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Identify Technical Challenges in Safeguards Measurements of Advanced Small Modular Reactor Fuel Elements

Advanced small modular reactor (SMR) designs use various nuclear fuel element types that can be significantly different than conventional light water reactor (LWR) fuels, including differences in size, composition, and chemical form (e.g., oxide, carbide, metallic). Nearly all the proposed advanced fuels use high-assay low-enriched uranium (HALEU), which can have much higher enrichments than those of LWR fuels (currently limited to < 5 wt.% ^{235}U). The overarching goal of this work is to identify the potential technical challenges in safeguards verification measurements of these advanced fuel elements. This paper focuses on using modeling and simulation to assess (1) the performance of the existing instruments that are commonly used for safeguards measurements of advanced fuel elements, (2) how such performance for advanced fuel elements differs from that for LWR fuel elements, and (3) the potential challenges of using the existing instruments in meeting technical safeguards objectives for the advanced fuel elements. This paper will first present simulation results of safeguards measurements of select fresh advanced fuel elements (e.g., pebble, prismatic fuel bundle, and metal fuel bundle) using commonly-applied safeguards instruments including a high-purity germanium (HPGe) gamma detector, Uranium Neutron Coincidence Collar (UNCL) –II, and Fast Neutron Collar (FNCL). Results will also be presented for irradiated advanced fuel elements using a fork detector, which has been a primary instrument for spent fuel safeguards measurements. The performance of these instruments for advanced fuel elements are then compared with that of LWR fuel elements and the potential safeguards challenges of the advanced fuel elements are summarized and discussed. Such findings are expected to be useful to the safeguards community and the SMR developers as new or alternative safeguards technologies can take a long time to develop and mature.

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