2-D Analysis of Neutron Streaming Through Helium Access Tubes

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ARIES-CS Project Meeting
September 15 – 16, 2005
PPPL
Issues and Concerns

Manifolds reweldability:

- Previous ARIES designs did not require reweldability of manifolds.
- Last February, Malang/Wang indicated a need to cut and reweld manifolds at He and LiPb access tubes. Could ARIES-CS design meet reweldability limit without adding more shield to protect manifolds?

Neutron streaming through He access tubes (32 cm OD):

- Streaming results in Hot spots at VV and magnets. How to fix the problem?
Reference Radial Build
(3 MW/m$^2$ peak $\square$)

**Thickness (cm)**

- **Blanket/Shield Zone**
  - 18 cm

- **Shield Only Zone**
  - @ $D_{\min}$
  - 119 cm

**Dimensions**

- 5 cm
- 18 cm
- 35 cm
- 28 cm
- 2 cm
- 31 cm
- 18 cm

**Materials**

- FW/Blkt/BW
- Zonal Breeding
- SiC Insert
- WC Shield-only or Transition Region

**Layers**

- Plasma
- SOL
- Blanket
- Shield
- Manifolds
- Magnet
- VV
Xn through He Access Tube
(3 MW/m² peak)

**Diagram:**

- **Plasma**
- **SOL**
- **FW/Blkt/BW**
- **5 cm Back Wall**
- **FS Shield**
- **Manifolds**
- **Vacuum Vessel**
- **Gap**
- **Gap + Th. Insulator**
- **FS Shield**
- **Winding Pack**
- **Coil Case & Insulator**
- **External Structure**

**Thickness (cm):**
- **Blanket/Shield Zone**
- **Branding Zone-I**
- **Breeding Zone-II**

**Key Parameters:**
- $D_{min} = 119$ cm
- $D \geq 171$ cm
- $V = 171$ cm
- $FW = 5$ cm
- $5.38$ cm
- $18$ cm
- $35$ cm
- $28$ cm
- $31$ cm
- $18$ cm

**Materials:**
- Blanket
- Shield
- WC Shield-I
- WC Shield-II
- Silicon Carbide (SiC) Insert
- He
- He ACCESS TUBE

**Notes:**
- Transition Region
- He Manifolds
- Magnetic Structure
He access Tubes

<table>
<thead>
<tr>
<th>Design Approach</th>
<th>Port Maintenance</th>
<th>FP Maintenance</th>
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<tbody>
<tr>
<td>Total # of Tubes</td>
<td>206</td>
<td>144</td>
</tr>
<tr>
<td># of Tubes per m*</td>
<td>~ 4</td>
<td>~ 3</td>
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* Toroidal length. Assuming R= 8.25 m.

- Streaming problem encountered in both designs.
- Reported results pertain to port maintenance approach.
Innovative Manifold Design
(S. Malang)

**Old**

Welds moved away from tube surface and protected by 10 cm thick WC ring

**New**
He Production at Manifolds
(2-D results; 3 MW/m² peak)

- He level at welds still exceeds reweldability limit (1 appm).
- Thickening WC ring (> 10 cm) does not help.
- 2-D analysis could overestimate damage
  - perform 3-D analysis for better estimate.

- 4.6 appm @ 40 FPY
- 3.8 appm @ 40 FPY
- 35 appm @ 40 FPY
He Production at Manifolds (Cont.)

Potential solutions:
- Move welds radially out.
  Practical?
- Thicken HT shield by ~ 10 cm
  □ 28 cm shield.
• 18 cm thick shield along with He manifolds protect VV and magnet.

• Radially, He access tube replaces 25 cm of FS/He damage behind He access tubes exceeds limit.

• There are 206 He access tubes (4 He access tubes / toroidal m).

• Other He tubes are needed for divertor.

• 2-D and 3-D analyses needed to address streaming problem as 1-D overestimates damage.
2-D Results
(3 MW/m² peak)

• 20 cm thick local shields (FS/B/FS/He) attached to manifolds behind 206 He access tubes help protect VV and magnet.

• Radius of local shield?
Damage Profile at VV
(2-D results; 20 cm thick local shields, 3 MW/m² peak)

- Poloidal/toroidal damage covers wide range (up to 60 cm radius).
- **Radius** of local shield will be > 16 cm (tube radius). TBD.
- For 25 cm radius, 206 local shields cover ~3% of manifolds’ surface area and amount to 8 m³. Net increase in shield volume is ~ 2%.
He Production at VV @ Tube Centerline
(2-D results; 20 cm thick local shields, 3 MW/m² peak)

The graph shows the peak He production at VV (appm @ 40 FPY) with different configurations:

- **No Tube**: Peak He production is very low.
- **1-D**: A significant increase in peak He production is observed.
- **2-D**: Even higher peak He production compared to 1-D.
- **2-D with 20 cm Local Shield**: The peak He production is reduced compared to 2-D.

The graph also indicates a limit beyond which the production is not shown.
Fluence at Magnet @ Tube Centerline
(2-D results; 20 cm thick local shields, 3 MW/m² peak [ ])
Heating at Magnet @ Tube Centerline
(2-D results; 20 cm thick local shields, 3 MW/m² peak)
Future Plan

• Using 2-D analysis, check effect on reweldability of manifolds due to:
  – Moving welds outward
  – Thickening HT shield by 10 cm.

• Optimize radius of local shield and determine toroidal/poloidal damage profile.

• Perform 3-D analysis for proposed design.
Submitted final papers to:

- **FS&T journal**: Evolution of Clearance Standards and Implications for Radwaste Management of Fusion Power Plants
  L. El-Guebaly, P. Wilson, and D. Paige

- **FED journal**: Managing fusion high level waste – a strategy for burning the long-lived products in fusion devices
  L. El-Guebaly

Potential coatings for Li/V system: nuclear performance and design issues
L. El-Guebaly

**Provided US input for ICFRM-12 manuscript:**
The Feasibility of Recycling and Clearance of Active Materials from a Fusion Power Plant
M. Zucchetti, L. El-Guebaly, R. Forrest, T. Marshall, N. Taylor, K. Tobita