Profile</td>
<td>6/10/72</td>
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<tr>
<td>29. Extreme Temperature and Vacuum Firing</td>
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<tr>
<td>30. Decontamination and Contamination Check</td>
<td>6/20/72</td>
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<td>31. Insulation Verification</td>
<td>7/28/72</td>
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<td>32. Contamination Check</td>
<td>7/28/72</td>
</tr>
<tr>
<td>33. Alignment</td>
<td>8/14/72</td>
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<td>34. Internal Leakage</td>
<td>8/15/72</td>
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<tr>
<td>External Leakage</td>
<td>8/16/72</td>
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<td>35. Electrical Check</td>
<td>8/18/72</td>
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<td>36. Post Test Inspection</td>
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<td>1</td>
<td>System Firing Basepoint</td>
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<td>5</td>
<td>Mass Properties</td>
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<td>6</td>
<td>Contamination</td>
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<td>7</td>
<td>Acceleration</td>
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<td>8</td>
<td>Contamination</td>
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<tr>
<td>9</td>
<td>Leakage</td>
</tr>
<tr>
<td>10</td>
<td>Electrical</td>
</tr>
</tbody>
</table>

**Test Results**

Testing performed at GSFC, Reference NASA GSFC Mass Properties Report Appendix E of this report.

**Actual No. Particles**

- 10
- 8
- 7
- 1
- 0

Test performed at D. T. Brown

Resultant load 15 g's applied at 137.5 in at 62 RPM for 1 minute.

**Actual No. Particles**

- 2.5
- 1
- 0
- 0

**Sum of Latching Valves:** 1.4 scc/hr H₂<br>**Sum of REAs:** 0.6 scc/hr H₂<br>**Total VCPS External:** 1.15 x 10⁻¹¹ scc/sec He

**Pressure Transducer**

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>105 psia</td>
<td>1.67 VDC</td>
</tr>
<tr>
<td>102 psia</td>
<td>3.16 VDC</td>
</tr>
<tr>
<td>260 psia</td>
<td>3.99 VDC</td>
</tr>
</tbody>
</table>

**Thermistor:**

- Room Ambient: 76°F<br>- Tank #1: 75°F Line<br>- Tank #2: 74°F Bracket<br>- 73°F
<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Name</th>
<th>Test Name</th>
<th>Spec. Para.</th>
<th>AT Sheet Pages</th>
<th>Specification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Vibration</td>
<td>4.3.7</td>
<td>92 - 96</td>
<td>Vibration - See Appendix C for levels required and visual examination for structural damage.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Contamination</td>
<td>4.3.2</td>
<td>99 - 100</td>
<td>Same as Sequence 2.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Proof</td>
<td>4.3.8</td>
<td>102</td>
<td>450 ± 10 psia.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Internal Leakage</td>
<td>4.3.3</td>
<td>103 - 104</td>
<td>Same as Sequence 3</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Engine Alignment</td>
<td>4.3.10</td>
<td>117 - 118</td>
<td>Each REA must be within ±30 minutes of the spacecraft center of gravity location.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Electrical</td>
<td>4.3.4</td>
<td>119 - 136</td>
<td>Same as Sequence 4.</td>
<td></td>
</tr>
</tbody>
</table>

**Test Results**

**Heater Circuit Resistance**
- REA and Tank: 20.8 ohms
- REA: 73.8 ohms
- Bracket: 34.75 ohms
- Line: 143.0 ohms

Visual examination of valve traces showed no discrepancies.

See Appendix C for control accelerometer plots. No structural damage noted.

**Actual No. Particles**

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
</table>

150 psia, visually examination showed no structural damage.

Sum of latching valves: 1 sec/hr ON max.

Sum of REAs: NIL

Actual misalignment:
- REA #1: 9.0 minutes max.
- REA #2: 7.5 minutes max.

**Pressure Transducer**

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 psia</td>
<td>1.62 VDC</td>
</tr>
<tr>
<td>205 psia</td>
<td>1.20 VDC</td>
</tr>
<tr>
<td>298.4 psia</td>
<td>3.98 VDC</td>
</tr>
</tbody>
</table>

**Thermistors**: Ambient temperature 75°F
- Tank 1: 75°F
- Bracket: 74.5°F
- Tank 2: 74.5°F
- Line: 75°F
<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Name</th>
<th>Test Name</th>
<th>Spec. Para.</th>
<th>AT Sheet Pages</th>
<th>Specification Requirement</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SVHSER 6226</td>
</tr>
<tr>
<td>17</td>
<td>External Leakage</td>
<td></td>
<td></td>
<td></td>
<td>Total VCPS external leakage shall be 1 x 10^{-4} scc/sec He max.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Visual Examination</td>
<td></td>
<td></td>
<td></td>
<td>Visually examine the VCPS for physical damage.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Thermal Verification</td>
<td>4.3.11</td>
<td>137 - 145</td>
<td></td>
<td>No recorded VCPS temperature shall exceed the range of 45°F to 140°F.</td>
<td>The tank heater actuated in the 0° cold case.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Corrective action for this malfunction is detailed in the engineering report of Appendix D.</td>
</tr>
<tr>
<td>20</td>
<td>Contamination Check</td>
<td>4.3.2</td>
<td></td>
<td></td>
<td>Same as Sequence 2.</td>
<td>Actual No. Particles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>Thermal Vacuum</td>
<td>4.3.12</td>
<td>146 - 155</td>
<td></td>
<td>Temperature cycle the VCPS between 45°F and 140°F;</td>
<td>a) Thrust Control Valve’s average power:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 times;</td>
<td>REA #1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>a) Thrust Control Valves - power drain shall not exceed 10 watts.</td>
<td>@ 45°F 1.38 watts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) Latch Valve shall actuate as indicated by position switch</td>
<td>REA #2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>c) A thermostat shall actuate between 55 ± 5°F and deactivate between 65 ± 5°F.</td>
<td>@ 45°F 1.38 watts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>@ 140°F 1.17 watts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>b) No discrepancies.</td>
</tr>
</tbody>
</table>
TABLE III (continued)

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Name</th>
<th>Spec. Para.</th>
<th>AT Sheet Pages</th>
<th>Specification Requirement</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Test Results**

<table>
<thead>
<tr>
<th>Cycle</th>
<th>On 1</th>
<th>Off 1</th>
<th>On 2</th>
<th>Off 2</th>
<th>On 3</th>
<th>Off 3</th>
<th>On 4</th>
<th>Off 4</th>
<th>On 5</th>
<th>Off 5</th>
<th>On 6</th>
<th>Off 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
</tr>
<tr>
<td>Bracket</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
<td>(*)</td>
</tr>
<tr>
<td>Tank</td>
<td>56.0</td>
<td>(*)</td>
<td>52.5</td>
<td>(*)</td>
<td>52.0</td>
<td>(*)</td>
<td>52.0</td>
<td>(*)</td>
<td>52.0</td>
<td>(*)</td>
<td>52.0</td>
<td>(*)</td>
</tr>
</tbody>
</table>

*NOTE: (*) The recorded line and tank thermostat temperatures during the first three cycles were in error due to the time lag in the VCPS temperature duration.

22 Contamination Check 4.3.2 156 - 158 Same as Sequence 2.

23 Leakage 4.3.3 159 - 171 Same as Sequence

24 Electrical Check 4.3.4 172 - 189 Same as Sequence 4.

Actual No. Particles

<table>
<thead>
<tr>
<th>Actual No. Particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>1.0</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Latchin Valve - Nil
Thrust Control - Nil
Total VCPS External Leakage - \(0.336 \times 10^{-4}\)

Pressure Transducer

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.0 psia</td>
<td>1.60 VDC</td>
</tr>
<tr>
<td>201.4 psia</td>
<td>3.14 VDC</td>
</tr>
<tr>
<td>261.7 psia</td>
<td>4.02 VDC</td>
</tr>
</tbody>
</table>

Thermistor - Room Ambient Temp. 73.0°F
Tank #1 73.5°F Bracket 73.0°F
Tank #2 73°F Line 73°F

Heater Circuit Resistance

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>REA and Tank</td>
<td>20.8 ohms</td>
</tr>
<tr>
<td>REA</td>
<td>73.8 ohms</td>
</tr>
<tr>
<td>Bracket</td>
<td>34.7 ohms</td>
</tr>
<tr>
<td>Line</td>
<td>142.1 ohms</td>
</tr>
</tbody>
</table>

*FOLDOUT FRAME 2*
<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Name</th>
<th>Spec. Para.</th>
<th>AT Sheet Pages</th>
<th>Specification Requirement</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Spin Firing</td>
<td>4.3.16</td>
<td>21h-219</td>
<td>VCPs shall not exhibit any abnormal firing characteristics such as ( P_c ) discontinuities or roughness when compared to previous non-spinning firings.</td>
<td>Visual examination of valve traces showed no discrepancies.</td>
</tr>
<tr>
<td>26</td>
<td>System Firing Basepoint</td>
<td>4.3.1</td>
<td>190-195</td>
<td>Impulse delivered shall be within 5% of the Sequence 1 basepoint data.</td>
<td>Engine ( P_c ) and tank pressure traces were visually examined and found to be smooth and continuous.</td>
</tr>
<tr>
<td>27</td>
<td>Wet Weight</td>
<td>4.3.13</td>
<td>196-199</td>
<td>VCPs wet weight shall not exceed 66 lbs. The propellant consumed during the mission profile test shall be determined.</td>
<td>Impulse delivered by VCPs in 2 minutes.</td>
</tr>
<tr>
<td>28</td>
<td>Mission Profile</td>
<td>4.3.14</td>
<td>200-205</td>
<td>The VCPs mission average ( I_{sp} ) shall be 220 sec. or greater.</td>
<td>Initial Tank Pressure</td>
</tr>
<tr>
<td>29</td>
<td>Extreme Temperature and Vacuum Firing</td>
<td>4.3.15</td>
<td>206-213</td>
<td>Demonstrate thermal vacuum operation of the REAs at 140,000 ft. altitude min. and 45°F and 120°F.</td>
<td>Sequence #1</td>
</tr>
</tbody>
</table>
<pre><code>                                                                                                                               | Tolerance | - 2.1% | - 3.1% |
                                                                                                                               | VCPs weight | 65.8 lbs.                                                                                     | Propellant consumption | 42.4 lbs |
</code></pre>
<p>| 30            | Decontamination and Contamination Check       | 4.3.2       | 220-223        | Same as Sequence 2.                                                                         | Mission Average ( I_{sp} ) 225.6 sec.                                                                                                               |
| 31            | Propellant Line Insulation Verification Test  | Appendix #1 | 1-10           | The VCPs propellant lines temperature shall not be less than 45°F.                           | Reference Figure 3 for impulse delivered by VCPs.                                                                                                  |
| 32            | Contamination Check                           | Appendix #1 | 11-13          | Same as Sequence 2.                                                                         | Actual No. Particles | 10 | 2 | 1 | 0 | 0 | 0 |
|               |                                               |             |                |                                                                                             | Actual minimum line temperature was 51°F. See Appendix B for full thermal report.                                                                    | Actual No. Particles | 8 | 3 | 1 | 1 | 0 | 0 |</p>
<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>Test Name</th>
<th>Spec. Para.</th>
<th>AS Sheet Pages</th>
<th>Specification Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>Alignment</td>
<td>4.3.10</td>
<td>Appendix #1</td>
<td>Same as Sequence 15.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>45 - 47</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Leakage</td>
<td>4.3.3</td>
<td>Appendix #1</td>
<td>Same as Sequence 15.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14 - 25</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Electrical Check</td>
<td>4.3.4</td>
<td>Appendix #1</td>
<td>Same as Sequence 4.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27 - 44</td>
<td></td>
</tr>
</tbody>
</table>

**References**

**Test Results**

**Actual Misalignment**
- REA #1: 15 minutes
- REA #2: 12 minutes

**Internal Leakage**
- Reating Valves: 0.4 scc/hr \( \text{GN}_2 \)
- Thrust Control Valve: 0.7 scc/hr \( \text{GN}_2 \)

**External Leakage**
- Total VCPS: \( 0.5 \times 10^{-6} \) scc/hr \( \text{GN}_2 \)
- Pressure Transducer Output:
  - 101.7 psia: 1.61 VDC
  - 203.0 psia: 3.17 VDC
  - 255.7 psia: 3.94 VDC
- Thermistor: Ambient Temperature: 72°F
  - Tank #1: 71.5°F
  - Line: 71.4°F
  - Tank #2: 71.5°F
- Heater Circuit Resistance:
  - REA and Tank: 20.7 ohms
  - REA: 71.6 ohms
  - Bracket: 36.0 ohms
  - Line: 35.7 ohms

Visual examination of valve traces showed no discrepancies. All data conformed to specification requirements or was reviewed and found acceptable via MRA.
4.1 System Firing Base Point, Sequence 1 and 28

The purpose of this test was to provide a firing base point for comparison of VCPS performance before and after the structural and environmental qualification tests.

Both sequences were performed at identical conditions in the H-5 vacuum test cell. The VCPS was loaded with 12 lbs of hydrazine and pressurized to 260 psia. The unit was fired for 2 minutes with an initial pressure of 260 psia and then refired for 2 minutes after venting the VCPS pressure to 100 psia. No test anomalies were encountered during either test sequence.

The following table shows the impulse delivered by the VCPS and each RBA for each firing.

<table>
<thead>
<tr>
<th></th>
<th>Sequence 1</th>
<th>Sequence 28</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>@ 100 psia</td>
<td>@ 260 psia</td>
</tr>
<tr>
<td>VCPS Total</td>
<td>667</td>
<td>1413</td>
</tr>
<tr>
<td>RBA #1</td>
<td>333</td>
<td>707</td>
</tr>
<tr>
<td>RBA #2</td>
<td>334</td>
<td>706</td>
</tr>
</tbody>
</table>

Impulse delivered by the system was repeated within 3.2% of the initial base point after being subjected to test sequences 2 thru 25. This repeatability is considered excellent and demonstrates that the VCPS performance capabilities were unaffected by the structural and environmental testing.

4.2 Decontamination and Contamination Check, Sequence 2, 8, 12, 20, 22, 30 and 32

The VCPS was decontaminated after each test sequence in which the unit was loaded with hydrazine or reffluor fluid. Contamination checks were made after each decontamination check and after major structural and environmental tests and prior to delivery.

The purpose of the decontamination procedure was to assure the complete removal of hydrazine propellant from the system. This was done by gravity draining the residual hydrazine and flushing the VCPS with high purity water. The water is then drained and removed by an IPA flush and vacuum drying of the system.

A contamination check was made during the IPA flushing sequence by withdrawing an effluent sample and performing a particulate count on the sample. Each contamination check made during the qualification test was found to be well within the allowable CE-5 cleanliness level.
4.2 continued

<table>
<thead>
<tr>
<th>CE-5 Cleanliness Level</th>
<th>Particle Size</th>
<th>Allowable Count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 5 Micron</td>
<td>Unlimited</td>
</tr>
<tr>
<td></td>
<td>5 = 10</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>10 - 25</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>25 - 50</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>50 - 100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>50 Metallic</td>
<td>0</td>
</tr>
</tbody>
</table>

4.3 Leakage, Sequence 3, 9, 14, 17, 23

Internal leakage test was performed after various environmental tests to verify the leakage rate between the propellant source and the thrust chamber. Four internal leakage measurements were made during each sequence:

1. the sum of the latching valve leakage at 300 psia
2. the sum of the latching valves leakage at 15 psia
3. the REA #1 thrust control valve at 300 psia
4. the REA #2 thrust control valve at 300 psia

The internal leakage rates were measured by pressurizing the VCPS, as required, with the appropriate valves closed and collecting the gaseous nitrogen leakage via the water displacement method. The external leakage was measured by the mass spectrometer method with the unit pressurized to 300 psia \( G_{\text{He}} \).

The following table shows the allowable leakage rates compared to the maximum values exhibited during any of the test sequences.

<table>
<thead>
<tr>
<th>Leakage Check</th>
<th>Allowable Rate</th>
<th>Maximum Recorded Rate</th>
<th>Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of Latching Valves</td>
<td>8 scc/hr ( G_{\text{N}_2} )</td>
<td>1.4 scc</td>
<td>9</td>
</tr>
<tr>
<td>Sum of REAs</td>
<td>8 scc/hr ( G_{\text{N}_2} )</td>
<td>.6 scc</td>
<td>9</td>
</tr>
<tr>
<td>External Leakage</td>
<td>( 1\times10^{-4} ) scc/sec ( G_{\text{He}} )</td>
<td>3.4( \times )( 10^{-5} ) scc/sec ( G_{\text{He}} )</td>
<td>23</td>
</tr>
</tbody>
</table>

4.4 Electrical Check, Sequence 4, 10, 16, 24, 35

The purpose of the electrical check was to verify the nominal operation of each electrical component by a functional check at appropriate intervals throughout the qualification test. Included in the test are functional checks of the REA valves, latching valves, pressure transducer, electrical heaters, thermostats and thermistors.
4.4 continued

All the electrical components checked out properly throughout the qualification test except the REA heater. During the first electrical check, sequence 4, an REA heater was found to be defective. The defective unit was removed and replaced with a spare heater. The malfunction analysis of the REA heaters is covered in RDR #02908 in Appendix B. As a result of the investigation, heater manufacturing procedures were revised and all REA heaters were replaced with new units made to the revised procedures.

Test Sequence 35 shows a line heater circuit resistance of 36 ohms compared to 144 in previous tests, this change reflects the line heater wiring change from series to parallel heating elements, required as a result of the propellant line temperature problem.

4.5 Mass Properties

Sequence 5

This test was performed at the NASA facility at GSFC. The NASA provided test report is included in Appendix D. During the mass properties testing it was found that the balance of the VCPS could be varied by the propellant filling rate. The proper fill rate will subsequently be determined by GSFC after delivery of the unit.

4.6 Acceleration

Sequence 7

Acceleration testing was conducted at D. T. Brown test facility. The VCPS contained high purity water and was pressurized to 250 psia. The mounting fixture was designed to provide 3 g's in the X or Y axis while applying 14.7 g's simultaneously in the Z axis. Two one minute runs were made accelerating the unit in the +X, +Z and +Y +Z axes. The acceleration parameters were: arm length - 137.5 inches, 62 RPM with a resultant load of 15 g's. All test parameters were within specification.

4.7 Vibration

Sequence 11

The purpose of the vibration test was to demonstrate that the VCPS and GFE transtage could structurally withstand and successfully operate after being subjected to the required vibration levels. Since the transtage hub was to be tested at the same time as the VCPS, GSFC provided Hamilton Standard with a mass simulating spacecraft and the personnel to assemble the system. The VCPS/spacecraft assembly was tested as a unit during the sinusoidal vibration below 200 Hz and for the entire random input. The spacecraft was removed for sinusoidal inputs above 200 Hz. The VCPS was fully loaded with high purity water and pressurized to 245 psia. Figure 3 shows the test set up and Table 4 provides a listing of the recording accelerometers used. The test engineering report including the control input level plots are provided in Appendix C.
null
Install accelerometers on the test item and record outputs during testing as shown in the following table:

<table>
<thead>
<tr>
<th>ACCELEROMETER LOCATIONS</th>
<th>VIBRATION INPUT AXIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixture (Control)</td>
<td>X, Y, Z</td>
</tr>
<tr>
<td>Spacecraft C.G.</td>
<td>X, Y, Z</td>
</tr>
<tr>
<td>REA Mount</td>
<td>X, Y</td>
</tr>
<tr>
<td>Tank Mount</td>
<td>X</td>
</tr>
<tr>
<td>Latch Valve Mount</td>
<td>X</td>
</tr>
<tr>
<td>Junction Box Mount</td>
<td>X</td>
</tr>
<tr>
<td>Pressure Transducer</td>
<td>X</td>
</tr>
<tr>
<td>Hub (Inside, near arm bracket mount)</td>
<td>X</td>
</tr>
</tbody>
</table>
4.8 Proof Pressure

The purpose of the proof pressure test was to verify the integrity of the VCPS tanks and manifold after the structural qualification test sequences. The VCPS was pressurized to 450 psia for 2 minutes. No visual damage was incurred by the VCPS and the unit passed all subsequent leakage tests.

4.9 Engine Alignment

The REAs were initially aligned during the VCPS assembly. The alignment tests were performed after the structural qualification test and after the firing test prior to shipment. Auto collimators and optical targets were used to initially align and subsequently check the alignment of the REAs to within ± 30' from the theoretical VCPS C.G. The test values in all cases fell between 7.5 and 13 minutes from the C.G.

4.10 Visual Examination

At the completion of the structural qualification tests the VCPS was thoroughly examined by Hamilton Inspection personnel for any damage which may have been incurred. No damage was noted.

4.11 Thermal Verification

The purpose of the thermal verification test was to demonstrate the capability of the VCPS thermal design to maintain the propellant system within the temperature range of 45°F to 140°F, under solar simulated flight conditions. Testing was performed at General Electric's test facility in Valley Forge, Pennsylvania.

The VCPS was instrumented throughout with non-flight thermocouples, loaded with 6 lbs of referee fluid and pressurized to 100 psia. Figure 4 shows the spacecraft/VCPS sun angle relationship. The spacecraft/VCPS was mounted on a spin fixture which was capable of rotating the system to achieve sun angles of 120° (warm cruise) and 60° (cold cruise), while spinning at 55 rpm. The zero degree sun angle was achieved by turning of the solar simulator. Although the problems associated with the use of thermocouples readout through a slip ring greatly reduced the amount of useful data achieved, it was evident that the VCPS was unable to maintain propellant lines and tanks pressure above freezing during the 60° and 0° sun angle modes. The following table briefly summarizes and compares the test results to the expected temperatures.
4.11 continued

<table>
<thead>
<tr>
<th>Thermocouple Location</th>
<th>Sun Angle 120°</th>
<th>60°</th>
<th>0°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Actual</td>
<td>Predicted</td>
</tr>
<tr>
<td>Propellant Tank Outlet</td>
<td>82°F</td>
<td>84°F</td>
<td>112°F</td>
</tr>
<tr>
<td>Bracket Area</td>
<td>ALL READINGS WERE WITHIN SPECIFICATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propellant Line</td>
<td>N/A</td>
<td>101°F</td>
<td>55°F</td>
</tr>
</tbody>
</table>

This problem and the subsequent corrective action, as agreed to by Hamilton Standard and GSFC is documented in GSFC Malfunction Report D02909 ref. Appendix B. A detailed description of the subsequent thermal analysis and verification test is provided in the engineering report included as Appendix

4.12 Thermal Vacuum Sequence 21

The purpose of this thermal vacuum test was to demonstrate the operation of the VCPS components, except engine firing, at the specified temperature extremes of 45°F and 140°F. This testing was performed in Hamilton Standard's 10 ft. x 10 ft. thermal vacuum chamber. The VCPS was loaded with referee fluid and pressurized to 250 psia for the testing.

The unit was subjected to six (6) temperature cycles between the temperature limits with a 2 hour hold period at each extreme. The operation of each component was checked during each temperature hold and the electrical heaters and thermostats operation was tested on each cycle. All components demonstrated satisfactory operation.

Two test conditioning problems were encountered during the thermal vacuum testing. First, some difficulty in maintaining the required $1 \times 10^{-5}$ torr pressure was encountered. The chamber pressure slipped up to $1.5 \times 10^{-5}$ torr for two short periods during the 48 hour test. The second problem involved the rate of temperature cycling. The rate of temperature change during the first three cycles was too fast causing a temperature distribution within the VCPS because of what appeared to be improper thermostat activation. During the last three temperature cycles the cycling rate was sufficiently slow to allow the proper recording of the thermostat temperatures.
UNIT ROTATION IS CLOCKWISE WHEN VIEWED IN DIRECTION OF ARROW

FIGURE 4 THERMAL VERIFICATION
4.13 Spin Firing

The spin firing test was conducted to demonstrate that the engine thrust and tank blowdown characteristics are not affected by the vehicle spin rate.

Testing was performed in the H-4 firing cell at ambient temperature and pressure. The VCPS was loaded with 45 lbs of hydrazine and pressurized to 245 psia. REA chamber pressure and the VCPS pressure transducer were recorded via a slip ring during each firing. Two firings of 2 minutes each were conducted at 55 ± 5 rpm and 12 ± 2 rpm for a total of 8 minutes firing time. Visual examination and comparison of the REA $P_e$ and tank pressure traces show the traces to be smooth, continuous and typical of non-spin firing traces.

4.14 Wet Weight

The purpose of the wet weight test was to determine the mass of propellant consumed during the mission profile test. In order to achieve the accuracy required to provide significant data, a balance scale was built into the firing cell for this test.

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Weight</td>
<td>45.65 lbs</td>
</tr>
<tr>
<td>Propellant Loaded</td>
<td>+145.20</td>
</tr>
<tr>
<td>Gas</td>
<td>+0.42</td>
</tr>
<tr>
<td><strong>Total Wet Weight</strong></td>
<td><strong>91.27</strong></td>
</tr>
</tbody>
</table>

Less Weight of VCPS after Mission Profile: 48.87 lbs.

Propellant Consumed: 42.4 lbs.

