Estimation of Burnup with Caesium isotopes based on Gamma-scanning of a instrumented fuel capsule(02F-11K) in Hot-cell

UngsupSong, Heemoon Kim, Daegyu Park, Seungje paik, Honggi Lee, Yongsun Choo, Kwonpyo Hong
Irradiated Materials Examination Facility, Korea Atomic Energy Research Institute, Ducjin, Yusung, Taijeon, Korea,305-353 (nussong@kaeri.re.kr)

1. Introduction

Many experimental inspection have been performed to obtain the burnup of fuel. In the case, chemical analysis were popular with high reliability. High radioactivity of fuel was severe problem during destructive procedure. Afterward, many researchers have studied calculation of burnup using gamma detector as the non-destructive method[[vi]]. methodologies of gamma-scanning test have been developed as well as higher accuracy of detector.

Generally, Cs-137 and Cs-134 are standard isotopes for long-term cooling spent fuel to estimate burnup, because atomic ratio of them follows the linearity with burnup.

2. Experimental

2.1 Specimen preparation

Five UO_2 pellets were made with 2.42% of enrichment and contained small fuel rig which was placed in instrumented capsule for irradiation[[vii]]. Two and half of pellets from top position were punctured at center of them to set up thermocouple. The capsule was irradiated for 55days with 300w/cm ~ 330w/cm of linear power in OR hole in HANARO research reactor. After irradiation and cooling, it was moved to Hot-cell to do gamma-scanning test.

2.2 Gamma-scanning test

The fuel rig contained irradiated five UO_2 pellets set vertically to the bench device. It can be moved up and down. Two punctured pellets, half punctured one and two solid ones were placed in order from top of fuel rig. Three points for gamma-scanning test were selected as top, middle, and bottom of the rig as shown fig.1.

The distance between pellet and detector is 1.6m including thickness of Hot-cell wall. The slit size of Collimator is 1mm x 1mm as square type. First of all, background checking was performed before the experiment for the fuel rig to consider special peaks from other materials which make severe counting errors. After gamma-scanning test for fuel rig, that for Cs-137 standard source, known activity, was done with same way. Detecting time was set up by 10^6 sec.

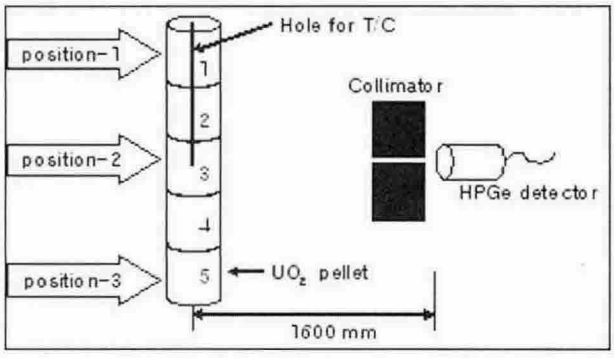

Fig. 1 structural geometry for gamma-scanning test

3. Results and Discussion

Atomic ratio of Cs-137 to Cs-134 is available to calculate burnup because this ratio is linear proportion to burnup. Using ORIGEN-2 code[viii], burnup related to this ratio can be found. To obtain the ratio(R), the equation is as follows[[ix]];

$$\frac{N_{134}\varepsilon(E_{137})}{N_{137}\varepsilon(E_{137})} = \frac{N_{134}}{N_{137}} = R_{\exp} \qquad (1)$$

Where, N is atomic amount and ε is energy efficiency of detector, energy in here is 662 keV(gamma energy of Cs-137). R is experimental value.

Efficiency (ε) at 662keV was obtain from interpolation with several energy peaks of Cs-134 with equation as bellows;

$$C(E_i) = \lambda NP(E_i)\varepsilon(E_i)$$

Where, C is gamma counts, λ is decay constant, N is atomic amount, P is decay branch ratio with energy. λN is radioactivity in here.

But, every seven gamma energies of Cs-134 are not shown in high peaks. In this study, just two gamma energies were available due to very small peaks of the others. High peaks of 605keV and 796keV were chosen to calculate efficiency at 662keV.

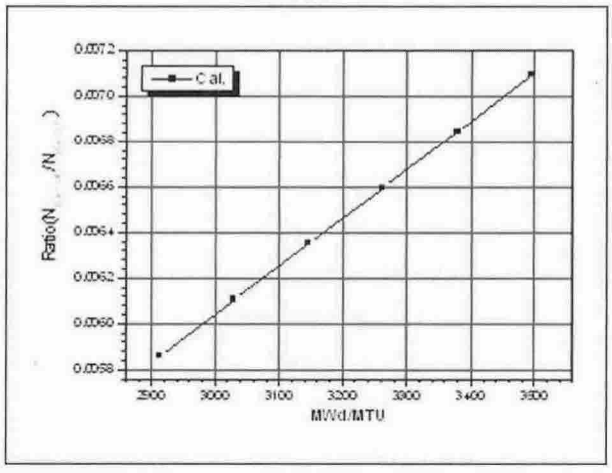

Fig. 2 plot of ratio Cs-134 to Cs-137 with burnup (ORINGEN-2)

R-values from measurement were 0.00658 at top position(no. of pellet is 1), 0.00659 at middle position(no. of pellet is 3) and 0.00664 at bottom position(no. of pellet is 5), respectively. Burnup is approximately 3.22~3.26 Gwd/MTU. Linear power of this fuel rig is assumed to be about 275~285 w/cm considering irradiation time and pellet weight, but this data would be under-estimated by ~10% comparing the calculation neutronics code for HANARO.

4. Conclusion

5 UO_2 pellets were irradiated in reactor for 55days and moved to Hot-cell. Gamma-scanning test was performed at three point of fuel rig contained pellets. Ratios of Cs-134 to Cs-137 were measured in each points. Burnups related to measured ratios were found using ORIGEN-2 code. The results were approximately 3.22~3.26 Gwd/MTU. It is assumed to be under-estimated comparing the calculation of neutronics code for HANARO.

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