Final 3-D Neutronics Results

Laila El-Guebaly
Fusion Technology Institute
University of Wisconsin - Madison

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Nuclear Parameters

- 20 cm thick helium cooled i/b shield is optimal for ARIES-ST
- Overall $\text{TBR} = 1.1$ (1 m thick LiPb/FS/SiC/He Blanket, 60% enriched Li)

- Overall $M_n = 1.11$ (excluding heating of TF coil and LT div. shield)
- FW/B End-of-Life Fluence = 18 MWy/m² for FS

- Lifetimes:
  - o/b FW/Blanket/Manifolds: 3 FPY
  - i/b FW/Shield: 3 FPY
  - Div. Plates and Manifolds: 3 FPY
  - Center Post: 6 FPY
  - TF-coil Shell: 40 FPY
  - PF Magnets: 40 FPY
  - Div. HT and LT shields: 40 FPY
W Stabilizing Shells

3(?) FPY

Nuclear Heat Loads to All Components

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\( (P_f = 2859 \text{ MW}, P_n = 2287 \text{ MW}) \)

<table>
<thead>
<tr>
<th>Nuclear Heating (MW)</th>
<th>Inboard</th>
<th>Outboard</th>
<th>Divertor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inboard W Shells</td>
<td>71</td>
<td>----</td>
<td>----</td>
<td>71</td>
</tr>
<tr>
<td>FW or Div. Plates</td>
<td>18</td>
<td>100</td>
<td>42</td>
<td>160</td>
</tr>
<tr>
<td>Blanket</td>
<td>----</td>
<td>1929</td>
<td>----</td>
<td>1929</td>
</tr>
<tr>
<td>Manifolds</td>
<td>----</td>
<td>15</td>
<td>64</td>
<td>79</td>
</tr>
<tr>
<td>Shield</td>
<td>199</td>
<td>----</td>
<td>95</td>
<td>294</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>288</td>
<td>2044</td>
<td>201</td>
<td>2533</td>
</tr>
</tbody>
</table>

\( \Rightarrow M_n = 1.11 \)

| Surface Heating      | 117     | 198      | 345      | 660   |
| Total Thermal Power  | 405     | 2242     | 546      | ~3200 |

Low Grade Heat (MW):

- CP ........................................ 164
- TF-coil Shell (21 in collar + 18 in shell) 39
- Total in TF coil 203
- Div. LT Shield 8
- Total 211 (9% of \( P_n \) or 6% of \( P_{th} \))
Radiation Damage to PF Coils

- PF coils 1,2 are well protected by HT and LT divertor shields
- Outboard blanket and TF-coil shell protect PF coils 3,4,5. One of following options should be considered to satisfy PF magnets radiation limits:
  - 30 cm thick Cu/H₂O (85/15) TF-coil shell
  - 50 cm thick Al/B-H₂O (85/15) TF-coil shell
  - 70 cm thick Al/H₂O (85/15) TF-coil shell
Radiation Streaming Through NBI

- 2 NBI’s were included in 3-D model

- NBI sets on insulator between upper and middle TF-coil shells

- Neutrons streaming through NBI will induce swelling in insulators

- Swelling depends on insulator type and fluence level

- Spinel has high radiation resistance to swelling (compared to BeO, Al₂O₃, MgO)

- \(10^{22}\) n/cm² fast n fluence \((E_n > 0.1\ \text{MeV})\) results in 1% swelling in spinel

- 3-D calculations indicate that fast n flux \((E_n > 0.1\ \text{MeV})\) at insulator is \(5 \times 10^{12}\) n/cm²s, resulting in < 1% swelling at end of plant life (40 FPY). This means spinel will exhibit no significant change in volume and will not cause any stress problem to TF-coil shell.
20 cm Thick He-Cooled Inboard Shield is Optimal for ARIES-ST

- Inboard power losses (and thus COE) minimize near 20 cm thick shield

- Net i/b power losses (in MW\(_{th}\))=

\[ P_{\Omega} / \eta + NH_{\text{CP}} + PP/\eta - [SH + NH_{\text{FW/Shell}} + NH_{\text{shield}} + 0.9 PP ] \]

where
- \( P_{\Omega} \) is CP Joule losses,
- \( \eta \) is thermal conversion efficiency,
- SH is Surface Heating,
- NH is Nuclear Heating,
- PP is He Pumping Power (90\% of PP is recovered as thermal heat)
• Designs with i/b shields thinner than 20 cm will have higher COE (and lower breeding, higher CP damage, shorter CP lifetime, higher Cu radwaste stream, and higher CP decay heat)