Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 30-31, 2008

Conceptual Design of SDT Spectrometer for Fissile Assay

YongDeok Lee, Chang-Je Park, Jae Hoon Song and Kee Chan Song

Korea Atomic Energy Research Institute, P.O. Box 105, Yusung, Daejon, Korea 305-600, ydlee@kaeri.re.kr

1. Introduction

A drastic increase in the energy demand is expected by the development of the industries and requests for an improvement of life. The global expansion of nuclear power through an advanced nuclear fuel cycle program is the most suitable option. The energy production by a nuclear power plant satisfies economics and sustainability. Therefore, the facilities on the fuel cycle will be increased in the future. However, by producing the energy using nuclear power plant, an inevitable situation happens in the production of radioactive wastes, called a spent nuclear fuel. Therefore, the management for spent fuel is an urgent problem and issue to be resolved for a safe next generation.

Pyro-processing can be developed to reduce the volume and the radiotoxicity of spent fuels for a permanent storage, to reuse fissionable elements in a spent fuel and to transmute long lived fission products. The pyro-processing involves the conversion of spent oxide fuel to a metallic form. The metallic spent fuel material is treated to produce a uranium and uranium-TRU (transuranic, neptunium, plutonium, and americium) mixture. The uranium-TRU is fabricated for the nuclear fuel for a sodium fast reactor (SFR). Some fission products are involved in the fuel. The plutonium can not be separated in this process, which satisfies a proliferation resistance.

The isotopic fissile assay is very important for a fuel cycle, integrated storage and reuse of a fissile material. Specially, the accuracy of a fissile assay is crucial for a fabricated fuel including TRU using spent fuels for nuclear safety and economy in a nuclear power plant operation. The advanced fissile assay technology will increase the transparence and proliferation resistance of a future nuclear energy system.

There are several non-destructive assay techniques for quantifying the fissile content in a spent fuel: delayed neutron counting, differential die-away, slowing down time spectrometer, neutron resonance absorption, passive multiplicity counting, passive neutron albedo reactivity and x-ray fluorescence[1]. Each methodology has advantages and disadvantages. Spent fuel emits intense gamma rays and neutrons. This intense background is an inevitable environment in the assay of fissile materials. Therefore, the applicable nondestructive assay is to overcome the background and the methodology is restricted for an application. Slowing down time spectrometer (SDTS) has a good feature to analyze the fissile materials isotopically in a near real time without an interference of neutron and gamma rays background from spent fuels[2]. Another advantage of the slowing down time spectrometer is the direct assay of fissile materials.

2. Design of SDT Spectrometer

The development of a practical application for the assay of special nuclear materials was initiated for pyro-process related SFR fuel, storage design of a high level waste and a safety enhanced fuel reloading. Several slowing down mediums were considered. Monte Carlo calculation was used to determine the proper medium, geometry, source position[3]. Fig. 1 shows the neutron property in a graphite and lead medium. Lead has a continuous slowing down feature, however, graphite has more slowing down power as neutron travels further and the total neutrons are accumulated in the thermal energy region. Therefore, lead is a proper medium for a continuous neutron energy slowing down, a low neutron absorption and a relatively good conservation of the energy resolution of a source neutron[4]. The requirements for a assay of fissile materials in a spent fuel are to overcome a large neutron background and to be insensitive to fertile isotopes. One of the challenges using a neutron source is to distinguish the fission signals from the background, spontaneous fission by curium and californium. The source neutron in an evaporation spectrum was adopted. The evaporation spectrum is given by

$$N(E) = c \exp[-E/T], \quad (1)$$

where T is the photonuclear target temperature in MeV and E is the neutron energy.

A broad range of interrogation neutron energies is available with the lead spectrometer. The energy between 100 keV to 0.1 eV is very sensitive to the fissile material fission and a good energy resolution in the fission signatures of the fissile isotopes allows us to distinguish these isotopes from each other. The fission threshold detectors are insensitive to gamma radiation from the irradiated fuel and to interrogation neutrons. The lead also serves as a shield to the intense gamma rays from spent fuels.