4.15 Mission Profile

The purpose of the mission profile test was to subject the VCPS to a typical mission firing sequence and verify the average specific impulse for that mission. The system was initially loaded with 45.2 lbs of $N_2H_4$ pressurized to 245.5 psia. Testing was conducted in the H-5 firing cell with the initial chamber pressure at 100,000 ft. minimum. Four (4) firings were performed with firing time based on the engine performance required to provide impulse of 7253, 770, 1377 and 151 lbs/second respectively. No test anomalies were encountered. The test result for the mission profile are summarized in the following table.
4.15 continued

Initial Conditions

<table>
<thead>
<tr>
<th>Tank Press.</th>
<th>REA Temp.</th>
<th>Firing Time</th>
<th>Delivered Impulse</th>
<th>Mission Isp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 245.5 psia</td>
<td>68°F</td>
<td>870 sec</td>
<td>7356 lb-sec</td>
<td></td>
</tr>
<tr>
<td>2 123 psia</td>
<td>87°F</td>
<td>114 sec</td>
<td>726 lb-sec</td>
<td></td>
</tr>
<tr>
<td>3 112 psia</td>
<td>93°F</td>
<td>222 sec</td>
<td>1312 lb-sec</td>
<td></td>
</tr>
<tr>
<td>4 100 psia</td>
<td>94°F</td>
<td>24 sec</td>
<td>125 lb-sec</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL | 1230 sec | 9519 lb-sec | 225.6 secs |

4.16 Extreme Temperature and Vacuum Firing

The purpose of this testing was to provide firing data for temperature performance prediction and to demonstrate the operation of the REA in thermal vacuum environment. Testing was conducted in the H-5 firing cell with the chamber initially evacuated to 140,000 feet min. prior to each firing. The VCPS was installed loaded with 45 lbs. of propellant and pressurized to 245 psia.

Temperature conditioning was accomplished by preconditioning the VCPS and propellant prior to loading the system and evacuating the cell. The VCPS was then loaded with conditioned fuel and the VCPS temperature was maintained by conditioning the transtage mounting block while slowly evacuating the test cell. For the 40° firing, the firing cell had to be backfilled with dry GN2 to prevent condensed moisture from freezing on the unit as the cell was evacuated.

The following table outlines the test conditions and results of the thermal vacuum firing test.

<table>
<thead>
<tr>
<th>Run</th>
<th>VCPS Bracket Temp.</th>
<th>Propellant/REA Tank Temp.</th>
<th>Initial Tank Pressure</th>
<th>Run Time (mins.)</th>
<th>REA #1 Impulse</th>
<th>REA #2 Impulse</th>
<th>Total Impulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>145°F</td>
<td>136°F</td>
<td>125°F</td>
<td>242 psia</td>
<td>2</td>
<td>624</td>
<td>630</td>
</tr>
<tr>
<td>2</td>
<td>70°F</td>
<td>80°F</td>
<td>60°F</td>
<td>180 psia</td>
<td>2</td>
<td>502</td>
<td>507</td>
</tr>
<tr>
<td>3</td>
<td>42°F</td>
<td>45°F</td>
<td>50°F</td>
<td>113 psia</td>
<td>2</td>
<td>428</td>
<td>431</td>
</tr>
<tr>
<td>4</td>
<td>143°F</td>
<td>125°F</td>
<td>136°F</td>
<td>163 psia</td>
<td>2</td>
<td>471</td>
<td>476</td>
</tr>
<tr>
<td>5</td>
<td>60°F</td>
<td>75°F</td>
<td>60°F</td>
<td>132 psia</td>
<td>2</td>
<td>402</td>
<td>405</td>
</tr>
<tr>
<td>6</td>
<td>40°F</td>
<td>45°F</td>
<td>40°F</td>
<td>112 psia</td>
<td>2</td>
<td>365</td>
<td>364</td>
</tr>
</tbody>
</table>
Propellant Line Insulation Verification Test Sequence 31

The testing was performed in addition to the original qualification test program as a result of the malfunction of the VCPS during the thermal verification test, sequence 19. The purpose of the testing was to verify the selection of the proper insulation thermal characteristics, demonstrate the acceptability of the insulation assembly procedure, and to provide the data necessary for the thermal model to generate the space/flight temperatures.

The test was conducted at Hamilton Standard in the 10 ft. x 10 ft. thermal vacuum chamber. Test conditions were set to simulate worst case conditions by having zero sun input and controlling the line interfaces, hub and tanks, to minimum expected temperatures. Three thermal modes were tested. First, the VCPS was allowed to reach steady state with 12 VDC input to the line heaters. Secondly, heater input was then increased to 13.8 VDC until steady state was achieved. Finally, the heaters were deactivated and the VCPS temperatures were monitored during a 2 hour cool down.

The test results showed that the propellant line temperatures were maintained above freezing even in this worst case test and that the minimum expected line temperature under flight conditions is 51°F. A detailed description of this testing and the results of the subsequent thermal analysis is provided in the engineering report in Appendix E of this report.

Post Test Inspection Sequence 36

This test sequence included a final visual examination of the VCPS by HS Inspection and DCASO personnel and a complete review of the test data for compliance to the specified requirements.

The visual examination revealed no major discrepancies although some minor cosmetic flaws were noted. These were repaired by simple cleaning or in the case of the gold surfaces, the flaws were covered by vapor deposited gold kapton tape. The test data was reviewed and found to be compliant with the specified requirements.
5.0 TANK THERMAL ANALYSIS AND PROPELLANT LINE THERMAL ANALYSIS
FIGURE 5b
RAE-B VCPS

TANK THERMAL ANALYSIS REPORT
1.0 INTRODUCTION

The intent of this report is to document the thermal analysis effort relative to the VCPS tanks conducted since the thermal verification test of May 1972. The pretest analysis and test results are included along with subsequent analyses which served to correlate the thermal model and provide definition of the tank coating changes required for operation within specification limits.

2.0 SUMMARY

The solar thermal verification test showed a large discrepancy between the pre-test tank temperature predictions and the actual test results. A large predicted thermal gradient across the tank failed to materialize and the cooldown rate during the 2 hour transient dark period exceeded the predicted rate by a large amount resulting in temperatures far below the specification minimum. Subsequent analyses have produced a thermal model which duplicates the test results. The original discrepancy has been found to be a combination of oversimplified thermal modeling together with factors unique to the test setup and solar lamps. The mission thermal analysis has been redone using the improved thermal model with the result that 56% of the Black Paint stripe on each tank must be taped over with vapor deposited gold to insure satisfactory operation in space.

3.0 DISCUSSION

3.1 Requirements

The VCPS specification S-723-P-19 requires that tank propellant temperatures remain between 45°F and 140°F with the additional requirement that the tank heaters not turn on; implying that the minimum tank temperature allowable is 50°F at the tank outlet. These criteria must be met over environmental variations characterized by two extremes, hereafter referred to as "HOT CASE" and "COLD CASE" defined as follows:

HOT CASE

Steady state cruise at 120° spin axis inclination (to the solar vector) followed by a 2 hour transient period at 180° inclination with minimum fuel load in the tanks of 6 lbs $N_2H_4$, total.

COLD CASE

Steady state cruise at 60° spin axis inclination followed by a 2 hour transient period at 0° inclination with minimum fuel load of 6 lbs $N_2H_4$, total.
3.2 Thermal Design Philosophy

The principal thermal design objective was to establish a passive thermal control coating system which would minimize the difference in propellant temperature between the hot case and cold case cruise conditions so that the subsequent full sun and dark transients would not yield out of spec temperature excursions. This required that the effective solar absorbance of the tank be higher for the cold case than for the hot case to compensate for the difference in solar projected area (incident solar flux) between the 120° and 60° spin axis angles. Another requirement was to provide a low overall emittance to minimize the 0° spin axis cooldown rate while maintaining the proper d%/e ratio for cruise operation. The coating arrangement selected was vapor deposited gold (Vacuum Metallizing Corp.) with a stripe of black paint applied to the upper (+Z) half of the tank to reduce the overall % to the desired value (2.2) and simultaneously, by its placement, effect a higher absorbance in the 60° spin axis attitude. Figure 1 shows the tank stripe orientation relative to the solar vector at the 60° and 120° spin angle. Vapor deposited aluminum would have been a more desireable coating, since it has a lower % and the same e as gold, but the tank vendor was worried about a possible corrosion problem involving aluminum and the tank material. Figure 2 shows the solar projected area of the black paint stripe in its original configuration as a function of spin angle inclination. The effective solar absorbance of the tank with this stripe configuration is .412 at the 60° spin angle and .30 at the 120° spin angle.

3.3 Thermal Design Analysis

The original thermal design analysis was accomplished using the VCPS system thermal model which contains three tank nodes with associated vehicle and VCPS connectors. This model, the tank portion of which is shown in Figure 3, was input to HSD's general heat transfer computer program and run on the IBM 370-165 computer. A significant portion of the information required to set up this model was supplied by NASA/GSFC early in the design. These data, Table I, included the solar projected area of the tanks, arms and transtage, the view factors from the tanks to space and nearby vehicle surfaces, the temperatures of nearby spacecraft surfaces, and the emittance and solar absorbance of all system external surfaces. Since the tank model has three nodes, it was necessary to apportion the NASA/GSFC supplied solar inputs among the three equal surface area nodes. This was accomplished approximately through the use of the GSFC shadow photographs and hand calculations. The resulting solar projected area of the three nodes for the hot and cold cases is shown below:
3.3 (continued)

Solar Projected Area (4 tanks) \( \sim \) \( \text{FT}^2 \)

<table>
<thead>
<tr>
<th>Spin Angle</th>
<th>HOT CASE</th>
<th>COLD CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Ap</td>
<td>120°</td>
<td>180°</td>
</tr>
<tr>
<td>Nodes 1</td>
<td>.5076</td>
<td>.633</td>
</tr>
<tr>
<td>2</td>
<td>.4804</td>
<td>.916</td>
</tr>
<tr>
<td>3</td>
<td>.384</td>
<td>.633</td>
</tr>
</tbody>
</table>

It should be noted that the solar input is much more evenly distributed in the 120° spin axis case than in the 60° spin axis case where the input to the outboard tank node is considerably higher than that to the other nodes. The increase shadowing corresponding to the 60° spin angle intercepts the inboard areas of the tanks.

3.3.1 Pre-Test Predictions

Hot case and cold case temperature predictions were made after the VCPS had received the vapor deposited gold coating and the black tank stripe had been applied. The analysis was performed for space operation (as opposed to test chamber conditions which were not known at the time) with the intent of adjusting the model after the test to interpret the data at test conditions. Since the test was planned not to include the hot transient condition (180° spin angle) the predictions presented below omit this case. The predictions are based on a solar constant of 442 BTU/\( \text{FT}^2 \)-\( \text{HR} \), 0°R radiation sink and the spec minimum fuel load of 6 lbs \( \text{N}_2\text{H}_4 \) (1.5 lbs per tank).

<table>
<thead>
<tr>
<th>NODE</th>
<th>Tank 1</th>
<th>Tank 2</th>
<th>Tank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Case Cruise (60° spin angle)</td>
<td>112</td>
<td>88</td>
<td>32</td>
</tr>
<tr>
<td>Cold Case Transient (0° spin angle, 2 hrs)</td>
<td>67</td>
<td>-4</td>
<td>-13</td>
</tr>
<tr>
<td>Hot Case Cruise (120° spin angle)</td>
<td>82</td>
<td>85</td>
<td>79</td>
</tr>
</tbody>
</table>

The most significant aspect of these predictions was the large temperature gradient between the outlet (fuel) end of the tank (NODE "Tank 1") and the opposite end ("Tank 3") for cold case cruise. The clarity afforded by hindsight would suggest that transport mechanisms within the tank tending to relax this favorable temperature gradient should have been added to the model at that point since the absence of the gradient at the design \( \frac{1}{2} \) would have resulted in excessively low fuel temperatures during the transient (0° spin angle) condition. This was not apparent at the time.
Test Conditions and Operation

The test was conducted in the General Electric Co. solar simulator at Valley Forge Space Center, King of Prussia, Pa. The VCPS was mounted to a GSFC supplied engineering model of the spacecraft, which was in turn coupled at the +z end of the spin fixture. The combination was rotated at 55 RPM during the test and was processed from the initial 120° spin axis inclination (hot case), after equilibrium was achieved, to the 60° attitude (cold case cruise). At the latter spin angle, the spacecraft Z axis was at 30° to the horizontal (the solar source is reflected from ceiling mounted mirrors). The tanks contained 5.3 lbs of isopropyl alcohol which was added to the 1 lb of water already in the system (but probably not in the tanks). The intent was that the tanks contain 6.3 lbs of alcohol-water mixture to match the thermal mass of 6 lbs of N_2H_4. After equilibrium was achieved at the 60° spin angle, the solar source was turned off for 2 hours to simulate the transient condition at 0° spin angle.

A considerable amount of difficulty was encountered with thermocouple data errors generated by the slip ring temperature gradients. Fortunately, the flight thermistors were utilized in the test providing very accurate tank temperatures at the outlet end and the means for correcting thermocouple data taken elsewhere on the tanks. The tank meridian thermocouple (NODE "Tank 2") failed early in the test.

The test conditions are summarized below:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Power Intensity</td>
<td>118 w/ft^2</td>
</tr>
<tr>
<td>Cold Wall Temperature</td>
<td>-270°F</td>
</tr>
<tr>
<td>Tank Pressure</td>
<td>100 psia</td>
</tr>
<tr>
<td>Tank Load</td>
<td>5.3 lbm isopropyl alcohol</td>
</tr>
<tr>
<td>Vacuum</td>
<td>9.5 x 10^-7 torr</td>
</tr>
<tr>
<td>Spacecraft RPM</td>
<td>55</td>
</tr>
</tbody>
</table>

Test Results

Table II shows the tank temperatures from the various test conditions compared to the pre-test predictions. The data shows two significant discrepancies when compared to the predictions:

The predicted temperature gradient was absent (the test data temperatures are roughly equal to the average value of the three predicted temperatures).

The cooldown rate during the 2 hour dark transient was far greater than predicted.
3.5 (continued)

Both discrepancies suggest the presence of some type of transport phenomena "shorting" the three tank nodes together, evening out the gradient and increasing the heat loss during the transient by distributing the stored heat of the liquid in NODE "Tank 1" over the entire tank surface.

3.6 Data Analysis

The post test analysis had the following major objectives:

1) Review the thermal model for errors and oversimplifications which may have contributed to inaccurate predictions.

2) Investigate the test conditions for phenomena peculiar to the test which will not occur in space.

3) Produce a thermal model which duplicates test results.

4) Replace "test conditions" with "space conditions" in the model and determine coating changes required for satisfactory thermal performance in space.

Prior to going into the details of converting the model to the G.E. test conditions, some runs were made using the space model with the following changes:

Run "A" - All 3 tank nodes were thermally shorted together and the cold case rerun. The results (Table III) agree far better with respect to cooldown rate and cold case temperature distribution than do the original predictions. A re-evaluation of the model calculations failed to reveal any errors other than failure to predict the thermal coupling of the 3 tank nodes. At this point, the various possible internal transport mechanisms were listed, evaluated, and added to the model if found significant:

1. Internal Radiation Among Tank Nodes and Fuel Puddle - A radiation network linking the 3 tank nodes (the fuel puddle is lumped into "Tank 1") and the tank attachment (NODE "ARM") was set up using 0.8 for the internal emittance. The effect of tank radiation alone is significant (Run B, Table III) and the conclusion must be drawn that it should have been in the model from the beginning. The coupling afforded by radiation alone, however, is insufficient to explain the test results.
2. Natural Convection in the Pressurant Gas - The presence of a large radial acceleration in the tanks (2.3 g's at 55 RPM) and a high pressurant density (100 psi \( N_2 \)) produces significant convective coefficients between the warm end (NODE Tank 1) and colder tank areas. Convective coefficients were estimated treating the internal geometry as parallel plates with appropriate separation. Both horizontal and vertical plates were calculated reasoning that the tank geometry would produce convective coefficients somewhere between those two extremes. Figure 4 is a plot of the convective coefficients vs. tank delta T. These were added to the model along with the radiation (Run "C" Table III). These results show further improvement in the direction of matching the test data, but not to the degree of Run "A" (complete thermal short of the 3 tank nodes).

3. Mass Transfer (Diffusion) - Diffusion rates for alcohol through nitrogen were calculated to assess the relative importance of evaporation from the fuel puddle and subsequent condensation on colder areas of the tank. Calculated mass transfer rates were found to be negligible.

4. Fuel Sloshing - During the test, the orientation of the tanks was such that a ±1.0 g oscillatory side loading was applied to the fuel puddle along with the constant 2.3 g radial acceleration normal to the puddle surface. An estimate of slosh natural frequency gave a value of 2 hz. Since the system was spinning at 1 hz, and the unamplified response of the puddle to the ±1.0g would include an angle of 30° about the normal axis of the puddle, the proximity of the slosh excitation to the natural frequency suggests that the fuel was probably sloshing all over the inside of the tank during the test. This has been modeled as run "A" Table III.

The conclusion drawn from these preliminary runs, "A" through "C", is that sloshing probably isothermalized the tank during the test although as run "C" suggests, the data would have been nearly the same without sloshing due to radiation and convection. Sloshing will be precluded in space, but the radiation and convection effects were left in the model for later predictions of space temperatures with new tank coating distributions in the cold case. If the natural convection values utilized in the model are excessive, this will tend to make the resulting design conservative. The natural convection was not added to subsequent hot case runs because leaving it out is conservative.

At this stage in the analysis, the G.E. test conditions were added to the model. These changes consisted of the following:
3.6 (continued)

1. Changing the radiation sink temperature to -270°F, the measured cold wall temperature plus 30°C to provide a realistic effective value of -215°F.

2. Changing solar flux from 129 w/ft² to 118 w/ft² with 3% added to account for chamber reflections.

3. Adjusting absorbtance of the vapor deposited gold tank coating to account for the deviation of the G.E. solar lamp spectrum from the solar spectrum. The data below was generated by GSFC from tank coating samples provided by HSD and the G.E. lamp spectrum:

<table>
<thead>
<tr>
<th>Tank Sample #</th>
<th>GE</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/N 002</td>
<td>.172</td>
<td>.219</td>
</tr>
<tr>
<td>S/N 011</td>
<td>.200</td>
<td>.258</td>
</tr>
</tbody>
</table>

4. Altering the paddle and spacecraft skin cooldown rate to correspond to cutting off the solar source during the 2 hour transient dark period from the GSFC provided cooldown rates which reflected a precession to a 0° spin angle.

**Cold Case Cooling Rates**

<table>
<thead>
<tr>
<th>60° Cruise Temp °F</th>
<th>Temp. At End of 2 HR Transient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space</td>
<td>Paddle = 32°F, Skin = -60°F</td>
</tr>
<tr>
<td></td>
<td>Paddle = 23°F, Skin = -200°F</td>
</tr>
<tr>
<td>Solar Sim Test</td>
<td>Paddle = 32°F, Skin = -200°F</td>
</tr>
<tr>
<td></td>
<td>Paddle = 50°F, Skin = 50°F</td>
</tr>
</tbody>
</table>

With these changes, the model was run for both the hot and cold test conditions. The results showed computed cruise temperatures, especially in the hot case, to be significantly below the test results when using the higher of the two sets of absorbtance values in item 3 above. In order to force correlation of the model with the test results, the solar projected area of the tanks was increased by 5% in the cold case and 15% in the hot case. The original and final solar projected areas for the 3 tank nodes are given below:

<table>
<thead>
<tr>
<th>Node</th>
<th>Tank 1 60°</th>
<th>Tank 2 60°</th>
<th>Tank 2 120°</th>
<th>Tank 3 60°</th>
<th>Tank 3 120°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orig Ap</td>
<td>.547  .5076</td>
<td>.394  .4804</td>
<td>.122  .384</td>
<td>.128  .440</td>
<td></td>
</tr>
<tr>
<td>Final Ap</td>
<td>.573  .582</td>
<td>.413  .551</td>
<td>.128  .440</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With these changes, the model was run for both the hot and cold test conditions. The results showed computed cruise temperatures, especially in the hot case, to be significantly below the test results when using the higher of the two sets of absorbtance values in item 3 above. In order to force correlation of the model with the test results, the solar projected area of the tanks was increased by 5% in the cold case and 15% in the hot case. The original and final solar projected areas for the 3 tank nodes are given below:

<table>
<thead>
<tr>
<th>Node</th>
<th>Tank 1 60°</th>
<th>Tank 1 120°</th>
<th>Tank 2 60°</th>
<th>Tank 2 120°</th>
<th>Tank 3 60°</th>
<th>Tank 3 120°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orig Ap</td>
<td>.547  .5076</td>
<td>.394  .4804</td>
<td>.122  .384</td>
<td>.128  .440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Ap</td>
<td>.573  .582</td>
<td>.413  .551</td>
<td>.128  .440</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.6 (continued)

This adjustment can be justified physically in terms of including in the model the additional solar input of reflected sunlight from the spacecraft and paddles. The reflected solar flux was not included in the tank model input originally. A comparison of the adjusted model output with test temperatures is given by Run D, Table III.

3.7 Coating Modification Analysis

Having matched the test data with the adjusted model, the inputs were changed to space conditions:

1) Solar constant = 430 ETV/ft² hr (125) W/ft²
2) Sink temp. = -460°F
3) Tank gold absorbance from .200 to .258
4) Slosh connectors removed
5) Natural convection connectors removed for hot case runs (left in for cold case)
6) Fuel load thermal mass was changed to 6 lbs of N₂H₄

A nodal diagram of this model configuration is given by Figure 5. A cold case run was made to determine what would happen if the mission were flown with the tanks "as is". The results, Run E, Table III, show that although the propellant (Tank 1) does not fall to as low a temperature in space as in the test, it does fall far below the spec minimum of 45°F and, in fact, would freeze. An obvious solution to this problem would be to eliminate enough of the black paint stripe to raise the cruise temperature and reduce the cooldown rate in the dark transient with the overall constraint of not exceeding specification maximum temperatures during the hot case transient (180° spin angle) condition.

Since physical removal of the black paint stripe is not possible nondestructively, a mystic vapor deposited gold Kapton tape was selected to cover the stripe where necessary. A sample of this tape was sent to GSFC and the emittance and solar absorbance were measured.

\[ \varepsilon_n = 0.02 \quad \alpha_{\text{solar}} = 0.215 \]

Both the radiative properties and physical appearance of this material are quite close to those of the gold tank coating.

Using the properties above for the gold tape, a series of hot case and cold case runs were made varying the percentage of black stripe area taped over (uniformly). The results are plotted on Figure 6.
Based on these results, it was decided to tape 56% of the black stripe area. The taping pattern, chosen for simplicity and to avoid wrinkles is shown by Figure 6. The predicted operating temperature extremes for this configuration are given below:

<table>
<thead>
<tr>
<th></th>
<th>Tank 1</th>
<th>Tank 2</th>
<th>Tank 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cold Case Cruise</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(60° Spin Angle)</td>
<td>99</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td><strong>Cold Case Transient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0° Spin Angle, 2 hrs)</td>
<td>53</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td><strong>Hot Case Cruise</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(120° Spin Angle)</td>
<td>135</td>
<td>138</td>
<td>131</td>
</tr>
<tr>
<td><strong>Hot Case Transient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(180° Spin Angle, 2 hrs)</td>
<td>145</td>
<td>154</td>
<td>145</td>
</tr>
</tbody>
</table>

As indicated in the transient hot case above, the predicted propellant temperature can be 145°F which is 5°F higher than the VCPS specification S-723-P-19 max. propellant temperature of 140°F. The HS position has been to establish an upper limit of 140°F on hydrazine systems which will be operational in space for two or more years primarily to minimize hydrazine gas evolution. The hydrazine decomposition process occurs at all temperatures but can be accelerated by increasing temperature or by using materials which tend to promote the reaction. In the VCPS the gold nickel braze is more catalytic than any of the other materials used in the system. A test program was conducted by the Rocket Propulsion Laboratory of the Air Force to study the effect of hydrazine gas evolution in the presence of gold, nickel braze material. The results of this study are reported in AFRPL-TR-69-77 entitled "The Catalytic Decomposition of Hydrazine on Gold, Nickel, and a Gold/Nickel Brazing Alloy". From this report it has been concluded that a 140°F maximum hydrazine temperature for three months in the VCPS will produce decomposition at levels acceptable to the VCPS. In addition, short term exposure of temperature as high as 250°F for several one day periods can also be accommodated. Also, the VCPS was passivated with hydrazine at 120°F for 2½ hours with no indication of pressure rise. Therefore, the transient (less than 2 hours) hot case temperature of 145°F is not considered a problem based on the above information.
FIGURE 1. TANK STRIPE PLACEMENT

60° SOLAR VECTOR

120° SOLAR VECTOR
FIGURE 2. STRIPE PROJECTED AREA VS SPIN ANGLE (ONE TANK)
### TABLE I

**GSFC SUPPLIED DATA**

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>$\varepsilon_n$</th>
<th>$\alpha_{solar}$</th>
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</thead>
<tbody>
<tr>
<td>Vapor Deposited Aluminum</td>
<td>.04</td>
<td>.12</td>
</tr>
<tr>
<td>Black Paint</td>
<td>.87</td>
<td>.96</td>
</tr>
<tr>
<td>Vapor Deposited Gold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Tank)</td>
<td>.02</td>
<td>.22</td>
</tr>
<tr>
<td>Paddles</td>
<td>$\varepsilon_H = .82$</td>
<td>.71</td>
</tr>
</tbody>
</table>

**View Factors from tanks**

<table>
<thead>
<tr>
<th>To:</th>
<th>$F_{IU}$</th>
<th>Radiating Area</th>
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</thead>
<tbody>
<tr>
<td>Paddles</td>
<td>.21</td>
<td>37.3 ft²</td>
</tr>
<tr>
<td>Cylindrical Skin</td>
<td>.055</td>
<td>8.0 ft²</td>
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<tr>
<td>Conical Skin</td>
<td>.035</td>
<td>5.34 ft²</td>
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<tr>
<td>Space</td>
<td>.70</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Cold Cruise</th>
<th>Cold Transient</th>
<th>Hot Cruise</th>
<th>Hot Transient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Projected Area (1 Tank)</td>
<td>.265 ft²</td>
<td>0</td>
<td>.343 ft²</td>
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</table>

