A New Method for Analyzing Special Nuclear Material in the Differential Die-Away Device

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1. Introduction

Recently, with the increase of serious conflicts between races, religions, and boundaries around the world, even nuclear terror in anywhere becomes a feasible scenario. To prevent the possibility of terrors, SNM (Special Nuclear Material) should be controlled and handled in a recommended procedure by IAEA, and detection and analysis of SNM are one of the important mission in this process.

SNM is hidden or kept in a container using various methods such as solid state, liquid state, powder, or mixture with others. Several passive and/or active techniques are used in detecting SNM depending on different situation. DDA (Differential Die-Away) technique [1] is one of the active method that uses neutron source as a probing tool, and this is applied to detect and analyze SNM, nuclear waste drum and nuclear spent fuel assembly by counting fission neutrons in a short time bin. A schematic diagram of a DDA equipment of spent fuel assembly is shown in Fig. 1. Usually DDA technique is powerful in detecting SNM, but to analyze the nuclides in it other methods should be introduced such as gamma ray spectroscopy or others. Here a new method to analyze SNM with a DDA equipment is suggested.
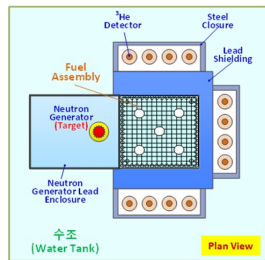

Fig. 1. Schematic diagram of a fuel rod scanner based on DDA technology.

2. Methods and Detection Scenario

2.1 Motivation

Usually ^{232}Th, ^{233}U, ^{235}U, ^{238}U and ^{239}Pu are considered as SNM, and spectrum analysis of gamma ray energies are made to differentiate these nuclides with active or passive method [2, 3]. But these methods need relatively long time in counting to get a useful data for the analysis because of absorption and distortion of the gamma ray energies by the surrounded materials of SNM.

The motivation of this study is to develop a faster and reliable equipment not only to detect SNM but also to analyze the nuclides in an unknown SNM by a DDA based system. The difference of die-away times of the delayed fission gamma-rays from SNM materials during very short time interval just after the end of neutron irradiation is the key to open the way.

2.2 Characteristics of Delayed Fission Gamma Ray

Recently Sandia National Laboratories had published a report [4] on nuclear data for delayed fission gamma-ray characteristics, and Fig. 2 shows the emission rates of delayed gamma-rays from a fission with time for the important SNM such as ^{232}Th, ^{235}U, ^{238}U and ^{239}Pu. The graphs in Fig. 2 show that there are some differences in the time variances of the gamma-ray emission between four nuclides. By using the data tables of fission gamma-ray characteristics of ^{232}Th, ^{235}U, ^{235}U, ^{238}U and ^{239}Pu based on the thermal ENDF fission yield [4], the time characteristics of differential number of gamma-ray in the very early time just after a fission event could be summarized as in Fig. 3. The graph shows that there are clear differences in decay times of the emission rate of delayed gamma-ray from the nuclides. And also Fig. 4 shows the differences of the decay times in a different way by starting the gamma emission from a same calibrated value. In the bases of this idea, the decay time, during about 1 second just from the fission events made by a pulse neutron generator, is measured and compared with the estimated or simulated one, then the nuclide of SNM could be analyzed.
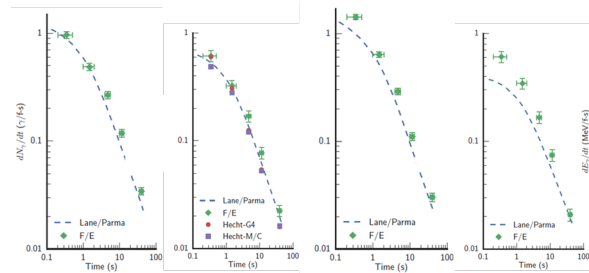

