Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Comparative Analysis of results according to the measurement direction of spent fuel burnup

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1. Introduction

The burnup of spent nuclear fuel released from a nuclear reactor is one of the important management items not only for dry storage but also for transportation and disposal in the future. Currently, KHNP is conducting the measurement of spent fuel burn-up to verify the reliability of the actual fuel burn-up data calculated at the power plant.

As for the burnup measurement equipment, the burnup measurement equipment (SICOM-NG-FA) developed by ENUSA in Spain was introduced. The SICOM-NG-FA is a device that analyzes the axial profile of spent nuclear fuel using gamma and neutron detector.

The burnup is measured while moving the spent fuel in the axial direction (up & down), and measurements are made on a total of 4 sides of the fuel.

This paper describes the comparison of the results according to the measurement direction of spent fuel burnup.

2. Measurement Process

In this section, the measurement process from fuel selection to measuring spent fuel burnup is described.

2.1 Fuel Selection

For the spent fuel burnup measurement, a total of 43 assemblies were selected according to the type of fuel, fuel history, enrichment, and cooling period.

2.2 Fuel Information

The cooling time of 43 assemblies of fuel measuring burnup is about 7.7 to 20.5 years. The burnup distribution ranged from 27,777 MWd/tU to 53.466 MWd/tU. Out of a total of 43 assemblies, a total of 10 assemblies are fuels that do not contain burnable poison rod assembly (Gd). Figure 1 below shows the burnup distribution for each cooling time of the fuel to be measured.

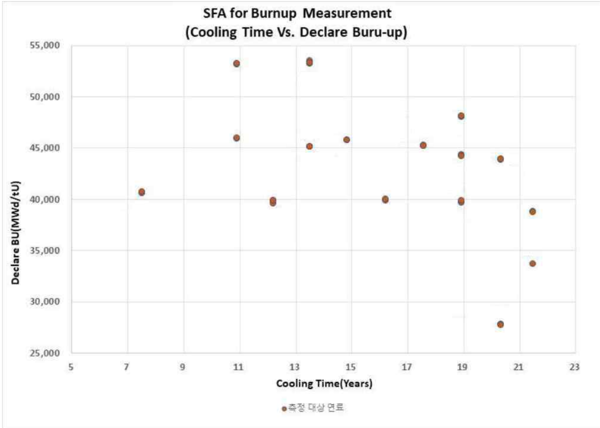

Fig. 1. Distribution of burnup by cooling period of target nuclear fuel

3. Burnup Measurement & Analysis

Burnup measurement was carried out up/down considering the large measurement error due to low gamma and neutron emission rates in the case of fuel with a cooling period of 19 years or more, and only down measurement was performed for fuels with a cooling period of less than 19 years.

3.1 Up & Down Measurement

For burnup analysis, burnup calibration must be performed through data measured from multiple fuels. The calibration fuel selected for up/down measurement burnup analysis is as follows.

- Fuel for gamma calibration: total 43 assemblies
- Fuel for neutron calibration: total 10 assemblies without Gd

The burnup Root Mean Squared Error (RMSE) (%) for the total fuel was evaluated as 4.10% for gamma rays, 2.04% for neutrons, and 2.75% for composite. The burnup uncertainty (total) for the measured count rate was calculated as 0.148%, (σ=1).

In the case of gamma measurement burnup, the deviation compared to the published value of the plant was larger than the neutron result, and the analysis tended to be larger than the published value of the plant when the measured count rate of CS-137 peak was high, and smaller than the published value when the measured count rate was low.