**Temperatures**

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<tr>
<th>Item</th>
<th>Temperature</th>
<th>Cold Transient</th>
<th>Hot Cruise</th>
<th>Hot Transient</th>
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</thead>
<tbody>
<tr>
<td>Cyl. Skin</td>
<td>10°C</td>
<td>-50°C @ 2 hrs</td>
<td>5°C</td>
<td>-50°C @ 2 hrs</td>
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<tr>
<td>Lower Conic</td>
<td>-15°C</td>
<td>-30°C @ 2 hrs</td>
<td>3°C</td>
<td>38°C @ 2 hrs</td>
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<tr>
<td>Paddle</td>
<td>0°C</td>
<td>-5°C @ 2 hrs</td>
<td>-2°C</td>
<td>-5°C @ 2 hrs</td>
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</tbody>
</table>
### TABLE II

**COMPARISON OF TEST RESULTS TO PRE-TEST PREDICTIONS**

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<thead>
<tr>
<th>NODE</th>
<th>Hot Case Cruise</th>
<th>Cold Case Cruise</th>
<th>Cold Case Transient</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>120° Spin Angle</td>
<td>60° Spin Angle</td>
<td>2 hrs sun off</td>
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<td></td>
<td>Prediction</td>
<td>Test</td>
<td>Prediction</td>
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<td>Tank 1 (Fuel)</td>
<td>82</td>
<td>84</td>
<td>112</td>
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<td>Tank 2</td>
<td>85</td>
<td>-</td>
<td>88</td>
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<td>Tank 3</td>
<td>79</td>
<td>78</td>
<td>32</td>
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### TABLE III

**THERMAL MODEL RESULTS**

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<tr>
<th>Run</th>
<th>Case</th>
<th>Tank 1</th>
<th>Tank 2</th>
<th>Tank 3</th>
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<tbody>
<tr>
<td>Solar Simulation</td>
<td>Hot Cruise</td>
<td>84</td>
<td>-</td>
<td>78</td>
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<td>Test Data</td>
<td>Cold Cruise</td>
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<td>65</td>
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<td>Cold Trans</td>
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<td>&quot;A&quot; Slosh (Nodes Shorted)</td>
<td>Cold Cruise</td>
<td>66</td>
<td>66</td>
<td>66</td>
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<tr>
<td>&quot;B&quot; Tank Internal Radiation</td>
<td>Cold Trans</td>
<td>22</td>
<td>21</td>
<td>21</td>
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<tr>
<td>&quot;C&quot; Radiation + Gas Convection</td>
<td>Cold Cruise</td>
<td>77</td>
<td>72</td>
<td>56</td>
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<td></td>
<td>Cold Trans</td>
<td>38</td>
<td>10</td>
<td>9</td>
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<tr>
<td>&quot;D&quot; Radiation, Convection, Slosh, G.E. Test Conditions and Solar Flux Adjustment</td>
<td>Cold Cruise</td>
<td>73</td>
<td>73</td>
<td>72</td>
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<td>Cold Trans</td>
<td>8</td>
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<td>7</td>
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<tr>
<td></td>
<td>Hot Cruise</td>
<td>84</td>
<td></td>
<td>81</td>
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<tr>
<td>&quot;E&quot; Run &quot;D&quot; Tanks</td>
<td>Cold Cruise</td>
<td>81</td>
<td>80</td>
<td>73</td>
</tr>
<tr>
<td>&quot;As Is&quot; in Space</td>
<td>Cold Trans</td>
<td>28</td>
<td>18</td>
<td>17</td>
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</tbody>
</table>
Figure 6. Tank Coating Modifications
RAE-B VCPS

PROPELLANT LINE THERMAL REPORT
1.0 INTRODUCTION AND SUMMARY

This report presents the development and qualification of the RAE-B Velocity Control Propulsion System propellant line thermal configuration. Subsequent to a propellant line low temperature problem experienced during a solar simulation test at G.E., thermal analyses and propellant line development tests were performed. The resulting configuration indicated that significant improvement in line insulation could be attained but increased heater power would also be required. The new line insulation/increased heater power configuration was then incorporated in the VCPS and a thermal vacuum test was performed. Analysis of these test results indicate propellant line temperatures will be within specification under flight conditions.

2.0 DISCUSSION

The solar simulation test conducted on the VCPS at G.E. showed that the thermal design of the propellant lines was inadequate to maintain the propellant line temperatures above freezing.

2.1 Development Program

A development program was initiated where the test data was analyzed and tests of line insulations were performed at the detail level. This program provided the results shown in Table I and the following conclusions:

a) Line insulation thermal effectiveness could be improved by utilizing loose wrap multilayer insulation with an overlapping seam covered by gold Kapton tape.

b) The propellant line would require additional heater power even with the best insulation.

2.2 Verification Test

The VCPS propellant line thermal design was modified and the VCPS reassembled by rewiring the line heater to provide 1 watt/line at 12 VDC and reinsulating with loose wrap insulation utilizing gold Kapton tape (configuration #3 on Table I). In addition the existing thermocouples were removed and replaced with GFE thermistors in the locations shown in Table II and Figure 1. The propellant tanks and +Z surface of the hub were covered with aluminized Mylar insulation to control the propellant line end condition in a zero sun angle condition.

A thermal vacuum test was conducted in the Hamilton Standard 10’ x 10’ vacuum chamber to provide temperature distribution data on the propellant line at zero sun angle, or worst case condition. This data was then reduced, via the VCPS thermal model, to provide the propellant line thermal characteristics for the appropriate VCPS flight conditions.

48

54<
2.3 Test Results

The VCPS was operated in three modes during the thermal vacuum test to provide adequate data for analysis and to check the thermal model at more than one point. The three test conditions were steady state with 12 VDC heater input, steady state with 13.8 VDC heater input and 0 VDC heater input for 2 hours. Table III shows the raw data for each test phase. The chamber conditions were monitored throughout the test. Chamber pressure was maintained below $10^{-5}$ torr and the effective chamber sink temperature is shown in Table III.

The transient (power off) cooldown was performed to obtain an effective thermal mass per unit length characteristic for the lines. The effective cold wall temperature, measured with a suspended blackbody within the chamber, was approximately $-190^\circ$F while data was being taken. Tank temperatures at the outlets were $50^\circ$F or below (they were cooling very slowly throughout the test).

The data analysis involved inputting the test conditions to the propellant line thermal model and "tuning" the insulation properties until the model reproduced the test data, resulting in insulation performance characteristics measured at the system level. Insulation conductance, emittance, and line thermal mass measured in this manner provide the basis for a new set of predictions for space operation. These predictions were made with the thermal model by replacing the test effective cold wall temperature with the space sink ($-460^\circ$F) and adding solar input.

At both power settings, the minimum temperature occurred at position A-4, the tube clamp near the end of the arm. There appears to be a local heat leak at this point caused by the insulation penetration of the clamp itself, along with instrumentation lead heat leaks from the many wires leaving the blanket at that location. (These leads will be clipped before flight, substantially reducing this heat loss). Minimum line temperature was $41.8^\circ$F at 12 volts and $48.5^\circ$F at 13.8 volts. The one hour transient cooldown produced an $18^\circ$ temperature drop ($480^\circ$F to $30^\circ$F) at location A-4 and similar $\Delta T$'s elsewhere. It should be noted that the line temperatures on the other instrumented arm were at least $10^\circ$F higher throughout. The more heavily instrumented line is the coldest of the four because it incorporates the fill and drain valve, the four thermostats and does not have the double insulation wrap in as many places as do the three other lines.

2.4 Thermal Model

The propellant line program divides a pair of lines (a tank on each end and the transtage Tee in the middle) into 70 nodes, 35 line nodes and 35 insulation nodes. The program has stored in a data file such data as the heater locations, clamp locations, and locations of Tee's (fill and drain tee and transtage tee) which are treated as heat leaks. A separate data file holds a solar input
table for each spin axis angle. The solar input was calculated earlier in the RAE-B program thermal studies. The propellant lines were sketched onto the GSFC shadow photographs to determine the location of dark areas on the lines. Solar projected area outside of shadowed locations was then determined by drawing board projection of the solar vector onto the propellant line axis. This was done in 15° increments throughout the vehicle spin (360°) and the results numerically averaged over one spin to yield a table of solar intensity versus position for each propellant line.

The program is operated on a Tymshare Corp. Terminal. This allows rapid manipulation of the model to achieve a desired result.

2.5 Data Correlation and Extrapolation

The program was input for the 12 volt and 13.8 volt steady state conditions. It was found necessary to simulate the heat leak at location A-k by decreasing the clamp thermal resistance from 500 BTU/°F-hr to 150 BTU/°F-hr. The primary criteria for acceptable correlation was matching the minimum temperature. Table IV shows the temperature distribution (key temperatures) for the test conditions and corresponding analysis results. The insulation properties necessary to produce these calculated distributions are shown also. It should be noted that the 13.8 volt case yields a higher insulation conductance (poorer performance) than does the 12 volt case. A tendency toward this behavior is expected since the conductance of superinsulation increases with insulation temperature. The higher conductance (C = .029) was used in the extrapolation of these results to space operation.

A number of transient cooldown runs were made to match the cooldown rate experienced in test. This yielded a thermal mass per inch value of .003 BTU/°F-in for later use in the space transient analysis.

The values of insulation conductance measured in this series of tests are somewhat higher than those measured in the tube element tests shown in Table I. This discrepancy was anticipated owing to the fact that it was much more difficult to apply insulation at the system level than it was to insulate the free piece of propellant line in the tube element test.

The higher insulation conductance was left in the model for conservatism and the solar input and space temperature (-60°F) were added. For cold case cruise (60° spin axis angle), an average power consumption of .64 watts/line (64% duty cycle) will occur with the temperature distribution shown in Table IV. From this temperature distribution, the cold case transient condition was input (1 hour
2.5 (continued)

with no solar flux ~ 0° spin axis angle). A line power value of one watt was utilized along with the effective thermal line mass determined in the test. The temperature distribution after the one hour dark period is shown in Table IV. The temperatures are above the specified minimum 45°F.
### TABLE I
**LINE INSULATION SUMMARY**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>O. D. (in.)</th>
<th>Conductivity (BTU/ft²-hr-°F)</th>
<th>$\varepsilon$ outside</th>
<th>Power Required</th>
<th>Margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Pt.</td>
<td>.75</td>
<td>.02</td>
<td>.05</td>
<td>1/3</td>
<td>.68</td>
</tr>
<tr>
<td>#1 Original VCPS (Test Sample)</td>
<td>.75</td>
<td>.19</td>
<td>.12</td>
<td>Excessive</td>
<td>-</td>
</tr>
<tr>
<td>#2 2nd Generation (Overlap Seam, Gold Kapton Tape)</td>
<td>1.0</td>
<td>.025 (SS)</td>
<td>.053 (SS)</td>
<td>.7</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.035 (T)</td>
<td>.06 (T)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3 3rd Generation (2nd + overwrap 5 layer)</td>
<td>1.35</td>
<td>.011 (SS)</td>
<td>.048 (SS)</td>
<td>.5</td>
<td>.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.013 (T)</td>
<td>.06 (T)</td>
<td></td>
<td>&lt;.1</td>
</tr>
</tbody>
</table>

**Notation:**  
SS = Steady State  
T = Transient
### TABLE II

**RAE-B VCPS THERMISTOR LOCATION**

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Code</th>
<th>Old Code (Thermocouple)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Line A @ Line/Tank Vert Port</td>
<td>A-1</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>Line A @ Line/Tank Horz Port</td>
<td>A-2</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>Line A</td>
<td>A-3</td>
<td>11A 1</td>
</tr>
<tr>
<td>4</td>
<td>Line A</td>
<td>A-4</td>
<td>11A 2</td>
</tr>
<tr>
<td>5</td>
<td>Line A @ Thermostat</td>
<td>A-5</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Line A @ Tee</td>
<td>RA-1</td>
<td>Flt Hardware</td>
</tr>
<tr>
<td>6</td>
<td>Line A</td>
<td>A-6</td>
<td>11A 4</td>
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<tr>
<td>7</td>
<td>Line A @ Thermostat</td>
<td>A-7</td>
<td>N/A</td>
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<tr>
<td>8</td>
<td>Line A @ Tee</td>
<td>A-8</td>
<td>11B 1</td>
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<td>9</td>
<td>Line B @ Tee</td>
<td>A-9</td>
<td>11B 2</td>
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<td>Line B</td>
<td>A-10</td>
<td>11B 3</td>
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<td>11</td>
<td>Tank on Paint Stripe</td>
<td>B-1</td>
<td>9A</td>
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<td>12</td>
<td>Tank Equator</td>
<td>B-2</td>
<td>9C</td>
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<td>Tank in Mount Area</td>
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<td>Tank Thermistor #1</td>
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<td>Arm</td>
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<td>Hub Exterior</td>
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<td>Hub Shelf #1</td>
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<td>18</td>
<td>Line A Internal</td>
<td>D-1</td>
<td>10-1</td>
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<td>Line B Internal</td>
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<td>REA #1 on Chamber</td>
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<td>REA #2 on Chamber</td>
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<td>Latch Valve</td>
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<td>Bracket Thermistor</td>
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Ref: Attached drawing for thermistor locations.
<table>
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<tr>
<th>Time (hrs @ 52°F)</th>
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</table>

**Effective Start**

**PART III**

**ACTUAL VERS TEMPERATURES (°C)**

**Note:** The table contains values for wind-chill, temperature, and other meteorological conditions that are not clearly visible due to the image quality. The table includes columns for different time intervals (e.g., 0.00 to 0.50 hours) and various conditions (e.g., E-2, E-3, E-4, E-5, E-6, E-7, E-8). The exact values are not legible due to the image quality.
### TABLE IV

**Propellant Line Temperature Correlation (°F)**

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<tr>
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<td>Cold Transient</td>
<td>57.8</td>
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<td></td>
<td>1 hr @ 0° spin angle, 1 watt</td>
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## 6.0 HSD POST DELIVERY ACTIVITIES

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<th>TASK</th>
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<tbody>
<tr>
<td>3/19-3/22/73</td>
<td>1. Performed fluid load using H₂O to determine effect on system unbalance caused by fluid distribution in tanks. Results were acceptable within specified requirements.</td>
</tr>
<tr>
<td>GSFC</td>
<td>2. Performed proof pressure test.</td>
</tr>
<tr>
<td>KSFC</td>
<td>4. Performed internal leakage test on VCPS latch valves and thrust chamber valves.</td>
</tr>
<tr>
<td></td>
<td>5. Loaded VCPS with N₂H₄ on balance table to verify proper fluid distribution and pressurized with GN₂ for flight.</td>
</tr>
</tbody>
</table>

The above tasks all gave acceptable results within specified requirements.
APPENDIX A

PHOTOGRAPHS

Ai

63<
COMPLETED VCPS

A1

64<
INTERIOR OF VCPS HUB
VCPS IN THERMALLY CONDITIONED FIRING FIXTURE
(Sides removed for clarity)
APPENDIX B

GSFC MALFUNCTION REPORTS

69<

Bi
<table>
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<th>Serial Number</th>
<th>Manufacturer</th>
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<td>Standard</td>
</tr>
<tr>
<td>E*pfnmrnt</td>
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<td></td>
<td>Standard</td>
</tr>
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<td>f-psv</td>
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<td>Systems</td>
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<th>MANUFACTURER</th>
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<td>Systems</td>
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**INSTRUCTIONS**

1. **Originator** – Fill in blocks (1) through (18), with all known information, as defined in instructions on the back of this form.

2. Distribute copies in accordance with project directions.

---

**Description of the Malfunction:**

After engine firing heater resistance was 56 ohms vs required value of 714 ± 5%. Resistance from heater element to case was 5000 ohms vs required value of "open circuit". Investigation has been initiated.

Target closure date is 1/17/72.

Responsible Engineer is Mr. E. K. Moore.

---

**REFERENCE**

Aircraft Log Book ____________  Page ____________

Test Procedure  SVHS 5619  Page ____________

Institution: Hamilton Standard
### GSFC MALFUNCTION REPORT

**NOD 029**

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<tr>
<th>Project</th>
<th>RAS-B</th>
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<td>System or Experiment</td>
<td>CPS</td>
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**CPS**

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<th>SERIAL NUMBER</th>
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<th>Occurred During</th>
<th>Environment</th>
<th>When Failed</th>
<th>Hardware Level</th>
<th>When Failed</th>
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<td>1 Qualification Test</td>
<td>1 Acceleration</td>
<td>1 Component</td>
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<td>(14)</td>
<td>2 Acceptance Test</td>
<td>2 Shock</td>
<td>2 Sub-Assembly</td>
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<td>8 Post Launch</td>
<td>6 Vibration</td>
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**REFERENCE**

Spacecraft Log Book # Page Test Procedure SWE 5619 Para

13 4.2.2.2

**Description of the Malfunction:** After engine firing heater resistance was 56 ohms vs required value of 74 ± 5%. Resistance from heater element to case was 5000 ohms vs required value of "open circuit". Investigation has been initiated.

**Target closure date is 4/17/72**

**Responsible Engineer is Mr. E. K. Moore**

**Cause of the Malfunction:** Failure analysis included X-ray, insulation resistance, heater resistance spectral analysis, conductometric carbon analysis and ignition test. Analysis indicated that organic contamination of the heater wire or MgO insulation, or both, resulted in the presence of elementary carbon in the MgO. This caused a partial electrical short between the heater wires and between the wires and the case.

**Corrective Action Taken:** All heaters will be replaced by new heaters manufactured with the inclusion of the following steps:

A. Heater element supplier to degrease resistance wire in acetone.

B. Heater element supplier to cut resistance wire to desired length and heat electrically in air: (1) wire unsupported except at ends later removed, (2) heat to maintain approximately 1,700° surface temperature for 2 minutes minimum, (3) prevention of any

**Rework/Repair**

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**Failure Analysis**

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**Action Taken on Failed Unit**

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**Is Rework Required?**

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**Rework Results**

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**Unit May Be Used For**

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**Date MR Closed**

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**Copy 4**
**GSFC MALFUNCTION REPORT**

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<th>System or Experiment</th>
<th>(6) Date &amp; Time of Malfunction</th>
<th>(7) Date of Report</th>
<th>(8) Criticality</th>
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<th>SERIAL NUMBER</th>
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**NAME**

**IDENTIFICATION NUMBER**

**SERIAL NUMBER**

**MANUFACTURER**

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**Operation**

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<th>(14) Environment When Failed</th>
<th>(15) Hardware Level When Failed</th>
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<tr>
<th>(1) Qualification Test</th>
<th>(2) Acceptance Test</th>
<th>(3) Integration Test</th>
<th>(4) Launch Operations</th>
<th>(5) Post Launch</th>
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<th>(1) Acceleration</th>
<th>(2) Shock</th>
<th>(3) Thermal-Vacuum</th>
<th>(4) Temperature</th>
<th>(5) Humidity</th>
<th>(6) Vibration</th>
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**REFERENCE**

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<th>(22) Action Taken on Failed Unit</th>
<th>(23) Is Retest Required?</th>
<th>(24) Retest Results</th>
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<th>GSFC MRRT Approval</th>
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**Corrective Action Taken:**

- Contact of wire and any other heater element component with organic material.
- C. Thermal Systems shall bake each unterminated heater assembly in air at 1,700°F for a minimum of one hour.

**Corrective Action is Required on Other Units, List Units by Serial No.:** S/N 001, 002, 004

**Do Not Write in This Space**

**Cause of the Malfunction:**

**Corrective Action Taken:**

- [ ] Yes
- [ ] No
- If Yes, State Retest Requirements

**Do Not Write in This Space**

**GSFC Project Approval**

**GSFC MRRT Approval**

**Date**

**Contractor Approval**

**Closed**

**Copy 4**
INSTRUCTIONS

(1) Originator – Fill in blocks (1) through (18), with all known information, as defined in instructions on the back of this form.

(2) Distribute copies in accordance with project directions.
A failure analysis of the VCFS thermal design was conducted at Hamilton Standard by comparing the reduced data from the thermal verification test to the original model. The thermal model input parameters were varied until the model prediction approximated the test results. This analysis yielded the following conclusions:

- The tank temperature distribution and rapid loss of temperature were duplicated by shorting internal tank thermal nodes together.
- The tank nodes were shorted during the thermal verification test via natural connection of the pressurant gas, internal contamination, and propellant sloshing.
- The convection and radiation phenomenon will exist under the condition and should be included in the thermal model.
- The thermal properties of the line insulation would have to have been significantly poorer than expected by the model to yield the test results. Tests subsequently performed on line insulation revealed that the insulation thermal properties were as poor as the VCFS model.

**Active Action is Required on Other Units, List Units by Serial No.**

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**Reference**

- Test Log Book
- Phone: 146-1521
- Organization: Hamilton Standard
(17) Description of the Malfunction: VCS was undergoing thermal verification testing at G. E. Valley Forge
(18) Originator: K. DeLaur, Phone: (215) 623-3137, x 344 Organization: Hamilton Standard
Do Not Write in This Space
(19) Cause of the Malfunction: (continued) test results indicated. Hamilton then conducted a series of development tests on various insulation configurations. It was found that line insulation could be manufactured and assembled with substantially improved thermal characteristics but that it would require additional line heater power even when the best line insulation configuration was used.

(20) Corrective Action Token: Agreement was then reached with NASA to proceed with the following action:
a) determine by analysis any changes to the tank thermal design required to maintain proper flight temperatures b) remove and replace the line insulation with the best available configuration c) replace the thermocouple instrumentation with G.P.E. thermistors d) rewire the propellant line heaters to provide 1 watt heat input to each line e) conduct a thermal vacuum test on the VCS propellant line, simulating worst case specification with zero sun input. The test
If Corrective Action is Required on Other Units, List Units by Serial No. (20 continued on attached sheet)

(21) Failure Analysis
(22) Action Token on Failed Unit
(23) Is Retest
(24) Retest Results
(25) Unit May Be Used For

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<th>Mo</th>
<th>Day</th>
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B6
When the propellant tanks modified in this way, the standard cruise temperature is calculated to be 51° F. This Malfunction Report is prepared on the basis of the above action and the acceptance Hamilton Standard Thermal Report S-2093-2.3-099.

Thermal vacuum test was performed and test data analyzed. The minimum temperatures under any flight is calculated to be 51° F. This Malfunction Report is based on the basis of the above action and the acceptance Hamilton Standard Thermal Report S-2093-2.3-099.

Directed Action is Required on Other Units, List Units by Serial No.

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<th>Retest Results</th>
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Page 2 of 2
APPENDIX C

VIBRATION REPORT
SLS TEST ENGINEERING
TEST REPORT

FILE CODE TER 2767
DATE __________

PROGRAM RAE-8 TEST ITEM 5N748720 S/N 1

NAME OF TEST QUAL VIBRATION DATE OF TEST 4/15 - 4/18/72

TEST SPECIFICATION 5V135 5619 TEST PLAN __________

CONCLUSIONS

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

RECOMMENDATIONS (OPTIONAL)

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

OBSERVATIONS (OPTIONAL) INCLUDED HERE ARE ACCELEROMETER RESPONSE CURVES, LOG SHEETS AND PHOTOS OF ABOVE VIBRATION TEST.

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

____________________________________________________________________________

TOTAL TEST TIME ________________

ENDURANCE CYCLES ________________

ORIGINAL COPY ________________

CC: CHIEF OF RELIAB/CHIEF OF DESIGN

TEST ENGINEERING FILE

TEST ENGINEER WESMITH APPROVED/DATE R. Mero 6/20/72

SIGNATURE WESMITH

DATE 6/20/72 78<
Memorandum to: Program

RAE-B

Date of Test 4-15-72

Name of Test QUALIFICATION

Specification AT-VCPS

Subject:

THE ABOVE ITEM WAS VIBRATED AT HSD ON RIG 26 IN A LOADED AND PRESSURIZED CONDITION. THE VCPS WAS MOUNTED ON FIXTURE 72594. PORTIONS OF THE TESTING WERE PERFORMED WITH THE VCPS ONLY AND OTHERS WERE PERFORMED WITH THE SPACECRAFT MOUNTED TO THE VCPS.

CONCLUSION: THE VCPS CAN WITHSTAND THE SPECIFIED VIBRATION WITH NO SIGNS OF STRUCTURAL DEGRADATION WHILE LOADED WITH 45±0.5LBS HIGH PURITY WATER, AND PRESSURIZED TO 260±PSIA GN2.

CON'T

Test Engineer S. MEHMED JR
Signature
Sami Mehmend Jr
Date of Report 5-12-72
Approved Suli Mehmend
Date May 12, 1972
DEVIATIONS:

1) RESPONSE DATA FROM LOCATION [Hz], PRESSURE TRANSUCER MOUNT, TEST 14 LOOKS VERY QUESTIONABLE AS SHOWN BY TRACE 49. THE ACCELEROMETER AT LOCATION [Hz] WAS NOT DAMAGED OR UNFASTENED, HOWEVER THE SIGNAL SHOWN ON TRACE 49 REPRESENTS NOISE ONLY.

2) TEST 16, TRACE 60 REPRESENTING LOCATION [Hz] MUST BE QUESTIONED SINCE TRACE 49 DOES NOT LOOK REALISTIC. TRACE 60 HOWEVER DOES APPEAR TO REPRESENT A REALISTIC LEVEL.

3) TEST N° 16 WAS ACCEPTED BY NASA REPRESENTATIVE, MR M. CALABRESE, AFTER THE FOLLOWING OVERTEST OCCURRED. (T.O.C. ACCEPTING THE TEST IS INCLUDED IN THE REPORT), SUBJECTED TEST ITEM TO 16.2 Gpk FROM 23-37Hz AND 129 Gpk AT 82Hz. THE CAUSE WAS DUE TO A MALFUNCTION IN THE ELECTRONIC SWEEP/HOLD CONTROL LOGIC.

