DCLL Tritium Processing Systems Design and Fabrication Plan and Costing

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Outline

- Tritium Processing Mission/Objectives
  - Scope
- WBS structure
- WBS description
- Costing
- Risk assessment
- Schedule
Mission/Objective (Scope)
Overarching drivers

- Must handle tritium in TBM properly
  - For safety concerns (tritium control)
  - To accurately characterize TBM performance
- In addition TBM will be a unique opportunity
  - To develop and demonstrate tritium extraction concepts
  - To characterize tritium migration
  - To test tritium containment technologies
- Time phasing
  - Non-ITER, non-tritium testing
  - ITER year 1-10 tests
  - ITER year 11-20 tests
  - DEMO
Tritium process overview

- **Tritium control important throughout**
- **Also use as test station**

**Use He to strip T from PbLi**

**He loop**
- Recover tritium from He
- Breeder, T₂, He

**PbLi loop**
- Heat Exchanger
- Dual Coolant Blanket
- Breeder, T₂, He
- T₂/Breeder Separator
- Breeder, T₂

**T₂/Breeder**
- Heat Exchanger
- Permeator
- T₂, He
- To Tritium Plant

**Permeator**
- To Tritium Plant

Avg. T₂ breeding rate: 0.024 sccm

T permeation thru HX tubes
Mission/Objectives

• **Mission**
  – Provide a system to extract tritium from the ITER DCLL TBM. The system must provide adequate tritium control for the safe operation of the DCLL TBM and contribute to characterizing its performance. It should also lay the groundwork for subsequent development and deployment of the DCLL.

• **Objectives**
  – Evaluate tritium extraction options
  – Perform R&D on favorable options
  – Select a final technology set
  – Design
  – Fabricate
  – Test
  – Install
Summary of tritium processing concepts for DCLL-Extraction of tritium from PbLi

- Vacuum permeator with Ta or Nb membrane (bare or coated)
- Vacuum permeator with Pd or Pd alloy membrane
- Vacuum permeator with ferritic steel membrane
- Bubble column
- Vacuum disengager
- Getter
- Use heat exchanger to transfer tritium to He and subsequently separate T from He.
Summary of tritium processing concepts for DCLL-
Extraction of tritium from He

- Vacuum permeator with Pd alloy membrane
- Vacuum permeator with Ta or Nb membrane (bare or coated)
- Oxidation/adsorption of tritium in He at elevated temperatures
- Cryogenic molecular sieve
WBS Structure and Definitions
## WBS Definitions (1/2)

<table>
<thead>
<tr>
<th>WBS Elements</th>
<th>Description</th>
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<tbody>
<tr>
<td>1.8.1.4 Tritium Processing</td>
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<tr>
<td>1.8.1.4.1 Administration</td>
<td>Accounts for managing the tritium processing system project and for project controls including reporting, statusing and scheduling.</td>
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<td>1.8.1.4.2 R&amp;D</td>
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<tr>
<td>1.8.1.4.2.1 Modeling</td>
<td>Modeling is needed to predict tritium processing system performance and perform sensitivity analysis. This will guide both design and R&amp;D.</td>
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<tr>
<td>1.8.1.4.2.2 Tritium extraction from PbLi</td>
<td>A number of methods have been proposed for tritium extraction from PbLi, but little experimental work has been performed. This task will use both process analysis and experiments to determine the best strategy for extraction of tritium from the ITER TBM PbLi.</td>
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<tr>
<td>1.8.1.4.2.3 Tritium extraction from He</td>
<td>A number of methods have previously been used to extract tritium from helium. However, there are some unique challenges associated with this technology for the TBM. Experiments and analysis will be used to determine the best technology.</td>
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<td>1.8.1.4.2.4 Fate of tritium in PbLi</td>
<td>Separation of tritium from PbLi will depend on the physical and chemical properties of this “binary” system. Examples of parameters needed are mass transfer coefficients, chemical speciation and liquid (PbLi side)-solid (tube wall) equilibrium. Experiments and model will be run to determine these parameters.</td>
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## WBS Definitions (2/2)

