3-D Assessment of Neutron Streaming through Inboard Assembly Gaps

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Outline

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Introduction

• Assembly gaps between modules allow increased levels of radiation to reach components
• Radiation streaming through these gaps needs assessment to be sure components are well protected
• Previous Work:
• During operation, gaps will close due to thermal expansion and neutron induced swelling
• Will examine range of gap sizes from no gap to some reasonable maximum gap size
ARIES 3-D Inboard Model

• Basis is ARIES-AT DCLL radial build by El-Guebaly (1/21/2009 presentation)
• MCNPX v27a 3-D Monte Carlo transport code
• FENDL v2.1 cross section library
3-D Model

- 3-D partially homogenized model
- 11.25° sector (1/2 module) (w/ reflecting boundaries)
- Vertical extent 100 cm (w/ reflecting boundaries)
- Uniform volumetric source \( r=460-625 \text{ cm} \)
  - IB NWL = 3.4 MW/m\(^2\)
No gap model

- Sidewalls included
- Manifolds included
Straight gap model

- 1, 2 cm gaps examined
- Gap reaches vacuum vessel

3-D Model
Stepped gap model

- 1, 2 cm gaps
- Double step
- WC block
- Offset 5 cm

3-D Model
No gap—Overall IB flux levels

- Almost 6 orders of magnitude attenuation
- Increased levels behind He manifolds (e.g. WP ~2x)
dpa Shield Front (2 cm gaps)

- Both gaps lead to strong peaking
  - Straight Gap \((\text{gap/nogap})_{\text{max}} = 1.3\)
  - Stepped Gap \((\text{gap/nogap})_{\text{max}} = 1.1\)

All cases exceed the dpa limit so the front part of shield must be replaceable.
dpa Shield Front (1 cm gaps)

- Reduced dpa levels and peaking compared to 2 cm gaps
- Still exceed the limit

All cases exceed the dpa limit so the front part of the shield must be replaceable
He production Manifold Front (2 cm gaps)

- Both gaps lead to very strong peaking
  - Straight Gap (gap/nogap)$_{\text{max}}$ = 30
  - Stepped Gap (gap/nogap)$_{\text{max}}$ = 8

- Stepped gap shifts peak

All cases exceed the He production limit so the front part of the manifold is not reweldable (note: new design requires no manifold on IB)
He production Manifold Front (1 cm gaps)

- Reduced He levels and peaking compared to 2 cm gaps

All cases exceed the He production limit so the front part of the manifold is not reweldable.
He production Vac Vessel Front (2 cm gaps)

- Straight gap leads to very strong peaking
  \[(\text{gap/nogap})_{\text{max}} = 900\]

- Stepped gap not as strong
  \[(\text{gap/nogap})_{\text{max}} = 1.7\]

The stepped gap with WC shield block meets the He production limits so the VV is reweldable.
• Reduced He levels and peaking compared to 2 cm gaps

The stepped gap with WC shield block meets the He production limits so the VV is reweldable
• Smoother peaks due to shielding effect of VV

• Straight gap has significant peaking 
  \[(\text{gap/nogap})_{\text{max}} = 9.5\]

The stepped gap with WC shield block meets the winding pack fast fluence limit
Fast Fluence Winding Pack Front (1 cm gaps)

- Reduced fluence levels and peaking compared with 2 cm gap

The stepped gap with WC shield block meets the winding pack fast fluence limit.
Heating in WC Shield Block (2 cm stepped gap)

Per S. Malang, radiative cooling is feasible if average heating is below 15 W/cm$^3$. 

Peak 16.7 W/cm$^3$

Ave 1.0 W/cm$^3$

Ave 6.2 W/cm$^3$

Ave 3.1 W/cm$^3$
Materials experts need to decide if WC or W can be used as a structural component.
Conclusions

• Straight gaps allow too much radiation to reach components on the IB side for the ARIES-AT DCLL design
• Stepped gaps with WC shield blocks are needed to protect the IB components
• Will need to account for uncertainty in nuclear data
• Safety factor used with 1-D models should be adjusted accordingly