Development of a Supercritical Air Environmental Control Unit for the Propellant Handler’s Ensemble

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• What is the PHE? (Propellant Handler’s Ensemble)
  – Self contained, whole body, protective ensemble
  – Provides protection from rocket fuels & oxidizers
  – Approximately 5000 suitings per year at KSC
  – Various configurations since it was first developed in 1964 with an excellent safety record
  – Category I suit is a 2 hour self-contained configuration using a liquid air based ECU (Environmental Control Unit)
  – Supercritical Air ECU in development
Cryogenic Air Basics

- KSC uses high purity, low dew point air for spacecraft processing
- Created by mixing liquid nitrogen and liquid oxygen
- Liquid air can be stored in a compact space using light weight storage vessels (dewars → thermos jug)
- Can be stored at 0 – 120 psi and -320°F @ density ~ 53 lb/ft³
- Typical storage time for liquid air is 24 days
- Liquid air expands (728 times) and warmed by an internal heat exchanger before being made available to the user at 55°F
Environmental Control Unit (ECU)
Environmental Control Unit

- Dewar holds 15 lb cryogenic air

- Cryogenic liquid air @ -320º F

- Density = 53 lb/ft³

- Air warmed and expanded for distribution into the suit

- Composition is 20-30% Oxygen and Nitrogen

- Three selectable flow rates

- Operational Time = 2 hr

- Total serviced weight = 41 lb.
## Liquid Air VS Supercritical

<table>
<thead>
<tr>
<th>Liquid Air</th>
<th>Supercritical Air (single phase fluid (gas))</th>
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<tbody>
<tr>
<td><strong>Oxygen Enrichment</strong></td>
<td>Liquid air experiences nitrogen boil-off first leaving liquid somewhat oxygen rich</td>
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<tr>
<td><strong>Quantity Measurement</strong></td>
<td>No reliable method for measuring very cold, mobile, storage vessel quantity On ECU, liquid is used at a constant rate and this rate is set and controlled by procedure</td>
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<tr>
<td><strong>Attitude Dependence</strong></td>
<td>Liquid air pickup tube can come out of the liquid when unit is non-vertical</td>
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Supercritical Air Characteristics

- Density of supercritical equal to liquid air (53 lb/ft³)
- Liquid air - mix of liquid nitrogen & liquid oxygen @ -320º F < 575 psi
- Supercritical air - gaseous air @ -320º F > 575 psi
- Production:
  - Can chill dry air at pressures > 575 psi
  - Can apply pressure head (>575 psi) to liquid
- **Safety** – store in low pressure (< 950 psi) vessels
Mollier Chart for Air

Operate supercritical ECU in this region

Typical Pressure Decay
Supercritical Air Loading Schematic
Supercritical Air ECU

2 hour - Supercritical Air Environmental Control Unit
Testing of Supercritical ECU

Modified Liquid Air Environmental Control Unit to Supercritical air

• Environmental Control Unit
  – Same physical size, similar weight
  – Provides 2 hour duration
  – Is attitude independent
  – Has quantity sensor

• Performed unmanned testing
• Performed manned testing
Physiological Tests

- Dexterity – pickup coins
- Roll Drum – remove lid and sandbag
- Environmental Chamber 20º F, 110º F
- Stack/unstack concrete blocks

Laboratory
Body Temperature Data for the Supercritical ECU

PHE - Supercritical ECU - Mod 2
Test 2625 - DR - 20 Nov 01

Room Temperature

Temperature - F

Time - minutes

- forehead
- chest
- back
- core
- Exercises
Conclusions

• Cryogenic supplied suits have been used safely and successfully at KSC for 40 years
• History of Failure- No Serious Injuries
• Performance of supercritical air ECU similar to Liquid Air, but is attitude independent w/ quantity measurement.
• Cryogenic based PPE is especially advantageous in warm climates and for long durations
• Commercial application of this technology would advance the state-of-the-art from conventional compressed air
Questions

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