US DCLL TBM Status

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For the U.S. DCLL TBM Team

TBM
Hot cell
Tritium building

Port cell
He loops
Ancillary systems

Interaction with IO

VLT Conference Call, March 17, 2010
US DCLL TBM Team

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R. Kurtz, G. E. Youngblood – PNL
M. Sawan, E. Marriott, P. Wilson, B. Smith – UW
Y. Katoh, A. Lumsdaine – ORNL
D. K. Sze – UCSD
S. Willms – LANL
M. Ulrickson, R. Nygren, D. Youchison – SNL
S. Malang – Consultant, Germany
R. Munipalli, P. Huang – Hypercomp
B. Williams – Ultramet; R. Shinavski – Hypertherm HTC
The US-Selected Dual Coolant (He & PbLi) Lead Lithium (DCLL) TBM concept provides a pathway to high coolant outlet temperature using current generation of structural materials:

- Use of RAF/M steel with He cooling and SiC for flow channel insert (FCI) for thermal and electrical insulation between PbLi and RAF/M steel structure
- Breeder PbLi moves at a slow velocity of < 10 cm/s, leading to Tout @ 700° C and combined gross ηth > 40% with the use of CCGT

**DCLL Evolution:**
- Developed in ARIES-ST US-APEX and in the EU-PPS
- Adopted for ARIES-CS
- Similar concept considered in US-IFE-HAPL program
Recent Actions on ITER TBM

- The ITER TBM program has been formalized by the ITER Council as an important part of ITER and as essential to ITER achieving its objectives.
- A TBM program committee (TBM-PC)* was formed with official participation by the 7 parties.
- TBM-PC reports directly to the ITER Council.
- TBM-PC-1 met March 2009.
- TBM-PC-1 assigned half-port in ITER to test DCLL. The US agreed to serve as “interface coordinator” for this DCLL half-port.

  - US “interface coordinator” function is similar to that of a “concept leader”, but with the understanding that the US does not have the resources at present to fulfill the responsibilities of a concept leader. The US will do only limited effort – often on delayed time schedule, and will seek support from other parties.

*TBM-PC US: Member: J. Hoy
Experts: M. Abdou, M. Hechler, L. Leiken “DOE lawyer”, R. Goldston
The proposed six TBM systems to be installed in ITER in the initial ITER H-operation are the following:

<table>
<thead>
<tr>
<th>Port No. and PM</th>
<th>TBM Concept</th>
<th>TBM Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 (PM : EU)</td>
<td>HCLL (TL : EU)</td>
<td>HCPB (TL : EU)</td>
</tr>
<tr>
<td>18 (PM : JA)</td>
<td>WCCB (TL : JA)</td>
<td>DCLL (InCo : US (KO))*</td>
</tr>
<tr>
<td>2 (PM : CN)</td>
<td>HCCB (TL : CN)</td>
<td>LLCB (TL : IN)</td>
</tr>
</tbody>
</table>

*Interface Coordinator (acting as provisional TBM Leader), PM: Port Master, TL: TBM Leader

HCLL : Helium-cooled Lead Lithium  
HCPB : He-cooled Pebble Beds (Ceramic/Beryllium)  
WCCB : Water-cooled Ceramic Breeder (+Be)  
DCLL : Dual Coolant (He & PbLi) Lead Lithium  
HCCB : He-cooled Ceramic Breeder (+Be)  
LLCB : Lithium-Lead Ceramic Breeder  
(DC type, He & PbLi)
US DCLL TBM Approach, August 2009

• The US serves as interface coordinator (InCo) and will do its best to fulfill this function. In 09 we had good meetings with EU, Japan and Korea.

• The US will need support from other parties with expertise and interest in lead-lithium blanket in developing the interface information for integration in ITER.

• We continue the DCLL TBM design with focus on the last DT module, address critical issues for DEMO and technology and scientific challenges via R&D tasks.

For InCo, the most urgent duties are:

• Interact with IO technically and on interfaces in a timely manner
• Participate in the required integration effort with other ITER systems
• Participate in the review process of all ITER-TBM documents
• Provide information to IO on the corresponding TBM R&D programs
• For the TL and InCo, interact with the corresponding PM to allow the PM to perform his duties.
Immediate Activities and Events

1. Complete the equipment layout of our helium loop equipment in the assigned TBM Tokamak Cooling Water System (TCWS) area
2. Complete the equipment layout of all Ancillary Equipment Unit (AEU) equipment with the new port cell details
3. Complete the design and analysis of all helium pipes from the port cell to the TCWS area
4. Support the maintenance procedure review of different systems
5. Complete the RPrS report (Preliminary Safety Report)
6. Complete the 2010 DDD report

TBM FS impacts meeting will be held in Cadarache on April 13-15.