Fig. 2. The emission rates of delayed gamma-ray from a fission with time for ^{232}Th, ^{235}U, ^{238}U and ^{239}Pu [4].
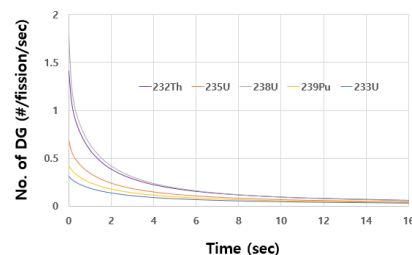

Fig. 3. Time characteristics of differential number of gamma-rays just after an ENDF fission event.
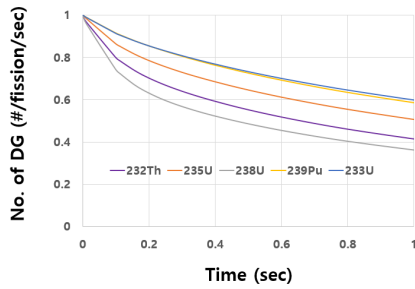
Fig. 4. Time characteristics of the normalized differential number of gamma-rays during 1 second just after an ENDF fission event.

2.3 The Suggested System and Detection Scenario

The suggested system for detection and analysis of SNM with a same machine is shown in Fig. 5. Four sets of ^{3}He tubes surrounded by PE to detect fission neutrons from SNM, one bare ^{3}He tube to measure the flux of a neuron generator, and one photon detector to count the gamma-ray the SNM are arranged in a proper position around the neutron source and target. The same MCS (Multichannel Scaler) system of the standard DDA system to detect SNM could be used in measuring the emission rate of delayed gamma-ray in a short time bin as shown in Fig. 6. The summarized detection scenario in analyzing SNM is as follows;

- Detection of SNM by a DDA scenario
- Start new nuclide analysis scenario if detected
- Pulse neutron generation (~ 1 msec)
- Gamma counting start after DDA time
- MCS counting (~ 1 sec)
- Have enough cooling time
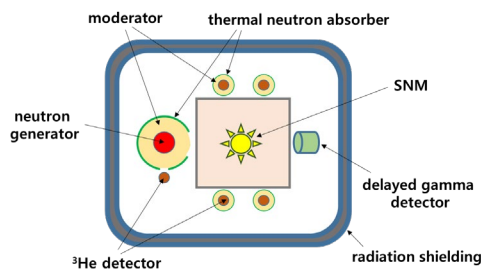- Repeat the above active delayed gamma counting

Fig. 5. Schematics of the suggested system for detection and analysis of SNM in a same machine.

The repeated number of gamma-ray counting and neutron generation would be determined by the resolution of the accumulated data and the amount of specified nuclide in the SNM.

2.4 Future Works

To realize the SNM analysis scenario by counting the delayed gamma-ray in a short time bin with MCS, estimations of optimum operation conditions of neutron radiation time, delay time for counting from the stop of neutron generator, counting time of delayed gamma-rays, counting time bin, and radiation cooling time needed to start next neutron generation are essential to design and operate the system. Some simulation tool or MCNP code will be used for this estimation.
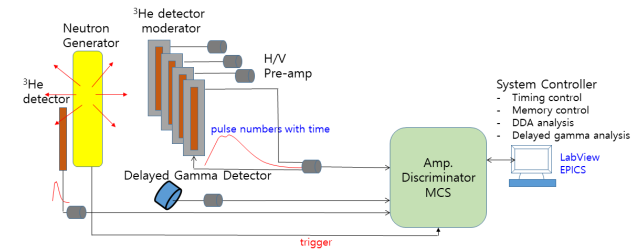

Fig. 6. Circuit diagram of the suggested system.

3. Conclusions

A new method to analyze SNM material such as ^{232}Th, ^{233}U, ^{235}U, ^{238}U and ^{239}Pu by counting delayed gamma-rays during the initial transient time of a fission is suggested. The new method could be realized by adding a fast photon detector system to a standard DDA equipment. Compared with the present one that is using gamma-ray spectrum analysis methods, the new system could make faster results with less efforts and money.

ACKNOWLEGEMENT

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