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Progress in the understanding of fuel retention and inventory management in the full-tungsten ITER

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Fuel inventory management in ITER's new baseline is significantly influenced by the transition from beryllium (Be) to tungsten (W) as the first wall material, alongside the implementation of a diborane Glow Discharge Conditioning (GDC) boronization system. Boron (B) replaces the gettering function of Be, aiming to lower impurity influx and mitigate risks associated with achieving $Q = 10$. The primary factor driving tritium (T) inventory buildup in the re-baseline is retention in B deposits. This talk discusses the analysis conducted to define the ITER fuel recovery strategy, with a focus on hydrogen retention, B layer dynamics, and fuel removal methods.

A recent review of hydrogen retention in laboratory B layers has been extended with magnetron sputtered layer results, confirming that ITER's conservative inventory estimate (0.5 H,D,T/B) remains valid. Updated WallDYN3D simulations of B layer erosion and migration with improved description of thin layers confirm that boronization cycles in ITER last up to two weeks, with the possibility of longer intervals being feasible. Strong deposition is initially observed at the divertor baffles where up to 2.8 microns of B accumulate per boronization cycle.

Baking at temperatures up to 240°C, applied between campaigns, is ineffective for thick B layers (>10 microns) which accumulate through multiple boronization cycles. Tokamak plasmas with Raised Inner Strike Points (RISP) are effective in recovering fuel from thin layers on the inner divertor target due to strong heating by plasma, and can be applied before a new boronization layer is deposited. Ion Cyclotron Wall Conditioning (ICWC) depletes T from the near-surface layers of both W and B (~100 nm) within a pulse sequence of ~20 minutes at a 15% duty cycle. ICWC effectively controls the T content in subsequent tokamak plasmas and is planned to be applied in combination with RISP plasmas to minimize redeposition during RISP pulses.

T permeation to the water coolant loops occurs predominantly during baking periods. Whilst it is low through W PFCs unless they are exposed to very high temperatures, significant permeation can occur through stainless steel 316L. A parametric study on plasma-driven permeation in ITER-like conditions, including different material parameters, baking conditions and barrier coatings is being undertaken to improve understanding of means to mitigate permeation risks in ITER.

The Hydrogen Inventory Simulations for PFCs (HISP) tool is being developed to evaluate the dynamic T inventory alongside fuel removal strategies, comparing different scenarios using RISP, ICWC, GDC, and baking. First results suggest that an inventory reduction of up to 70-80% may be achievable compared to the estimated worst case fuel retention scenario in the absence of any active fuel recovery strategy.