OPAL CNS Moderator Performance

Weijian Lu
OPAL CNS Reliability from Commissioning (Nov 2006) to Present

CNS Reliability (%) vs Reactor Cycle No.

CNS Reliability (%)  |  OPAL Reliability (%)
What Happened to CNS Flux?

• In early 2017, neutron users have noticed a significant drop in cold neutron flux ~ -20%
• Possible causes
  – Neutron guides (fault discovered in 2011)
  – Source flux
Heat Load vs Reactor Power

Measured Heat Load on the CNS In-pile by Cryogenic Helium Thermal Balance
Linear fits indicate nuclear heat load (W/MW) by the slope and non-nuclear heat load by the offset (W)

- Liquid Deuterium
- Gas Deuterium
- Linear (Gas Deuterium)
- Linear (Liquid Deuterium)

\[ y = 180.49x + 387.57 \]
\[ R^2 = 0.9999 \]

\[ y = 85.666x + 363.1 \]
\[ R^2 = 0.9988 \]
Sensors had recently been checked

Measured a stable bias of ~1 K subject to slow drift (years), but no evidence for cycle-to-cycle “oscillation”

<table>
<thead>
<tr>
<th>Process Conditions (nominal)</th>
<th>Sensitivity</th>
<th>Typical Operational Variation by Conservative Estimation</th>
<th>Resultant CNS Flux Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium temp. sensor drift</td>
<td>15%/K</td>
<td>~ -1 K</td>
<td>-15%</td>
</tr>
</tbody>
</table>
## CNS Flux Sensitivity (1)

<table>
<thead>
<tr>
<th>Process Conditions (nominal)</th>
<th>Sensitivity</th>
<th>Typical Operational Variation by Conservative Estimation</th>
<th>Resultant CNS Flux Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2O purity (99.5%)</td>
<td>6.66%/%</td>
<td>±0.5%</td>
<td>±3.33%</td>
</tr>
<tr>
<td>D2O temp. (35 °C)</td>
<td>-0.0228%/°C</td>
<td>±1 °C</td>
<td>±0.0228%</td>
</tr>
<tr>
<td>D2O gap between CNS thimble and beam tube (1 mm)</td>
<td>-5.52%/mm</td>
<td>negligible</td>
<td>negligible</td>
</tr>
<tr>
<td>LD2 temp. (24.5 K)</td>
<td>-4.38%/K</td>
<td>±0.5 K</td>
<td>±2.2%</td>
</tr>
<tr>
<td>LD2 ortho/para ratio (3:1)</td>
<td>0.288%/%</td>
<td>Unknown but expected to be small</td>
<td>±1% (order of magnitude estimation)</td>
</tr>
</tbody>
</table>
MCNP Calculation vs Measurement

CNS Gain from 20.5 K to 19.6 K (4 Dec 2016)

Ratio vs Neutron Wavelength

- Green line: BILBY 5-Dec / 3-Dec
- Blue line: MCNP Calc.
<table>
<thead>
<tr>
<th>Process Conditions (nominal)</th>
<th>Sensitivity</th>
<th>Typical Operational Variation by Conservative Estimation</th>
<th>Resultant CNS Flux Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control rod positions (critical positions for the first core)</td>
<td>5.58% between actual configuration and that after 180° rotation</td>
<td>Control rod movement pattern is repeated in every reactor cycle</td>
<td>N/A</td>
</tr>
<tr>
<td>Reactor core (first core and equilibrium core)</td>
<td>4.56% between the two cores</td>
<td>Fuel management strategy</td>
<td>To be assessed further</td>
</tr>
</tbody>
</table>
Fuel Management Programs

- Cell code: CONDOR
- Diffusion code: CITVAP
  - Flux and power density
  - Reactivity
  - Poison transients
  - Adjoint flux
  - Kinetic parameters
Core Power Density – Flux Tilt

- CG1-3 beam tube
- CGA beam tube
- D$_2$ moderator
- D$_2$O moderator

Reactor Core
CNS Heat Load vs Reactor Power

Nuclear Heat Load (normalised to 3.6 kW)
OPAL Thermal Power (normalised to 20 MW)
Flux Tile N-S biased to average
Conclusions

• CNS heat load is an excellent indicator of source flux
• Core configuration can have a significant impact on the CNS flux
• Can be predicted by numerical calculations