CO$_2$ Removal and Atmosphere Revitalization Systems for Next Generation Space Flight

ARC Air Revitalization Group

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Outline

• Design Objectives of Atmosphere Revitalization
  • Reliability
  • Low Power
  • Loop Closure
• ISS CO2 Removal
• Low Power CO2 Removal System
• Next Generation Atmosphere Revitalization
**Current ISS**

Cabin air → 4BMS → Vent to space

Basis: one Human Equivalent Unit (1 kg CO₂ generated / day)

Future ISS

Cabin air → 4BMS → Sabatier → Separator → Electrolyzer

- CO₂ → Vent to space (0.5 kg CO₂ / day)
- CH₄, H₂O → Vent to space (0.18 kg CH₄ / day)
- H₂O → Electrolyzer (H₂)
- H₂ → Electrolyzer (O₂)

Excess H₂ is vented also (about 0.05 kg / day)
Increased Loop Closure

- 4BMS
- Sabatier
- Separator
- Electrolyzer
- CO₂
- CH₄, H₂O
- H₂O
- H₂
- O₂
- C₂H₂
- CH₄ reactor/sep
- H₂
- cabin air
Low Power CO2 Removal - LPCOR

- Passive membrane drying technology for low power
- Structured residual dryers for low power and reliability
- Integrated CO₂ capture and compression for loop closure and low power
## Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew-size</td>
<td>4 (max)</td>
</tr>
<tr>
<td>CO₂ concentration</td>
<td>2600 ppm (average)</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>60 minutes</td>
</tr>
<tr>
<td>Flow rate: process air inlet</td>
<td>850 slm</td>
</tr>
<tr>
<td>Temperature: process air inlet</td>
<td>8-10°C</td>
</tr>
<tr>
<td>Dewpoint: process air inlet</td>
<td>8°C</td>
</tr>
<tr>
<td>CO₂ delivery pressure</td>
<td>133 kPa</td>
</tr>
<tr>
<td>Adsorbent Cooling Method</td>
<td>process air and rack air for additional cooling</td>
</tr>
</tbody>
</table>
Test Stand

- Test platform for evaluation/characterization of AR components
- Air Flow range: 0-1275 slm
- Air Temperature: 5°C-20°C
- Air Dewpoint: 5°C-20°C
- Air Relative Humidity: 35%-100%
- Supplemental Air Flow Range: 0-1416 slm
- Supplemental Air Flow Dewpoint: -70°C
Dryer Orientation

- Tube flow - 850 slm, Shell flow - 722 slm (85% of tube flow), Inlet DP - 8°C
- 70% water-removal efficiency in horizontal orientation
- 81% water-removal efficiency in vertical orientation
Efficient Heating – In-line vs. proximal

Desiccant Air Pre-Heater
60-minute adsorption/desorption cycles

Average power for desiccant regeneration – 250 W
Passive membrane drying technology for low power
Structured residual dryers for low power and reliability
Integrated CO₂ capture and compression for loop closure and low power
2-Stage Compressor

- Built-in inlet and outlet valves with integrated valve actuation assembly
- Concentric design with stage 1 embedded inside of stage 2
- Coiled heater assembly for uniform heating of each stage
Operating Principle of TSAC

An adsorption-based compression cycle

1. Intake
   - Cool, low pressure
2. Pressurization
   - Warming, rising pressure
3. Production
   - Warming further, steady pressure
4. Depressurization
   - Cooling, falling pressure

Loading (grams gas/gram sorbent)

- Low-pressure intake
- High-pressure setpoint

Low temp
- Cycle starting point
- Production
Adsorption vs. Mechanical Compressor

- No rapidly moving parts
- No vibration
- Proven reliability and sustainability
ISS CO2 and TCCS - separate loops

Cabin Air Inlet (15.3 m³/hr)
Speed Sensors
Fixed Charcoal Bed (22.7 kg Charcoal)
Blower
Flow Meter
Orifice Plate
10.7 m³/hr bypass
Postsorbent Bed (1.4 kg LiOH)
Cabin Air Outlet (to THC)
Process Sample Line

Catalytic Oxidizer Assembly
(0.5 kg 0.5-percent Pd on Alumina)
673 K Operating Temperature
811 K Maximum Temperature

Temperature Sensors
Next Generation

- Combine CO₂ and TC functions
- Structured sorbents for low pressure drop and longevity
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• QUESTIONS