Cubical geometry was eventually decided to apply the system to a hot cell application with an easy maintenance

and stability. Fig. 2 shows the interrogation flux for the medium size with the source located at the center. A

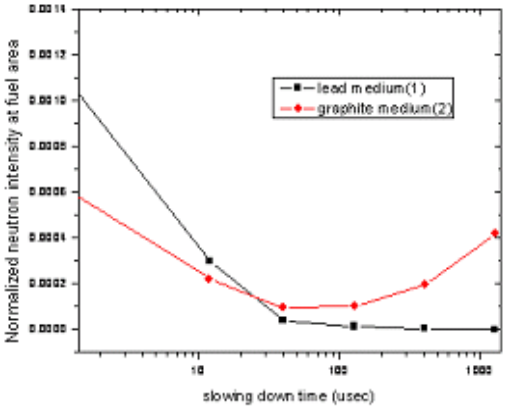

Fig. 1. Neutron slowing down in graphite and lead medium.

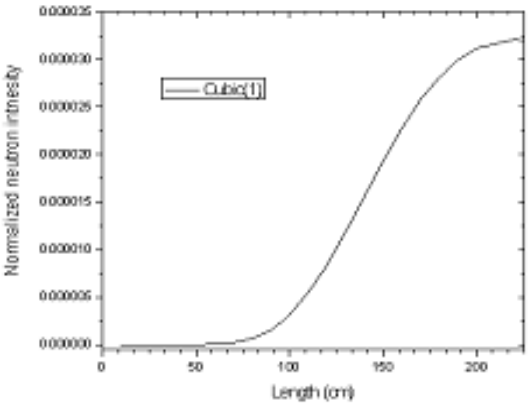

Fig. 2. Interrogation neutron flux as a function of medium size.

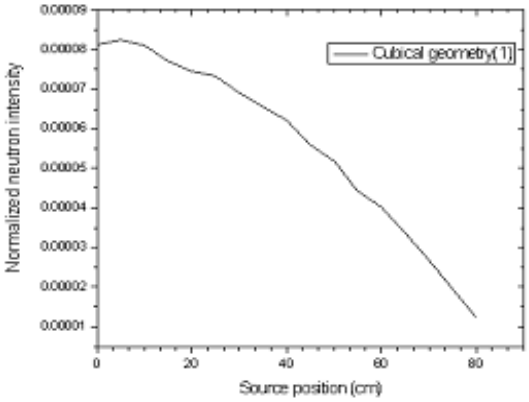

Fig. 3. Neutron intensity as a function of source position.

length of 170cm was selected as a trade-off between the need to reduce the lead mass while still achieving 80.1% of the maximum central flux. The neutron source was moved out from the center to the outside and the intensity at the fuel region was determined as a function of the source position. A 20cm distance between the source and the center of the fuel zone was selected for the source position as it gave ~91.8% of the intensity when the source was located at the center as shown in Fig. 3.

3. Results and Conclusion

The geometry of a lead slowing down time spectrometer was decided with the source position. The neutron source using an electron linear accelerator with a photoneutron target can produce the proper interrogation neutron to overcome the neutron background from the spent fuels. The optimized SDTS assay device reduces the capital cost of the equipment, the operation difficulty and the maintenance problem.

In the fuel assay area, the self shielding effect must be considered because of the presence of a large amount of fissile materials for a SFR fuel. From the sensitivity study, if the number of fuel rods is not greater than 25 rods, a self shielding is not a serious problem in the spectrometer. A further calculation will be performed for an optimum design of the SDTS.

Acknowledgement

This work is performed under the auspices of Korea Ministry of Science and Technology as a long-term R&D project.

REFERENCES

[1] M. E. Abhold et. al., "Survey of Seven Measurement Techniques for Quantifying the Fissile Content of Spent Fuel", ESARDA 29th Annual Meeting, Symposium of Safeguards and Nuclear Material Management, Aix en Provence, May 22-24, 2007.
[2] N. M. Abdurrahman, et. al., "Spent Fuel Assay Performance and Montel Carlo Analysis of Rensselaer Slowing Down Time Spectrometer," Nucl. Sci. & Eng., 115, 279, 1993.
[3] MCNP: A General Monte Carlo Code for Neutron and Photon Transport," LA-7396-M, J. F. Briesmeister, Ed., Los Alamos National Laboratory, 1986.
[4] Yong-Deok Lee et. al., "Design of a Spent Fuel Assay Device Using a Lead Spectrometer," Nucl. Sci. & Eng., 131, 45, 1999.