Determination of the Slope of the relative efficiency from Gamma-ray Pair of Cs-134 and Ru-106

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1. Introduction

In the gamma-ray spectroscopy of a nuclear fuel, its absolute detection efficiency is difficult to be determined because a spent PWR fuel generally contains numerous nuclides and has a somewhat complex geometry. On the other hand, the determination of a relative detection efficiency is a more convenient method with respect to measuring multi gamma-ray emitting nuclides.

For a more precise determination of a relative efficiency, a radionuclide that emits at least two gamma-rays should be used[1]. Also, the nuclide needs to have a relatively high gamma-ray intensity.

In this study, the 512 and 622 keV lines of Ru-106, and the 605 and 796 keV lines of Cs-134 were selected. Each of the emission probability of the Ru-106 and Cs-134 gamma-ray pair is 0.204, 0.0993, 0.9762 and 0.851, respectively. The Cs-134 gamma-ray pair has a higher emission probability than Ru-106. Therefore, Cs-134 is a more effective nuclide for the determination of the relative efficiency. The current work yields a relative detection efficiency for a commercial PWR fuel rod.

For two distinct gamma-rays, the ratio of the peak detection efficiencies can be written as[2]

$$\frac{\epsilon_1}{\epsilon_2} = \left(\frac{E_1}{E_2}\right)^m \qquad (1)$$

Where ε_i and E_i mean detection efficiency and gamma-ray energy respectively, and m indicates the slope.

2. Methods and Results

2.1 Experimental techniques

Axial gamma scanning was carried out on a commercial PWR rod, using a high purity Ge detector (HPGe) with each slit of 25.0 mm × 0.5 mm. The dwelling time for the acquisition system is 600 seconds. Operation of the scanning mechanism and data acquisition and analysis are done by an on-line computer.

The commercial PWR rod for the experiments has a rod average burnup of 45.6 GWd/tU. The designed active fuel length is 3657.6 mm and the pellet diameter is 8.19 mm. The rod was decayed during 1289 days after its discharge.

2.2 Axial gamma scanning

Table 1 shows the result of the slope m obtained from the Cs-134 and Ru-106 gamma-ray pair. In 16 points across the whole length of the fuel rod, the gamma-ray spectrum was obtained. Upper 2 points and lower 2 points are part of the axial blanket as the natural uranium pellet. The slope m of Ru-106 shows large deviation in the whole range but that of Cs-134 is uniform. Excepting points of the axial blanket, the average slope m of Cs-134 is -0.4477, and the standard deviation is 0.0199.

In the central 8 points that belong to the region of the relatively flat axial burnup distribution, the relative standard deviation of the gamma-ray intensity of the Ru-106 622 keV line is 7.2 %. The value is much higher than that of 512 keV line, 1.8 % so that the gamma-ray intensity ratios between the 512 and 622 keV line is considered to have a large deviation.

Table 1. Slope m determined from Ru-106 and Cs-134

Distance from rod bottom, mm	Slope, m	
	Ru-106	Cs-134
56	-1.1427	-0.5886
150	-0.9423	-0.5158
495	-0.5913	-0.4262
585	-0.5507	-0.4588
1000	-0.5365	-0.4629
1465	-1.3348	-0.4756
1848	-1.3314	-0.4477
2106	-0.6937	-0.4287
2363	-1.3829	-0.4552
2641	-0.8574	-0.4209
2858	-0.5875	-0.4390
3090	-1.1210	-0.4342
3225	-1.0355	-0.4776
3345	-1.3590	-0.4244
3573	-0.7215	-0.5022
3645	-1.2145	-0.5424

2.3 Short decay time

If the decay time of the spent fuel is under 1 year, Zr-95 could be considered as the important nuclide for the determination of the relative efficiency. The half life of

Zr-95, 64 days is shorter than that of Cs-134 and Ru-106, but Zr-95 has a gamma-ray pair of the 724 and 757 keV line with a higher emission probability. Each of the emission probabilities of them is 0.4417 and 0.5446, respectively. Figure 1 shows the decay scheme of Zr-95. Specific example of the PWR rod with a 50 GWd/tU burnup shows radioactivity changes of each nuclide according to the decay time as in figure 2. The estimation of the radioactivity was carried out by using Origen-S code.

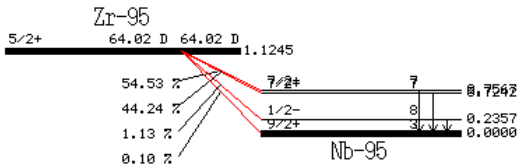

Figure 1. Decay scheme of Zr-95

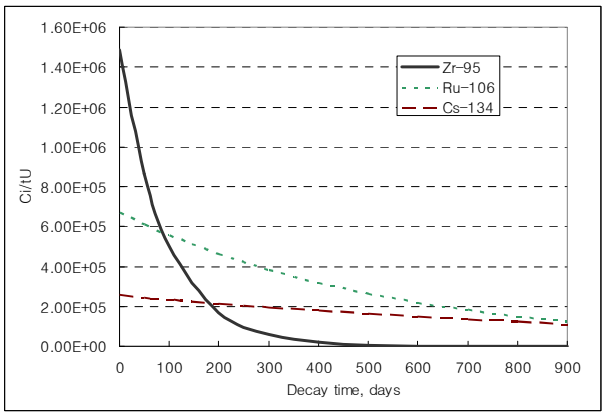

Figure 2. Specific example of the PWR rod with 50GWd/tU burnup

3. Conclusion

As the relative efficiency was assumed to be a linear relationship for the energy on a log-log plot, the m slope was determined for each nuclide of a spent fuel which emitted a gamma-ray pair.

REFERENCES

[1] Ayman Ibrahim Hawari et al., Nuclear Instrument and Methods in Physics Research A, p. 398, 1997
[2] Gordon Gilmore et al., Practical Gamma-ray Spectrometry, John Wiley & Sons, 1995