Assay uncertainty comparison between thermal and fast neutron detection systems for nuclear material accountancy

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Neutron detection is a widely used non-destructive assay (NDA) method in nuclear material accountancy (NMA) for nuclear safeguards purposes. Conventionally He-3 gas proportional counter has been used to detect thermal neutrons as one of the representative neutron detectors with its high detection efficiency. Thermal neutrons can be measured by detecting neutron capture reactions in He-3, and coincidence counting algorithm is usually applied to the measurement system. Coincidence counting makes possible to detect fission-correlated neutrons with respect to fissionable nuclear materials. Thus, higher reliability of measurement results can be achieved compared to normal total counting method. However, the conventional system became economically limited because demand of He-3 raised with interest in global nuclear security issues. Furthermore, the thermal neutron detection system showed difficulty to satisfy sufficient assay uncertainty where large nuclear material samples is needed to be measured. This is because contribution of assay uncertainty stemmed from accidental counts during coincidence gate width became dominant compared to statistical uncertainty. To this end development of substitutive technique for the thermal system is urged. Fast neutron detection based on detecting proton recoil in organic scintillation detectors is considered as a possible approach. In this study, ASNC (ACP-Safeguards Neutron Counter), a conventional thermal system developed by KAERI in 2017, and fast neutron detection assemblies are compared in terms of relative assay uncertainty through Monte Carlo codes, MCNP6 and Geant4. Coincidence counting algorithm was coded and applied to compare assay uncertainty of reals rate for two fissionable nuclides, Cm-244 and Pu-240. Assay uncertainty was estimated according to the number of organic plastic scintillators, sample mass and assay time. Calculated assay uncertainties of the assemblies for the fast system were compared to ASNC, and cross-over points of sample mass where the precision of fast system surpasses ASNC were investigated with accordance to detection efficiency of the fast system. Through this study, it was verified fast neutron detection system is qualified as a substitutive for the conventional thermal system, even though much lower detection efficiency is shown. In addition, the fast system can achieve sufficient assay uncertainty, especially for larger mass of fissionable samples as an advanced NDA technique for NMA with shorter measurement time and lower cost. Finally, the results will be useful when new fast neutron detector assemblies are designed for specific applications.