PMG-18-3 meeting will be held in Cadarache on April 16, with focus on the RPrS details and program up-date
TBM Building and DCLL He Cooling System

TCWS vault annex

VOLUME = 3130 m³
Floor area

8 = 481.5 m²

Top view TCWS area

DCLL
TBM

Port plug

TCWS vault annex

Port cell area

AEU

Tube forest

Port plug

US DCLL TBM
We are working on the He loop details and AEU equipment to fit into available space.

Port Plug & AEU

Two He loops @ TCWS

He pipe routing

AEU backside
# Reviewed PBS-56 ICDs and ISs

<table>
<thead>
<tr>
<th>PBS</th>
<th>Link on IDM</th>
<th>ICD Status</th>
<th>Number of associated ISs</th>
<th>ISs: status and due dates</th>
<th>Comments</th>
</tr>
</thead>
</table>

ICD: ITER control document
IS: Interface document
PBS-56: is the PBS for TBM
Impact of TBM ferromagnetic effects on ITER performance

Experimentally assessed in DIII-D in Nov. 2009
A community meeting is organized for April 13-15, 2010
A presentation will be made at the June VLT conference call

ITER $B_{\phi}$
Mockup $B_{\phi}$ in DIII-D
Main DCLL Related R&D Topics

- MHD flow and heat transfer and mass transfer for liquid metal blankets (UCLA: Smolentsev, Messadek, Morley, Ying; SBIRS: Hypercomp)
- Tritium permeation and recovery (INL: Sharpe, Calderoni; UCLA: Ying)
- Safety analysis and modeling (INL: Merrill, Sharpe)
- FCI material/component development & properties (ORNL: Katoh, PNL: Youngblood; SBIRS: Ultramet, Hypertherm)
- Irradiation effects in RAF/M steels and SiC (Materials program in general)
- Integrated modeling / Virtual TBM (UCLA: Ying, Liu; UW: Sawan, Marriott, Hypercomp)
- Beryllium armor joining to RAF/M steel (UCLA: Ying, Hunt)
- Interfacial phenomena, Compatibility, Corrosion (ORNL: Pint; UCLA: Smolentsev; SBIRS: Ultramet, Hypertherm)
Impact of Buoyancy effects in blanket thermal performance and tritium transport

Investigated by Buhler and others in the EU for impact on HCLL heat and mass transfer

In the DCLL, can be 2-3 times stronger than forced flows. Forced flow: 10 cm/s. Buoyant flow: 25-30 cm/s

In buoyancy-assisted (upward) flows, buoyancy effects may play

- a positive role on FCI peak temperature due to the velocity jet near the “hot” wall, reducing the FCI $\Delta T$
- a negative effect on heat loss from hot PbLi to colder He coolant
- Effect on tritium transport and permeation, FCI compatibility, RAFS compatibility still unknown

Vorticity distribution in the buoyancy-assisted (upward) poloidal flow

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ITER</th>
<th>DEMO OB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ha</td>
<td>6500</td>
<td>12,000</td>
</tr>
<tr>
<td>Re</td>
<td>30,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Gr</td>
<td>$7.0 \times 10^9$</td>
<td>$3.5 \times 10^{12}$</td>
</tr>
</tbody>
</table>

At UCLA experimental facility is used to address fundamental MHD critical areas
Flow Channel Insert (FCI) Material Options

- SiC-fiber/SiC-matrix composites are promising candidates
- Other forms of SiC (porous SiC), such as SiC-Foam are alternatives

![Diagram of CVD SiC Closeout Layers/SiC foam (5X)]

- Conductive pyrocarbon interphase
- Semi-conductive SiC fibers and matrix
- CVD-SiC
- SiC-Foam

[Logos of Oak Ridge National Laboratory and Ultramet, Advanced Materials Solutions]
Tritium Transport Experiments (INL)

Hydrogen isotope solubility in PbLi Eutectic (LLE): Adsorption/desorption system for solubility measurements

Experiment configuration
Jan 24, 2008
- Demonstrated performance with H2
- Minimum admissible steady-state pressure in test section 0.1 Pa
- Maximum evacuation time with 100 l/s change: 15 seconds
- Gas T tested with heating block in air: -250 °C (temp difference = 2 °C)

Preliminary correlation for H2 solubility:
Ks = 2.77e^-7 e^15415/RT
US DCLL TBM Status Summary

We are ready to go

ITER TBM