Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Preliminary Experimental Results of an Active Neutron Counter for Fissile Contents in the Uranium Oxide Powder

Seong Kyu Ahn*, Tae-Hoon Lee, Hee-Sung Shin and Ho-Dong Kim
Korea Atomic Energy Research Institute, 1045 Daedeokdaero, Yuseong-gu, Daejeon 305-353, Korea
**Corresponding author: skahn76@kaeri.re.kr*

1. Introduction

An active neutron counting method is one of the possible approaches to measure fissile material, in which a neutron interrogation source is adapted for induced fissions from fissile materials [1]. A well-type passive neutron counter could be used in an active-mode by adding an interrogation source as an external source.

Korea Atomic Energy Research Institute (KAERI) had developed several neutron coincidence counters for the safeguards of spent fuel management technologies [2] [3]. And these technologies and experiences have been being applied to develop a safeguards system for the pyroprocess of spent fuels. In the process, it is necessary to assay the recovered uranium from the electro-refining process. There is also some possibility of including some other unwanted material, which disturbs the active coincidence counting method for uranium. It means we may need more than a single non-destructive assay method, for example both a passive and an active neutron coincidence counting method. One method would use a neutron generator as an interrogation source. The major advantage of using a neutron generator is the ability to control the emission of neutrons. Therefore, it is easy to assay in a passive and also in an active mode for a single sample loading.

Previous study introduced an active mode operation using a passive neutron counter and the simulation results for moderator modification [4]. In this study, consequent preliminary experimental results of an active neutron coincidence counting for the fissile contents in the uranium sample using a neutron generator and a ^{252}Cf source have been described and discussed. The results could be applied to determine the possibility and necessary modification for an active-mode operation of a developed neutron counter.

2. Methods and Results

In this section, the neutron counter and sample material used in the experiments are described. The experimental results are discussed for several important aspects with regard to an active-mode operation.

2.1 Experimental Setup

The neutron counter consists of 16 ^{3}He tubes, appropriate polyethylene moderators and an external neutron source. The applied high voltage on the tubes was 1680V and the pre-delay and gate widths were 4.5 μs and 64 μs respectively. Four natural, one depleted and 3 low enriched (2.67 wt%) uranium oxide power samples with a density of 2.9 g/cm^{3} were prepared for the experiment. Each sample powder was contained in a aluminum container with a thickness of 2 mm.

Based on the simulation results [5] and a practical consideration of the geometry, we prepared a 2.4 cm-thick polyethylene side-moderator wrapped around a neutron generator tube and a 15 cm-thick bottom-moderator. With these side- and bottom moderators, the measured die away time is 88 μs. There is a 20 cm-high fixed sample location space in the center of the cavity between the bottom moderator and the neutron generator. For the measurements of the 2.5 - 3.5 kg range of uranium oxide, two samples were stacked vertically. The intensity of the neutrons from the neutron generator was 3.34 x 10^{5} n/s, and 5,200 n/s from the ^{252}Cf source. Counting time was 1,200 seconds for each measurement.

2.2 Experimental Results

The experiments using the neutron generator showed measured active-background coincident rate of 5.0 ± 9.6 cps. Every measured rate is corrected by a background rejection value. As shown in Figure 1, the coincident rate increase as the mass of ^{235}U and its average coincident events rate per unit mass is 2.64 cps/g-^{235}U in the range of 0.5 - 3.5 kg natural uranium oxide (up to 21.7 g of ^{235}U). Each measured rate has around a 10 cps count error in its coincidence rate and it results in an error of 13.8 cps for the background subtracted coincidence rate. This relatively high error is caused by background error. The electrical deviation of the neutron generator power may be one of the reasons for this. And the long die-away time may be another source of the increasing background of the accidental coincidences [6]. It is also noted that the error is significantly higher for a small amount of fissile material [7] as in the case of this study.

In case of using ^{252}Cf neutron source, the error was 6% to 10% for 15 ~ 30 g-^{235}U, 5.2% for 67.2 g-^{235}U, and 3.86% for 100.8 g-^{235}U, as shown in the Figure 2 and Figure 3. The standard deviation of each measurement is much smaller than the case of using the neutron generator.

Non-linearity between the mass and coincidence rate is caused by a change of the distance from the sample to the neutron generator. Because the distance is shorter for a larger sample (due to vertical stacking) than a smaller one, more interrogation neutrons can reach a sample and the induced fission neutrons per unit mass will be increased as shown in Figure 1. It should be noted that stacking of three samples made the distance larger than other situation and resulted lower counting rate as shown in far right point in Figure 2 and Figure 3.

