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DEVELOPMENT OF LEAD SLOWING DOWN SPECTROMETER FOR ISOTOPIC FISSILE ASSAY

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A lead slowing down spectrometer (LSDS) is under development for analysis of isotopic fissile material contents in pyro-processed material, or spent fuel. Many current commercial fissile assay technologies have a limitation in accurate and direct assay of fissile content. However, LSDS is very sensitive in distinguishing fissile fission signals from each isotope. A neutron spectrum analysis was conducted in the spectrometer and the energy resolution was investigated from 0.1eV to 100keV. The spectrum was well shaped in the slowing down energy. The resolution was enough to obtain each fissile from 0.2eV to 1keV. The detector existence in the lead will disturb the source neutron spectrum. It causes a change in resolution and peak amplitude. The intense source neutron production was designed for ~E12 n's/sec to overcome spent fuel background. The detection sensitivity of U238 and Th232 fission chamber was investigated. The first and second layer detectors increase detection efficiency. Thorium also has a threshold property to detect the fast fission neutrons from fissile fission. However, the detection of Th232 is about 76% of that of U238. A linear detection model was set up over the slowing down neutron energy to obtain each fissile material content. The isotopic fissile assay using LSDS is applicable for the optimum design of spent fuel storage to maximize burnup credit and quality assurance of the recycled nuclear material for safety and economics. LSDS technology will contribute to the transparency and credibility of pyro-process using spent fuel, as internationally demanded.

KEYWORDS : Fissile Assay, Slowing Down, Neutron Source, Fuel Cycle, Nuclear Material Utilization, Resolution, Radiation Measurement

1. INTRODUCTION

A optimum design of LSDS is performed for analysis of isotopic fissile content in pyro processed material and spent fuel at KAERI [1,2,3]. An isotopic fissile assay in spent fuel and recycled fuel is very difficult in a real application because of intense radiation background and weak radiation emission from fissile materials. Therefore, a direct use of emitting radiation from isotopic fissile material is very hard in the material content assay. Normally, an indirect mechanism is used for the content assay of fissile material [4]. However, an indirect methodology has a limitation in obtaining the accurate fissile content. In addition, error propagation by several steps in an indirect way results in increasing errors. Therefore, to obtain the direct signal from isotopic fissile material, an external radiation source is recommended.

The pyro processed material has a spent fuel property as well even though several fission products are extracted in the process. LSDS with an external neutron source is the most feasible technology to get a direct fission signal from isotopic fissile in the intense radiation background and to analyze the content of isotopic fissile material [5,6]. Moreover, LSDS does not need the burnup history information or burnup code help in a fissile assay. Also, a lead spectrometer itself has a shielding property of intense gamma emission from spent or pyro material. There are several reasons why the accurate fissile contents must be analyzed in spent fuel and pyro material:

1) Internationally, IAEA wants to verify the plutonium content at the storage site
2) Nationally, nuclear material approval in the shipping and receiving of spent fuel
3) For safe and economical reuse of fissile in spent fuel
4) For optimum storage design and maximum burn up credit application
5) For public acceptance of storage site and effective storage management.

The accurate content of fissile is very important data in reuse of fissile material and storage design of spent fuel. For the LSDS system operation, several calculations were done on the neutron spectrum analysis [7].

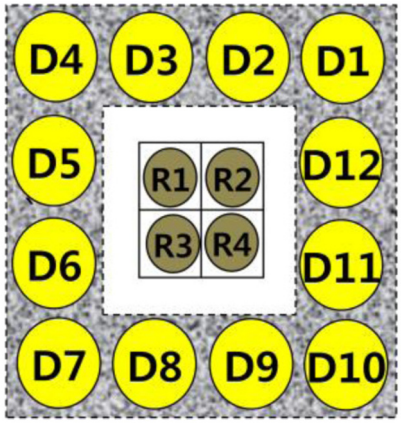

Fig. 1. Fuel and Detector Configuration.

