Analysis of SCALE Criticality and Sensitivity Calculations for Reflected HEU Cylinders

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The SCALE code package offers several nuclear data libraries to support Monte Carlo (MC) transport, as well as MC-based derivation of k_{eff} sensitivity and uncertainty (S/U) data. The CSAS sequence using the KENO MC code can utilize continuous-energy (CE) cross sections, or pre-generated multigroup (MG) cross section libraries. The use of MG libraries introduces bias into calculations in exchange for faster transport solutions. The TSUNAMI-3D sequence also utilizes KENO MC calculations. TSUNAMI-3D has two CE calculational methods: the Iterated Fission Probability (IFP) method, and the Contribution-Linked eigenvalue sensitivity/Uncertainty estimation via Tracklength importance CHaracterization (CLUTCH) method. Previous work has shown poor agreement between CLUTCH and confirmatory direct perturbation calculations in specific applications, e.g., fissionable and polyethylene reflectors.

The HEU-MET-FAST-084 ICSBEP evaluation consists of 27 cylindrical HEU metal cores with a set of 14 unique materials used as reflector in 0.5- and 1-inch thicknesses. Included in this list of reflector materials are natural uranium and polyethylene. This work utilized SCALE 6.2.4 models of the HMF-084 evaluation, with additional non-physical configurations to test both the MG bias and CLUTCH functionality across a variety of reflector materials. The base case, in either its 0.5- or 1-inch configuration, was reproduced such that the reflector thickness varied from 0.5-, 1-, 2-, 4-, and 8-inch thicknesses. These models were run with ENDF/B-VII.1 CE cross sections, then the 252-group general purpose MG library, and finally the 302-group fast reactor MG library available in SCALE 6.3b16. Because of the evaluation's use of concentric cylinders, the geometry allowed for additional testing of several multigroup self-shielding methods: infinite homogenous, 1D cylindrical (using cylinder radius), and spherical (using a volume equivalent spherical radius). These configurations were converted to IFP and CLUTCH inputs for S/U calculations.

The results indicated that the use of polyethylene reflectors with CLUTCH is not fundamentally impossible, but sensitive to geometry. The poor performance of CLUTCH with fissionable reflectors, however, was reaffirmed. The 2-inch and greater polyethylene-reflected calculations demonstrate the necessity of using the 302-group library only for fast spectrum systems. The nickel multigroup bias was also substantial, as discussed in a companion paper, as were cobalt and iron. Evidence was also produced that showed a trend in bias of the 252-group library with increasing reflector thickness as a result of neutron energy spectrum softening relative to CE calculations.