3. Conclusions

In this study, the preliminary experimental results of an active neutron coincidence counting has been described as a non-destructive assay method for the accounting of nuclear materials in a pyroprocess. Using a previously developed passive neutron coincidence counting system, we modified it, added an interrogation source of a radio-isotope or a neutron generator, and evaluated its performance.

The experimental results showed larger error for the case of neutron generator as an interrogation source than the case of isotope source. The current status of an active counting using a neutron generator has some challenges to overcome and there should be more efforts to reduce the error. If we overcome this challenge and use its advantages, the safeguards techniques for a spent fuel management process will be expanded and have a high confidence by combining with other conventional non-destructive assay methods. More precise experimental setup and tests with higher enriched samples will follow to develop a system to apply to an active measurement for the safeguards of a spent fuel treatment process.

REFERENCES

[1] H. O. Menlove, Description and Operation Manual for the Active Well Coincidence Counter, Los Alamos Scientific Laboratory Report LA-7823-M, 1979

[2] Y. G. Lee, Development of DUPIC Safeguards Neutron Counter, Korea Atomic Energy Research Institute Report KAERI-TR-1381-99, 1999

[3] T. H. Lee, H. O. Menlove, S.-Y. Lee, H.-D. Kim, Deveopment of the ACP safeguards neutron counter for PWR spent fuel rods, Nuclear Instruments and Methods in Physics Research A, V. 589 (1) p. 57, 2008

[4] S.-K. Ahn, T.-H. Lee, H.-S. Shin, H.-D. Kim, Monte Carlo Simulation of an Active Neutron Counter for Fissile Material Accounting, Transactions of the Korean Nuclear Society Spring Meeting, Gyeongju, Korea, 29-30 May 2008

[5] S.-K. Ahn, T.-H. Lee, H.-S. Shin, H.-D. Kim, Modification of a Neutron Counter for an Active-Mode Operation Using a High Energy Interrogation Neutron Source, 2008 International Pyroprocessing Research Conference, Jeju, Korea, 24-27 Aug. 2008

[6] N. Ensslin, W. C. Harker, M. S. Krick, D. G. Langner, M. M. Pickrell, J. E. Stewart, Application Guide to Neutron Multiplicity Counting, Los Alamos Scientific Laboratory Report LA-13422-M, 1998

[7] W. El-Gammal, W. I. Zidan, E. Elhakim, A proposed semi-empirical method for 235U mass calibration of the active-well neutron coincidence counter, Nuclear Instruments and Methods in Physics Research A, Vol. 565 pp. 731-741, 2006

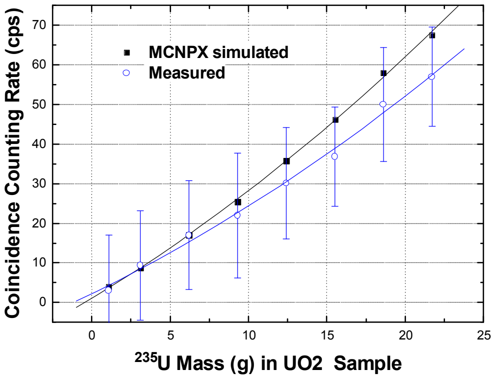

Fig 1. The simulated and measure coincidence count rate for natural uranium oxide power using a neutron generator as an interrogation source.

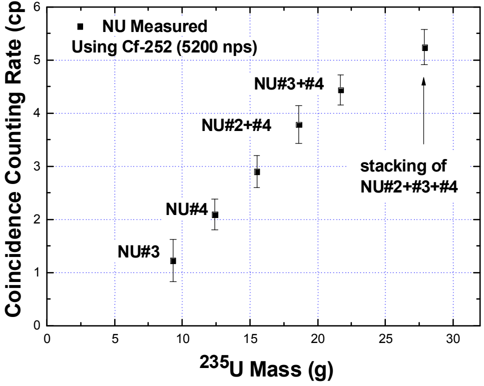

Fig 2. The measure coincidence count rate for natural uranium oxide power using ^{252}Cf as an interrogation source.

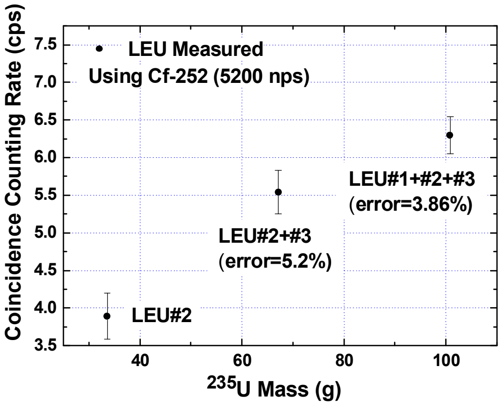

Fig 3. The measure coincidence count rate for low enriched uranium oxide power using ^{252}Cf as an interrogation source.