TESTING AND ANALYTICAL MODELING FOR PURGING PROCESS OF A CRYOGENIC LINE

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ABSTRACT
To gain confidence in developing analytical models of the purging process for the cryogenic main propulsion systems of upper stage, two test series were conducted. Test article, a 3.35 m long with the diameter of 20 cm incline line, was filled with liquid (LH₂) or gaseous hydrogen (GH₂) and then purged with gaseous helium (GHe). Total of 10 tests were conducted. Influences of GHe flow rates and initial temperatures were evaluated. Generalized Fluid System Simulation Program (GFSSP), an in-house general-purpose fluid system analyzer, was utilized to model and simulate selective tests.

INTRODUCTION
• Cryogenic main propulsion systems of upper stage purging scenarios
  - Purging of the Fill/Drain line after completion of propellant loading
  - Purging of the Feed/Drain line if the mission is scrubbed
• Flow rate of purging gas should be regulated
  - Exceeding maximum allowable pressure may lead to structural damages
• Objectives of the testing was
  - to measure how purging GHe behaved when it was injected into cryogenically chilled LH₂/GH₂ filled line
  - to support analytical purge model development applicable to any future launch vehicle that uses LH₂ as a propellant and purges Fill/Drain/Feed lines with GHe
TEST SETUP

- Insulated stainless steel incline line 3.35 m long with the diameter of 20 cm
- Fluid and wall temperatures and fluid pressures were measured at stations 1-6 and 1, 2, 4, and 6, respectively
- At station 6, two residual gas analyzers (RGA) were installed to measure the concentration of both GH₂ and GHe
- LH₂ entered and exited the test article via PV-11 and PV-12, respectively. Both valves were closed when test article reached steady state conditions
- Purging was accommodated via Purge Entry, as shown in Figure 1

Figure 1. Test Article Schematic
TEST PROCEDURES
Two test series, as shown in Table 1, were conducted at the Hydrogen Cold Flow Facility of West Test Area of Marshall Space Flight Center (MSFC)
• Test article was filled with
  - LH₂ in first series, tests 1-6
  - GH₂ in second test series, tests 7-10

<table>
<thead>
<tr>
<th>Test #</th>
<th>Fluid</th>
<th>GHe Initial Temperature (K)</th>
<th>Purge Flow rate g/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LH₂</td>
<td>291.5</td>
<td>3.18</td>
</tr>
<tr>
<td>2</td>
<td>LH₂</td>
<td>291.5</td>
<td>3.18</td>
</tr>
<tr>
<td>3</td>
<td>LH₂</td>
<td>291.5</td>
<td>5.9</td>
</tr>
<tr>
<td>4</td>
<td>LH₂</td>
<td>291.5</td>
<td>5.9</td>
</tr>
<tr>
<td>5</td>
<td>LH₂</td>
<td>330</td>
<td>5.9</td>
</tr>
<tr>
<td>6</td>
<td>LH₂</td>
<td>330</td>
<td>5.9</td>
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<tr>
<td>7</td>
<td>GH₂</td>
<td>291.5</td>
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<td>9</td>
<td>GH₂</td>
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</tr>
<tr>
<td>10</td>
<td>GH₂</td>
<td>330</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Table 1. Description of Each Test

RESULTS AND DISCUSSIONS
• Higher purge flow rate would lead shorter purge duration, as shown in Figure 2
• Purge process would not influence significantly by initial GHe temperature, as shown in Figures 3 and 4
• Utilizing GFSSP [1], tests 1, 3, and 7, were selected, simulated, and compared with test data
• Figures 5–7 depict reasonable agreements between predicted and measured GH₂ concentration at exit

ACKNOWLEDGEMENTS
Authors would like to extend their appreciation to Kent Chojnacki from MSFC XP-30 and Carl Ise from MSFC-XP03 for their support. The authors would also like to thank Mike Nichols from MSFC-ET10 and test team at Hydrogen Cold Flow Facility of MSFC West Test Area. Special thanks also go to Ken Knable and Mathew Miles from MSFC-ESSSA.

REFERENCES
Figure 2. Purge Durations for Test 1 and Test 3.

Figure 3. Purge Durations for Test 3 and Test 5.

Figure 4. Purge Durations for Test 7 and Test 9.

Figure 5. Concentration Histories for Test 1.

Figure 6. Concentration Histories for Test 3.

Figure 7. Concentration Histories for Test 7.