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Development of Neutron Measurement System for Direct Fissile Assay

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1. Introduction

Nuclear energy is the most feasible option to meet the energy demand as a sustainable manner. Pyro-processing linked sodium fast reactor (SFR) program is under development to re-use the PWR spent fuel and produce the energy. Pyro-processing involves the conversion of spent oxide fuel to a metallic form. In the process, plutonium is not separated, which will satisfy a proliferation resistance. The metallic material is treated to produce a uranium and uranium-TRU (transuranic, neptunium, plutonium, and americium) mixture. The uranium-TRU is fabricated for SFR fuel. The burning the recycled uranium-TRU mixture in the reactor is to solve the current spent fuel storage problem and to minimize the actinides 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. Therefore, about 1.5 % fissile materials still exist in the spent fuel. Therefore, spent fuel is not only waste but energy resource. Usually, I, Tc and MA in spent fuel have long half-life. Therefore, using pyro-process, special treatment of long half-life materials will help waste storage saving.

The isotopic fissile assay can be applied for fuel cycle, integrated storage, nuclear material accounting and reuse of nuclear 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. 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. Therefore, external source is needed to overcome the background and analyze the fissile material. Slowing down time spectrometer (SDTS) is the most feasible option to analyze the isotopic fissile materials in a near real time without an interference of neutron and gamma rays background from spent fuels[1].

In the study, the neutron background from spent fuel was examined and SDT spectrometer was explained for fissile assay. From the geometry setup[1], the sensitivity calculation was performed for the fuel assay zone which nuclear material will be located.

The advanced fissile assay technology will increase the international transparence and credibility on a nuclear energy system development.

2. Slowing Down Time Spectrometer

The development of a practical application of SDTS system for the assay of isotopic nuclear materials was initiated for the quality assurance of recycled fuel[2]. The feasible option to produce the proper external source is to use the accelerator. 35 MeV energy, 200 mA beam current, 500Hz frequency and 300 nsec pulse width electron linear accelerator produces 1 kW power and it produces ~10^{12} n's/sec with Ta target. This neutron intensity can overcome the neutron background from the one spent fuel assembly (45,000MWd/MTU from 4.0 % initial enrichment).

As a source term, the nuclear material production was calculated using ORIGEN2 code[3]. Curium has very low gram weight production relative to that of the uranium and plutonium, however, the majority of neutron emission from spent fuel is from curium isotopes. Because of the short half-life of Cm242, after long cooling, Cm244 is the major neutron source material for spent fuels. Table I shows the neutron intensity from the Curium with respect to the different cooling time.

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.

From the preliminary conceptual design of SDTS system[1], the position sensitivity calculation was performed between source and fuel area using MCNP code[4]. Five situations were considered: 1) fuel at -x axis and source at center, 2) fuel at center and source at 20 cm at x, 3) fuel at y axis and source at 20 cm at x, 4) fuel above y axis and source at center and 5) fuel at diagonal direction (14.2, 0, 14.2) and source at center. This calculation is for the hot cell condition because the inner hot cell size is limited and the equipment must be fit in the cell with management. Fig. 1 shows the results of calculation. From the results, the neutron intensity at fuel area was not much different at the range of 0.1 eV to 100 keV energy range if the distance between the fuel area and neutron source was consistent. Therefore, the position of fuel assay area can be located in any place of spectrometer in order to control and manage the fuel easily in the hot cell.

Table I: Spontaneous neutron production (4.0 w/o initial enrichment and 45,000MWd/500gU)

Isotope	Discharge (n's/sec)	10yrs	20yrs
Cm242	2.194E5	3.776E1	3.591E1
Cm244	4.036E5	2.758E5	1.880E5

I) Fuel at -x axis & source at center

Energy	Intensity
0.1eV-100keV	5.04654E-4

II) Fuel at center & source at 20 cm at x

Energy	Intensity
0.1eV-100keV	5.05414E-4

III) Fuel at y axis & source at 20 cm at x

Energy	Intensity
0.1eV-100keV	5.12628E-4

IV) Fuel above y axis & source at center

Energy	Intensity
0.1eV-100keV	5.12391E-4

V) Fuel at (14.2, 0, 14.2) & source at center

Energy	Intensity
0.1eV-100keV	4.96233E-4

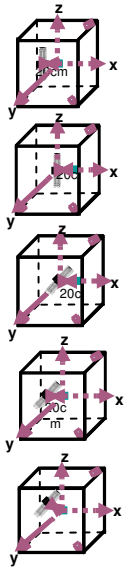

Fig. 1. Neutron slowing down in graphite and lead medium.

3. Results and Conclusion

The neutron source using an electron linear accelerator with a Ta target can produce the proper interrogation neutrons to overcome the neutron background from the spent fuels. The SDTS system is the most feasible choice to analyze the isotopic fissile contents directly in the spent and recycled fuels. The SDTS has the power to resolve the fission characteristics from each nuclear material.

From the sensitivity study with respect to the position of fuel area, if the distance between the fuel area and neutron source is consistent, the easily manageable and controllable position of fuel area in the SDT spectrometer is recommended. An accurate fissile material analysis will contribute to the fuel stability, reactor operation economy and safety increase. Furthermore, it will increase the international transparency on the nuclear fuel cycle.

Acknowledgement

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