Demonstration Testing for Ground Servicing of the Commercial Crew Vehicle Emergency Breathing Air Assembly

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Overview

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• Constraints
• Proposed Process
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Background

What is CEBAA and why is it needed?

- ISS Temperature regulation uses NH3
- New Capability to support Commercial Crew
- Emergency breathing air for crew evacuation
Flight Requirements

• Service a COPV with a specific mixture of breathing air

• Specifications based on:
  – Support five crew
  – Up to one hour breathing time
  – Flammability limits of materials within cabin

Specific Air Composition (GN2/GO2)
Specific Air Quantity (lbm)
Constraints

Budget & Schedule

Utilize existing GO2/GN2 servicing capabilities

First flight servicing potentially within 1 year of requirements development

Use existing GSE

CEBAA can use same GSE as NORS to deliver GO2 and GN2 to ISS

Minimal, if any, GSE modifications

Service gas serially

NORS GSE only allows serial addition of gases to COPV
Proposed Process

1. Calculate target GN2 load
2. Load GN2 and allow for thermal stabilization
3. Calculate target GO2 load
4. Load GO2 and allow for thermal stabilization
5. Top-off gas to reach flight requirements as needed
6. Allow COPV to dwell to achieve adequate mixing
7. Perform final flight sampling to verify BAIR composition
Proposed Process

Mixing Period

Nitrogen Addition → Oxygen Addition

Mixing Period
Assumptions

- Non-Ideal Fluid
- Ideal Mixture
- Temperature-Pressure-Density relationship available from REFPROP
### Concerns and Test Objectives

<table>
<thead>
<tr>
<th>Concern</th>
<th>Test Objective</th>
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<tbody>
<tr>
<td>Reduced diffusivity at high pressure slows mixing</td>
<td>Achieve adequate mixing at high pressure in a reasonable time</td>
</tr>
<tr>
<td>Error may prevent ability to meet concentration requirement</td>
<td>Demonstrate that NORS GSE can accurately deliver GN2 and GO2 to meet requirements</td>
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<tr>
<td>Stratification may cause samples to misrepresent tank contents</td>
<td>Show that stratification of gases within the COPV does not persist after fill</td>
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• **Testing broken into two parts: Stratification and Accuracy**
  – Same process used in both tests to fill COPV with GN2 and GO2

• **Stratification Testing**
  – Test for adequate mixing by filling a COPV and collecting a series of purity samples at various pressures
  – COPV weight measurements pre- and post- GN2 and GO2 fill used to corroborate sample results
  – First iteration of testing dwelled over 2 days and increased as necessary based on test results

• **Accuracy Testing**
  – Three attempts made using proposed process with oxygen concentration analyzed to determine process accuracy
  – One attempt intentionally missed target GO2 to test correction method
Test Results

• Stratification

<table>
<thead>
<tr>
<th>Trial</th>
<th>Sample 1 O₂ Concentration Deviation from Target (mol%)</th>
<th>Sample 2 O₂ Concentration Deviation from Target (mol%)</th>
<th>Sample 3 O₂ Concentration Deviation from Target (mol%)</th>
<th>Dwell Time (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.78</td>
<td>-0.12</td>
<td>-0.12</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0.03</td>
<td>0.07</td>
<td>0.03</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>0.06</td>
<td>0.06</td>
<td>0.16</td>
<td>7</td>
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<tr>
<td>4</td>
<td>0.08</td>
<td>0.08</td>
<td>-0.02</td>
<td>7</td>
</tr>
</tbody>
</table>

• Accuracy

  – Stratification tests were more successful than predicted, so results were used to validate accuracy objectives
Conclusion

• Testing shows that some stratification does occur as a result of the serial addition of GN2 and GO2
• Testing indicated that GN2 and GO2 mixing in a COPV reaches acceptable mixing levels within 7 days
• Process error is small enough to make the process viable
• NORS GSE is validated for CEBAA processing
Backup
Convergence of Oxygen Mole Fractions at Different Positions

0 in
5.4 in
10.8 in
16.2 in
21.6 in
27.0 in
Acronyms

BAIR – Breathing Air
CEBAA – Commercial Crew Vehicle Emergency Breathing Air Assembly
COPV – Composite Overwrapped Pressure Vessel
GN2 – Gaseous Nitrogen
GO2 – Gaseous Oxygen
GSE – Ground Support Equipment
ISS – International Space Station
Lbm – Pound (mass)
Mol% - Mole Percent
NH3 – Anhydrous Ammonia
NORS – Nitrogen/Oxygen Recharge System
REFPROP – Reference fluid Properties