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High Fidelity Simulation of Crud Deposition on a PWR Fuel Cell with Spacer Grids over a 500 Day Depletion Cycle

The operational issues that arise due to crud build-up on PWR fuel pins include crud induced power shift (CIPS) and crud induced localized corrosion (CILC). These phenomena lead to reduced operating margin and compromised fuel rods. The work presented here develops a framework for the high fidelity simulation of crud deposition. This framework includes the three primary physics of neutronics (DeCART), thermal-hydraulics (STAR-CCM+), and coolant and crud chemistry (MAMBA), and the prominent feedback mechanisms between each of the physics. A fully coupled simulation of a single pressurized water reactor fuel pin cell with 365 cm of 2.9 wt% enriched UO_2fuel was performed over a cycle length of 500 days. The fully-coupled simulation recreated the classic "striped" crud pattern often seen on pulled fuel rods where heavy crud deposition has occurred. It is concluded that this striping is caused by the flow swirl induced by spacer grid mixing vanes. The flow swirl yields large azimuthal temperature variation, which impact the location where crud deposits. On the other hand, the flow swirl is correlated to increased shear stress along the cladding surface and subsequent erosion of the crud layer. The CIPS condition of the core is concluded to be controlled by competing effects of displacement of coolant boron due to crud layer growth and lithium tetraborate precipitation. This precipitation occurs when soluble boron and lithium species reach their solubility limit within the regions of the crud where localized subcooled nucleate boiling has occurred. As a result, solid lithium tetraborate precipitates out of solution and deposits as a solid in regions where this threshold has been exceeded. A localized reduction in core power occurs due to the high absorption cross section of boron-10.