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Zirconium Scattering Sensitivity in Neutron Transport Calculations of Multiplying Systems

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The ability for neutron transport methods to correctly represent the behavior of physical systems is directly related to the accuracy of the evaluated nuclear data. Most legacy differential and integral nuclear data measurements of high importance nuclei studied the total and radiative neutron capture cross sections to solve the neutron diffusion equation. Modern computational resources however make solving the neutron transport equation using Monte-Carlo methods feasible and are employed in MCNP, Serpent, and OpenMC. Contrary to the diffusion equation, the neutron transport equation is heavily dependent on the double differential scattering cross section of a given nuclei. Zirconium's (Zr) presence in the nuclear industry, as fuel rod cladding or a reflector, was used to study the impact of perturbations to the double differential scattering cross sections when predicting the time independent eigenvalue of a multiplying system using MCNP6. Manual perturbations to the double differential elastic and inelastic scattering cross sections and radiative neutron capture cross sections using ENDF/B-VIII.0, JEFF-3.3, and JENDL-5.0 nuclear data were performed for stable Zr isotopes in a suite of accepted integral nuclear data experiments from the International Handbook of Evaluated Criticality Safety Benchmark Experiments (ICSBEP). System Keff values were observed to be most sensitive to the double differential elastic scattering cross section of 90Zr, 92Zr, and 94Zr in energy range of 100 keV to 5 MeV. Predicted system Keff values for ICSBEP cases were observed to differ by up to 700 PCM between the JEFF-3.3, JENDL5.0, and ENDF/B-VIII.0 evaluations with over 500 PCM contributions to ΔKeff attributable to differences in the double differential elastic scattering cross sections. The contribution of the elastic scattering angular distributions to the observed 500 PCM difference was higher than that of the differential elastic scattering cross section for all cases. Differences in the differential inelastic scattering cross sections of these isotopes also contributed over 100 PCM to the observed ΔKeff of 700 PCM in certain cases. In addition, disagreements were observed between these evaluated nuclear data libraries and high energy quasi-differential neutron scattering measurements of elemental Zr performed at Rensselaer Polytechnic Institute (RPI). These findings were identified by the Nuclear Criticality Safety Program (DOE-NCSP) as a criticality safety issue and an integral measurement campaign (IER:516 ZTA) was funded to create more highly sensitive critical systems to validate current and future evaluated Zr nuclear data. Preliminary design efforts for the experiments emphasized the importance of the Zr scattering reactions by creating more sensitive systems. System Keff values predicted for certain configurations using different evaluated nuclear data for the double differential elastic scattering cross section were observed to differ by over 5000 PCM. Ultimately, new measurements of the double differential elastic and inelastic scattering cross sections of the 90Zr, 92Zr, and 94Zr isotopes in the energy range of 500 keV to 5 MeV are recommended to compliment the current integral measurement campaign to enhance future Zr evaluations.

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