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Status of the Gamma Scanning Techniques for the Spent PWR Fuel in KAERI-PIEF

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1. Introduction

Gamma spectroscopic analysis is a common tool for inspecting the geometrical burnup distributions of spent nuclear fuel. Measured gamma scanning data could be used to confirm the expected burnup of the fuel design and to feed back on the manufacturing process. In KAERI-PIEF, a lot of gamma scanning examinations have been conducted for the past few decades. The status of the gamma scanning techniques in KAERI-PIEF was reported by using the experimental results on the spent fuel assembly of Kori-2 core. Three different kinds of gamma scanning techniques were applied to an assembly, a rod, and a section of the spent fuel.

2. Experimental Equipment

Gamma scanning equipment in KAERI-PIEF is comprised of the scanning bench, the high precision collimator, the high purity Ge detector, and the multi-channel analyzer (MCA).

2.1 Scanning Bench

An assembly scanning bench can conduct the non-destructive inspection by an up-and-down motion and a rotation for the PWR fuel assembly, which includes 14×14, 16×16, and 17×17 assemblies. A rod scanning bench also used for the non-destructive inspection of the PWR fuel rod, which is 1000 to 4900 mm in length and 9.49 to 10.72 mm in diameter.

Destructive inspection was conducted in a section scanning bench with a sample carrying assembly unit which can control the distance between the sample and the detector from 410 mm to 980 mm in perpendicular direction. A sample could be moved by 200 mm and 50 mm in X- and Y- direction, respectively, in an X-Y table

2.2 Collimators

The slit width of the collimator is decreasing in order of the assembly, rod, and section gamma scanning. Two different slit width of the collimator are existed such as 5×5 mm and 5×20 mm for the assembly scanning equipment. In case of the rod scanning, the slit width are 2×25 mm, 1×25 mm, and 0.5×25 mm. The slit width of the section scanning are 0.5×0.5 mm and 1×1 mm.

2.3 Multi-Channel Analyzer (MCA)

The energy of the radiation is converted to the digital signal by the analog-to-digital converter (ADC). The digital signal generates the radiation energy spectrum through the multi-channel analyzer.

3. Experimental Method

Figure 1 shows the schematics of the whole gamma scanning system.

An assembly gamma scanning was conducted on four different faces through the whole length of the fuel assembly by the side measurement method. Gross gamma ray measurement was used during a rod gamma scanning analysis in order to inspect the inner state of the fuel pellet. After the fuel rod was cut and mounted, a section gamma scanning was conducted. The distance between the detector and sample was 40.5 cm and that between the collimator and sample was 2 cm. The distribution of Cs-137 was measured by using the collimator with the slit width of 0.5×0.5 mm.

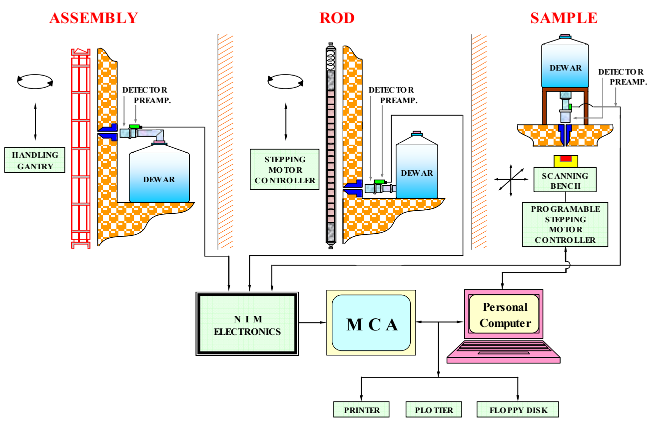

Fig. 1. Gamma-ray Scanning System of KAERI-PIEF.