4) TEST 10, TRACE 23, LOCATION [BY] DATA WAS NOT SECURED BECAUSE THE ACCELEROMETER LOOSENED FROM ITS ATTACHMENT POINT.

CONT
5) A reduced control curve for Test No. 7, y axis, is not included. The information was not recorded for this test because the data patch cord was not properly connected to the recorder input.

6) Test number 17 and test number 10 traces 24 and 13 respectively indicated tolerance deviations at 60 Hz and 120 Hz. These deviations were caused by 60 Hz noise which was not detected during the test.

RESULTS:

1) The spacecraft C.G. did not exceed ±4.5 GRP during testing between 16 and 23 Hz as limited by the specification.

2) The spacecraft C.G. did exceed ±4.5 GRP as shown on trace 24 test 7 only.

3) No visible structural damage was detected.
Table of Contents

Test Background
   A) Instrumentation and Calibration List
   B) Block Diagram of Test System
   C) Illustration of Item & Transducer Location
   D) Random Analysis Outline

X - Axis
   A) Sine Data
   B) Random Data

Y - Axis
   A) Sine Data
   B) Random Data

Z - Axis
   A) Sine Data
   B) Random Data

Logs
   A) Operator Log
   B) Instrumentation Master & Running Log
   C) Data Reduction Log
Section I

Test Background
A) Instrumentation and Calibration List
B) Block Diagram of Test System
C) Illustration of Item & Transducer Location
D) Random Analysis Outline
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Standard Calibration Period - Entire system 2 months and also item * are 4 months.
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Standard calibration period is 2 months.

A = Used for this test.
Test Item ----- VCPS
Test Type ----- Qualification
Test Date ----- 4-16-72
RANDOM VIBRATION ANALYSIS

METHOD B

The power spectrum density analyzer is a SD301B REAL TIME ANALYZER and a SD302A ENSEMBLE AVERAGER whose calibration for each test is based on a calibrated signal supplied from equipment listed in the instrumentation section.

1. ANALYZER PARAMETERS

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<th>Bandwidth (Hz)</th>
<th>*Resolution (Hz)</th>
<th>Effective (Noise) Bandwidth (Hz)</th>
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<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>100</td>
<td>0.30</td>
<td>0.2</td>
<td>0.32</td>
</tr>
<tr>
<td>50</td>
<td>0.15</td>
<td>0.1</td>
<td>0.16</td>
</tr>
<tr>
<td>10</td>
<td>0.03</td>
<td>0.02</td>
<td>0.032</td>
</tr>
</tbody>
</table>

*Spacing of filter location.

2. DEGREES OF FREEDOM

For real time analysis the bandwidth resolution is the reciprocal of the analysis period (BT = 1).

\[ N = 2 \times B \times T \times (\text{No. of Ensembles}) \]

\[ N = 2 \times \text{No. of Ensembles} \]

No. of Ensembles available:

1, 2, 4, 8, 16, 32, 64 (normally used unless specified), 128, 256, 512, 1024.
Section II

X - Axis

A) Sine Data

B) Random Data
SINE VIBRATION TEST

RIG 26
OPERATOR JODON
CHECKED BY GEIB
PROJECT RAE-8
PLotted BY MICKET
DATE 4-14-72
TIME 10:20

INPUT LEVEL
EXCIT, AXIS
ACCEL S/N
SENSING AXIS
VARI
ACCEL SENSITIVITY

2.956

FILTER
10/60/200 HZ B.W.
FILTER CROSSOVER
@ 70-700 HZ
TAPER INTEGER SWEEP RATE
CHGO
CHGO

VAR DB/SEC
CHGO DB/SEC

NON-OPERATING
CONTROL
TEMP 74 °F
RESPONSE

LOCATION A4X

SPECIAL CONDITIONS
MASTER PG 1774

FREQ. RANGE & DIRECTION 5-2000 HZ
SPECIFICATION A7-UCPS

ITEM 39594
CODE-
SERIAL NO-

TYPE OF TEST FIXTURE SURVEY
NAME OF TEST SINEUSOIDAL SCAN

10 100 1000 2000
SINE VIBRATION TEST

INPUT LEVEL ± 1 g
ACCEL S/N TE 83
ACCEL SENSITIVITY 2.722
FILTER 10/100/200 Hz B.W.
FILTER CROSSOVER @ 70 - 700 Hz
TAPER EELNOSWEEP RATE 0.23284 s OCT/MIN
COMPR. SPEED VAR DB/SEC
CHG@ - Hz TO - DB/SEC
CHG@ - Hz TO - DB/SEC
NON-OPERATING CONTROL
TEMP 74 °F RESPONSE
LOCATION A1Y
Hooke #3
SPECIAL CONDITIONS MASTER II 1714

FREQ. RANGE & DIRECTION 5 - 2000 Hz
ITEM SIK577594
SPECIFICATION PARA.
AMPL. PHASE SINUSOIDAL SCAN
SERIAL NO.
AMEND.
NAME OF TEST FIXTURE SUREY
TYPE OF TEST FIXTURE
# SINE VIBRATION TEST

**Rig:** 26  
**Operator:** JPD01N  
**Plotted By:** MICKET  
**Date:** 4-14-72  
**Time:** 11:20

**Input Level:**  
- **Excit. Axis:** X  
- **Accel S/N:** T675  
- **Sensing Axis:**  
- **Accel Sensitivity:** 2.791

**Filter:**  
- **Filter Crossover:** 70 - 700 Hz  
- **Taper Rate:** 0.229 Hz Oct/Min

**Compr. Speed:** VAR

**Temp.:** 74°F  
**Test No.:** 7  
**Trace No.:** 19

**Location:** A32 A32

**Note:** Hook-up #3  
**Special Conditions:** MAST RA/7774

## Frequency Hz

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>Item</th>
<th>Code</th>
<th>Serial No.</th>
<th>Type of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2000 Hz</td>
<td>A/V</td>
<td>57544</td>
<td></td>
<td>Fixture</td>
</tr>
</tbody>
</table>

**Specification:** AT-UCPS  
**Amend:** 437  
**Phase:** Bare  
**Fixture Name:** SINUSOIDAL SCAN

---

**ACCELERATION**

**INPUT LEVEL**
- **Excit. Axis:** X
- **Accel S/N:** T675
- **Sensing Axis:**
- **Accel Sensitivity:** 2.791

**FILTER**
- **Filter Crossover:** 70 - 700 Hz
- **Taper Rate:** 0.229 Hz Oct/Min

**Compr. Speed:** VAR

**Temp.:** 74°F

**Test No.:** 7

**Location:** A32 A32

**Note:** Hook-up #3

**Special Conditions:** MAST RA/7774

---

**FREQ. RANGE & DIRECTION**

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>Item</th>
<th>Code</th>
<th>Serial No.</th>
<th>Type of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2000 Hz</td>
<td>A/V</td>
<td>57544</td>
<td></td>
<td>Fixture</td>
</tr>
</tbody>
</table>

**Specification:** AT-UCPS  
**Amend:** 437  
**Phase:** Bare  
**Fixture Name:** SINUSOIDAL SCAN

---

**REPORT NO.**
SINE VIBRATION TEST

TEST NO. 2

DATE 4-15-72
TIME 14:10

ENGINEER
MEHMEM

OPERATOR
JO DOIN

CHECKED BY
GEIB

PROJECT
RAE-B

INPUT LEVEL

EXCIT. AXIS

ACCEL S/N

SENSING AXIS

7D4C

ACCEL SENSITIVITY

MV RMS

GP

COL

GP

FILTER

-10U - 200 HZ B.W.

FILTER CROSSOVER

- 700 HZ

Sweep Rate

4 OCT/Min

TAPERED NO. 0/2295

LINE FROM TAPE

COMPR. SPEED

VAR DB/Sec

CHG. @ HZ TO DB/Sec

CHG. @ HZ TO DB/Sec

NON OPERATING

CONTROL

TEMP. 74°F

RESPONSE

LOCATION

AIX

SPECIAL CONDITIONS

HOOK-UP #1

VCPS

ITEM LOADED AND PRESSURIZED.

FREQUENCY HZ

200 - 2000 Hz

ITEM VCPS

CODE SV 748720

SERIAL NO. 00001

SPECS. AT-VCPS 4.3.7

AMEND. -

FREQUENCY HZ

200 - 2000 Hz

ITEM VCPS

CODE SV 748720

SERIAL NO. 00001

SPECS. AT-VCPS 4.3.7

AMEND. -
C3T 11 S

SINE VIBRATION TEST

INPUT LEVEL

EXCIT. AXIS

+ 7.5

ACCEL S/N

SENSING AXIS

TD44

ACCEL SENSITIVITY

3.035

FILTER

100/200 HZ B.W.

FILTER CROSSOVER

@ 700 HZ

TAPE REEL NO.

Sweep Rate

012295 4 OCT/Min

COMPR. SPEED

VAR DB/SEC

CHG@ — HZ TO — DB/SEC

CHG@ — HZ TO — DB/SEC

NON-OPERATING

CONTROL

TEMP.

73 °F

RESPONSE

LOCATION

BX

HUB

HUB-UP#1

SPECIAL CONDITIONS

VCPS LOADED

AND PRESSURIZED

THIS PORTION OF THE TEST PERFORMED WITH THE VCPS ONLY

FREQ. RANGE & DIRECTION

200-2000 Hz

ITEM

VCPS

CODE 5V

SERIAL NO.

743720-1

TYPE OF TEST

00001 QUAL

SPECIFICATION

AT-VCPS

PARA.

4.3.7.5

AMEND.

NOTE 2

NAME OF TEST

VCPS ONLY SINUSOIDAL VIBRATION

PAGE NO.

RPG

TEST NO.

7"
SINE VIBRATION TEST

Input Level
± 7.5 g

Excit. Axis
X

Accel S/N
WF7.5

Sensing Axis
X

Accel Sensitivity

1.051

Filter
100/200 Hz B.W.

Filter Crossover
@ 700 Hz

Taper/Reel No.
02297-14 Oct/Min

Comp. Speed
Yard/db/sec

CHG@ - Hz to - db/sec

CHG@ - Hz to - db/sec

Non-Operating

Temp.
73 °F

Dist. of Test
EX

Tank Mount Hook-up #1

Special Conditions
VCPS Loaded and Pressurized

This portion of the test performed with VCPS only

Freq. Range & Direction
200-2000 Hz

Spec.
AT-VCPS

Item
VCPS

Code
791720-1

Ser. No.
00001

Type of Test
QUAL

Phase

Name of Test
SINUSOIDAL VIBRATION
SINE VIBRATION TEST

INPUT LEVEL: 7.5 g
ACCEL S/N: WR11
ACCEL SENSITIVITY: 3.016 MV RMS

FILTER: 100/200 Hz B.W.
FILTER CROSSOVER: @ 700 Hz
TAPER REEL NO. SWEEP RATE: 012295 4 OCT/MIN
COMPR. SPEED: VAR DB/SEC
CHG@ — HZ TO — DB/SEC
CHG@ — HZ TO — DB/SEC

NON-OPERATING TEMP: 73°F
LOCATIONS BY

HUB HOOK-UP #1
SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED
THIS PORTION OF THE TEST PERFORMED WITH THE VCPS ONLY

FREQ. RANGE & DIRECTION: 200 - 2000 Hz
ITEM: VCPS
CODE: S
SERIAL NO.: 748720-1 00001
TYPE OF TEST: QUAL

SPECIFICATION: PARA.
AMEND. PHASE
NAME OF TEST: VCPS ONLY SINUSOIDAL VIBRATION
SINE VIBRATION TEST

TRACE NO. 7
TEST NO. 3
DATE 4-15-72
TIME 1420

INPUT LEVEL EXCIT. AXIS
+ 7.5 X
ACCEL S/N
X 32
SENSING AXIS
Y
ACCEL SENSITIVITY
1.261 MV RMS

FILTER
100/200 HZ B.W.
FILTER CROSSOVER
@ 700 HZ

TAPER LENGTH SWEEP RATE
612165 4 OCT/MIN
COMPR. SPEED
VAR DB/SEC

CHG@ - HZ TO - DB/SEC
CHG@ - HZ TO - DB/SEC

NON-OPERATING
CONTROL
TEMP.
73 OP

LOCATION
EY

TANK MOUNT
HOOK-UP#1

SPECIAL CONDITIONS
VCPS LOADED
AND PRESSURIZED

THIS PORTION
OF THE TEST
PERFORMED WITH
VCPS ONLY

FREQUENCY Hz

FREQ. RANGE & DIRECTION
200 - 2000 Hz

ITEM VCPS

SPECIFICATION
AT-VCPS

CODE SY 746720-1

SERIAL NO. 00001

TYPE OF TEST QUAL

NAME OF TEST SINUSOIDAL VIBRATION
SINE VIBRATION TEST

RIG: 26
OPERATOR: JORDIN
CHECKED BY: MEHMEK
PROJECT: RAEM

TRACE NO.: 34
TEST NO.: 1

DATE: 4-18-72
TIME: 0715

INPUT LEVEL: ± 1.5
EXCIT, AXIS: X

ACCEL S/N: XM21
SENSING AXIS: X

ACCEL SENSITIVITY: 1.370

FILTER: 10/100 HZ B/W
FILTER CROSSOVER: @ 70 HZ

TAPERELNO: SWEEP RATE: 012295 4 OCT/MIN
COMPR. SPEED: VAR DB/SEC
CHG@ - HZ TO - DB/SEC
CHG@ - HZ TO - DB/SEC

LOCATION: DX
REA MOUNT
HOOK-UP#1

SPECIAL CONDITIONS: SPECIFICATION MODIFIED BETWEEN 5-15 HZ
COMPLETE PACKAGE: VCPS LOADED AND PRESSURIZED.

FREQUENCY HZ

5-2000 Hz
Item: [unknown]
Code: SV
Serial No.: 00001
Type of Test: QUAL

Specification: PARA, 4.3.7.5
Amend.: NOTE 1/3
Phase: VCPS and Spacecraft
Name of Test: SINUSOIDAL VIBRATION

FREQ. RANGE & DIRECTION: 5-2000 Hz
VCPS

REPORT NO.: [unknown]
SINE VIBRATION TEST

RIG 26
OPERATOR JO DOYIN
CHECKED BY GEIB
PROJECT PRL-R

DATE 4-18-72
TIME 0715

INPUT LEVEL ±1.5
EXCIT. AXIS X
ACCEL S/N TD48
SENSING AXIS Y
ACCEL SENSITIVITY MVRMS
GP COL GP
2.788

FILTER 10/100 HZ B.W.
FILTER CROSSOVER @ 70 HZ
TAPE REEL NO. SWEEP RATE 012795 4 OCT/Min
COMP. SPEED VAR DB/SEC
CHG@ HZ TO DB/SEC
CHG@ HZ TO DB/SEC

LOCATION CY
SPACECRAFT C.O. HOOK-UP #1

SPECIAL CONDITIONS
SPECIFICATION MODIFIED BETWEEN 5-14/72
COMPLETE PKG
VCPS LOADED AND PRESSURIZED

FREQ. RANGE & DIRECTION 5-2000 HZ
SPECKTATION PARA. 4, 3, 7, 5
CODE EV 746720-1
SERIAL NO. 000001
TYPE OF TEST QUAL

PHASE VCPS AND SPACECRAFT SINUSOIDAL VIBRATION
**SINE VIBRATION TEST**

**RIG** 26  
**OPERATOR**  
**CHECKED BY** GEIB  
**PROJECT**  
**PLOTTED BY**  
**DATE** 4-18-72  
**TIME** 0715

<table>
<thead>
<tr>
<th>INPUT LEVEL</th>
<th>EXCIT. AXIS</th>
<th>ACCEL S/N</th>
<th>SENSING AXIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 1.5 g</td>
<td>X</td>
<td>YK20</td>
<td>Y</td>
</tr>
</tbody>
</table>

**ACCEL SENSITIVITY** 1.523  
**FILTER** 10/100  
**FILTER CROSSOVER** @ 70  
**TAPER NUMBER/SWEEP RATE** 0/2295  
**COMPR. SPEED** VAR DB/SEC  
**CHG@ — Hz TO — Hz DB/SEC**  
**NON-OPERATING**  
**TEMP.** 74°F  
**LOCATION**  
**SPECIAL CONDITIONS** SPECIFICATION MODIFIED BETWEEN S-1/W2  
**COMPLETE PKG VCPS LOADED AND PRESSURIZED**

**FREQ. RANGE & DIRECTION** S-200 HZ  
**FREQUENCY Hz**  
**FREQUENCY LEVEL** LOW SIGNAL TO NOISE RATIO  
**FREQUENCY LEVEL**  

**NAME OF TEST** QUAL
### Random Vibration Test Analysis Method B

**Report No.**

<table>
<thead>
<tr>
<th>RIG</th>
<th>Operator</th>
<th>PLOTTED BY</th>
<th>Trace No.</th>
<th>Test No.</th>
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</thead>
<tbody>
<tr>
<td>26</td>
<td>B. M.</td>
<td>S. M.</td>
<td>13</td>
<td>10</td>
</tr>
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</table>

**Test Engineer**

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-18-72</td>
<td>0650</td>
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</table>

**Input Level**

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<tr>
<th>Excitation Axis</th>
<th>ACCEL SERIAL NUMBER</th>
<th>ACCEL SENSING AXIS</th>
<th>ACCEL SENSITIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>TD40</td>
<td>X</td>
<td>2.805 GP</td>
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**Analysis Filter**

<table>
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<tr>
<th>Hz B.W.</th>
<th>Sweep Speed</th>
<th>Time Constant</th>
<th>Analysis Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 ± 1</td>
<td>1 ± 1</td>
<td>1 ± 1</td>
<td>1/23 l² Hz F.S.</td>
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**Period of Test**

<table>
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<th>Start</th>
<th>End</th>
<th>Duration</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>2.0 MIN</td>
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</table>

**Operating Temperature**

<table>
<thead>
<tr>
<th>Non Operating</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>74 °F</td>
</tr>
</tbody>
</table>

**Tape Reel No.**

| C12295        |

**Setup and Response**

<table>
<thead>
<tr>
<th>Pickup Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI X</td>
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</tbody>
</table>

**Special Conditions**

- VCP5 Loaded
- Pressurized

---

**Project and Item Specification**

<table>
<thead>
<tr>
<th>RAE-B</th>
<th>VCPS</th>
<th>Code</th>
<th>SERIAL NUMBER</th>
<th>Type of Test</th>
</tr>
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<tbody>
<tr>
<td>74720-1</td>
<td>00001</td>
<td>QUAL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Phase VCPS and Spacecraft**

- RANDOM
### Project Information

- **RAE-B**
- **VCPS**
- **AT-VCPS**

### Spec. Information

- **437.51**

### Test Details

- **Type of Test**: QUAL

### Trace No. 22

- **Test No.**: 10

#### Date: 4-18-72

#### Time: 0650

### Input Level

- **9.2 GRMS**

### Excitation Axis

- **X**

### Accel Serial Number

- **TD44**

### Accel Sensing Axis

- **X**

### Accel Sensitivity

- **3.935 MV RMS**

### Analytical Filter - Hz B.W.

- **6**

### Sweep Speed - OCT/Min

- **..**

### Time Constant - SEC

- **..**

### Analytical Calibration

- **108.26 Hz**

### Period of Test

- **START**

### Duration

- **2.0 MIN**

### Non Operating Temp.

- **74**

### Tape Reel No.

- **012295**

### Control Response

- **HUB**

### Special Conditions

- **VCPS Loaded and Pressurized**

### Plot Details

- **Frequency (Hz)**
- **Spectral Density $g^2/Hz$**

---

**Note:** The image contains a graph with frequency data and some textual information related to random vibration test analysis methods. The graph shows various plotted points and lines indicating spectral density and frequency response over different intervals.
RANDOM VIBRATION TEST
ANALYSIS METHOD B

RIG: 26
OPERATOR: B. M
PLOTTED BY: S. M
TRACED BY: S. M
TEST NO.: 17
DATE: 4-18-72
TIME: 0650

INPUT LEVEL: 9.2 GRM
EXCITATION AXIS: X
ACCEL SERIAL NUMBER: T045
ACCEL SENSING AXIS: X
ACCEL SENSITIVITY: 2.650 MV RMS/GRM
ANAL FILTER - BW: 6 OCT/MI
SWEEP SPEED - OCT/MI: 6
TIME CONSTANT - SEC: 2.450
ANAL. CALIBRATION: 1.398 F.S.
PERIOD OF TEST:
START: 012095
END: 210900
DURATION: 210 MIN
TEMP.: 74 DEG.
TAPE REEL NO.: 012295

PICKUP LOCATION: CX
SPACECRAFT C.G.:
HOOK-UPS: 1
SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

PROJECT CODE: RAE-B
VCPS SERIAL NUMBER: 748720-1 0001
TYPE OF TEST: QUAL

SPEC. PARA. AMEND. NOTE PHASE VCPS AND SPACECRAFT
AT-VCPS 4.3.7.5 184
RANDOM VIBRATION TEST
ANALYSIS METHOD B

RIG: 26  OPERATOR: B.M  PLOTTED BY: S.M
TEST ENGINEER: S.M  CHECKED BY: T.G

DATE: 4-18-72  TIME: 0650

INPUT LEVEL: 0.12  GRMS
EXCITATION AXIS: X
ACCEL SERIAL NUMBER: YK20
ACCEL SENSING AXIS: Y
ACCEL SENSITIVITY: 1.523 MV RMS

ANAL FILTER - HZ B.W.: 6
SLEEP SPEED - OUT/MIN:
TIME CONSTANT - SEC:

ANAL. CALIBRATION: 429.9 l^2 F.S.

PERIOD OF TEST: START X END
DURATION: 2.0 MIN
NON OPERATING TEMP.: 74 °F
TAPE REEL NO.: 012295

PICKUP LOCATION: DY
REAR MOUNT
HACK-UFP W1

SPECIAL CONDITIONS:
VCPS LOADED AND Y RESURFACED


SPEC: AT-VCPS  PARA: 4.37.5  AMEND. NO.  00001  PHASE: VCPS AND SPACECRAFT

PAGE NO.: 065
Hamilton Standard
RANDOM VIBRATION TEST
ANALYSIS METHOD B

MODELS OF UMTIME

TEST ENGINEER

CHECKED BY

DATE

TIME

PROJECT ITEM

SERIAL NUMBER

TYPE OF TEST

RAE B VCPS 74870-1 0000/ QUAL

SPEC PARA AMEND NOTE PHASE VCPS AND SPACECRAFT RANDOM

10 100 1000 2000 FREQUENCY - HZ

1.0 0.8 0.6 0.4 0.2 0.0 SPECTRAL DENSITY g/Hz

INPUT LEVEL

9.2 GRMS

EXCITATION AXIS

ACCELERATION SERIAL NUMBER

NBG 2

ACCELERATION SENSING AXIS

ACCELERATION SENSITIVITY

3.052 MV RMS

FILTER - Hz B.W.

SWEEP SPEED - OCT/MIN

TIME CONSTANT - SEC

ANNUAL, CALIBRATION

PERIOD OF TEST

DURATION

2.0 MIN

NON OPERATING TEMP.

Tape Reel No.

012295

CONTROL RESPONSE

PICKUP LOCATION

A12

HOOUP #1

SPECIAL CONDITIONS

VCPS LOADED AND Pressurized.

148-
Section III

Y - Axis

A) Sine Data

B) Random Data
<table>
<thead>
<tr>
<th>FREQ. RANGE &amp; DIRECTION</th>
<th>ITEM</th>
<th>CODE</th>
<th>SERIAL NO.</th>
<th>SPEC.</th>
<th>PARA.</th>
<th>AMEND.</th>
</tr>
</thead>
<tbody>
<tr>
<td>52K Hz</td>
<td>S/759</td>
<td>S/759</td>
<td>AT-VCPS</td>
<td>4.3</td>
<td>7</td>
<td>-</td>
</tr>
</tbody>
</table>

**ACTION SHEET NO.**

**ATA NO.**

**TYPE OF TEST**
- Accept Test
- Sine Scan

**INPUT LEVEL**
- 1.0

**ACCEL S/N**
- TE83

**ACCEL SENSITIVITY**
- 1000

**FILTER**
- 10-100-200 Hz B.W.

**FILTER CROSSOVER**
- 76.7 Hz

**SWEEP RATE**
- 4.0 Oct/min

**TAPEREEL NO.**
- 01294

**COMPR. SPEED**
- Var db/sec

**CHG. TO**
- 0 db/sec

**TEMP.**
- 74°F

**LOCATION**

**SPECIAL CONDITIONS**
- Bare Fixtures

**MASTER NO.**
- 1774
SINE VIBRATION TEST

RIG 26
OPERATOR JOHNSON
CHECKED BY GEIB
PROJECT RAE-B

TRACE NO. 14
TEST NO. 5 ch'7
DATE 4-19-72
TIME 1540

INPUT LEVEL EXCIT. AXIS
+ / - Y

ACCEL S/N SENSING AXIS
VG57 Y

ACCEL SENSITIVITY
10.886 MV RMS

FILTER
10 - 100 - 200 Hz B.W.
FILTER CROSSOVER
@ 70 - 700 Hz

SWEEP RATE
01234 4 OCT/MIN

COMPR. SPEED
YAR DB/SEC

CHG@ HZ TO DB/SEC

NON-OPERATING □ CONTROL
TEMP. 75 0F □ RESPONSE

LOCATION A5Y

SPECIAL CONDITIONS

FREQ. RANGE & DIRECTION
5 - 2000 Hz

ITEM SPECIFICATION
SVSK 7859

CODE PARA.