<table>
<thead>
<tr>
<th>1.8.1.4.3  Engineering</th>
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<tr>
<td>1.8.1.4.3.1  Design</td>
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<tr>
<td><strong>1.8.1.4.3.1.1  Tritium extraction from PbLi</strong></td>
<td>This element will design systems for extracting tritium from PbLi. This may include a bubbler and a vacuum permeator. This must be closely integrated with the heat exchanger and other tritium-permeable surfaces.</td>
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<tr>
<td><strong>1.8.1.4.3.1.2  Tritium extraction from He</strong></td>
<td>This element will design systems for extracting tritium from 1) the “dual-coolant” He stream and 2) the heat exchanger He. Permeators, oxidation/adsorption or other technologies may be used.</td>
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<td><strong>1.8.1.4.3.1.3  System integration</strong></td>
<td>This task will integrate all tritium processing systems as well as interfaces to other systems such as the Tritium Plant, safety systems, TBM diagnostics, control systems, etc.</td>
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<tr>
<td><strong>1.8.1.4.3.2  Title III</strong></td>
<td>This task includes preparation of the RFQ, bid evaluation, awarding contracts, engineering follow of the contracts and factory acceptance testing</td>
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<tr>
<td><strong>1.8.1.4.4  Fabrication/Procurement</strong></td>
<td>It is expected that industry will fabricate the TBM tritium processing system. This task will include manufacturing design (shop drawings), fabrication R&amp;D, purchasing materials, fabrication, quality assurance, documentation, factory testing, purchasing of spares, packaging and delivery.</td>
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<td><strong>1.8.1.4.5  Assembly/Installation</strong></td>
<td>This task will include installation of the tritium processing sub-system as part of the overall TBM; and interconnection with the TBM, the Tritium Plant and with other systems. This also include initial check-out and operation as an installed system.</td>
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</table>
Major hardware deliverables

- One extractor for tritium from PbLi (two?)
- Two extractors for tritium from He
- Three (or four) tritium-compatible vacuum pumping systems
- Gas analysis system?
- Process tritium concentration measurement system
- Collection tank
- Gas addition system (flush gas, exchange gas, oxidation, etc.)
- Secondary containment
- Control strategy/system
- Transducers (pressure, temperature, vacuum, flow, flow control, humidity)
- Valves
- Off-normal controls (e.g. over-pressure protection)
Procurement/Management strategy

• Oversight of Tritium Processing Systems procurement
  – ITER central team is responsible for experimental envelop
  – ITER TBWG is responsible for overall TBM integration and coordination
  – A US ITER TBM body is responsible for coordinating the DCLL experiment

• Performance of Tritium Processing Systems tasks
  – Labs/universities responsible for performing the TBM Tritium Processing system R&D, design, title III (incl testing)
  – Industry responsible for procurement/fabrication
  – ITER and laboratories are responsible for assembly and installation
Proposed procurement package integration organization for ITER TEP
Costing
Costing principles used

• Minimize R&D as much as possible by using ITER-installed equipment as test bed
• For hardware, perform rough scaling from TSTA and other experience
• Detailed cost estimation not possible, since technology choices have not been made
• No major secondary containment costs
• The Tritium Plant and other infrastructure will deal with all exhaust processing, tritium storage, waste handling, etc.
• The costing is not for a skid-mounted integrated system...rather it is for ~3 separate systems (some assembly required)
## Cost Summary

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<tr>
<th>WBS Elements</th>
<th>Cost ($K)</th>
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<td>1.8.1.4.2.3 Tritium extraction from He</td>
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<td>1.8.1.4.2.4 Fate of tritium in PbLi</td>
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<td>Total</td>
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Schedule
Overall ITER schedule (first plasma is not in 2017)
Schedule drivers

• System must be installed and operational in 2015
• Some schedule float is needed
• Modeling is needed to guide R&D
• Tritium extraction from PbLi will be the biggest R&D challenge
• Schedule assumes the installed system can itself (at least to some extent) be used as a test bed (avoids prototyping)
TEP procurement schedule. Note: ITER Tritium Plant is now planning for a 5-year break-in period

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Issue

• Should a substantial testing component be added after fabrication is complete?
Risk
Status of technology

- Tritium extraction system for DCLL never constructed and tested
- Tritium from PbLi
  - Bench-scale tests of bubbler are disappointing
  - Even bench-scale testing of other methods not yet performed
  - Computer modeling of a PbLi vacuum permeator indicates that it might work (based on extrapolation of mass transfer coefficients for benzoic acid and glycerine/water mixtures at room temperature)
- Tritium from He
  - Good bench-scale and prototype results
  - Testing only performed for limited time
  - Need to confirm results at DCLL conditions
Importance of technology for DCLL

• **ITER**
  – The DCLL will not generate a lot of tritium. The average generation rate over the course of a day is \(~0.024\) sccm or \(~34\) cc T/day or \(~0.01\) gm T/day.
  – The value of this tritium to ITER is nil
  – However, tritium can build up in the experiment to levels that may shut the operation down
  – The ITER DCLL TBM will be a unique opportunity to test the necessary tritium processing system under near real conditions

• **Demo and beyond:** A tritium processing system for the DCLL concept is essential
  – Efficient and cost effective
  – Tritium controlled to meet safety requirements
  – Tritium required for operation of machine

• **Conclusion:** Tritium processing needs to work for the ITER DCLL TBM. Currently there is significant risk associated with this system, and a risk mitigation program will be required.
Risk summary

• Risk associated with extraction of tritium from PbLi
  – Technology: High
  – Importance: High

• Risk associated with extraction of tritium from He
  – Technology: Low/moderate
  – Importance: Moderate

• Overall system
  – Technology: Moderate
  – Importance: High
Conclusions

• Initial project information has been collected and estimates made
• Experience from ITER Tritium Plant has been helpful
• All estimates for DCLL are rough at this point