High-temperature liquid lithium divertor targets and implications for advanced power cycles

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Liquid metal plasma-facing components (LM-PFCs) provide a potential alternative material for fusion experiments and future reactors. Liquid metals in general would separate neutron effects from plasma-material interaction effects, eliminate stress-induced fatigue of the plasma-facing surface, and eliminate net-reshaping of the components due to long-term plasma-transport of eroded material throughout the vessel. Criticism of liquid lithium in a fusion reactor scenario focus on three issues: surface temperature limitations, loss of thermal efficiency due to reduced surface temperatures and tritium retention in the interior of the vessel.

Modeling efforts have found a wide range of temperature limits from 300-450C and experiments on limiter machines have found temperature limits of 550C [1]. Such a range of temperature limits suggests the importance of exploring the question of the operational limits of a liquid lithium divertor target though this has not yet been accomplished on any device. A comparison of a wide range of existing and future fusion experiments and reactors indicates that temperatures between 750-850C will be required to balance target vapor pressures with plasma pressures of future devices.

Experiments have been conducted on the Magnum-PSI linear plasma device [2] to begin an assessment of high-temperature liquid lithium PFCs in a divertor-like plasma environment. The plasmas simulated NSTX divertor conditions during which the target surface reached over 1300C. During exposure, a stable cloud of intense lithium emission is developed directly in front of the target and persists for ~4s. No deleterious effects of the high-temperature lithium exposures were observed upstream indicating confinement of the lithium near the target. These provide an initial viability demonstration for liquid lithium vapor-shielded targets consistent with current cooling technologies that must be integrated into a global power-cycle.

A modified Brayton power-cycle with recompression is compatible with cooling of the LM-PFC by diverting a fraction of the recompressed gas to cool the divertor. Such gas cooling results in surface temperatures above 700C under 10 MW/m^2. The power-cycle implications of a liquid lithium divertor and first-wall reactor is presented.

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