SEERIAL NO. AMEND.

TYPE OF TEST Fixture Survey

NAME OF TEST SINE/SODIAL SCAN

MASTER NO 1774
### SINE VIBRATION TEST

- **Rig:** 26
- **Operator:** JO DON
- **Plotted By:** MICKET
- **Test No.:** 5
- **Date:** 4-13-72
- **Time:** 15:40

#### Nominal Input Level

- **Input Level:** OFF SCALE

#### Acceleration

- **Max. Acceleration:** 1562

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>5-1000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>1000</td>
</tr>
</tbody>
</table>

#### Special Conditions

- **Location:** AIX
- **Hook-Up:** AIX

#### Frequency Table

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>Code</th>
<th>Serial No.</th>
<th>Type of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixture Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sineoidal Scan</td>
</tr>
</tbody>
</table>

#### Specifications

- **Specification:** AT-VCP5
- **Amend:** 4.3.7

#### Operating Conditions

- **Temp:** 75°F
- **Filter:** 10-100-1000 Hz B.W.
- **Filter Crossover:** 70-700 Hz
- **Tapered No. Sweep Rate:** 0.2594 sec
- **Comp. Speed:** VAR DB/SEC
- **CHG @ Hz To:** DB/SEC

#### Notes

- **Hook-Up Notes:** AIX
- **Special Conditions:** Master 161774
SINE VIBRATION TEST

Rig: 26
Operator: P. Jodoin
Witness: A. M. Crothy

Project: RAE-B
Date: 4-15-72
Time: 1545

Input Level: 7.5
Excit. Axis: Y

Accel S/N: TE 83
Sensing Axis: Y

Accel Sensitivity: 0.722

Filter: 100-200 Hz
Filter Crossover: 70 Hz

Sweep Rate: 4.0 Oct/Min

Tapereel No.: 01295

Compr. Speed: Var

Chg. @ Hz to DB/Sec.

Non Operating: ON
Temp.: 14 Deg.

Location: A14

Special Conditions: This portion of the test performed with the VCPS only

VCPS Loaded: Pressurized

Freq. Range & Direction: 200 - 2000 Hz
Type of Test: Qual. VCPS only

Code: SV
Serial No.: 748726
Spec.: AT-VCPS
Para.: 43.7.5
Amend: Note 2

Name of Test: Sinusoidal Vibration
SINE VIBRATION TEST

TEST NO. 1545
DATE 4-15-72

HAMILTON STANDARD

C6M1001

FREQUENCY HZ

SERIAL NO.

PHASE

FREQ. RANGE &
DIRECT. 2000-20000 Hz

NAME OF TEST

CODE SV

PREL. RANGE &
DIRECT. 2000-20000 Hz

SPECIFICATION

ITEM NCPS

PAGE NO.

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### SINE VIBRATION TEST

**Rig:** 26  
**Operator:** Jodein  
**Plotter:** Jodein  
**Trace No.:** 18  
**Test No.:** 5  
**Date:** 4-15-72  
**Time:** 1545

**Input Level:** ± 7.5  
**Excit. Axis:** Y  
**Accel S/N:** WR11  
**Sensing Axis:** Y  
**Accel Sensitivity:** 3.016  
**Filter:** 100/200 Hz B.W.  
**Filter Crossover:** @ 700 Hz  
**Taper Reel No.:** 0/2295  
**Sweep Rate:** 4 Oct/min  
**Comp. Speed:** VAR  
**Gain:** —  
**Temp.:** 75 °F  
**Location:** HUB  
**Hook-up #:** 2  
**Special Conditions:** VCPS Loaded and Pressurized  
**Test Performed With:** VCPS Only

**Frequency (Hz):**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Code SV</th>
<th>Serial No.</th>
<th>Type of Test</th>
<th>Name of Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-2000</td>
<td>VCPS</td>
<td>748728-1</td>
<td>00001</td>
<td>QUAL</td>
</tr>
</tbody>
</table>

**Page No.:** 1

**Artifact Description:**

- **Artifact:** Graph of sine vibration test results.
- **Details:** The graph shows frequency vs. acceleration with a focus on the frequency response of the VCPS component.

---

*Note: The graph details include specific test parameters and conditions, which are essential for understanding the test results.*
SINE VIBRATION TEST

Nominal Input Level

INPUT LEVEL
± 7.5

ACCEL S/N
TD90

ACCEL SENSIVITY
2.805

FILTER
100/200 Hz B.W.

FILTER CROSSOVER
@ 700 Hz

TAPE REEL NO.
012295

COMPR. SPEED
VAR

CHG @ — Hz TO — DB/SEC

NON-OPERATING

TEMP.

LOCATION
AIX

SPECIAL CONDITIONS:
VCPS LOADED AND PRESSURIZED

THIS PORTION OF THE TEST PERFORMED WITH THE VCPS ONLY
SINE VIBRATION TEST

INPUT LEVEL: ± 7.5 %

ACCEL AXIS: X
SENSING AXIS: Y

ACCEL S/N: TD44

ACCEL SENSITIVITY: 3.035 MV RMS

FILTER: 100/200 Hz B.W.
FILTER CROSSOVER @ 700 Hz

TAPE REEL NO.: 012295
SWEEP RATE: 4 OCT/MIN

COMPR. SPEED: VAR

MONTH @ — HZ TO — DB/SEC

NON-OPERATING □ CONTROL
TEMP. 75 °F X RESPONSE

LOCATION: BX

HUB Hook-up #2

SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

THIS PORTION OF THE TEST PERFORMED WITH THE VCPS ONLY

FREQ. RANGE & DIRECTION: 200-2000 Hz

SPECIFICATION: AT-VCPS 4.3.7.5

ITEM: VCPS
CODE SY: 748720-1
SERIAL NO.: 00001

TYPE OF TEST: QUAL

NAME OF TEST: SINUSOIDAL VIBRATION

TRACe NO.: 17
TEST NO.: 5
DATE: 4-15-72
TIME: 154.5
SINE VIBRATION TEST

RIG 26
OPERATOR JODIN
PLOTTED BY JODIN
TEST ENGINEER MEHED
CHECKED BY GEIB
PROJECT VCS

TRACE NO. 1
TEST NO. 5
DATE 4/15/72
TIME 15:45

INPUT LEVEL EXCIT. AXIS
± 7.5 g

ACCEL S/N XM21
SENSING AXIS X

ACCEL SENSITIVITY 1.325 MV RMS
GP COL

FILTER 100/200 Hz B.W.
FILTER CROSSOVER @ 700 Hz
TAPER EEL NO., SWEEP RATE 01295 4 OCT/MIN

COMPR. SPEED VAR DB/SEC

CHG@ — Hz TO — DB/SEC

NON-OPERATING CONTROL
TEMP. 75 °F RESPONSE

LOCATION DX
REA MOUNT
HANG-UP # 2

SPECIAL CONDITIONS VCS LOADED AND PRESSURIZED

THIS PORTION OF THE TEST PERFORMED WITH THE VCS ONLY
SINE VIBRATION TEST

NO. 167

TRACe NO. 14

TEST NO. 5

DATE 4-15-72

TIME 1545

INPUT LEVEL EXCIT. AXIS ± 7.5

ACCEL S/N NB62

SENSING AXIS Z

ACCEL SENSITIVITY 3.052

FILTER 100/200 Hz RB/W

FILTER CROSSOVER @ 700 Hz

TAPER REELED NO. SWEEP RATE 0/229.5 4 Oct/Min

COMPR. SPEED YAR DB/SEC

CHG@ Hz TO Hz DB/SEC

CHG@ Hz TO Hz DB/SEC

LOCATION A12

HOO-UP #2

SPECIAL CONDITIONS VCPS LOADED AND PRESSURIZED

THIS PORTION OF THE TEST PERFORMED WITH THE VCPS ONLY

<table>
<thead>
<tr>
<th>FREQ, RANGE &amp; DIRECTION</th>
<th>ITEM</th>
<th>CODE</th>
<th>SERIAL NO.</th>
<th>TYPE OF TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-2000 Hz</td>
<td>5V</td>
<td>748720-1</td>
<td>0001.0001</td>
<td>QUAL</td>
</tr>
</tbody>
</table>

SPECIFICATION PARA. AMEND. PHASE NAME OF TEST
SINE VIBRATION TEST

RIG: 26  
OPERATOR: JODIN  
CHECKED BY: MEHMED  
PROJECT: RA2-2  
DATE: 4-17-72  
TIME: 11:45

INPUT LEVEL: 3.25  
ACCEL S/N: XM21  
ACCEL SENSITIVITY: 1.325

FILTER: 10/100 Hz  
FILTER CROSSOVER: 70 Hz

LOCATION: DX  
REAG MOUNT: Hook-up # 2

SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

REPORT NO.

FREQ. RANGE: 5 - 200 Hz
DIRECTION: 4

ITEM: X
SERIAL NO.: 748720-1
TYPE OF TEST: QUAL

NAME OF TEST: 1
APPROVED: 1

TEST NO.: 1
TRACE NO.: 1
<table>
<thead>
<tr>
<th>INPUT LEVEL</th>
<th>9.2 GRMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCITATION AXIS</td>
<td>Y</td>
</tr>
<tr>
<td>ACCEL SERIAL NUMBER</td>
<td>TD48</td>
</tr>
<tr>
<td>ACCEL SENSING AXIS</td>
<td>Y</td>
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<tr>
<td>ACCEL SENSITIVITY</td>
<td>7.78 MV</td>
</tr>
<tr>
<td>ANAL FILTER - Hz B.W.</td>
<td>6</td>
</tr>
<tr>
<td>SWEEP SPEED - OCT/MIN</td>
<td></td>
</tr>
<tr>
<td>TIME CONSTANT - SEC</td>
<td></td>
</tr>
<tr>
<td>ANNAL, CALIBRATION</td>
<td>1.27 g²/Hz²</td>
</tr>
<tr>
<td>PERIOD OF TEST</td>
<td>2.0 MIN</td>
</tr>
<tr>
<td>DURATION</td>
<td></td>
</tr>
<tr>
<td>NON OPERATING TEMP.</td>
<td>74 °F</td>
</tr>
<tr>
<td>TAPE REEL NO.</td>
<td>P12295</td>
</tr>
<tr>
<td>CONTROL RESPONSE</td>
<td></td>
</tr>
<tr>
<td>PICKUP LOCATION</td>
<td>CY</td>
</tr>
<tr>
<td>HOOK-UP #</td>
<td>2</td>
</tr>
</tbody>
</table>

**SPECIAL CONDITIONS**
- VCPS Loaded and Pressurized
### Random Vibration Test

**Analytical Method B**

**Report No.**

**HSF-1635 B**

**RIG**

26

**Operator**

P.J.

**Plotted by**

T.G.

**Checked by**

Mehmed

**Date**

4/17/72

**Time**

1700

### Input Level

- 9.2 GRMS

### Excitation Axis

- Y

### Accelerometer Serial Number

- XK32

### Accelerometer Sensing Axis

- Y

### Accelerometer Sensitivity

- 1.247 MV RMS

### Analytical Filter

- HZ B.W.
  - 6

### Sweep Speed

- OCT/MIN

### Time Constant

- SEC

### Annular Calibration

- 52.5 Hz

### Period of Test

- START
- END

### Duration

- 2.0 MIN

### Non-Operating Temp.

- 74 °F

### Tape Reel No.

- 012295

### Pickup Location

- "XY"

### Hook-Up

- #2

### Special Conditions

- VCPS Loaded and Pressurized

### Project

**RAE-B**

**Code**

SV 748720-1

**Serial Number**

0001

**Type of Test**

QUAL

**Spec.**

SVH 5611

**Para.**

4.3.7

**Amend. Note**

164

**Phase Simple**

PKG

**Random**

---

**Page No.**

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### Random Vibration Test Analysis Method B

**Report No.**

**Rig**
- 2G

**Operator**
- P. J

**Plotted By**
- T. G

**Trace No.**
- 7

**Test No.**
- 9

**Date**
- 4/17/72

**Time**
- 1700

**Input Level**
- 9.2 GRM

**Excitation Axis**
- Y

**Accel Serial Number**
- N632

**Accel Sensing Axis**
- Z

**Accel Sensitivity**
- 3.052 MVRMS

**Anal Filter - Hz B.W.**
- 10

**Sweep Speed - OCT/MIN**
- 10

**Time Constant - SEC**
- 10

**Anal Calibration**
- 19.2

**Period of Test**
- Start

**Duration**
- 2.0 MIN

**Temp.**
- Non Operating
- 74

**Tape Reel No.**
- 0/2275

**Control**
- Yes

**Response**
- Yes

**Pickup Location**
- A12

**Hook-Up**
- A

**Special Conditions**
- VCPS Loaded AND Pressurized

**Project**
- RAE-B

**Item**
- VCPS

**Code**
- 5V

**Serial Number**
- 00001

**Type of Test**
- QUAL

**Spec. at VCPS**
- SVHS 5619

**Para.**
- 4.3.7

**Amend. Note**
- 1

**Phase Complete**
- FKG

**Random**
- C104

**Page No.**
- 185
### Project

- **Code**: SVHS
- **Serial Number**: 0006

### Type of Test

- **Type**: Random

### Test Details

- **Input Level**: 9.2 GRMS
- **Excitation Axis**: Y
- **Acceleration Serial Number**: TD40
- **Acceleration Sensing Axis**: X
- **Acceleration Sensitivity**: 2.805
- **Analyzer Filter - Hz B.W.**: 6
- **Sweep Speed - Oct/Min**: 1
- **Time Constant - Sec**: 1
- **Analyzer Calibration - Hz F.S.**: 1.25
- **Duration**: 2.0 MIN
- **Non-Operating Temp.**: 74 °F
- **Tape Reel No.**: 0/22.95
- **Special Conditions**: Vents Loaded and Pressurized

### Graph Details

- **Frequency - Hz**: 10, 100, 1000, 2000
- **Spectral Density - g²/Hz**: Off Scale

### Diagram

The diagram shows a graph with frequency on the x-axis and spectral density on the y-axis. The graph has peaks and valleys indicating the frequency response of the test.

### Table

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<thead>
<tr>
<th>Project</th>
<th>Item</th>
<th>Code</th>
<th>Serial Number</th>
<th>Type of Test</th>
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<tbody>
<tr>
<td>SVHS</td>
<td>vCP</td>
<td>748728-1</td>
<td>00061</td>
<td>Random</td>
</tr>
</tbody>
</table>

**Note**: The note indicates an amendment to the test phase.
Random Vibration Test

**Analysis Method B**

**Input Level:**
- Frequency: 9.2 GRM
- Excitation Axis: Y

**Acceleration Serial Number:**
- serial number

**Acceleration Sensing Axis:**
- Y

**Acceleration Sensitivity:**
- MV RMS
  - GP
  - COL
  - GR

**Anal Filter - Hz Bandwidth:**
- 6.10 | 20 | 50

**Sweep Speed - Oct/Min:**
- 0.7 | 0.2 | 0.3

**Time Constant - Sec:**
- 2.5 | 1.25 | 0.5

**Annal Calibration:**
- 1.41 ft/s²

**Period of Test:**
- Start [ ]
- End [ ]

**Duration:**
- 2.0 min

**Non Operating Temp.:**
- 74 °F

**Tape Reel No.:**
- 012295

**Pickup Location:**
- CX

**Hook-Up #:**
- Special Conditions: VCP5 Loaded and Pressurized

**Project:**
- RAE-B

**Item:**
- VCP5

**Code SV:**
- 7487201

**Serial Number:**
- 0001

**Type of Test:**
- Qual

**Spec. AT:**
- VCP5

**Para.:**
- 5619

**Amend.:**
- 194

**Phase Complete PKG:**
- Random

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<table>
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<tr>
<th>Project</th>
<th>Item</th>
<th>Code</th>
<th>CV</th>
<th>Serial Number</th>
<th>Type of Test</th>
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</thead>
<tbody>
<tr>
<td>RAE-B</td>
<td>VCPS</td>
<td>748720-1</td>
<td>00001</td>
<td>QUAL</td>
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</tr>
</tbody>
</table>

**SPEC.**
AT-VCPS 4.3.7

**AMEND.**
NOTE 154

**PHASE**
COMPLETE PKG

**RANDOM**

**PAGE NO.**

---

**INPUT LEVEL**
9.2 G RMS

**EXCITATION AXIS**
Y

**ACCEL SERIAL NUMBER**
YK20

**ACCEL SENSING AXIS**
X

**ACCEL SENSITIVITY**
1.523 MV RMS

**ANAL FILTER - Hz**
60 B,W

**Sweep Speed - Oct/M**

**TIME CONSTANT - SEC**

**ANNAL, CALIBRATION**
68.76 in² F.S.

**DURATION**
2.0 MIN

**TAPE REEL NO.**
012295

**PICKUP LOCATION**
DX REA MOUNT

**Hook-up**

**SPECIAL CONDITIONS**
VCPS LOADED AND PRESSURIZED

---

**Trace No.**
9

**Date**
4-17-74

**Time**
1700
Section IV

Z - Axis

A) Sine Data

B) Random Data
<table>
<thead>
<tr>
<th>FREQ. RANGE &amp; DIRECTION</th>
<th>ITEM CODE</th>
<th>SERIAL NO.</th>
<th>SPEC. CODE</th>
<th>PARA.</th>
<th>AMEND.</th>
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</thead>
<tbody>
<tr>
<td>5-20 KHz</td>
<td>SYSK79594</td>
<td>AT-VCPS</td>
<td>4.13.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SPECIAL CONDITIONS**

- Hook-Up
- Bare Fixture
- SYSK79594

**LOCATION**

- Alz

**TEMP.**

- 75°F

**SWEEP RATE**

- 4.0 OCT/MIN

**FILTER**

- 10-100-200 Hz B.W.

**FILTER CROSSOVER**

- @ 70-700 Hz

**ACCEL. S/N**

- NS82

**SENSING AXIS**

- 77

**EXCIT. AXIS**

- 1.0

**ACC. SENSITIVITY**

- 2.698 MV RMS

**GP**

- 1.0

**COL**

- 1.0

**OC**

- 1.0

**RESPONSE**

- 1.0

**CONTROL**

- 1.0
SINE VIBRATION TEST

RIG: 26
OPERATOR: JOADOIN
PLOTTED BY: MICKET
TEST ENGINEER: MEHMED
CHECKED BY: GE18
PROJECT: RAE-B
DATE: 4-13-72
TIME: 1:00

INPUT LEVEL
ACCEL S/N: VG57
ACCEL SENSITIVITY: 10.886

EXCIT. AXIS
SENSING AXIS

FILTER
10 - 100 - 200 Hz B.W.
FILTER CROSSOVER
@ 70 Hz

TAPER ENL., SWEEP RATE
012294
4 OCT/MIN

COMPR. SPEED
VAR

CHG@—Hz TO—Hz

NON-OPT OPERATING
TEMP: 75°F

LOCATION
A5Z

SPECIAL CONDITIONS
BARE FIXTURE

FREQ. RANGE & DIRECTION
ITEM: SHOC01
SERIAL NO.: SVSK0159
TYPE OF TEST: FIXTURE SURVEY

MASTER FS I774
<table>
<thead>
<tr>
<th>ITEM</th>
<th>VC/S</th>
<th>VC/P</th>
<th>S/P</th>
<th>V/C</th>
<th>S/C</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC/S</td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>VC/P</td>
<td></td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tabular Data:**
- **VC/S:** Variable Component Speed
- **VC/P:** Variable Component Power
- **S/P:** Static Power
- **V/C:** Variable Component
- **S/C:** Static Component
- **2000:** Specific Value

**Graphical Representation:**
- The graph shows a plot with various axes and readings.
- The plot includes a linear scale with values ranging from 0 to 2000.
- There are annotations and numbers indicating specific data points and measurements.

**Notes:**
- The graph is labeled with a scale indicating measurements and data extraction points.
- The annotations include symbols and measurements, possibly indicating time or frequency.

**Additional Information:**
- The graph appears to be part of a technical report or analysis, with specific measurements and conditions noted.
- The labels and values suggest a focus on dynamic or performance analysis, possibly related to mechanical or engineering data.

**Contextual Insights:**
- The data points and measurements are crucial for understanding the performance characteristics under various conditions.
- The graph may be used to validate theoretical models or to interpret experimental results.
SINE VIBRATION TEST

INPUT LEVEL
$+10\text{ dB}$

EXCIT. AXIS
$Z$

ACCEL S/N
$NB62$

SENSING AXIS
$Z$

ACCEL SENSITIVITY
$2.698\text{ mV RMS}$

FILTER
$100/200 \text{ Hz B.W.}$

FILTER CROSSOVER
$@ 700 \text{ Hz}$

TAPEREEL NO. SWEEP RATE
$0.52 \% / \text{ sec} \times \text{ min}$

COMPR. SPEED
$VAR \text{ DB/sec}$

CHG@ Hz TO DB/sec

NON-OPERATING
$X \text{ CONTROL}$

TEMP.
$74 \text{ °F}$

LOCATION
$A1Z$

HOOK-UP #3

SPECIAL CONDITIONS
VCPS LOADED AND PRESSURIZED.

FREQ. RANGE & DIRECTION
$200 \rightarrow 2000 \text{ Hz}$

ITEM
VCPS

CODE
748720-1

SERIAL NO.
00001

TYPE OF TEST
QUAL

NAME OF TEST
SINUSOIDAL VIBRATION
### SINE VIBRATION TEST

<table>
<thead>
<tr>
<th>Rig</th>
<th>Operator</th>
<th>Plotter</th>
<th>Trace No.</th>
<th>Test No.</th>
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</thead>
<tbody>
<tr>
<td>Z6</td>
<td>P. J</td>
<td>P. J</td>
<td>42</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Engineer</th>
<th>Checked By</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. M</td>
<td>T. G</td>
<td>RAE-5</td>
</tr>
</tbody>
</table>

#### Trace Details
- **Date**: 4-18-72
- **Time**: 1:10:5

---

#### Graph Details
- **Input Level**: 10
- **Excit. Axis**: Z
- **Sensing Axis**: Z
- **Accelerometer**: TG75
- **Acceleration**: 2.791

#### Filter Details
- **Crossover Frequency**: 100/200 Hz
- **Filter**: 700 Hz
- **Sweep Rate**: 1/2 96

#### Additional Information
- **Compr. Speed**: VAR DB/SEC
- **Temp.**: 74°F
- **Location**: B2
- **Hub**: Hook-up #3
- **Special Conditions**: VCP Loaded and Pressurized

---

#### Chart Details
- **Frequency (Hz)**: 200-2000 Hz
- **Item**: VCPS
- **Code**: 748720-1
- **Serial No.**: 00001
- **Type of Test**: QUAL
SINE VIBRATION TEST

RIG 26 OPERATOR P. J.
TEST ENGINEER S. M.
CHECKED BY T. G.
PROJECT FAE-D

TRACE NO. 44 TEST NO. 14
DATE 4-18-72 TIME 10:5

INPUT LEVEL EXCIT, AXIS
+ 10 dB
ACCEL S/N
YK20
ACCEL SENSITIVITY
1.596

FILTER 100/200 HZ B.W.
FILTER CROSSED
700 Hz
TAPER/REEL NO.
SWEEP RATE 4 OCT/MIN

COMPRESSOR SPEED
VAR DB/SEC

RESPONSE
TEMPERATURE 74 °F

LOCATION E-2
TANK MOUNT
HOOK-UP #3
SPECIAL CONDITIONS
VCPS LOADED AND PRESSURIZED

FREQ. RANGE & DIRECTION 200 - 2000 Hz
ITEM VCPS CODE 5V
SERIAL NO. 748720-1 00001
TYPE OF TEST QUAL
INPUT LEVEL: 10
EXCIT. AXIS: Z
ACCEL S/N: WF75
SENSING AXIS: Z
ACCEL SENSITIVITY: 1.001

FILTER: 100/200 Hz B.W.
FILTER CROSSOVER @ 700 Hz
TAPE REEL NO. SWEEP RATE 01/296 4 OCT/Min
COMPR. SPEED VAR DB/SEC
CHG@ Hz TO DB/SEC
CHG@ Hz TO DB/SEC

NON-OPERATING 
TEMP. 74°F
LOCATION F2
LATCH VALVE MT
HOOK-UP #3

SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

FREQ. RANGE & DIRECTION 200-2000 Hz
SPECIFICATION AT-VCPS
ITEM VCPS
CODE SV 748720-1
SERIAL NO. 00001
TYPE OF TEST QUAL
NAME OF TEST SINUSOIDAL VIBRATION
DATA SHOWN IS QUESTIONABLE

INPUT LEVEL
± 10

ACCEL S/N
XJ29

ACCEL SENSITIVITY
1.626 MV RMS

FILTER
100/200 Hz B.W.

FILTER CROSSOVER
@ 700 Hz

TAPER EL. NO.
0/2296

COMPR. SPEED
VAR DB/SEC

CHG@ — HZ TO — DB/SEC

CHG@ — HZ TO — DB/SEC

NON-OPERATING

TEMP.

LOCATION

PRESSURE

HOOK-UP

SPECIAL CONDITIONS
VCPS LOADED AND PRESSURIZED.

FREQ. RANGE & DIRECTION
200 - 2000 Hz

SPECIFICATION
AT-VCPS

ITEM
VCPS

CODE SY
748720-1

SERIAL NO.
00001

TYPE OF TEST
QUAL

NAME OF TEST
SINUSOIDAL VIBRATION

PAGE NO.
1

PAGE NO.
1

PAGE NO.
1
SINE VIBRATION TEST

RIG 2G
OPERATOR P. J.
TEST ENGINEER S. M.
CHECKED BY T. S.
PROJECT RAE-209

TRACE NO. 46
TEST NO. 14
DATE 4-18-72
TIME 170-5

INPUT LEVEL
Excit. Axis
10
2

ACCEL S/N
Sensing Axis
TE83 Y

ACCEL SENSITIVITY
MV RMS
2.979

FILTER
150/200 Hz B.W.

