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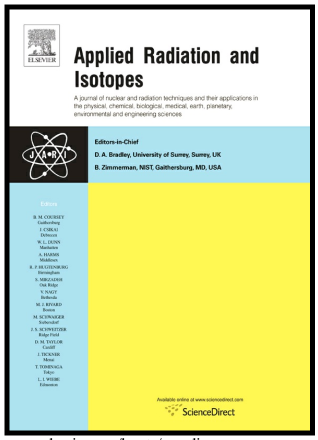

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Simulation Study on Neutron Multiplicity of Plutonium Based on Liquid Scintillation Detector

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Abstract: Fast neutron multiplicity counting (FNMC) is a new method of non-destructive analysis for nuclear materials. Using fast neutron detector array to detect the neutrons emitted from a sample, it obtains measurements according to the multiple counting method and analyzes the mass of plutonium in the sample. In this paper, A FNMC measuring device model has been constructed for simulation study in reference to the most advanced FNMC experimental device in the world. A series of typical plutonium sample models, including samples of plutonium metal and samples of plutonium oxide with different isotopic abundance and in different mass, have been designed. The correctness of the newly established fast neutron multiplicity measuring equation and the necessity of modifying the classical measuring equation have been verified by the computer simulated measurements. Compared with the calculation result from the equation developed in this paper and the calculation result from the classical NMC model, the simulated result shows that the new method is better than the classic method in result deviation.

Key words: Fast neutron multiplicity counting (FNMC)，Geant4 simulation，liquid scintillation detector

As an important non-destructive assay (Non-Destructive Assay, NDA), the Neutron Multiplicity Counting (NMC(Baeten, 1999; Ensslin et al., 2007; Ferrer et al., 2007; Langner et al., 1998)analytical technique, which is based on the feature that the plutonium emits 0 to 8 neutrons simultaneously in the fission process, is one of the major techniques used in accountancy and quality and attribute authentication of nuclear materials. Under the basic assumption of "point model", a quantitative relationship between the three measured parameters--the total neutron count rate (Singles, S), double coincidence neutron counting rate (Doubles, D) and three coincidence neutron counting rate (Triples, T)--and spontaneous fission rate F, self-propagation coefficient M and (α, n) reaction rate was established to conduct quantitative analysis for the quality of nuclear materials. The NMC measurement usually employs a well-type measuring device based on ^{3}He proportional counter. The samples are placed in the well-type device, the detection efficiency of the whole device can be more than 50%; moreover, the NMC measuring device often has been optimized, its detection efficiency has a good agreement for neutron of different energies and sample's spatial positions. It provides high measurement accuracy for the plutonium samples. In 1990s, the classical NMC measurement technology was mature, nowadays, it has been widely used in areas such as nuclear material accounting, verification and confirmatory measurements; the inspection of excessive nuclear weapon materials; and the international nuclear safeguards and nuclear arms control verification etc.

However, the NMC based on ^{3}He measurement technology also has two inherent disadvantages. First, most of fission neutrons are fast neutrons while the ^{3}He proportional counter is only sensitive to thermal neutrons, in order to achieve high detection efficiency, it is necessary to moderate fast neutron to thermal neutron before measurement, but in the meantime, the time information of the measured neutrons are contaminated seriously and the energy information are lost completely. In addition, for the coincidence gate are expanded due to the moderation of the fission neutrons, and that in turn will cause bigger statistical error when sampling material with higher fission rate or more (α, n) neutrons. Second, the current supply shortage of ^{3}He(Bentz et al., 2010; Shea and Morgan, 2010). Prior to that, as a byproduct of the Russian and US nuclear arsenals to maintain tritium