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LSDS Development for Isotopic Fissile Content Assay

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1. Introduction

Concerning the sustainable energy supply and green house effect, nuclear energy became the most feasible option to meet the energy demand in Korea. However, the production of the spent nuclear fuel is the inevitable situation. Since the first nuclear power plant started to produce the electricity in Korea, the accumulated amount of spent fuels exceeded 10k tomes recently. The accumulation of the spent fuels is the big issue in the society. Therefore, as an option which strengthens the nuclear proliferation resistance and reduces the amount of spent fuels, sodium fast reactor (SFR) program linked with pyro-processing is under development to re-use the PWR spent fuel and produce the energy. In the process, the produced metallic material involves uranium and TRU (transuranic; neptunium, plutonium, and americium). The uranium-TRU is used to fabricate SFR fuel. The burning the recycled fuel in the reactor is to solve the current spent fuel storage problem and to minimize the actinides accumulation having long half-life.

Generally, the spent fuel from PWR has unburned ~1 % U235, produced ~0.5 % plutonium from decay chain, ~3 % fission products, ~ 0.1 % minor actinides (MA) and uranium remainder. About 1.5 % fissile materials still exist in the spent fuel. Therefore, spent fuel is not only waste but energy resource. ㅆ he direct and isotopic fissile content assay is the crucial technology for the spent fuel reuse. Additionally, the fissile content analysis will contribute to the optimum storage design and safe spent fuel management.

Several nondestructive technologies have been developed for the spent fuel assay; gamma ray measurement, passive and active neutron measurements[1]. Spent fuel emits intense gamma rays and neutrons by (α, n) and spontaneous fission. This intense background has the limitation on the direct analysis of fissile materials. Recently, to analyze the individual fissile content, lead slowing down spectrometer (LSDS) has been being developed in Korea Atomic Energy Research Institute(KAERI). LSDS has the feature to analyze the isotopic fissile material contents in a near real time without an interference of neutron and gamma rays background from spent fuels[2,3]. The optimized geometry was setup and several system parameters were calculated for the spectrometer working. Sensitivity calculations were done on the selected geometry. In the paper, the multiplication effect is introduced and the neutron resolution broadening is analyzed in the slowing down medium. The energy resolution is important factor to extract the individual fission signal from the mixture of U235, Pu239 and Pu241. The advanced isotopic fissile assay technology will give an increased international proliferation resistance on the spent fuel re-utilization and management.

2. Lead Slowing Down Spectrometer

The LSDS system consists of lead slowing down medium, interrogation neutron source, radiation detection, data treatment and analysis and remote control system. The optimized LSDS system for a practical application is under development. The external neutron source slows down in the medium and finally enters the fuel. The prompt fast fission neutrons with respect to the fission characteristics of fissile materials can be detected at the surrounding neutron detectors. The detected signals have direct relationship to the content of fissile materials. 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 good choice for detecting the prompt fast fission neutrons from the fissionable materials.

40MeV, 200mA, 500Hz, and 300nsec linear accelerator which approximately produces 1kw power is proper neutron generator and it is equivalent to the neutron intensity, ~10^{12} n's/sec, with Ta target[4]. The source neutron in an evaporation spectrum was adopted, which is given by

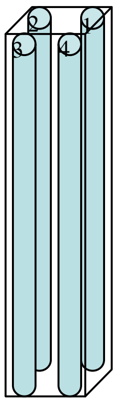
$$N(E) = c \exp[-E/T], \tag{1}$$

where T is the photonuclear target temperature in MeV, E is the neutron energy and c is normalization constant.

Based on the optimized geometry, several sensitivity calculations were done. Table I is the multiplication effect in the adjacent fuel rods, #2 and #3 from the fission neutron occured at fuel rod #1. From the table, the multiplication at the adjacent rods is ~10^{-3}, around MeV neutron energy. Fig. 1 shows the neutron energy resolution at 100keV and 0.28eV in the lead. Pu-239 has the dominant fission characteristic at 0.3eV neutron energy. The resolution value is 0.3 and 0.42 at 100keV and 0.28eV. Therefore, from the figure, the neutron energy resolution is broadened as the interrogation neutron slows down in the lead medium. However, the broadening is not severe not to distinguish the Pu239 from the U235. Therefore, the neutron energy resolution is proper in the assay energy range.

Table I: Fission multiplication in adjacent rods (from rod #1 to rod # 2 and # 3)

Energy (MeV)	Normalized fission neutron	
	At #2 fuel cell	At #3 fuel cell
1.0E-7	0.0	0.0
5.0E-7	4.7E-09	0.0
1.0E-6	2.6E-08	3.1E-08
5.0E-6	1.1E-06	1.0E-06
1.0E-5	1.0E-06	1.0E-06
5.0E-5	6.1E-06	5.8E-06
1.0E-4	4.6E-06	4.3E-06
5.0E-4	2.1E-05	2.1E-05
1.0E-3	1.4E-05	1.3E-05
5.0E-3	5.8E-05	6.0E-05
1.0E-2	4.2E-05	4.3E-05
5.0E-2	2.1E-04	2.2E-04
1.0E-1	1.8E-04	1.9E-04
5.0E-1	9.9E-04	1.0E-03
1.0	7.5E-04	8.8E-04
5.0	1.9E-03	2.4E-03
10	1.6E-04	2.3E-04
20	6.2E-06	8.6E-06



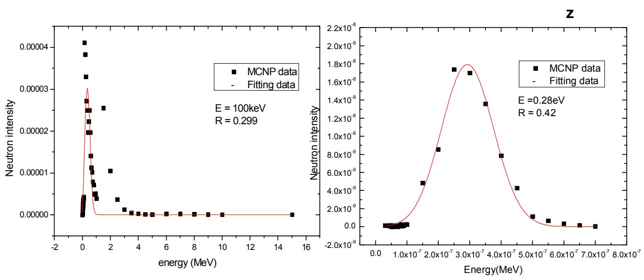


Fig. 1. Neutron energy resolution in the slowing down medium.

3. Results and Conclusion

The lead slowing down system is the most feasible choice to analyze the isotopic fissile contents directly in the spent fuel. However, for overcoming the neutron background of spent fuel, an intense external neutron source is required. The LSDS has the power to resolve the fission characteristics from each fissionable nuclear material. From 100keV to 0.1eV interrogation energy range are reasonable to obtain the different fission signature from the fissile isotopes.

From the calculation, the multiplication is minor to neglect the effect in the fuel rods. Even at low neutron energy, ~0.3eV, the energy resolution is kept to distinguish the fissile fission signals. However, several sensitivity calculations are necessary for the system optimization. An accurate fissile material analysis will contribute to the spent fuel re-utilization as well as the fuel stability and safety. Furthermore, the advanced fissile assay technology will increase the international transparence and credibility on a nuclear energy system development.

Acknowledgement

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