FILTER CROSSOVER
700 Hz

TAPERED TO CROSSOVER SWEEP RATE 012296 4 OCT/MIN

COMP. SPEED
VAR DB/SEC

CHG@ HZ TO DB/SEC

NON-OPERATING CONTROL
TEMP. 74 °C RESPONSE

LOCATION A1Y

Hook-up #3
VCPS Loaded
And Pressurized

REPORT NO.

FREQ. RANGE & DIRECTION 200-2000 Hz
Item VCPS
Code 5V
Serial No. 748720
Type of Test QUAL
Phase 00001
SINE VIBRATION TEST

Input Level: ±6.8

Accel S/N: WF75

Accel Sensitivity: 1.001

Filter: 10/160 Hz

Filter Crossover: 76 Hz

Taper Reel No.: 012296

Compr. Speed: VAR

Chg@HZ To DB/Sec

Non-Operating Temp: 74°F

Location: FZ

LATCH VALVE MOUNT Hookup #3

SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

TEST NO. 16

Date: 4-19-72

Time: 0930
SINE VIBRATION TEST

<table>
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<tbody>
<tr>
<td>OPERATOR</td>
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<td>TEST ENGINEER</td>
<td>MEHMET</td>
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INPUT LEVEL: EXCIT. AXIS ± 6.8 g N
ACCEL B/N: SENSING AXIS T&D40 X
ACCEL SENSITIVITY: 3.005 MV RMS
FILTER: 10/100 HZ B.W.
FILTER CROSSOVER: 70 HZ
TAPER REEL NO.: SWEEP RATE: 012296
COMPR. SPEED: VAR DB/SEC
CHG@ HZ TO DB/SEC
NON-OPERATING TEMP: 74°F
LOCATION: AIX

Hook-up #: 3
Special Conditions: VCPS loaded and pressurized.

FREQ. RANGE & DIRECTION: 5-2000 HZ
SPECIFICATION: AT-VCPS 4.3.7.5
CODE: SV 748720-1
SERIAL NO.: 00001
TYPE OF TEST: QUAL
NAME OF TEST: SINUSOIDAL VIBRATION

REPORT NO.
Standard H

RIG: 26
OPERATOR: JOOJIN
CHECKED BY: GEIB
PROJECT: HALF

DATE: 4-19-72
TIME: 0930

INPUT LEVEL
± 6.8 dB Z
ACCEL S/N
SENSING AXIS
TEB3 Y
ACCEL SENSITIVITY
2.979 MV RMS
FILTER
10/100 Hz B.W.
FILTER CROSSOVER
@ 70 Hz
TAPER E N.
Sweep Rate
0/2296 Oct/Min
COMPR. SPEED
VAR DB/SEC
CHG@ ~ Hz TO ~ DB/SEC
CHG@ ~ Hz TO ~ DB/SEC
NON-OPERATING
TEMP.
74°F
LOCATION
AIY

FREQ. RANGE & DIRECTION S-200 Hz
SPECIFICATION AT-VCPS 4.3, 7.5

SERIAL NO. 00001
TYPE OF TEST QUAL
NAME OF TEST
SINUSOIDAL VIBRATION

SPECS LOADED AND PRESSURIZED
EXCITATION ALONG Z AXIS
GRMS INPUT 9.2
NON-OPERATING
TEMP. 77 °F
PERIOD OF TEST
START ✔ END
DURATION OF TEST 2.0 MIN.
ACCEL. SERIAL NO. NB 62
ACCEL. SENSITIVITY MV RMS GP
2.698 COL GP
ACCEL. SENSING Z AXIS
ACCEL. LOCATION A12

TAPEREEL NO. 01226
SPECIAL CONDITIONS Qual Level 1
Comp PKG. Item Pressure
Random Vibration Test
Analysis Method B

Hamilton Standard

Report No.

Rig: 26
Operator: B.M.
Test Engineer: S.M.
Plotted By: S.M.
Trace No.: 25
Test No.: 17
Date: 4-9-72
Time: 10:15

Input Level: 9.2 GRMS
Excitation Axis: Z
Accel Serial Number: TG75
Accel Sensing Axis: Z
Accel Sensitivity: 2.791 MV RMS

Analysis Filter - Hz B.W.: 6
Sweep Speed - OCT/MIN:
Time Constant - SEC:

Annal. Calibration: 11.34 ft² Hz

Period of Test:
Start: 2.0
End: 2.0
Duration: 2.0 MIN

Non Operating Temp.: 74 °F

Tape Reel No.: 012296

Pickup Location: Bz
Hook-Up #: 3

Special Conditions: VCPS Loaded and Pressurized.

Project: RAE-B
Item: VCPS
Code 3V: 748720-1
Serial Number: 00001
Type of Test: QUAL

Spec: AT-VCPS
Para.: 4.3.7
Amend. Note: 164
Phase: VCPS and Aircraft
Random:

Page No.: C145
RANDOM VIBRATION TEST
ANALYSIS METHOD B

RIG: 26
OPERATOR: B.M.
PLOTTED BY: S.M.

TEST ENGINEER: S.M.
CHECKED BY: T.G.
DATE: 4-19-72
TIME: 1:015

INPUT LEVEL: 9.2 GRM
EXCITATION AXIS: Z
ACCEL SERIAL NUMBER: XM21
ACCEL SENSING AXIS: Z
ACCEL SENSITIVITY: 1.37 G/P MV RMS
ANAL FILTER - HZ B.W.: 6
SWEEP SPEED - OCT/MI: 
TIME CONSTANT - SEC: 
ANNAL. CALIBRATION: 47.08 E2 Hz F.S.
PERIOD OF TEST: 2.0 MIN
DURATION: 
NON OPERATING TEMP.: 74 deg F
TAPE REEL NO.: 012296

CONTROL RESPONSE

PICKUP LOCATION: D2
REA MOUNT
HOOK-UP #3

SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

PROJECT: RAE-B
ITEM: VCPS
CODE: 5V
SERIAL NUMBER: 748728-1 00001
TYPE OF TEST: QUAL

SPEC.: AT-VCPS
PARA.: 437
AMEND.: 154
PHASE VCPS AND SPACECRAFT: 
RANDOM: 

C146
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<td>SPECIAL CONDITIONS</td>
<td>VCPS LOADED AND PRESSURIZED</td>
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**PROJECT**

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**SPEC.**

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<th>NOTE</th>
<th>PHASE</th>
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<td>1.54</td>
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**PAGE NO.**

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RANDOM VIBRATION TEST
ANALYSIS METHOD B

PROJECT: RAE-13
ITEM: RAE-13
CODE: 74872-1
SERIAL NUMBER: 00001
TYPE OF TEST: QUAL

AT-VCPS 4.3.7 164
PHASE: VCPS AND SPACECRAFT
RANDOM

INPUT LEVEL
GR - 9.2
EXCITATION AXIS
Z
ACCEL SERIAL NUMBER
WF75
ACCEL SENSING AXIS
Z
ACCEL SENSITIVITY
1.001
ANAL FILTER - HZ B.V
6
SWEEP SPEED - OCT/M
-
TIME CONSTANT - SEC
-
ANNAL, CALIBRATION
995.2 6.2 Hz
PERIOD OF TEST
START
END
DURATION
2.1
TEMP.
74
TAPE REEL NO.
012296
CONTROL
RESP
PICKUP LOCATION
F Z
LATCH VALVE MT
HOOK-UP #3
SPECIAL CONDITIONS
VCPS LOADED AND PRESSURIZED
**Random Vibration Test Analysis Method B**

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<td>S. M</td>
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**Test Engineer**  
S. M  
**Checked by**  
T. G  
**Date**  
4-14-72  
**Time**  
1015

**Input Level**  
9.2 GRMS

**Excitation Axis**

**Accel Serial Number**  
XN32

**Accel Sensing Axis**

**Accel Sensitivity**  
1.261 MV RMS

**Anal Filter - Hz B.W.**  
6

**Sweep Speed - Oct/Min**

**Time Constant - Sec**

**Anal. Calibration**  
627.1 Hz F.S.

**Period of Test**

**Duration**  
2.0 MIN

**Non-Operating Temp.**  
74 °F

**Tape Reel No.**  
012296

**Control Response**

**Pickup Location**

**Hook-up #3**

**Special Conditions**

**RaE-B**

**Item**  
VCPS

**Code**  
E5

**Serial Number**  
00001

**Type of Test**

**Qual**

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RANDOM VIBRATION TEST ANALYSIS METHOD B

INPUT LEVEL: 9.2 GRI
EXCITATION AXIS: Z
ACCEL SERIAL NUMBER: XU29
ACCEL SENSING AXIS: Z
ACCEL SENSITIVITY: 1.636 MV RMS
ANAL FILTER - HZ B.V: 6
SWEEP SPEED - OCT/M: 1
TIME CONSTANT - SEC: 1
ANAL, CALIBRATION: 59.6 1^2 F.S
PERIOD OF TEST: START 2.0 M
DURATION: 2.0 M
 TEMP. OPERATING: 74
TAPE REEL NO.: 012296
CONTROL RESPONSE: NO
PICKUP LOCATION: H2
PRESSURE TRANSUCER: HOOK-UP #3
SPECIAL CONDITIONS: VCPS LOADED AND PRESSURIZED

PROJECT: RAE-B
ITEM: VCPS
CODE: 743720-1
SERIAL NUMBER: 00001
TYPE OF TEST: QUAL

SPEC.: AT-VCPS
PARA.: 4.3.7
AMEND.: NOTE 1/4
PHASE VCPS AND SPACECRAFT: RANDOM

PAGE NO.: 231
**Randum Vibration Test**

**Analysis Method B**

---

**Input Level**

9.2 GRMS

**Excitation Axis**

Z

**Accelerometer Serial Number**

TE83

**Accelerometer Sensing Axis**

Y

**Accelerometer Sensitivity**

2.979 MV RMS

**Analytic Filter**

- 6 Hz, B.W.

**Sweep Speed**

- Oct/Min

**Time Constant**

- Sec

**Analytic Calibration**

112.3 Hz

**Period of Test**

- Start

**Duration**

2.0 Min

**Temp. Operating**

74 °F

**Hook-Up #3**

**Special Conditions**

VCPS Loaded

AND Pressurized

---

**Project**

FAE-8

**Item**

VCPS

**Code SV**

748220-1

**Serial Number**

00001

**Type of Test**

QUAL

---

**Spec.**

AT-VCPS

**Para.**

4.3.7

**Amend/Vote**

1.4

**Phase**

VCPS AND SPACECRAFT

**Random**

---

---

---
**Title:** Random Vibration Test Analysis Method B

**Report No.:** HSF-1635 B

**Rig:** 26  
**Operator:** B M  
**Plotted By:** S M  
**Trace No.:** 29  
**Test No.:** 17  
**Date:** 4-19-72  
**Time:** 1015

**Input Level:** 9.2  
**Excitation Axis:** Z  
**Accel Serial Number:** 7D48  
**Accel Sensing Axis:** Y  
**Accel Sensitivity:** 2.788

**FREQUENCY - HZ**

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**Date:** 4-19-72  
**Test No.:** 17  
**Time:** 1015

**Input Level:** 9.2  
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PROJECT: \textit{HAE-B}  
ITEM: \textit{VCPS}  
CODE: 7487201  
SERIAL NUMBER: 00001  
NOTE: \textit{Phase VCPS and Tracecraft}  
RANDOM

FREE LEVEL
OFF SCALE

FREQUENCY - HZ

9.2

GRMS

INPUT LEVEL

ACCEL SERIAL NUMBER

TD40

ACCEL SENSING AXIS

X

ACCEL SENSITIVITY

3.005 MV RMS

GP

COL

ANAL FILTER - Hz B.W.

6

SWEEP SPEED - OCT/MIN

TIME CONSTANT - SEC

ANAL. CALIBRATION

10.4 Hz F.S.

PERIOD OF TEST

START END

DURATION

2.0 MIN

NON-OPERATING TEMP.

74 OF

TAPE REEL NO.

012296

CONTROL RESPONSE

PICKUP LOCATION

AIX'

Hook-up #3

SPECIAL CONDITIONS

VCPS LOADED AND PRESSURIZED

PAGE NO.

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Section V

Logs
A) Operator Log
B) Instrumentation Master & Running Log
C) Data Reduction Log
## LOG OF TEST

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Remarks:
- Random Complete PKG.
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**Remarks:**
- Complete test 1.5 m/s².
- Random test run 1.5 m/s².
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**REMARKS**

- 1.0Vpe pk@200Hz 2m/s² 7.5G 4.0 VAR
- Vcps only
- Item/Signal Scan
- Hook-up No. 2
- Qual Level
- 200-2000Hz Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- Hook-up No. 2
- Qual Level
- 200-2000Hz Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
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- Vcps only
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- Control pkg tem.
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- Vcps only
- 7.5G 4.0 VAR
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- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
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- QA/TL test
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- 1.0Vpe pk@200Hz
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- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
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- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
- Vcps only
- 1.0Vpe pk@200Hz
- Vcps only
- 7.5G 4.0 VAR
- QA/TL test
- Control pkg tem.
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**VIBRATION TEST LOG**

**TEST TITLE:** Acceleration Test

**ENGINEER:** S. Mishued

**DATE:** 4-13-73

**OPERATOR:** P. Jackson

**LOG PAGE NO:** 1744

**MASTER PAGE NO:** 1892
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**Remarks:**
- TP-4 57 TP-4 20 OUT
- CHANGED AI2 TO THE LOCATION CALLED AI1
MASTER VIBRATION LOG
WPUsyCODE

DATE

ITEM

PROJECT
TEST TITLE

RIG

LOG PAGE NO.

OPERATOR

ENGINEER
TRANSDUCER

MEASUREMENT

CH.
MO

MASTER PAGE NO

JUNCTION UNIT

REMARKS

SIGNAL
UD/EF

G/INCH

S/N

y

CONDITIONER

S/N

S/N

S/N

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## SINUSOIDAL DATA REDUCTION LOG

**RAE-B**

**PROJECT:** QUAL

**TEST DATE:** 4-13-72

**D.R. DATE:** 4-13-72

**TAPE REEL NO.:** 01294

**ITEM:** 506-79594

**SERIAL NO.:** WPI-AS2-02-1274

**CAL VOLTAGE:** 200 MVrms OR 1000 MVpk (AT 200 Hz)

**CALCULATION**

\[
\text{CALPt} = \frac{\text{RUN} \times \text{CAL VOLTAGE}}{\text{CAL ACCEL SENS}}
\]

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# RANDOM DATA REDUCTION LOG

**MASTER PAGE NO.** 1775  
**PROJECT** RAF-P  
**TEST DATE** 4-11-72  
**D.R. DATE**  
**TAPE REEL NO.** 012295 & 012396  
**V.C.R.S**  
**SERIAL NO.** 00001  
**W.P.I.**  
**CAL VOLTAGE** 200 MVrms  
**ITEM**  
**CALCULATION CONST.** $\frac{3989 \text{ MV}^2 \text{rms}(\text{Grms})^2}{\text{HZ}(\text{Gpk})^2}$  
**OR** $1000 \text{MVpk (AT 200Hz)}$  
**DEG. OF FREE.** 125  
**CALCULATION CONST.** $1595.6 \text{ OR } 9.928(10)^4$  
**Based on E.BW=16**  

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**DATA**
**Random Data Reduction Log**

**Master Page No.** 1775  
**Project** RAE-13  
**Test Date** 4-18-72  
**D.R. Date**  
**Tape Reel No.** 012296  
**Item** VCP S  
**Serial No.** 0001 WPI  
**Cal Voltage** 200 MVrms OR 1000MVpk (AT 200Hz)  
**Deg. Of Free.** 125

**Calculation Const.**  $3989 \frac{MV^2 \text{rms}(\text{Grms})^2}{HZ(Gpk)^2}$ OR $9.82(10)^4 \frac{MV^2 \text{pk}(\text{Grms})^2}{HZ(Gpk)^2}$  
Based on $E_BW=6.4$

**Calculation Const.** $159516$ OR $3.928(10)^{14}$  
Based on $E_BW=16$

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CALCULATION CONST. 1594.6 OR 3.928 (10)^4 Based on E.BW=16
**SINUSOIDAL DATA REDUCTION LOG**

**MASTER PAGE NO.** 1725  **PROJECT** RAE-8  **TEST DATE** 4-15/4-17  **D.R. DATE**

**TAPE REEL NO.** 012295  **ITEM** VCP 5  **SERIAL NO.** 00001  **W.P.I.** AS1-103-10/A

**CAL VOLTAGE**  200 MVrms OR 1000 MVpk (AT 200 Hz)

**CALCULATION**

Use Run 1 or 6 for Cal, Run 1 & 2 respectively. For Channel 7-12

\[
\text{CALpt} = \text{CAL volt} \times \text{CAL voltage}
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<th>RANGE ATT</th>
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<td>1</td>
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<td>1000</td>
<td>100</td>
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<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 8</td>
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<td>10.0/1.0</td>
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<td></td>
</tr>
<tr>
<td>17 10</td>
<td>10</td>
<td>TD44</td>
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<td>1</td>
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<td>10/1</td>
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<tr>
<td>18 12</td>
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<td>20</td>
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<td>10/1</td>
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### SINUSOIDAL DATA REDUCTION LOG

**Master Page No.**: 1775  
**Project**: RA-8  
**Test Date**: 1/15/94  
**D.R. Date**: 

**Tape Reel No.**: 012295  
**Item**: VCPS  
**Serial No.**: 00001  
**W.P.I.**: 8521-03-

**Cal Voltage**: 200 MVrms OR 1000 MVpk (AT 200 Hz)  
**Calculation**  

\[ \text{CALpt} = \text{RUN} \times \text{CAL VOLTAGE} \]

<table>
<thead>
<tr>
<th>CAL VOLTAGE</th>
<th>MVrms</th>
<th>MVpk</th>
<th>(CAL VOLTAGE)</th>
<th>MVrms</th>
<th>MVpk</th>
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<td>200 MVrms</td>
<td>1000 MVpk</td>
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<td></td>
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**Calculation Note**:  
USE CAL RUN #1 OR 6 FOR PN #1 OR 3 RESPECTIVELY FOR CHANNEL #1-6

**Cal Accel Sens**:  

<table>
<thead>
<tr>
<th>Cal Accel Sens</th>
<th>MVrms/Go pk</th>
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**Cal Accel SENS**:  

<table>
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**Cal Pt**:  

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### Trace Run Table

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<th>SENS</th>
<th>Run/CAL</th>
<th>Cal/CAL</th>
<th>Cal/Run</th>
<th>Cal/Run</th>
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<th>F.S.</th>
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<td>1000</td>
<td>10</td>
<td>1</td>
<td>3.65</td>
<td>1.0</td>
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<td>YK20</td>
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<td>1000</td>
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<td>1</td>
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<td>100</td>
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<td>1</td>
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<td>10</td>
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<td>33.3</td>
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**Note**:  
- The table above is a summary of test results.  
- The columns include Trace Run, Chan S/N, SENS, Run/CAL, Cal/CAL, Cal/Run, Cal Pt, and F.S.  
- The values represent the measurement of sinusoidal data reduction.  
- The F.S. column likely stands for the full scale reading or a reference scale.

---

249<
CAL VOLTAGE 200 MVrms OR 1000 MVpk (AT 200 Hz)

CALCULATION

\[ \text{CAL} \times \text{RUN} = \text{CAL VOLTAGE} \times \text{CAL ACCEL SENS} \]

MVrms OR MVpk

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<th>CHAN</th>
<th>S/N</th>
<th>SENS</th>
<th>RUN/CAL</th>
<th>(RUN/CAL) x SENS</th>
<th>CAL/RUN</th>
<th>CAL/RUN</th>
<th>RANGE ATT</th>
<th>CAL PT</th>
<th>F.S.</th>
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<td>1</td>
<td>11.3</td>
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<td>Y5</td>
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<td>TG75</td>
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<td>10 1000</td>
<td>10% 2.791</td>
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<td>XM21</td>
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<td>73</td>
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<td>1</td>
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</tbody>
</table>

CAL pt = RUN x CAL VOLTAGE

CAL ACCEL SENS

MVrms OR MVpk

C169

250<
APPENDIX D

GSFC MASS PROPERTIES REPORT
V.C.P.S. MASS PROPERTIES

**BALANCE**

---

**NOTE:** ALL ANGLES ARE REFERENCED AS FOLLOWS. THE S/C +X AXIS IS DEFINED AS 0°. ANGLES INCREASE C.W. LOOKING DOWN ON THE TOP OF THE V.C.P.S.


AFTER THE ADDITION OF THE ABOVE WT., THE RESIDUAL IMBALANCE LEVELS WERE DETERMINED TO BE AS FOLLOWS:

**RESIDUAL IMBALANCE (LIGHT SPOTS)**

<table>
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<th></th>
<th>ZERO FUEL CONDITION</th>
<th>FULL FUEL CONDITION</th>
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</thead>
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<td><strong>STATIC</strong></td>
<td>20.8 oz·in / 62°</td>
<td>14.4 oz·in / 165°</td>
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<tr>
<td><strong>DYNAMIC</strong></td>
<td>605.6 oz·in² / 115°</td>
<td>454.2 oz·in² / 123°</td>
</tr>
</tbody>
</table>

---

21 JUN 1972

252<
V.C.P.S. MASS PROPERTIES

WT, M.I., C.G., (ZERO FUEL CONDITION)

NOTE: ALL MEASUREMENTS MADE WITH BALANCE WT ADDED

TOTAL WEIGHT = 41.6 LBS.

SPIN M.I. = ... 1.703 SLUG-FT²

LATERAL #1 M.I. = 0.925 SLUG-FT²

LATERAL #2 M.I. = 0.883 SLUG-FT²

C.G. LOCATION = 4.33" (FORWARD OF THE AFT SEPARATION INTERFACE)

* LATERAL AXES ORIENTATION

21 JAN 1972
V.C.P.S. MASS PROPERTIES

WT, M.I., C.G. (FULL FUEL CONDITION)

NOTE: ALL OF THE VALUES FOR THE FULL FUEL CONDITION WERE OBTAINED BY ANALYTICALLY ADDING 45 LBS OF HYDRAZINE TO THE ZERO FUEL CONDITION. IT WAS ASSUMED THAT ALL OF THE FUEL WAS LOCATED IN THE TANKS.

THIS CREATES A SLIGHT ERROR DUE TO THE PRESENCE OF A CERTAIN AMOUNT OF FUEL IN THE FEED LINES.

TOTAL WEIGHT = 86.6 LBS.

SPIN M.I. = 7.2 SLUG-FT²

LATERAL #1 M.I. = 3.7 SLUG-FT²

LATERAL #2 M.I. = 3.7 SLUG-FT²

C.G. LOCATION = 5.11" (FORWARD OF THE AFT SEPARATION INTERFACE)
APPENDIX E

SVHSER 6184 – RAE-B

GAS MANIFOLD MODIFICATION REPORT
RAE-B VCPS GAS MANIFOLD

MODIFICATION REPORT

Prepared by: E. K. Moore
RAE-B Project Manager

Approved by: R. L. Steinberg
RAE-B Program Manager

Date: 15 March 1973
INTRODUCTION

This report summarizes the program undertaken by Hamilton Standard in response to contract change order #18 to modify the Radio Astronomer Explorer -B, Velocity Control Propulsion Subsystem (RAE-B, VCPS) to offset intertank transfer of fluids.

The need for such a modification was revealed during a Goddard Space Flight Center (GSFC) system analysis wherein it was shown that an initial minor VCPS fluid unbalance would ultimately cause major unbalance and vehicle Z axis perturbation.

The program at Hamilton Standard included a study of various methods to eliminate intertank transfer of fluids, the implementation of the selected system and acceptance testing to confirm system leakage and cleanliness integrity.
OBJECTIVE

To select and implement a method of preventing intertank transfer of fluids in the RAE-B VCPS with minimum impact on weight, reliability, schedule and the Propellant Servicing Cart (PSC) configuration.
CONCLUSIONS

1. A method was selected which did not require changes in basic loading and pressurizing procedures.

2. The method was implemented without sacrifice of system cleanliness or leakage as evidenced by acceptance testing.

3. Weight increase was minimal at plus 0.4 pounds.

4. The modification to the subsystem requires rebalancing and redetermination of mass properties.

5. The VCPS modification was accomplished within the time period allotted.
RECOMMENDATIONS

It is recommended that:

1. The VCPS be rebalanced and mass properties be redetermined by the NASA.

2. Liquid and gas loading procedures be reexamined including both vacuum and pressure fill methods.
DISCUSSION

I. Study Phase

A number of candidate methods to prevent intertank transfer of fluids were studied and were previously reported. See Appendix A, "RAE-B VCPS Intertank Propellant Transfer Modification Report". The report suggested either of two methods be used.

Method IV-B provided a weight saving but required new fluid and gas loading procedures. Method III added a small amount of weight but did not require new liquid and gas loading procedures. GSFC elected to use Method III.

II. Design Phase

The design requirements for implementing Method III, which utilizes four Fill and Vent Valves instead of a single Fill and Vent Valve, consisted of:

Establishing locations for four fill and vent valves so that; one common mounting bracket design could be used, pressurizing hoses could be installed without interference with each other or space vehicle components, weight increase was minimized and finally, unbalance was held to a minimum.

It was determined that two brackets and valves could be attached to the hub in quadrant + x-y and two in quadrant - x+y. In each quadrant the valves would face one another but be offset along the Z axis for hose clearance. The new gas lines from tanks to valves utilized existing arm mounted tube clamps to minimize new hardware and reduce hole drilling requirements. Page 2 of drawing SV748720 Appendix B, shows the new valve, bracket and gas line locations.