4. Results

The burnup distribution along the longitudinal direction of the fuel assembly of the Kori-2 core is shown in Fig. 2. It appears that Face 1 has been placed in the condition of a little higher power during the beginning stage because Face 1 is likely to be close to the reactor core. [1~2]

The gross gamma scanning profile of a fuel rod is shown in Fig. 3 which represents a relative axial burnup distribution of a fuel rod. The burnup shows a flat distribution except for the top and bottom of the

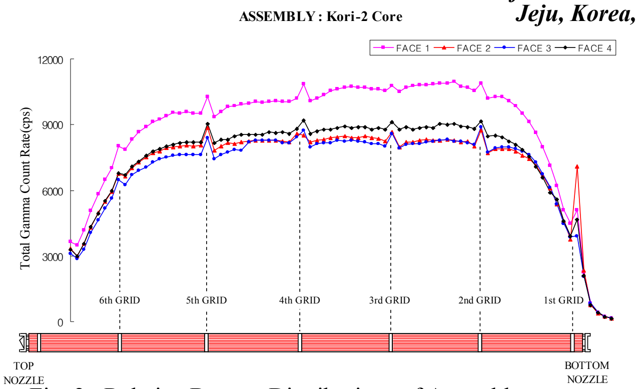

Fig. 2. Relative Burnup Distributions of Assembly.

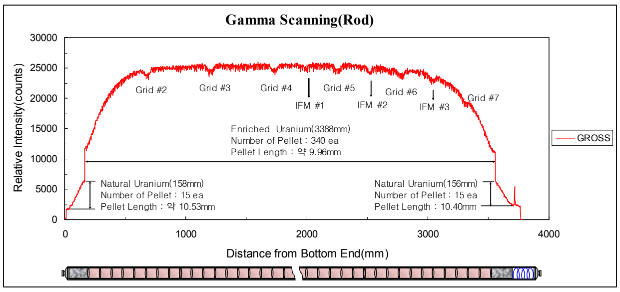

Fig. 3. GROSS Gamma Scanning of the Spent Nuclear Fuel.

fuel rod are slightly lower than the other regions. The burnups in the regions of the grids are also about 1% lower than the flat regions from the absorption effect of a thermal neutron.

The 662-keV-gamma ray from Cs-137 was usually used in a section gamma scanning experiment because Cs-137 has a similar fission yield with U-235 and Pu-239 and the intensity of Cs-137 has a linear correlation with a burnup. And its relatively high count rate also could reduce the statistical error. Figure 4 shows the

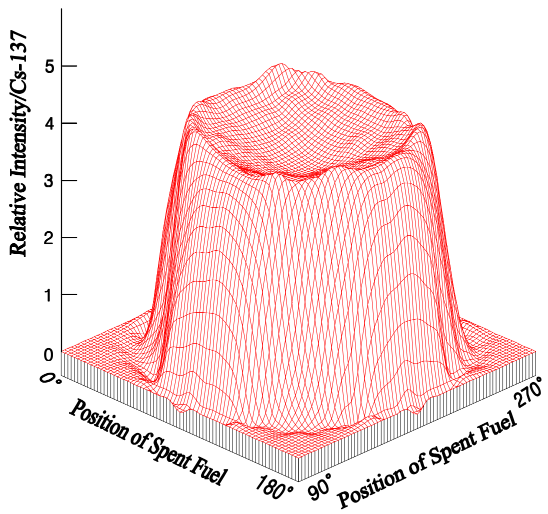

Fig. 4. Isometric Projection of Cs-137 Isotopic Radial Distribution.

intensity distribution of Cs-137 at the sectioned surface of the fuel rod. The Cs-137 intensity in the interior of the fuel pellet seemed to increase along the radial direction. It is attributed to the Cs migration from the high temperature region to the low temperature region of the fuel pellet.[3~5]

5. Conclusion

The burnup of the irradiated nuclear fuel is directly proportional to the total number of fission and can be estimated from the concentration of specific fission products measured by a gamma spectroscopic analysis. The burnup was determined from the results of the gross gamma scanning, the multispectral scanning, two-dimensional gamma scanning, and quantitative gamma scanning.

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