The Radial Distribution of Fission Products in the PWR Fuel Rod using the Gamma Scanning

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1. Introduction

The gamma-ray spectroscopy of nuclear fuel has been developed for safety purposes [1]. This technique has been employed for determination of the axial burnup of fuel rods in PIEF, KAERI. The local axial burnup has been analyzed by the γ-radiation ratio of Cs-134 and Cs-137 taken from gamma spectrum and the high activity Cs-137 has been used to determination of the relative axial burnup distribution.

In this study, the radial distribution of fission products was measured by gamma spectrometry and the radial burnup was concluded using Ru-106 γ-ray intensity. Also, the cesium release ratio was determined.

2. Methods and Results

2.1 Experimental techniques

Radial micro gamma scanning was carried out on a commercial PWR rod, using a high purity Ge detector (HPGe) with a slit of 0.5 mm × 0.5 mm. Operation of the scanning mechanism and data acquisition and analysis are done by an on-line computer.

Specimens from commercial PWR rod have high pellet average burnup, 65.4 GWd/tU. The thickness is 3.0 mm and the pellet outer radius is 8.22 mm. The gamma-ray emitting isotopes Cs-137, Cs-134, Ru-106 was measured.

2.2 Rradial burnup distribution

Figure 1 shows the distribution of Cs-134, Cs-137 and Ru-106 across a pellet cross section of a fuel rod segment. In nuclear fuel performance, cesium is an important nuclide due to its low solubility [2]. The ratio of the activity between pellet rim and center was found to be 1.12 for Cs-137. Since the theoretical ratio is 1.10 it is evident that some Cs has been released.

Ru-106 has been assumed to be a nonvolatile fission product precipitated in metallic form [3]. It has reported in [4] that a migration of Ru-106 is found at a center line temperature of 1470°C. In the case of steady operation, no migration or release of Ru-106 is forecasted. Therefore, Ru-106 has been considered as indication for the radial burnup profile.

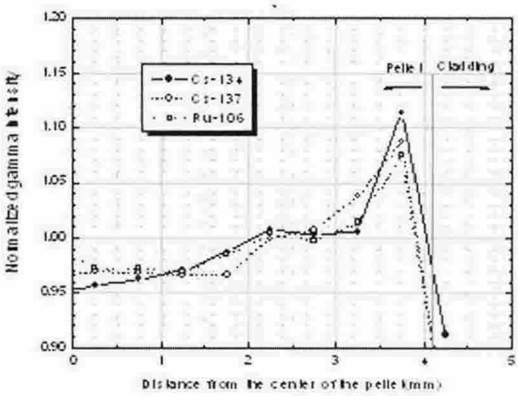

Figure 1. Cs-134, Cs-137 and Ru-106 profiles across a fuel pellet

Figure 2 shows results about the burnup profiles by RAPID code [5], Ru-106 profile and Cs-134/Cs-137 ratio. Because of the nonlinearity of the burnup profile as function of relative Ru-106 radioactive intensity, the correction is needed about Ru-106 γ-ray intensity profile.

Cs-134 is formed by neutron capture of Cs-133 with its gaseous precursor Xe-133 so that Cs-134 migration is influenced by an outward migration of gaseous fission products [4]. But this tendency is considered to have a small effect on Cs-134 migration in the steady operation. If Cs-137 and Cs-134 have similar migration, even in the center of pellet it is possible that a burnup for any radial point is determined by Cs-134 to Cs-137 nuclide ratio.

According to Figure 2, burnup profiles by Ru-106 and Cs-134/Cs-137 is mismatched. This may be caused by a low-dwelling time for the collection of γ-intensity or an unexpected factor of the cesium migration. And the burnup profile by Ru-106 is in reasonable agreement with the burnup profile by RAPID code.

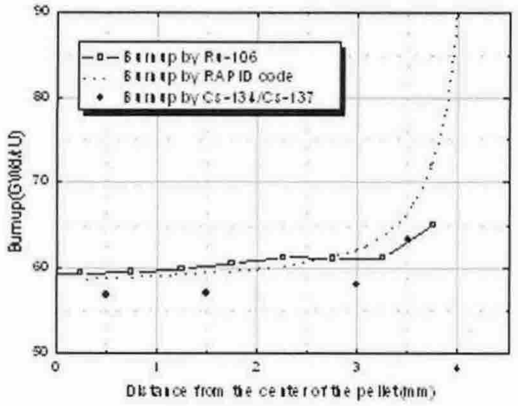

Figure 2. Radial burnup profiles

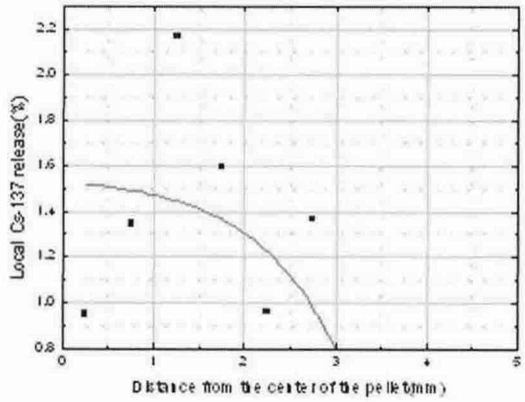

Figure 3. Cesium release rate across a fuel pellet

2.3 Cesium release

Difference between the relative burnup profile by Ru-106 and relative Cs-137 γ-intensity indicates a release of Cs-137. Figure 3 shows the calculated cesium release rate with values from 1 to 2. By the rod puncturing test, the rod from which this specimen was taken had 4.9% fission gas(Xe+Kr) release.

3. Conclusion

Micro-gamma scanning have been applied to determine the radial burnup profile. In order to burnup determination nonvolatile nuclide, Ru-106 has been used. Further work is required to extend the data bases and confirm that Ru-106 has possibility as indication for the radial burnup profile.

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