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Flowing Liquid Lithium for the Purpose of Reducing Tritium Inventory Levels in Fusion Energy Reactors

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***Abstract*—A concern for fusion energy production reactors is tritium inventory resident in vacuum vessel enclosures during and after D-T operations. An immediate issue is the radiological safety associated with large quantities of tritium at risk. Additionally, there is an economic concern associated with the cost of tritium, having a current value in excess of $30 K/gram. Lithium has safely been deployed in fusion research reactors with good success. Our concept builds upon existing work, exploiting the ability of lithium to flow in toroidal and poloidal directions. In our deployment configuration, Li is used to bind with tritium deposited on main surfaces within the reactor vacuum vessel and ancillary internal components. Lithium can be used to wet appropriate surfaces within the vacuum vessel for the purpose of removing surface tritium from internal reactor structures, thus making it available for reuse as fuel.**

Keywords—lithium; tritium

I. Introduction

The viability of fusion energy will greatly depend on the ability to operate safely, including the ability to remove, recycle, and reuse fuel. The burn rate of tritium in planned fusion reactors is a fraction to what will be injected into the device. Additionally tritium with a cost in excess of $30 K/gram is a major cost component for fusion energy reactors. In progenitor fusion energy devices such as TFTR and JET it was shown that a large fraction of tritium remained in the vacuum vessel post D-T operations. In both TFTR and JET various methods were employed in an attempt to reclaim tritium that was bound, and co-deposited in vacuum vessel wall surfaces, limiters, and in-vessel components [1]. One method employed for regaining tritium was baking out large parts of the vacuum vessel at temperatures ranging up to 300°C. Although this technique provided some level of reclamation of bound tritium, it also drove surface tritium deeper in the bulk of internal surfaces, thus subjecting the vacuum vessel to internal stresses caused by high bulk temperatures. We propose using flowing liquid lithium (FLiLi) for the purpose of reclaiming tritium resident in the vacuum vessel. Lithium has been used in fusion reactors for the purpose of increasing plasma performance. Our concept takes the current work with Li a step further. In our configuration, Li would be used to wet appropriate surfaces internal to the vacuum vessel and ancillary component surfaces. Lithium would be used to collect non-oxidized tritium, as well as other hydrogen species from surface areas [2]. The lithium would then be allowed to collect in reservoirs at the bottom of the reactor where it would be collected. Collected lithium would then be appropriately processed to remove tritium for future introduction into the fusion fuel cycle. Recovering tritium in this fashion also presents the possibility of eliminating some high temperature (300 C) bake-outs, thereby providing an opportunity for reducing stresses on the vacuum vessel and ancillary components.

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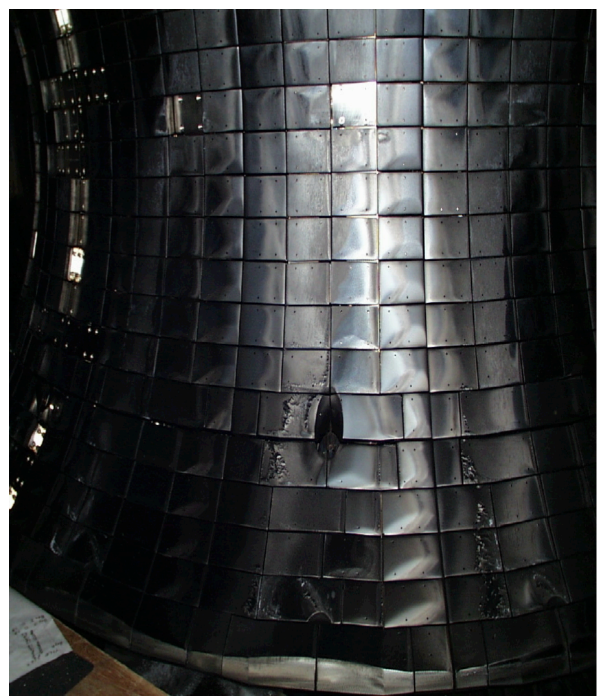


Fig. 1. TFTR Bumper Limiter Post D-T Operations

II. Discussion

Currently work is underway to develop deployable prototypes for flowing lithium under a variety of conditions found inside fusion reactors. During the 2012 HT-7 operational run, a prototypical flowing liquid lithium limiter was successfully deployed in the machine. As a result of this successful deployment, plans are in place for deploying a similar prototype on EAST. Although these deployments are geared mainly toward engineering and operational aspects associated with flowing liquid lithium behavior in magnetic confinement devices, this work lays the groundwork for deploying a flowing liquid lithium limiter for the purpose of attenuating valuable components of fusion fuel resident in vacuum vessel structures.