The neutron spectrum influence by detector material and detector impurity in the spectrometer was examined. The fission characteristics were investigated in the slowing down neutron energy. Based on the designed geometry, the neutron energy resolution was investigated from 0.1eV to 100keV. The neutron detection efficiency was analyzed for multi layer cases and the detection sensitivity was done using U238 and Th232 threshold chamber. To obtain the proper neutron source, the neutron production mechanism was decided and the yield was calculated with the different incident electron energy. Also, a target activation analysis was performed.

Additionally, the advanced fissile assay technology will contribute to an increase in the transparency and international credibility of the reuse of fissile materials in future nuclear energy system development [8].

2. LEAD SLOWING DOWN SPECTROMETER

The lead spectrometer needs an external neutron source [9,10,11]. A source neutron slows down its energy by interaction with the lead medium. Therefore, a continuous slowed down neutron energy is obtained in the lead medium. The slowed down neutron finally enters into the nuclear fuel area and induces fission from fissile materials. An individual fissile material has its own fission characteristic below the unresolved resonance energy region. Therefore, if such a characteristic fission is well detected, it represents an amount of isotopic fissile material because the characteristic fission occurs directly from the fissile isotopes. In the lead spectrometer, very complex radiations exist. The fissile fission signal must be distinguished from the complex radiation field. A fission chamber is the right choice for screening the fast fission neutrons [1]. A fission chamber has a threshold property and it is not sensitive to intense gamma background. An electron linear accelerator was selected to produce an intense source neutrons. The neutrons are produced in the optimum designed Tantalum target, by (e, γ)(γ, n) reaction.

2.1 Neutron Spectrum Analysis

In the lead spectrometer, the source neutron spectrum analysis was done at the fuel area. The source neutron spectrum represents a peak energy change and broadening when interacting with the lead and nuclear materials. The energy distribution was fitted to a Gaussian form. The detector is located in the first layer above the fuel. The fuel area is a 2x2 type assembly, as shown in Fig. 1. The presence of the detector in the lead will disturb the neutron spectrum. The U238 fission chamber was selected and the spectrum influence by the detector impurity was analyzed at 2, 4, and 6ppm of U235 as well. Fig. 2 shows the spectrum at the selected slowing down neutron energy, from 70keV to 0.4eV, in the case of no detectors and detectors with impurities. As shown in Fig. 2, the shape is consistent in all cases and the peak energy occurs at the same slowing down energy. The spectrum effect by detector is not severe. However, the detector existence gives a different energy resolution and peak amplitude change. The amplitude of the no detector case is generally higher than that of the case with a detector at all neutron energies. At higher energy, i.e., 70keV, the figure shows little difference, but, as the peak energy becomes lower, the peak gap between no detector and detector including impurity becomes larger. Specially, at 1.3keV, 110eV, 1.5eV and 0.47eV, the peak amplitude decreases by 11%, 17%, 18%, and 20%, respectively.

2.2 Energy Resolution

In the lead spectrometer, the resolving power of the neutron is an important parameter for the LSDS system operation. When the neutron shape follows a Gaussian distribution, the resolution is measured by the full width at half maximum.

$$R = \left(\frac{\Delta E}{E}\right)_{FWHM} \quad (1)$$

where E is the mean energy of the neutron distribution

The energy resolution was analyzed at the slowing down neutron energy. The resolution is important in getting individual isotopic fissile fission. Fig. 3 shows the energy resolution in the lead, from 1MeV to 0.1eV. The result shows a well-organized spectrum, with a ~0.3 resolution, from 3keV to 3eV. However, above 3keV and below 3eV, the resolution starts broadening. At 0.3eV, Pu239 has a big absorption resonance. Therefore, the resolution at 0.3eV is ~0.57. Therefore, by considering energy resolution, the expected assay energy range is approximately from 0.3eV to 20keV.

The inserted nuclear fuel produces a resolution function, which is different from that for homogeneous