Assessment of Power Core Parameters and Related Costs (Part-III)

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Contents

• Revised costing accounts (in 2004$):
  # 21: Structures & Site Facilities
    # 21.2: Reactor Building
  # 22: Reactor Plant Equipment
    # 22.1.5 Primary Structure
    # 22.1.6: Vacuum System

• Shield vs NWL scaling law.

• Cryogenic heat load to magnet.

• Sensitivity of COE to availability and LSA.

• Radwaste volume comparison

• Future plan.
Account # 21.2
(Reactor Building)

ARIES-CS building volume $V_{RB}$ (in m$^3$) = $1.3 \times 10^5 \times 1.3^#$, per Les and Xueren

<table>
<thead>
<tr>
<th>ARIES-</th>
<th>RS</th>
<th>AT</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

21.2 Reactor Bldg
(M$ - 2004$)

~ 160 old
~ 100 old
~ 140 old
~ 68 new

New costing algorithm results in factor of 2 lower building cost

#$ \quad \text{Correction factor to account for unaccounted buildings.}$

* 2004$ = 1992$ x 1.256, per Les.
Account # 22.1.5
(Primary Structure)

Cost (2004 M$) = [volume x steel density (7.8 gm/cm³) x vol. fract. (0.95) x unit cost (~25 $/kg)] x LSA Factor x 1.256

**Volume = 18.4% FPC volume**

FPC volume* = **actual** volume of FW + blanket + divertor + shield + VV + winding pack + coil structure (including bucking structure) ≈ 400 m³

<table>
<thead>
<tr>
<th>ARIES-</th>
<th>RS</th>
<th>AT</th>
<th>CS</th>
<th>1/06</th>
<th>3/06</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.1.5</td>
<td>67</td>
<td>34</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Str. (M$- 2004$)</td>
<td></td>
<td></td>
<td>~ 90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Should not include primary structure, cryostat, bioshield, nor buildings.
Account # 22.1.6
(Vacuum System)

Includes cost of VV, cryostat, and pumping system

<table>
<thead>
<tr>
<th>ARIES-</th>
<th>RS</th>
<th>AT</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>VV</td>
<td>62</td>
<td>922</td>
<td>53 (28 cm)</td>
</tr>
<tr>
<td>Cryostat</td>
<td>100</td>
<td>9</td>
<td>0 (0 cm)</td>
</tr>
<tr>
<td>Pumping System*</td>
<td>38</td>
<td>23</td>
<td>81</td>
</tr>
<tr>
<td>21.1.6 Vacuum System (M$- 2004$)</td>
<td>200</td>
<td>124</td>
<td>134 (should be &gt;130)</td>
</tr>
</tbody>
</table>

* Depends on plasma parameters.

ARIES-CS pumping system is too expensive. Why?
Shield vs NWL Scaling Law
(Near-final radial build; average $\bar{G} \sim 3 \text{ MW/m}^2$)

- Incremental change to nominal 30 cm FS shield:

\[ \Delta_{\text{FS-shield}} = 7.3 \ \ln \left( \bar{G} / 3 \right) \]

- Incremental change to 34 cm WC shield-II @ $\Delta_{\text{min}}$:

\[ \Delta_{\text{WC-shield-I}} = 5.9 \ \ln \left( \bar{G} / 3 \right) \]

* $\Delta$ in cm and average $\bar{G}$ in MW/m$^2$. 
Cryogenic Heat Load to Magnet
(Near-final radial build; average $\bar{G} \sim 3$ MW/m$^2$)

Assumptions:
– Winding packs (WP) cover 32% of area.
– Inter-coil structure covers 68% of area.
– WP and structure @ 4K.
– 300 $W_e$ to remove 1 W of nuclear heating.

<table>
<thead>
<tr>
<th>Component</th>
<th>Nuclear Heating (kW)</th>
<th>Cryogenic Load ($M_W$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 cm Coil Case</td>
<td>2.0</td>
<td>0.6</td>
</tr>
<tr>
<td>18 cm Winding Pack</td>
<td>2.9</td>
<td>0.7</td>
</tr>
<tr>
<td>66 cm External Structure*</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>subtotal</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>35 cm Inter-coil Structure</td>
<td>10.7</td>
<td>3.2</td>
</tr>
<tr>
<td>Total</td>
<td>16 kW</td>
<td>$\sim 5 M_W$</td>
</tr>
</tbody>
</table>

* Behind WP only.
Sensitivity of ARIES-AT COE to Availability and LSA

ARIIES-AT - $1992

COE (mills/kWh) vs. Availability (%)

ARIIES-AT - $2004

COE (mills/kWh) vs. Availability (%)

ARIIES-AT - $1992

COE (mills/kWh) vs. LSA Factor

ARIIES-AT - $2004

COE (mills/kWh) vs. LSA Factor
Sensitivity of COE to Availability and LSA

$2004$

COE (mills/kWh) vs. Availability (%)

AT
LSA=2
CS 9/05
LSA=2

AT
LSA=1
CS 1/06

$2004$

COE (mills/kWh) vs. LSA Factor

CS 1/06
85% Avail

AT
Avail= 80%

AT
Avail= 85%

CS 9/05
85% Avail
Radwaste Volume Comparison
(not compacted, no replacements)
(cryostat and bioshield excluded)

Compared to 8.25 m machine, more compact 7.5 m ARIES-CS and removal of bucking cylinder reduced waste volume by 30%
Future Plan

• Changes to Systems code:
  – 30 $/kg of WC, per Les
  – availability: 80 or 85% ? TBD.

• Provide radial build for LiPb/SiC design to systems code

• Provide radial build for 2 FP configuration to systems code