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Fusion Prototypic Neutron Source Risk Reduction Activity

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In response to a U.S. Department of Energy (DOE), Office of Fusion Energy Sciences (FES) request for information in 2023, sixteen different concepts were submitted by the community for consideration as a fusion prototypic neutron source (FPNS). The proposed concepts vary greatly in approach, maturity, and the degree to which they accurately mimic a fusion energy system environment. To gain a better understanding of the proposed concepts, an FPNS risk reduction activity was initiated with representation from across the U.S. fusion community. The goal of the assembled team is to provide a consistent, objective, and unbiased approach to understanding and articulating the risks and benefits of different concept approaches to an FPNS. The assessment of each concept is broken into three topical areas: 1) the ability to mimic a fusion energy environment, 2) the ability to meet the performance requirements, and 3) the overall system maturity.

The approaches to estimating system maturity, performance, and ability to mimic fusion conditions will be discussed. In the case of system maturity and performance, input from the concept proposers was critical to the effort which was then expanded upon by the FPNS risk reduction team. The ability to replicate fusion conditions was assessed first for the deuteron–lithium (D-Li) stripping concept in relation to existing reference fusion concepts such as ITER and DEMO. The methodology employed to that effect was designed to bridge neutronics with irradiation-induced microstructural transformations, using a combination of neutron transport calculations, molecular dynamics (MD) simulations, chemical inventory evolution calculations, and computational thermodynamics. This methodology represents the most advanced approach to assess fusion materials evolution under irradiation to date.

The risk/benefit analysis process begins with determining the neutron spectrum and the recoil energy distributions in each material. This is followed by large scale MD simulations of high-energy displacement cascades in the range of energies dictated by the recoil distributions. Next, gaseous and solid transmutant production rates are quantified for each concept, with the resulting information being used to perform a thermodynamic analysis of emerging phases during fusion operation. We have focused on the primary fusion structural material candidates, namely silicon carbide, reduced activation ferritic martensitic steels, vanadium-based alloys, and tungsten. The impacts of these results on other international facilities using D-Li stripping sources is also considered.

The result of the FPNS Risk Reduction Activity was a report to DOE FES. This presentation will summarize the main conclusions from the report. Follow on activities have included the exploration of an integrated blanket and fuel cycle facility.

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