The new bracket is similar in design to other brackets, but is covered with aluminized mylar tape instead of gold plate as a procurement expediency. Drawing SV755431, Appendix B, shows the new valve bracket.

The bracket used to locate the original Fill and Vent Valve was left attached to the +x arm so that the arm would not have to be detached to remove the loose rivet segments from the interior of the arm which would have resulted if the bracket were removed.
III. Qualification Test Phase

The valve and bracket were assembled and subjected to a qualification test per specification SVHS 5997 (See Appendix C).

The valve which was planned to be used for the test was the VCPS spare (GFE) Fill and Vent Valve. This valve leaked excessively when tested and rather than delay testing pending disposition of the valve by GSFC, a new valve was substituted and the test resumed.

The qualification test was completed without incident except that the test unit was misindexed relative to the X-Y axis by 36°. Since the misindexing resulting in higher effective loadings to the test unit than the true position, GSFC agreed that the outage was acceptable.

The leaking valve was delivered to GSFC for failure analysis. The bracket was delivered to government stores as a VCPS spare and the qualification valve was installed as one of the four on the VCPS.

The qualification test report is in Appendix D.

IV. VCPS Modification Phase

The VCPS modification was accomplished in several steps:

1. Gas manifold removal
2. Bracket and valve installation
3. Tube fit-up, cleaning and passivation
4. Tube welding
5. In process inspection

Step 1. To accomplish gas manifold removal without system contamination, the following procedure was used for each tubing cut:

a. Pressurize system to 5 psig using dry filtered nitrogen.

b. Slowly cut tubing using "chipless" tube cutter.

c. Install squaring tool and square end of cut tube using fine cut file.

d. Ream tube I.D. and remove burrs.

e. Remove squaring tool and flood area with clean Isopropyl Alcohol to remove all visible particles. Allow to dry.

f. Tape tube end.
Step 2. The hub bracket mounting holes were drilled and burred using the following procedure:

a. Remove insulation blanket from hub.
b. Establish hole locations
c. Set up shop vacuum to catch drill chips
d. Drill and burr holes
e. Assure all chips have been collected

After hole drilling and burring, the brackets were mounted to the hub, then the valves were mounted to the brackets using required bolts, washers and nuts. The brackets were taped with aluminized mylar tape before installation.

Step 3. After the valves had been installed, each tube which had been prebent to design layouts, was fitted and cut to length, following which it was cleaned to specification HS 3150 level CE-5. (See Appendix E for CE-5 level).

Following cleaning, the tubes and valves were passivated per note 68 of drawing SV749720 except pressure was 15 psia. The passivation procedure is as follows:

a. One hour application of a 30-35% N₂H₄ - remainder H₂O solution at 73 ± 10°F with wetted interior portions of the tubes and valves completely filled.
b. Fill completely as in step (a) with 100% N₂H₄ and attach an external ullage volume of 30 ± 2 cu. in. With the system vented, raise the temperature to 120 ± 5°F. After 4 hours, close the vent and maintain temperature for 24 hours while monitoring pressure. Pressure rise shall not exceed 7 psid in 24 hours. Note: If pressure rise does exceed 7 psid, terminate test.

No pressure rise was observed in the 24 hour period.

Following passivation, tube cleanliness was again verified to the CE-5 level.
Step 4. Prior to tube welding, the tubes were taped with aluminized mylar to within approximately 1 1/2 inches of the tube ends. The tubes were then held in position by a fixture clamp at one end and by the Astro-Arc welding head at the other. Each weld was made automatically using previously established machine settings. Two weld samples were made prior to welding and two additional samples were made after all welding was complete. All weld samples were radiographically examined.

Step 5. Following welding, each of the eight welds was die penetrant inspected and "snoop" checked at 300 psig. The system was then checked for cleanliness per HS 3150 using isopropyl alcohol.

Finally the insulating blanket was reinstalled and the VCPS released for Acceptance Testing.

V. Acceptance Test Phase

Following the modifications and in-process inspections (Phase IV), the unit was acceptance tested per SVHS 5618 ATA No. 2 (See Appendix D). The acceptance test consisted of the following individual tests:

- Examination of Product
- Weight
- Proof Pressure
- External Leakage
- Contamination Check
- Post Test Inspection

Following completion of the contamination check, and before Post Test Inspection, taping with aluminized mylar tape was completed.

All tests were completed in accordance with acceptance criteria.

VI. Schedule

The VCPS was modified in accordance with the plan and schedule of Appendix G.
APPENDIX

Intertank Propellant Transfer Modification Report
RAE-B VCPS

INTERTANK PROPELLANT TRANSFER MODIFICATION REPORT

PREPARED BY: Thomas Marotta

APPROVED BY: Earl K. Moore
CONTENTS

INTRODUCTION

SUMMARY

RAE-B VCPS PROPELLANT FEED SYSTEM MODIFICATION TRADEOFF

FLOW ANALYSIS OF HS SELECTED MODIFICATION

SUMMARY OF FLOW DEMONSTRATION TEST
At the direction of NASA/Goddard Space Flight Center to modify the VCPS to prevent intertank propellant transfer, a study of various system modifications was undertaken to decide which changes would have the least impact (manufacturing, weight and cost) to the subsystem. Also, a flow analysis of the selected tank isolation methods was prepared to further substantiate the choice. This report includes both the various system tradeoffs and the flow analysis associated with the VCPS modifications.
SUMMARY

After reviewing the various modification options which could be incorporated on the VCPS, the analysis associated with modification Method IV-B, and the demonstration flow test, changing the VCPS propellant feed system to the configuration illustrated in the Method IV-B schematic appears to be the best approach for retrofitting the VCPS. This method offers the advantages of lighter weight and minimum impact on mechanical changes to the VCPS and GSE Cart.

The addition of individual fill and drain valves for each tank is also an acceptable approach but results in additional VCPS weight and a more complex VCPS rework. This approach, Method III, was not analyzed since the fill procedure is identical to that used for the present system except for manifolding the four pressurant fill and drain valves together. This permits simultaneous gas pressurization of the tanks from a single source on the GSE Cart.
RAE-B VCPS PROPELLANT FEED SYSTEM MODIFICATION TRADEOFF

The following propellant feed system schematics represent methods of accomplishing prevention of intertank propellant transfer. Each schematic modification has comments regarding the impact of the change to the VCPS, to the RAE-B spacecraft, or to the GSE.

After reviewing the various options available to prevent intertank propellant transfer, the subsystem modification which appears to offer the greatest advantages is Method IV-B. This change offers the least impact to the system while providing a subsystem of lighter weight. The second choice would be Method III where the use of RAE-B qualified hardware could be utilized with no restraints on the spacecraft other than additional weight of the VCPS. The flow analysis which is in the following section is for Method IV-B.

The weight impact of the two modification methods considered is as follows. The results are for the worst case which assumes the VCPS balance weight to be in the region of the existing gas manifold.

Delta Weight

<table>
<thead>
<tr>
<th>Method</th>
<th>Weight Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method IV-B</td>
<td>≈ 0.41 lbs reduction</td>
</tr>
<tr>
<td>Method III</td>
<td>≈ 1.18 lbs additional</td>
</tr>
</tbody>
</table>
PRESENT VCPS CONFIGURATION

\[ \text{N}_2 \text{ H}_4 \text{ F} \& \text{D} \rightarrow \text{N}_2 \text{ F} \& \text{D} \rightarrow \text{TO SYSTEM} \]

INTERTANK ISOLATION CONFIGURATIONS

METHOD I

\[ \text{N}_2 \text{ H}_4 \text{ F} \& \text{D} \rightarrow \text{TO SYSTEM} \]

COMMENTS:

- VALVES ISOLATE TANKS ON GAS SIDE BUT PROVIDE NO REDUNDANCY
- NO VEHICLE POWER REQUIRED.
- NO EFFECT ON PROPELLANT FLOW.
- AVAILABILITY OF QUALIFIED VALVE IS QUESTIONABLE.
- SYSTEM WEIGHT INCREASE.

\[ \text{V \ VALVE (TYPE NOT ESTABLISHED)} \]
METHOD II

METHOD III

COMMENTS:
- Valves isolate tanks and provide redundancy.
- No vehicle power required.
- No effect on propellant flow.
- Availability of qualified valve questionable.
- System weight increase.

COMMENTS:
- Valves isolate tanks - no possibility of internal leakage.
- No vehicle power required.
- No GSE power req'd.
- No effect on propellant flow.
- Use of RAE-B qualified hardware.
- Four potential overboard leak sources.
- System weight increases.
**METHOD IV A&B**

TO SYSTEM

\[ \text{N}_2 \land \text{N}_2\text{H}_4 \text{ F & D} \]

**A** - LOAD \( \text{N}_2\text{H}_4 \) UNDER PRESSURE.

**B** - LOAD \( \text{N}_2\text{H}_4 \) UNDER LOW PRESSURE - THEN PRESSURIZE WITH \( \text{N}_2 \) TO OPERATING PRESSURE.

**COMMENTS:**

**A & B**
- VCPS CANNOT BE THRU FLUSHED, CLEANED OR PURGED.
- NO VEHICLE OR GSE. POWER REQUIRED.
- SYSTEM WEIGHT DECREASE
- FILL OF DEAD-ENDED TANK CRITICAL SINCE OVER PRESSURIZATION CANNOT BE VENTED.
- GSE CART CANNOT LOAD \( \text{N}_2\text{H}_4 \) UNDER REQUIRED PRESSURE WITHOUT CONSIDERABLE CART MODIFICATION.
- DO TANKS LOAD EQUALLY?
METHOD V

TO SYSTEM

N₂ F & D

COMMENTS:

- VALVES ISOLATE TANKS AND PROVIDE REDUNDANCY
- VEHICLE POWER REQUIRED
- ADDITIONAL TELEMETRY CHANNELS PROBABLY REQUIRED.
- IMPACTS SPACECRAFT ELECTRICAL EQUIPMENT.
- FAILED CLOSED POSITION CAN CAUSE LOSS OF MISSION.
- VALVES HAVE THERMAL IMPACT ON LINE THERMAL ANALYSIS AND MAY REQUIRE HEATERS.
- SYSTEM WEIGHT INCREASES
- AVAILABILITY OF QUALIFIED VALVE IS QUESTIONABLE.
METHOD VI

REMoval of two existing latching valves from system changes original philosophy of system.

- Valves isolate tanks but provide no redundancy.
- Latching valve circuit requires additional power.
- Impact on spacecraft electrical equipment.
- Failed closed position of any latching valve can cause loss of mission.
- Valves have thermal impact on line thermal analysis and may require heaters.
- System weight increase.

To System

LV Latching Valve

\[ N_2 \ F \& \ D \]
\[ N_2 \ H_4 \ F \& \ D \]
FLOW ANALYSIS OF HS SELECTED MODIFICATION

The flow analysis presented in this section is prepared against propellant feed system modification Method IV-B. The analysis is divided into the following three sections:

Propellant Fill

Pressurant Fill

Propellant Withdrawal

The primary objective of these analyses is to determine the unbalance effects, if any, on the VCPS.

The propellant fill case is not of primary concern other than assuring that propellant flows to all tanks equally with the exception of the line volume effects. The primary goal of the pressurant fill analysis is to determine the degree of unbalance that exists between propellant tanks after pressurant fill and the system pressure has stabilized -- equal pressure in all tanks. The objective of the propellant withdrawal analysis is to determine the propellant expulsion efficiency. Without the tank pressurant manifold, each tank blows down independently where it is possible for one tank to ingest pressurant just before the others because of slightly different initial pressurant volumes.

The analysis indicates that an unbalance of 13 oz-in may exist after propellant and pressurant loading without adjustment of the balance weight. To assure that the system does fill as predicted for Method IV-B, an evaluation of the fill process would be demonstrated using the actual VCPS. This would be accomplished by cutting into the pressurant manifold at discreet positions, which would not affect the final direction of the modification, and sealing off these lines.

The propellant "blow-down" analysis indicates that the expulsion efficiency will be 99.83 percent instead of 99.98 percent which was initially predicted.
Case I - **Unbalance Due To Liquid Filling**

![Diagram showing flow of gases and pressures](image)

**STATEMENT OF PROBLEM**

The problem is to determine any unbalance resulting from initial liquid fill. The problem stems from the initial gas volume in the tanks and particularly in the system lines. During the filling process, the gas in the lines is displaced to the tanks and combines with the gas already in the tanks to become compressed. The fact that the tanks will have a different amount of gas, because of the distribution of the plumbing, will result in some propellant mass unbalance upon pressure equalization in the system.

**ANALYSIS**

- Assume at end conditions $P_9 = P_{10} = P_{11} = P_{12}$
- Assume that during liquid filling, vapor-liquid interface is maintained such that gas in lines is completely displaced into the tanks. (Assumption visually confirmed)
**Assume Distribution of Gas in System**

Results as follows:

**Tank 9:**  \( V_9 = 25\% V_{1-2} + V_{2-5} + V_{9\text{ initial}} \)

**Tank 10:**  \( V_{10} = 25\% V_{1-2} + 33\% V_{2-3} + V_{3-6} + V_{9 \text{ initial}} \)

**Tank 11:**  \( V_{11} = 25\% V_{1-2} + 33\% V_{2-3} + 50\% V_{3-4} + V_{4-7} + V_{11 \text{ initial}} \)

**Tank 12:**  \( V_{12} = 25\% V_{1-2} + 33\% V_{2-3} + 50\% V_{3-4} + V_{4-8} + V_{12 \text{ initial}} \)

Where \( V \) is the volume associated with the different components shown in Fig. 1.

### A. Consider Nominal Case

**From Table I**

<table>
<thead>
<tr>
<th>Lines</th>
<th>( V_{1-2} )</th>
<th>( V_{2-5} )</th>
<th>( V_{2-3} )</th>
<th>( V_{3-6} )</th>
<th>( V_{3-4} )</th>
<th>( V_{4-7} )</th>
<th>( V_{4-8} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_9 )</td>
<td>0.4362 in(^3)</td>
<td>0.8376 in(^3)</td>
<td>0.1919 in(^3)</td>
<td>1.0295 in(^3)</td>
<td>1.1168 in(^3)</td>
<td>1.0295 in(^3)</td>
<td>1.0295 in(^3)</td>
</tr>
</tbody>
</table>

**Initial Gas Volumes**

\[
\begin{align*}
V_9 &= (0.25 \times 0.4362) + (0.8376) + 508.90 \\
V_{10} &= (0.25 \times 0.4362) + (0.33 \times 0.1919) + (1.0295) + 509.46 \\
V_{11} &= (0.25 \times 0.4362) + (0.33 \times 0.1919) + (0.50 \times 1.1168) + 1.0295 + 508.63 \\
V_{12} &= (0.25 \times 0.4362) + (0.33 \times 0.1919) + (0.50 \times 1.1168) + 1.0295 + 510.01
\end{align*}
\]

\[
\begin{align*}
\overline{V}_9 &= 509.847 \text{ in}^3 \\
\overline{V}_{10} &= 510.662 \text{ in}^3 \\
\overline{V}_{11} &= 510.390 \text{ in}^3 \\
\overline{V}_{12} &= 511.770 \text{ in}^3
\end{align*}
\]

\[
\overline{V}_7 = \text{Total Initial Gas Volume in System} = \overline{V}_9 + \overline{V}_{10} + \overline{V}_{11} + \overline{V}_{12} = 2042.667 \text{ in}^3
\]

Assume Initial Pressure = 15 psia

**OF SYSTEM**

\( \Delta P \approx 78 \)
Assume addition of 45/6s of propellant to the system

\[ V_P = \frac{45}{6 \text{ lbm}} = \frac{45 \text{ lbm}}{0.036 \text{ lbm}} = 1250 \text{ in}^3 \]

Final gas volume of system = \[ V_T - V_P \]

\[ V_{\text{fin}} = 2042.667 - 1250 = 792.667 \text{ in}^3 \]

Assume an isothermal fill process

\[ P_{\text{final}} = \frac{P_{\text{initial}} \times V_T}{V_{\text{fin}}} \]

\[ P_{\text{final}} = \frac{15 \times 2042.667}{792.667} = 38.654 \text{ psia} \]

With this final pressure in each tank, determine the final gas volumes in each tank:

**Gas Volumes, Final**

\[ V_9 = \frac{15 \times 508.90}{38.654} = 197.850 \text{ in}^3 \]

\[ V_{10} = \frac{15 \times 510.662}{38.654} = 198.164 \text{ in}^3 \]

\[ V_{11} = \frac{15 \times 510.390}{38.654} = 198.061 \text{ in}^3 \]

\[ V_{12} = \frac{15 \times 511.770}{38.654} = 198.594 \text{ in}^3 \]

**Tank Propellant Volumes, Final**

\[ V_{p9} = 508.90 - 197.850 = 311.050 \text{ in}^3 \]

\[ V_{p10} = 507.46 - 198.164 = 311.298 \text{ in}^3 \]

\[ V_{p11} = 508.63 - 198.061 = 310.569 \text{ in}^3 \]

\[ V_{p12} = 510.01 - 198.594 = 311.416 \text{ in}^3 \]
MASS OF PROPELLANT IN TANKS

\[ M_9 = 11.1978 \text{ lbs} \]
\[ M_{10} = 11.2066 \text{ lbs} \]
\[ M_{11} = 11.1804 \text{ lbs} \]
\[ M_{12} = 11.2109 \text{ lbs} \]

LOOK AT SYSTEM UNBALANCE DUE TO THE ABOVE PROPELLANT DISTRIBUTION - ASSUME A BALANCED DRY SYSTEM

\[ M_{10} = 11.2066 \text{*} \]

\[ M_{11} = 11.1804 \]

\[ M_{12} = 11.2109 \]

\[ \text{Mass System} = 65 \text{ lbs} \]

C.G. SHIFT

\[ \bar{Y} = \frac{(11.2109 - 11.1978) \times 23.5}{65} \]
\[ \bar{Y} = +0.00473 \]

\[ \bar{X} = \frac{(11.2066 - 11.1804) \times 23.5}{65} \]
\[ \bar{X} = +0.00946 \text{ in} \]

TORQUE DUE TO C.G. SHIFT:

\[ T = \frac{\text{Mass} \times \sqrt{\bar{X}^2 + \bar{Y}^2}}{16} \]
\[ T = \frac{65 \times 16.93 \times \sqrt{0.00473^2 + 0.00946^2}}{16} = 65 \times 169.0105 \]
\[ T = 11.00 \text{ in-lb} \]

280°
B. Consider an extreme case, where the tolerances of the tanks and lines are in a condition that will make the unbalance a maximum. Investigate effects of having lines in min & max condition.

Assume the following - (apparent worst condition)

\[ V_{2-5} = \text{Maximum} \quad V_{3-6} = \text{Minimum} \]

\[ V_{2-2} = \text{Nominal} \quad V_{9,10,11} \]

\[ V_{2-3} = \text{Nominal} \quad \{ \text{Actualls} \}
\quad V_{11,12} \]

\[ V_{3-4} = \text{Minimum} \]

\[ V_{4-7} = \text{Maximum} \]

\[ V_{4-8} = \text{Minimum} \]

- From Table I

\[ V_{2-5,\text{max}} = 9.741 \text{ in}^3 \]

\[ V_{1-2,\text{nom}} = 9.462 \]

\[ V_{2-3,\text{nom}} = 1.919 \]

\[ V_{3-4,\text{min}} = 0.9583 \]

\[ V_{4-7,\text{max}} = 1.1973 \]

\[ V_{4-8,\text{min}} = 0.8841 \]

**Gas Volume Before Liquid Filling**

\[ V_{T} = V_{q} + V_{o} + V_{i1} + V_{i2} \]

\[ V_{q} = (0.25 \times 9.462) + (9.741) + 508.90 = 509.983 \text{ in}^3 \]

\[ V_{o} = (0.25 \times 9.462) + (1.33 \times 1.919) + 0.8841 + 0.089 = 510.516 \text{ in}^3 \]

\[ V_{i1} = (0.25 \times 9.462) + (1.33 \times 0.9583) + 1.1973 + 508.63 = 510.49 \text{ in}^3 \]

\[ V_{i2} = (0.25 \times 9.462) + (1.33 \times 0.9583) + 0.8841 + 0.1001 = 510.49 \text{ in}^3 \]

\[ V_{T} = \text{Total Initial Gas Volume in System} = 2049.573 \text{ in}^3 \]

Assume initial pressure of system = 15 psia

After adding 45 lbs propellant what is gas vol

\[ V_{q,\text{final}} = 2049.573 - \frac{45}{0.036} = 792.523 \text{ in}^3 \]

**Final Pressure in Each Tank**

\[ P_{\text{final}} = \frac{15 \times 2049.573}{792.523} = 38.659 \text{ psia} \]
Tank Gas Volumes, Final
\[ V_9 = \frac{15 \times 509.943}{38.659} = 197.887 \text{ in}^3 \]
\[ V_{10} = \frac{15 \times 510.512}{38.659} = 198.084 \]
\[ V_{11} = \frac{15 \times 510.979}{38.659} = 198.069 \]
\[ V_{12} = \frac{15 \times 511.545}{38.659} = 198.483 \]

Tank Propellant Volumes, Final
\[ V_{p9} = 508.90 - 197.887 = 311.013 \text{ in}^3 \]
\[ V_{p10} = 509.46 - 198.084 = 311.376 \]
\[ V_{p11} = 508.63 - 198.069 = 310.561 \]
\[ V_{p12} = 510.01 - 198.483 = 311.527 \]

Mass of Propellant in Each Tank
\[ M_9 = 11.1964 \text{ lbm} \]
\[ M_{10} = 11.2095 \text{ lbm} \]
\[ M_{11} = 11.1802 \text{ lbm} \]
\[ M_{12} = 11.2149 \text{ lbm} \]

Look at C.G. Shift & Unbalance
\[ M_{10} = 11.2095 \]
\[ M_9 = 11.1964 \]
\[ M_{12} = 11.2149 \]
\[ M_{11} = 11.1802 \]

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C. G. Shift

\[ \bar{y} = \frac{(11.2149 - 11.1969) \times 23.5}{65} = +0.00668 \]

\[ \bar{x} = \frac{(11.2095 - 11.1902) \times 23.5}{65} = +0.01059 \]

Static Unbalance \((1.0125)\)

\[ T = 65 \times 16 \sqrt{0.00668^2 + 0.01059^2} = 13.024 \text{ in.-oz} \]

Conclusion: The Static Unbalance resulting from the liquid fill process is estimated to be 13.0 in.-oz max. However, this condition will change during the pressurization process, reference Case II.
### Table I

**LINE VOLUME SUMMARY**

<table>
<thead>
<tr>
<th>LINE</th>
<th>Vol Nom (in³)</th>
<th>Vol Max (in³)</th>
<th>Vol Min (in³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>0.4362</td>
<td>0.5074</td>
<td>0.3746</td>
</tr>
<tr>
<td>2-5</td>
<td>0.8376</td>
<td>0.9741</td>
<td>0.7193</td>
</tr>
<tr>
<td>2-3</td>
<td>0.1919</td>
<td>0.2231</td>
<td>0.1648</td>
</tr>
<tr>
<td>3-6</td>
<td>1.0295</td>
<td>1.1973</td>
<td>0.8841</td>
</tr>
<tr>
<td>3-4</td>
<td>1.1168</td>
<td>1.2988</td>
<td>0.9583</td>
</tr>
<tr>
<td>4-7</td>
<td>1.0295</td>
<td>1.1973</td>
<td>0.8841</td>
</tr>
<tr>
<td>4-8</td>
<td>1.0295</td>
<td>1.1973</td>
<td>0.8841</td>
</tr>
</tbody>
</table>

### Tank Volume Summary

<table>
<thead>
<tr>
<th>TANK</th>
<th>AXIS</th>
<th>Volume (Actuals) in³</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>-Y</td>
<td>508.90</td>
</tr>
<tr>
<td>10</td>
<td>+X</td>
<td>509.46</td>
</tr>
<tr>
<td>11</td>
<td>-X</td>
<td>508.63</td>
</tr>
<tr>
<td>12</td>
<td>+Y</td>
<td>510.01</td>
</tr>
</tbody>
</table>
Case II - Unbalance Due to Gas Filling

Statement of Problem

Determine what unbalance will result from the gas pressurization process and subsequent stabilization of liquid.

Analysis

The approach will be to take the results of the mass distribution determined in Case I-B and determine what the final distribution of propellant will be with the system fully pressurized.