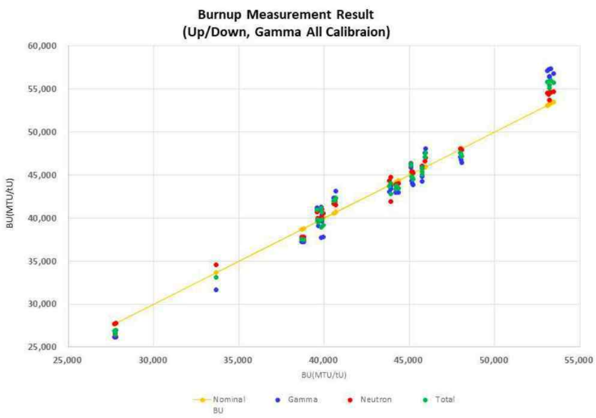

Fig. 2. Result of the up & down burnup measurement

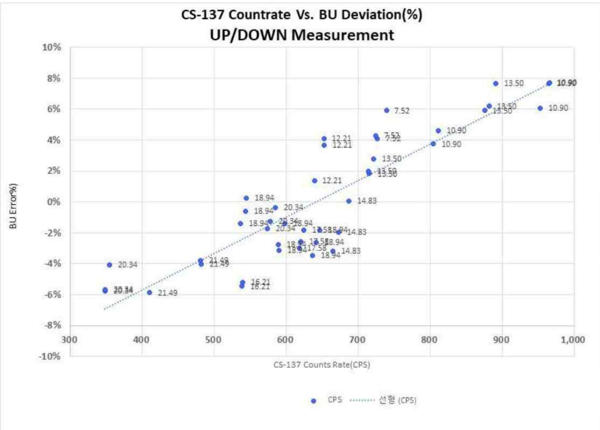

Fig. 3. Result of the Up & Down
CS-137 Count rate Vs. BU Deviation

3.2 Down Measurement

For the down measurement analysis, the calibration fuel was selected identically to the up/down measurement for comparative analysis with the up/down measurement.

- Fuel for gamma calibration: total 43 assemblies
- Fuel for neutron calibration: total 10 assemblies without Gd

The burnup Root Mean Squared Error (RMSE) (%) for the total fuel was evaluated as 4.18% for gamma rays, 2.06% for neutrons, and 2.80% for composite. The burnup uncertainty (total) for the measured count rate was calculated as 0.172%, (σ=1).

The burnup error and measurement uncertainty of the down measurement increased slightly compared to the up/down measurement, but the difference was not large. As for the tendency of the burnup error of the down measurement, similar to the up/down, in the case of the gamma measurement burnup, the deviation was larger than the neutron result compared to the published value of the plant, and the trend according to the measured count rate of the CS-137 peak was similar.

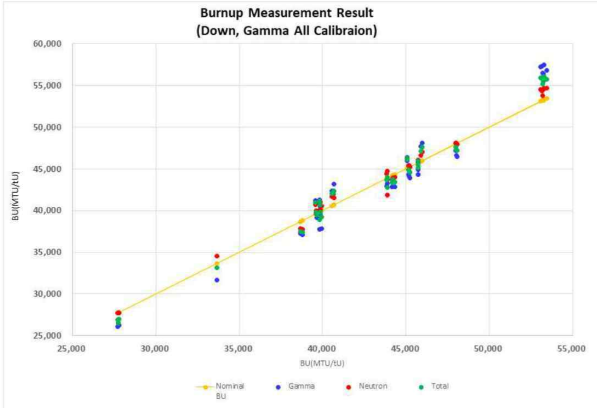

Fig. 4. Result of the down burnup measurement

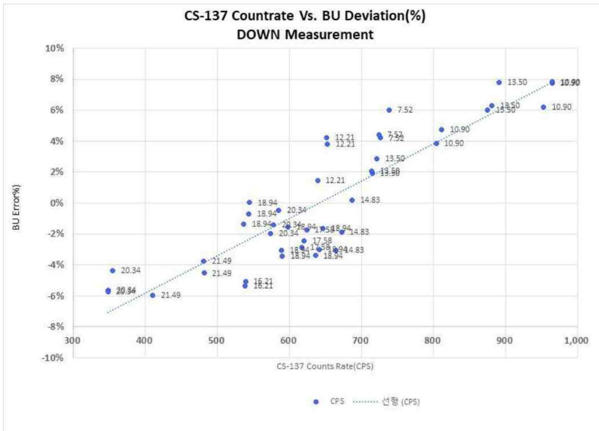

Fig. 5. Result of the Down
CS-137 Count rate Vs. BU Deviation

3. Conclusions

In this paper, the deviation according to the burnup measurement direction for 43 assemblies of spent fuel was described. Based on the cooling period of 19 years, fuels older than 19 years were measured up/down per side on 4 sides, measuring a total of 8 times per fuel, and fuels less than 19 years old measured only down measurements, measuring a total of 4 times per fuel. Burnup analysis included both up/down measurement data and analysis using only down measurement data to evaluate the burnup error and measurement uncertainty of 8 measurements and 4 measurements.

Analysis results the up/down measurement results show that the average burnup error (RSME, %) of gamma rays is 4.10%, neutron 2.04%, and total 2.75%. Down measurement results were analyzed as gamma rays 4.18%, neutrons 2.06%, and total 2.80%.

The uncertainty of the burnup by the measurement count rate was analyzed as 0.148% for up/down measurement and 0.172% for down measurement based on $\sigma = 1$. The difference in measurement uncertainty error between up/down measurement and down measurement was evaluated at a very insignificant level with a difference of 0.024%