Update of ARIES-AT Vacuum Vessel Design

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The Boeing Company

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ARIES Meeting at UW, Madison
ARIES-AT Study

ARIES-AT Power Core

- Sector replacement approach
- Individual doors and port enclosures for each power core sector
- Discrete vacuum vessel doors
- Vacuum vessel provides support for power core

Cross Section of ARIES-AT Power Core Configuration
Vacuum Vessel Port Design Approach

- Locking jacks secure doors during operation and swing away into pocket during maintenance
- High temperature wedge provides similar shielding to blanket and shield

Door Width at Midplane = 2.774 m \( (2 \cdot \pi \cdot 6.86/16 + 2 \cdot 0.04) \)

Pneumatic Screw Jacks, Locking
24 jacks per door

4 cm Step in Door

Pocket for Jacks

10 cm thick Port Enclosure, water cooled

TF (20 x 97 cm at 10.565 m to IB face)

Stowed Jack Position During Maintenance
HT Wedge Detail

- Door and frame steps attenuate neutron streaming and provide positive door positioning.
- LiPb coolant is routed in and out through upper and lower vacuum vessel spool flanges.
3-D View of Basic Vacuum Vessel

3-D Cutway View of Vacuum Vessel

Notes:
Vessel is a double-walled structure with internal ribs (not shown).
Water coolant is circulated between external walls.
Cutouts for plumbing connections are not shown.
Structure will be welded as required to form complete assembly.
Door frames will be welded to spool-shaped basic structure.
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Basic Structure, Elevation View

- Double-walled vessel allows internal water cooling
- Structure is constructed mainly of flat plates

Elevation View

Material: Low Activation Ferritic Steel, F82H (Fe-8%Cr-2%WVTa)
Structure Details

View C - Plumbing Cutout
Typical 16 places, 50 cm deep

View B - Rib Detail
(10 x view)

32 Internal Ribs, Full Length of cylinder, Extend radially in upper and lower flanges

A-A Midplane Crosssection
Basic Structure with Fill Hatches

Fill Hatches for WC spheres, 50 cm diameter, 32 required, welded at final assy.
Exterior Elevation View of Doors
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Door Details

Fabrication costs are reduced by using an extruded Z-section* for both the doors and frames and explosively-formed** door panels

* U. S. Profiles
** High Energy Metals, Inc

Door Cross-sections

Note: Thickness of Structure Material is 3 cm
Door Frame Details

- Constructing the frame in the I-shape improves the strength and reduces field welds
- Once-through cooling has highest velocity at mid-plane in highest heat flux zone
Enclosures are 10-cm-thick, double-walled structures with water cooling between 2-cm thick plates.
## Summary of Component Masses

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass*, Each</th>
<th>Mass*,Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spool Assembly</td>
<td>-</td>
<td>136,043 kg</td>
</tr>
<tr>
<td>Removable Doors</td>
<td>13,208 kg</td>
<td>211,328 kg</td>
</tr>
<tr>
<td>Door Frames</td>
<td>3,352 kg</td>
<td>53,632 kg</td>
</tr>
<tr>
<td>Port Enclosures**</td>
<td>44,528 kg</td>
<td>712,448 kg</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>1,113,451 kg</td>
</tr>
</tbody>
</table>

- Spool Assembly and Port Enclosures are 2 cm thick
- Doors and Door Frames are 3 cm thick

* Structure only
** With outer port doors
### ROM Cost Estimate

<table>
<thead>
<tr>
<th>Component</th>
<th>Total Mass</th>
<th>Matl Cost</th>
<th>Fab Cost</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>Spool Assembly</td>
<td>136,043 kg</td>
<td>$493,430</td>
<td>$2,614,897</td>
<td>$3,108,327</td>
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<td>Removable Doors</td>
<td>211,328 kg</td>
<td>$859,863</td>
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<td>Door Frames</td>
<td>53,632 kg</td>
<td>$356,555</td>
<td>$2,736,320</td>
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<tr>
<td>Port Enclosures</td>
<td>712,448 kg</td>
<td>$2,020,698</td>
<td>$14,309,096</td>
<td>$16,329,794</td>
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<tr>
<td><strong>Totals</strong></td>
<td>1,113,451 kg</td>
<td>$3,730,546</td>
<td>$25,902,193</td>
<td>$29,632,739</td>
</tr>
</tbody>
</table>

- **Contingency (20%)** $5,926,548
- **Prime Contractor Fee (12%)** $3,555,929
- **Total Subsystem Cost** $39,115,216

#### Unit Costs
- Spool Assembly $30/kg
- Removable Doors $44/kg
- Door Frame $76/kg
- Port Enclosure $30/kg
- Composite Rate $35/kg

- Date: 3 May 2000
Discussion of Cost Items

• Tooling costs not included (10th of a kind assumption)
• Fabrication costs dominate (87%)
  – Innovative design approaches would lower cost
• Welding dominates the fabrication cost (69%)
  – Reduce welding of components
• Interior bulkheads represent most of cost (52%)
  – Integral, stiffened structures would reduce cost
• Port enclosures are a major cost element (55%) - they need to be redesigned to reduce cost.
  – Use common, larger port enclosure
  – Single-walled enclosures might be possible