During the late 1990s and early 2000s a strong effort was undertaking in the U.S. and Europe to address issues associated with deposited and co-deposited tritium remaining in TFTR and JET post D-T operational runs. Various techniques were investigated for the removal of bound tritium resident within vacuum vessel components including glow discharge cleaning (GDC), moist air purges, in-situ and ex-vessel bake-outs. In one case JET tiles were subjected to direct high temperature (greater than 1000C) heating for the purpose of removing tritium from surfaces as well as the removal of tritium from bulk areas.

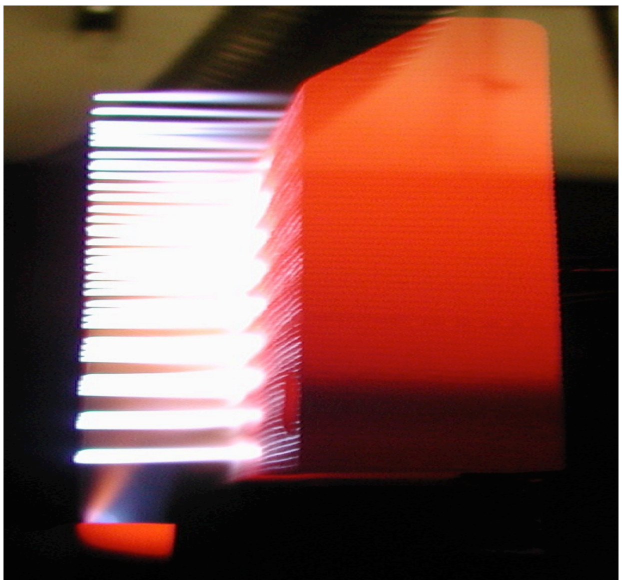
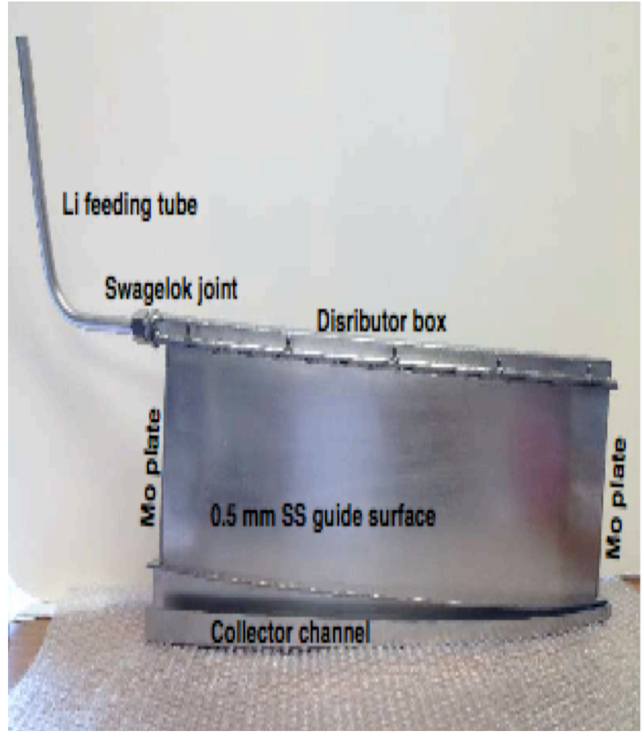


Fig. 2. JET Tile Heated to > 1000C for removal of surface and bound tritium

The use of high temperatures to treat in vessel components for tritium removal is costly, and in some configurations results in tritium being driven deeper into the bulk of vacuum vessel structures. A flowing liquid lithium process provides an opportunity for wetting appropriate surface within the vacuum vessel for the removal of tritium which can be collected and processed in either continuous or batch mode.

III. PATH FORWARD

Currently work is underway at PPPL for developing flowing liquid lithium limiters. The main trust of this work is aimed toward improving plasma performance, but this task also provides the groundwork for developing surfaces that can be wetted with thin films of lithium for the purpose of recovering



unused components of fuel. An upcoming deployment of a next step in this research and development activity is planned for EAST during the Fall/Winter of 2013.

Fig. 3. Operational Proof of Principal Flowing Liquid Lithium Limiter Successfully Deployed at H7-T

IV. CONCLUSION

The development of a working flowing lithium diverter is the first step in demonstrating the feasibility of using flowing lithium in fusion reactors for the purpose of recovering valuable un-burned components of fusion fuel. Employing this getter technology, tritium with a value > $30 K/g can be recovered for reuse. Additionally the reduction of tritium inventory at risk in the vacuum vessel and other internal spaces provides yet another level of safety in an already safe energy producing technology.

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