II. Assume that initially, the propellant distribution is the same as Case I-B

Vol. of propellant in each tank initial
\[ \begin{align*}
V_{P_9} &= 311.013 \text{ in}^3 \\
V_{P_{10}} &= 311.376 \text{ in}^3 \\
V_{P_{11}} &= 310.561 \text{ in}^3 \\
V_{P_{12}} &= 311.527 \text{ in}^3
\end{align*} \]

Ref Pg. 6
• Assume that upon initiation of gas flow, all the propellant in the lines flows into the tanks and remains in the tanks during filling of gas. (Assumption visually confirmed)

• Assume that equalization of pressures occurs without the flow of propellant from tank to tank. (Assumption visually confirmed)

Final volumes of propellant in each tank:

\[ \overline{V}_{p_9} = V_{p_9} + 25\% \times V_{1-2} + V_{2-5} \]

\[ \overline{V}_{p_{10}} = V_{p_{10}} + 25\% \times V_{1-2} + 33\% \times V_{2-3} + V_{3-6} \]

\[ \overline{V}_{p_{11}} = V_{p_{11}} + 25\% \times V_{1-2} + 33\% \times V_{2-3} + 50\% \times V_{3-4} + V_{4-7} \]

\[ \overline{V}_{p_{12}} = V_{p_{12}} + 25\% \times V_{1-2} + 33\% \times V_{2-3} + 50\% \times V_{3-4} + V_{4-8} \]

Using the same conditions as case I-B (pg.5)

\[ \overline{V}_{p_9} = 311.013 + (25 \times 4362) + (3.9741) = 312.0961 \text{ in}^3 \]

\[ \overline{V}_{p_{10}} = 311.376 + (25 \times 4362) + (33 \times 1919) \times 0.9841 = 312.4325 \]

\[ \overline{V}_{p_{11}} = 310.561 + (25 \times 4362) + (33 \times 1919) \times 0.50 \times 0.7583 \times 1.913 = \]

\[ \overline{V}_{p_{12}} = 311.527 + (25 \times 4362) + (33 \times 1919) + (50 \times 0.9583) + 0.9841 = 313.0626 \]
Assuming that these conditions are maintained after pressure equalization, the final mass of propellant in each of the tanks is

\[
M_{g_{\text{final}}} = 312.0961 \times 0.036 = 11.2355 \text{ lbm}
\]

\[
M_{10_{\text{final}}} = 312.4325 \times 0.036 = 11.2475 \text{ lbm}
\]

\[
M_{11_{\text{final}}} = 312.4096 \times 0.036 = 11.2467 \text{ lbm}
\]

\[
M_{12_{\text{final}}} = 313.0626 \times 0.036 = 11.2703 \text{ lbm}
\]

**Look at C.G. Shift & Unbalance**

\[
\bar{Y} = (11.2703 - 11.2355)(23.5) \div 65
\]

\[
\bar{Y} = +0.0125
\]

\[
\bar{X} = (11.2475 - 11.2467) \times 2 \div 65
\]

\[
\bar{X} = +0.000289
\]

**Torque Due to C.G. Shift**

\[
T = 65 \times 12 \sqrt{0.0125^2 + 0.000289^2}
\]

\[
T = 13.0 \text{ in.-lb}
\]

---

**E32**

**287**

**— No Change from C.G.**

**I.B.**
CASE III - UNBALANCE DUE TO LIQUID WITHDRAWAL

STATEMENT OF PROBLEM

- DETERMINE UNBALANCE RESULTING DURING LIQUID WITHDRAWAL FROM THE SYSTEM USING A SYSTEM WHERE THE TANKS ARE NOT JOINED TO A COMMON GAS MANIFOLD. THE FACT THAT THERE ARE INITIALLY DIFFERENT VOLUMES OF GAS AND PROPELLANT IN EACH TANK (AT THE SAME INITIAL PRESSURE) MEANS THAT EACH TANK WILL EXPELL PROPELLANT AT DIFFERENT RATES IN ORDER TO MAINTAIN A PRESSURE BALANCED SYSTEM. THE NET RESULT IS PROPELLANT MASS UNBALANCE IN THE VARIOUS TANKS.

- DETERMINE EFFECT ON EXPLOSION EFFICIENCY

ANALYSIS

THE APPROACH WILL BE TO ASSUME THAT THERE IS SOME PROPELLANT MASS AND GAS VOLUME DISTRIBUTION (BASED ON RESULTS OF CASE I & II ANALYSIS). REMOVING PROPELLANT FROM THE SYSTEM WILL PRODUCE A FINAL
CONDITION IN THE SYSTEM
($P_9 = P_{10} = P_{11} = P_{12}$) WHEREBY THE FINAL GASEOUS VOLUMES AND PROPELLANT MASSES IN EACH TANK CAN BE ESTIMATED AND RELATED TO UNBALANCE AND EXPULSION EFFICIENCY.
Assume a mass distribution as determined in Case II for initial condition.

Vol. of propellant in each tank:
\[
\begin{align*}
V_{P9} & = 312.0961 \text{ in}^3 \\
V_{P10} & = 312.4325 \text{ in}^3 \\
V_{P11} & = 312.4098 \text{ in}^3 \\
V_{P12} & = 313.0626 \text{ in}^3 \\
\end{align*}
\]
\text{(Ref. Pg. 10)}

The volume of gas in each tank is:
\[
\begin{align*}
V_{G9} & = 508.90 - 312.0961 = 196.8039 \text{ in}^3 \\
V_{G10} & = 508.96 - 312.4325 = 197.0275 \\
V_{G11} & = 508.63 - 312.4098 = 196.2202 \\
V_{G12} & = 510.01 - 313.0626 = 196.9474 \\
\end{align*}
\]

Total gas vol = 786.999 in\(^3\)

Assume initial pressure in each tank = 275 psia

After 1st mid-course correction, \(\Delta M = 31.41 \text{ lbm}\)
\[
\Delta V_p = \frac{31.4}{0.036} = 872 \text{ in}^3
\]

\[
\begin{align*}
P & = \frac{275 \times 786.999}{872 + 786.999} = 130.455 \text{ psia} \\
\end{align*}
\]

Volumes of gas in each tank after 1st mid-course correction:
\[
\begin{align*}
V_{G9} & = \frac{275 \times 196.8039}{130.455} = 414.8639 \text{ in}^3 \\
V_{G10} & = \frac{275 \times 197.0275}{130.455} = 415.3353 \text{ in}^3 \\
V_{G11} & = \frac{275 \times 196.2202}{130.455} = 413.6333 \text{ in}^3 \\
V_{G12} & = \frac{275 \times 196.9474}{130.455} = 415.1664 \text{ in}^3 \\
\end{align*}
\]
Therefore the mass of propellant in each of the tanks at the end of the 1st midcourse correction is:

\[ M_9 = (508.90 - 414.8639) \times 0.036 = 3.3853 \text{ lbn} \]
\[ M_{10} = (509.96 - 415.3353) \times 0.036 = 3.3946 \]
\[ M_{11} = (508.63 - 413.6333) \times 0.036 = 3.4198 \]
\[ M_{12} = (510.01 - 415.1664) \times 0.036 = 3.4179 \]

Look @ C.G. shift & static unbalance

\[ \frac{D}{2} \approx 28.5 - \frac{h}{2} \]
\[ h \approx 2.8 \]
\[ D = 27.1 \]

\[ \sum_{Y} = (3.4179 - 3.3853)(27.1) = + 0.263 \text{ in} \]
\[ \sum_{X} = (3.3946 - 3.4198)(27.1) = - 0.0203 \text{ in} \]

Static unbalance = \( (65 - 31.40)(16) \sqrt{0.07637 \times 0.0203^2} \)
\[ = 17.86 \text{ in.-oz} \]
Now look at end of mission where gas ingestion into the lines occurs:

At the time of gas ingestion, assume that the volume of propellant in the tank at which ingestion occurs is

\[ V_P = 0.031 \text{ in}^3 \]

(This quantity has been determined from previous analysis dated 7-71 by P. Falk)

As a first guess, assume that ingestion occurs at Tank 9.

\[ \text{Final pressure} = \frac{275 \times 196.8039}{509.90 - 0.031} = 106.355 \text{ psia} \]

\[ \text{Final volume of propellant in other tanks is} \]

\[ V_{P9} = 0.031 \text{ in}^3 \]

\[ V_{P10} = \frac{509.96 - 275 \times 197.0275}{106.355} = 0.010 \text{ in}^3 \]

\[ V_{P11} = \frac{508.63 - 275 \times 196.2202}{106.355} = 0.263 \text{ in}^3 \]

\[ V_{P12} = \frac{510.01 - 275 \times 196.9979}{106.355} = 0.755 \text{ in}^3 \]

Note: Since \( V_{P0} < V_{P9} \) ingestion will occur in Tank 10

For this condition then, the final pressure becomes

\[ P_F = \frac{275 \times 197.0275}{509.96 - 0.031} = 106.360 \text{ psia} \]

\[ \text{MP}_9 = \frac{(509.90 - 275 \times 196.8039) \times 0.036}{106.340} = 0.00173 \text{ lb} \]

\[ \text{MP}_{10} = 0.031 \times 0.036 = 0.00111 \text{ lb} \]

\[ \text{MP}_{11} = \frac{(508.63 - 275 \times 196.2202) \times 0.036}{106.360} = 0.04630 \]

\[ \text{MP}_{12} = \frac{(510.01 - 275 \times 196.9979) \times 0.036}{106.360} = 0.02829 \]
TOTAL PROPELLANT MASS IN TANK = 0.07743 lbm

LOOK AT O.G. SHIFT & STATIC UNBALANCE

\[ M_{10} = 0.0011 \]

\[ D = 28.5 \text{ TIP} \]

\[ M_{9} = 0.00173^* \]

\[ M_{11} = 0.0463^* \]

\[ M_{12} = 0.02829^* \]

\[ M_{c.g.} \]

Final Mass System:

\[ M_f = 65 - (45 - 0.07743) = 20.077 \text{ lb} \]

\[ \bar{y} = \frac{(0.02829 - 0.00173) \times 28.5}{20.077} = 0.0377 \text{ in} \]

\[ \bar{x} = \frac{(0.0011 - 0.0463) \times 28.5}{20.077} = -0.0641 \text{ in} \]

Static Unbalance = 20.077 x 16 x \( \sqrt{0.0377^2 + 0.0641^2} \) = 23.9 in-lb

Expulsion Efficiency = \( \frac{45 - 0.07743}{45} \) x 100 = 99.83%

Conclusions/Summary:

- Static Unbalance at start of liq. withdrawal = 13.0 in-lb
- Static Unbalance at end of 1st midcourse correction = 17.8 in-lb
- " " " " " Time of gas ingestion = 23.9 sec
- Expulsion Efficiency = 99.83\%
Prior to preparing the flow analysis for Method IV-B a laboratory test set-up was made of the system to demonstrate physically how the liquid and gas flowed in this configuration. Using flasks and tubing the conceptual arrangement of the VCPS tanks and lines was simulated. This set-up was then connected to a source of water and nitrogen to demonstrate the liquid and gas fill procedure. A sketch of the demonstration set-up is included.

The fill procedure was that which would be required to fill the arrangement as shown in Method IV-B where the propellant must be loaded prior to final pressurization thru the single fill and drain port. Water was introduced into the system and the flow observed as each of the line and flasks filled. As expected, the line to the flask closest to the fill port started to fill first with flow continuing to the remaining flasks. This filling sequence results because the gas remaining in the lines is displaced and compressed into each of the flasks. In the actual system this procedure will occur and the first part of the preceding flow analysis shows the magnitude of this effect. After partially filling the flasks with water, nitrogen was introduced slowly into the set-up and the flow visually observed. Again the fluid in the line closest the fill port was displaced first with the longest lines filling last. As the flasks were pressurized with nitrogen there was no evidence that any uneven flow condition existed other than the initial distribution of fluid within the feed lines to the flasks. The magnitude of the propellant quantity differences between tanks after final pressurization and stabilization is shown in the previous analysis section. As a part of the flow demonstration test, the flasks closest and farthest from the fill port were weighed prior to and after filling and pressurization. The difference in weight was that attributable to the fluid displaced in the manifold. The fluid flow analysis and demonstration test appear to indicate that the tanks will fill equally by Method IV-B with any propellant unbalance being the result of tank geometry tolerances and propellant displaced from the feed lines.
INLET CONNECTED TO SOURCE OF WATER & NITROGEN

METHOD IV-B TEST CONFIGURATION
APPENDIX

Specification SVHS 5997
"Valve and Bracket, Qualification Test Plan For"
SPECIFICATION TITLE: VALVE AND BRACKET.

QUALIFICATION TEST PLAN FOR:

PREPARED BY: ______________________  DATE: ________________
APPROVED BY: ________________  DATE: ________________
QUALITY  DATE: ________________
PROJECT  DATE: ________________
APPROVED BY: ________________  DATE: ________________
PURCHASING  DATE: ________________
TECH. STANDARDS DATE: ________________
APPROVED BY: ________________  DATE: ________________
MANUFACTURING  DATE: ________________
MATERIALS DATE: ________________
APPROVED BY: ________________  DATE: ________________
DESIGN  DATE: ________________
SPEC. CONTROL DATE: ________________
APPROVED BY: ________________  DATE: ________________
RELIABILITY  DATE: ________________
SPEC. CONTROL DATE: ________________
APPROVED BY: ________________  DATE: ________________
RELIABILITY  DATE: ________________
SPEC. CONTROL DATE: ________________
APPROVED BY: ________________  DATE: ________________
RELIABILITY  DATE: ________________
CUSTODIAN:

EXP. RELEASE DATE: ________________
PROD. RELEASE DATE: ________________

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1.0 SCOPE

This document specifies the Qualification Testing to be performed on the Valve and Bracket to be used on the RAE-B VCPS. The valve and bracket will be added to the VCPS subsequent to its qualification tests and the tests required herein will demonstrate the suitability of the valve and bracket for use on the qualified subsystem.

2.0 GENERAL

2.1 Applicable Documents

2.1.1 Military

MIL-STD-810 Environmental Test Methods

2.1.2 Others

S-723-P-19 Subsystem Specification, VCPS
S-320-G-1 General Environmental Test Specification for Spacecraft and Components
S-320-RAE-3 Subsystem Test Specification for RAE-B
NHB 5300.4 (LB) Quality Program Provisions for Space Systems Contractors
NFC 200-3 Inspection, System Provisions for Suppliers of Space Components
NFC 250-1 Reliability Program Provisions for Space Systems Contractors

3.0 TEST OBJECTIVE

The purpose of this qualification test is to demonstrate the suitability of a Fill and Vent Valve and Bracket subassembly for use on the qualified RAE-B VCPS.

4.0 TEST PROGRAM

The test program shall consist of the following tests:

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage</td>
<td>4.1.1</td>
</tr>
<tr>
<td>Vibration</td>
<td>4.1.2</td>
</tr>
<tr>
<td>Leakage</td>
<td>4.1.1</td>
</tr>
</tbody>
</table>
4.1 Test Descriptions

4.1.1 Leakage

4.1.1.1 Objective - The purpose of the leakage test is to demonstrate leakage integrity of the valve before and after being subjected to vibration.

4.1.1.2 Facilities - The leakage test shall be performed using standard helium leak test equipment, such as the Veeco leak detector.

4.1.1.3 Test Setup - The leakage test shall be setup and tested per Figure 1.

4.1.1.4 Test Procedure

a. Mount the valve per Figure 1.

b. Calibrate the helium leak detector.

c. Pressurize the valve to 300 ± 5 psia with helium with the cap off.

d. Record valve leakage rate for 3 minutes.

e. Depressurize and cap the valve.

f. Pressurize the valve to 300 ± 5 psia with helium.

g. Record valve leakage for 3 minutes.

h. Shut off helium supply and depressurize.

NOTE: To close fill and vent valves, torque nut to 25 ± 2 in-lbs above running torque. (Running torque is that torque required to turn nut before valve bottoms out). To open fill and vent valves, turn nut 1 1/2 turns in opening direction from closed position. When caps are installed, torque to 45 - 60 in-lbs.

4.1.1.5 Acceptance Criteria

a. Leakage in the uncapped condition shall not exceed $1.0 \times 10^{-4}$ scc helium.

b. Leakage in the capped condition shall not exceed $1.0 \times 10^{-6}$ scc helium.
4.1.2 Vibration

4.1.2.1 Objective - The purpose of the vibration test is to demonstrate the capability of the valve and bracket to withstand without deleterious effects, the vibration requirement of SP-723-P-19.

4.1.2.2 Facilities - The vibration test shall be performed at Hamilton Standard in the Space Systems Laboratory.

4.1.2.3 Test Setup - The valve and bracket shall be hard mounted to a fixture per Figure 2. Accelerometers shall be installed per Figure 2. The valve shall be closed and capped (see note paragraph 4.1.1.4). For axis definition see SV748720.

4.1.2.4 Test Procedure - Subject the valve and bracket to the vibration levels below.

Sinusoidal

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency (Hz)</th>
<th>Level</th>
<th>Sweep Rate Octave/Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>5-11</td>
<td>±2.3 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>11-17</td>
<td>±6.8 gpk</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>23-200</td>
<td>±2.3 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>200-700</td>
<td>±3.0 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>700-2000</td>
<td>±10.0 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td>X &amp; Y</td>
<td>6-8.9</td>
<td>±7.5 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>8.9-14</td>
<td>±3.0 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>14-200</td>
<td>±1.5 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>200-600</td>
<td>±5.0 gpk</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>600-2000</td>
<td>±7.5 gpk</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Random

<table>
<thead>
<tr>
<th>Axis</th>
<th>Frequency (Hz)</th>
<th>PSD</th>
<th>Grms</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y, Z</td>
<td>20</td>
<td>.0029 g²/Hz</td>
<td></td>
<td>4 min.</td>
</tr>
<tr>
<td></td>
<td>20-500</td>
<td>+3 dB/oct</td>
<td>.045 g²/Hz</td>
<td>per axis</td>
</tr>
<tr>
<td></td>
<td>300-2000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The filter roll off characteristic above 2000 Hz shall be at a minimum rate of 40 dB/octave or greater.

4.1.2.5 Acceptance Criteria - Visual examination shall reveal no permanent damage.
FIGURE 1
APPENDIX

Qualification Test Report
<table>
<thead>
<tr>
<th>SLS TEST ENGINEERING TEST REPORT</th>
<th>FILE CODE TER 2764</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROGRAM  RAE-B</td>
<td>TEST REPORT</td>
</tr>
<tr>
<td>TEST ITEM  VALVE &amp; BRACKET</td>
<td>DATE  3/30/73</td>
</tr>
<tr>
<td>S/N</td>
<td></td>
</tr>
<tr>
<td>NAME OF TEST  QUALIFICATION</td>
<td>DATE OF TEST  2/12 - 2/21/73</td>
</tr>
<tr>
<td>TEST SPECIFICATION  SVHS 5997</td>
<td>TEST PLAN</td>
</tr>
<tr>
<td>CONCLUSIONS  THE FILL AND VENT VALVE SATISFIED LEAKAGE</td>
<td></td>
</tr>
<tr>
<td>TEST REQUIREMENTS BEFORE AND AFTER BEING SUBJECTED TO THE VIBRATION TEST ENVIRONMENT. NO STRUCTURAL DAMAGE WAS OBSERVED ON THE VALVE OR BRACKET AS A RESULT OF VIBRATION.</td>
<td></td>
</tr>
<tr>
<td>RECOMMENDATIONS (OPTIONAL)</td>
<td></td>
</tr>
</tbody>
</table>

**OBSERVATIONS (OPTIONAL)**

The item which successfully completed the qualification test included bracket PIN 5V756131-1 and fill & vent valve PIN SV725430-1, S/N 31713-2.

Copies of the vibration test control curves and a summary of the leakage test results are included. Valve S/N 24512-2 failed leakage before vibration. The valve was flushed with IPA and retested, resulting in another leak test failure.

The valve was shipped to NASA for analysis and replaced with S/N 31713-2.

**TOTAL TEST TIME**

**INDURANCE CYCLES**  NONE

**ORIGINAL COPY**

C: CHIEF OF RELIABILITY/CHIEF OF DESIGN

TEST ENGINEERING FILE

TEST ENGINEER  WALTER E. SMITH  APPROVED/DATED  Robert Arm  5/30/73

SIGNATURE  W.E. Smith  DATE  3/30/73  E49

304<
<table>
<thead>
<tr>
<th>TEST DATE</th>
<th>LOG SHEET</th>
<th>P.O.T. REF.</th>
<th>SPEC. REF.</th>
<th>TEST TITLE</th>
<th>TEST CONDITIONS</th>
<th>SPEC. LIMITS</th>
<th>MEASURED VALUES</th>
<th>NO. SAMPLES</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/16/73</td>
<td>3V72-47</td>
<td>3V45-44</td>
<td></td>
<td>LEAKAGE BEFORE VIBRATION</td>
<td>CAPPED</td>
<td>1x10^-6 sec/sec, max</td>
<td>.6x10^-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNCAPPED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/21/73</td>
<td>3V72-47</td>
<td>3V45-44</td>
<td></td>
<td>LEAKAGE AFTER VIBRATION</td>
<td>CAPPED</td>
<td>SAME AS ABOVE</td>
<td>.2x10^-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNCAPPED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### LOG OF TEST

<table>
<thead>
<tr>
<th>Run #</th>
<th>Time Start</th>
<th>Axis Mode</th>
<th>$G^i_{pk}$</th>
<th>$G^i_{rms}$</th>
<th>Time min’s</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1405</td>
<td>X SINE</td>
<td>10</td>
<td>3.0</td>
<td>-</td>
<td>4.12-4</td>
</tr>
<tr>
<td>3</td>
<td>1425</td>
<td>X SINE</td>
<td>7.5</td>
<td>3.0</td>
<td>-</td>
<td>4.12-5</td>
</tr>
<tr>
<td>4</td>
<td>1505</td>
<td>Y SINE</td>
<td>10</td>
<td>3.0</td>
<td>-</td>
<td>4.12-4</td>
</tr>
<tr>
<td>5</td>
<td>1520</td>
<td>Y SINE</td>
<td>7.5</td>
<td>2.0</td>
<td>-</td>
<td>4.12-5</td>
</tr>
<tr>
<td>7</td>
<td>1820</td>
<td>Z RAND</td>
<td>9.16</td>
<td>4.0</td>
<td>4.12-5</td>
<td>10/19/73</td>
</tr>
<tr>
<td>8</td>
<td>1915</td>
<td>Z RAND</td>
<td>9.16</td>
<td>4.0</td>
<td>4.12-5</td>
<td>10/19/73</td>
</tr>
</tbody>
</table>

2-10-73

10 1050  - Z RAND  - - 9.16 4.0 4.12-5
11 1110  - Z SINE  7 2.0  - - 4.12-4
12 1135  - Z SINE  10 2.10  - - 4.12-5

FOR RUN 2 - 8 THE X, Y, Z axes were misaligned by 36°. SEE FIG. 2 FOR ACTUAL ORIENTATION.

REMARKS:
- Deas present at start of runs - A, 9° Thrly 2-19-73

8352
CE-5 Cleanliness Level

<table>
<thead>
<tr>
<th>Particle Size (Microns)</th>
<th>Particle Count (Particles/ft²)</th>
<th>Non-Volatile Residue (grams)</th>
<th>Visual Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10*</td>
<td>1200</td>
<td>N/A</td>
<td>Required</td>
</tr>
<tr>
<td>10-25</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-100</td>
<td>5**</td>
<td></td>
<td></td>
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<tr>
<td>100</td>
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</tbody>
</table>

*Particles below listed ranges shall cause no discoloration of membrane filters.

**Metal particles larger than 50 microns in size, shall not be allowed.
APPENDIX

Acceptance Test Plan
A modification to the VCPS requires that only a portion of the Production Acceptance Test be repeated.

<table>
<thead>
<tr>
<th>ITEM/TEST RECORDING</th>
<th>YES</th>
<th>NO</th>
</tr>
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</table>

<table>
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<tr>
<th>VCP F/N</th>
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<table>
<thead>
<tr>
<th>DESCRIPTION OF MARYS OR ASSEMBLIES INVOLVED</th>
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<table>
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<th>S/N OF MANUFACTURE</th>
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<th>INSTRUCTIONS</th>
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<th>UNITS</th>
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<tr>
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<td>SPECIFICATIONS CONTROL</td>
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<th>RELEASE DATE</th>
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<tbody>
<tr>
<td>Jul 9, 1973</td>
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</tbody>
</table>
3.0 Change to read: "The PAT is conducted to verify the leakage integrity of the VCPS."

4.3 Add - Isopropyl alcohol per TT-I-735

4.4 Change to read: "The Acceptance Test shall be conducted in the following sequence:

<table>
<thead>
<tr>
<th>Test</th>
<th>Ref. Paragraph</th>
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<tbody>
<tr>
<td>Examination of Product</td>
<td>4.5.1</td>
</tr>
<tr>
<td>Weight</td>
<td>4.5.3</td>
</tr>
<tr>
<td>Proof Pressure</td>
<td>4.5.4</td>
</tr>
<tr>
<td>External Leakage</td>
<td>4.5.6</td>
</tr>
<tr>
<td>Contamination Check</td>
<td>4.5.8</td>
</tr>
<tr>
<td>Post Test Inspection</td>
<td>4.5.7</td>
</tr>
</tbody>
</table>

4.5.2 Delete.

4.5.3.4 Change to read, "The dry weight of the completed VCPS shall be noted."

4.5.4.2 Add to end of sentence, "or equivalent."

4.5.4.3 Change to read:

"b. Connect the gas fill and vent valves to the gas manifold and open the four pressurant fill valves."

4.5.5 Delete.

4.5.6.3 Change to read: "a." delete

Figure I Delete

Figure II Delete

ADD

4.5.8 Contamination Check

4.5.8.1 Objective: To demonstrate that the VCPS modification has not contaminated the VCPS.

4.5.8.2 Description of Test

4.5.8.2.1 Test Facilities - The contamination check shall be performed using the Flush Rig 100 and shall be performed in the Hamilton Standard clean room facilities.

4.5.8.2.2 Test Instrumentation - Instrumentation shall be as required by SVP 161.
4.5.8.2.3 Procedure

a. With the four fill and vent valves open, load isopropyl alcohol into the VCPS until alcohol discharges from each of the four vent valves.

b. Close the vent valves and rotate the VCPS to wet tank internal surfaces.

c. Open the vent valves and drain the VCPS, collecting an effluent sample and verify the VCPS cleanliness as directed by SVP 161.

d. Vacuum dry the VCPS at 2000 microns until the VCPS does not exhibit a pressure rise to the vapor pressure of IPA after removing the vacuum source.

4.5.8.3 Acceptance Criterion - The effluent sample checked shall meet the cleanliness level of CE-5 per SVHS 3150.
APPENDIX

SCHEDULE