Isotopic Fissile Assay in Spent Fuel using Lead Slowing Down Technique

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1. Introduction

Recently, nuclear energy is reconsidered to provide a global energy need as a sustainable manner. Nuclear energy is the most feasible option to reduce the carbon dioxide production and global warming as a green energy. Many countries have a plan to construct nuclear power reactors and Korea also has a plan to build more nuclear power plants to supply the necessary energy. Currently, about 40 % of electricity originates from the nuclear power in Korea. However, the inevitable result is the production of high level radioactive waste during the utilization of a nuclear reactor. The nuclear spent fuel emits intense radiation, and some nuclides such as neptunium, plutonium, americium, have a very long half-life, more than thousands of years. Therefore, spent fuel management is a big issue for the current and next generation in Korea.

In 2009, more than 10,000 tones of spent fuel were stored at nuclear power reactor site pools in Korea. Every year, about 700 tones of spent fuel are newly produced. The amount of spent fuels will reach the maximum storage capacity soon. Therefore, various options were considered to manage the amount of spent fuels. An interim storage is being considered and the fuel cycle increasing proliferation resistance is being researched. More accurate fissile material inventory is to be fed back to integrated storage design, transport, management, fuel cycle safety, international transparency and economics.

The lead slowing down technology is being developed at KAERI (Korea Atomic Energy research Institute) for the isotopic fissile material contents analysis in spent fuel and recycled fuel. There are several existing technologies to analyze the fissile contents in the spent fuel[1]. Most of them do not have a capability for the direct isotopic fissile analysis. Some technologies still need the help of burnup codes to induce the fissile content. However, the lead slowing down spectrometer is possible to analyze the isotopic fissile content in the spectrometer without interference of the intense radiation background (neutron and gamma rays) or heat emission. In the spectrometer, U235 and Pu239 and Pu241 contents are analyzed. The accurate U235 and Pu239 and Pu241 contents will give an increased international transparence and credibility for spent fuel management and reutilization.

2. Lead Slowing Down Spectrometer

The spectrometer consists of lead slowing down medium, external neutron source, radiation detector, remote control system and data acquisition and processing system. Because of the neutron background by curium-244, the intense interrogation neutrons are required to induce the prompt fast fission neutrons from U235, Pu239 and Pu241 in spent fuel. Based on the simple calculation, 10^{12} or 10^{13} neutrons per second are necessary to get the proper detection statistics. One section accelerator tube is considered to get the neutrons. The external neutron source slows down in the lead medium. The continuous interrogation neutron energies are obtained and the neutrons finally enter the fuel. The prompt fast fission neutrons with respect to the fission characteristics of fissile materials(U235, Pu239 and Pu241) can be detected at the surrounding neutron detectors. The detected signals have direct relationship to the content of fissile materials.

$$\int_{S_{det}} \int_{E_1}^{E_2} \sigma_f \phi_f (r,E,t) dEdA \quad (1)$$

A broad range of interrogation neutron energies is available in the lead. The energy between 100keV to 0.1eV is very sensitive to distinguish the fissile material fissions. The fission threshold detectors are used for detecting the prompt fast fission neutrons from the fissionable materials. The detector faces the intense gammas from the spent fuel and the neutrons from the external neutron source. The detector must have an ability to distinguish between the prompt fast fission neutron and the neutron from the external source. The lead also serves as a shield to the intense gamma rays from spent fuels.

From the previous calculation[2], the spectrometer geometry and source position was decided. Based on the geometry, several sensitivity calculations were done: fuel position sensitivity, detection sensitivity, detector design, multiplication effect and energy resolution analysis in the lead and the fuel. The energy resolution was conserved in the lead and the fuel area to distinguish the fission signals from the U235, Pu239 and Pu241.

3. Conclusion

The lead slowing down spectrometer has been proposed to analyze the isotopic fissile content for the spent fuel management and the reutilization of recycled fuel. The new technology has good features for the analysis of the content of isotopic fissile materials. The lead slowing down system is the most feasible choice to analyze the fissile contents directly in the spent fuel. The spectrometer geometry was optimized and several sensitivity calculations were done. For the external neutron source, the linear accelerator is selected to produce the proper interrogation neutrons intensity to overcome the background. The threshold fission detector is used for resolving the fission characteristics of each nuclear material. Therefore, the detected fission signals have the direct relationship to each fissile material content.

4. Acknowledgement

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5. References

[1] S. J. Tobin, et al., Determining Plutonium Mass in Spent Fuel with Nondestructive Assay Techniques-Preliminary Modeling Results Emphasizing Integration among Techniques, Global 2009, Paris, Sept. 6-11, 2009.

[2] YongDeok Lee, et al., Development of lsdt spectrometer for nuclear fissile assay, Global2009, September 7-10, 2009.