Transforming Microreactor Economics Through Hydride Moderator Enabled Neutron Economy

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ABSTRACT:

In this research program, we use neutron economy as a core materials selection criterion to advance entrained hydride composite moderators and reflectors with the primary goal of significantly reducing fuel costs by exploiting the enhanced moderating power of these materials. Our team will explore two hydrides as the entrained moderating phase of the composites – ZrH_x and YH_x – and address knowledge gaps related to the optimal hydride loading configuration, stability of the entrained hydrides, scaling of the manufacturing process for economic production of moderator inserts, and designs for future reactor platforms that capitalize on their large moderating power for enhancing microreactor economics. Nested reactor physics calculations and composite design efforts will focus on optimized hydride loading in an annular spherical core design, which represents a favorable geometry for minimizing neutron leakage, critical size, and high assay low-enriched uranium (HALEU) requirements. The issue of hydrogen retention – a critical unknown for these materials – will be addressed in this project through synergistic experiments and modeling of hydrogen migration within the MgO structural matrix of the composite. By informing the BISON code with experimentally validated models, we will analyze the core neutronic impact of hydrogen transport and redistribution under projected steady-state and thermal transient conditions. The hydrogen diffusion models and neutronics simulations will guide the selection of encapsulating diffusion barriers to stabilize the hydride entrained composites for continuous operation at 800 °C and thermal transients up to 1000 °C. Major deliverables established for the proposed research include: (i) fabrication of crack-free (ZrH_x/YH_x)-MgO composites with optimized hydride loading and stability of encapsulated compacts demonstrated up to 1000 °C, (ii) optimized point designs based on the annular spherical core model optimized for entrained hydride composite moderators and reflectors, (iii) scaled fabrication of hydride entrained MgO composites with a minimum diameter of 10 cm and spatially indexed property measurements, and (iv) hydrogen migration model for MgO parameterized within BISON and validated using diffusion data from Static Gas Absorption and Permeation experiments conducted by the Idaho National Laboratory. The deliverables from the core neutronics and manufacturing studies combined with entrained hydride stability and transport measurements will ultimately be used in achieving the final project deliverable – a report on the economic viability, trade-off costs, and overall projected cost of electricity for hydride entrained composite moderated and reflected spherical microreactor designs. With the ability to manufacture the proposed ceramic composites, economic benefits from reduced core uranium loading enabled by their enhanced neutron economy can be realized – and they will be demonstrated through this project to be significant.