# Comparison Analysis of the Uncertainty Due to Fuel Depletion in the Criticality Analysis for OASIS-32D

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## 1. Introduction

The burnup credited criticality safety analysis shall consider the uncertainty due to fuel depletion. Historically the uncertainty has been based on a rough engineering judgment such as 5% of the reactivity decrement to the burnup according to Kopp's memo [1]. However, more definite validation analysis of the uncertainty due to fuel depletion has been performed and published as NUREG/CR-7108 [2].

In this study, a comparison analysis of the criticality uncertainty due to fuel depletion based on Kopp's memo and NUREG/CR-7108 is performed for the KEPCO E&C's OASIS-32D dual purpose metal cask model.

## 2. Uncertainty Analysis and Results

### *2.1 Uncertainty Calculation based on Kopp's memo*

Suggested by Kopp's memo, the reactivity uncertainty due to uncertainty in the fuel depletion calculations is assumed as 5% of the reactivity decrement to the burnup, which means that 5% of the calculated reactivity difference between fresh fuel and burned fuel models is the uncertainty involved.

The effective multiplication factors ($k_{eff}$) are calculated for the OASIS-32D cask model (Figure 1) with ACE7 fuel having various burnup-enrichment combinations using the SCALE6.0/CSAS5. The computer program and cross section library used for the fuel depletion calculation are SCALE6.0/ TRITON and ENDF/B-VII. The calculated reactivity decrement by fuel depletion is summarized in Table 1.

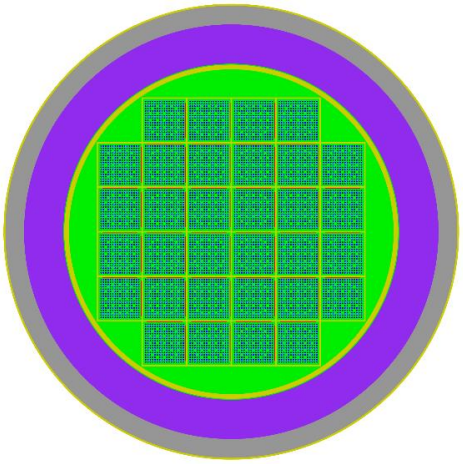

Fig. 1. Cross Section View of the OASIS-32D Cask.

Table 1. Uncertainty Calculated based on Kopp's memo

| Burnup (gwd/mtu) | The uncertainty (Δk) due to depletion | | | |
|---|---|---|---|---|
| | 2.0wt% | 3.0wt% | 4.0wt% | 5.0wt% |
| 2.25 | 0.00100 | 0.00137 | | |
| 9.00 | | 0.00471 | | |
| 15.75 | | | 0.00743 | |
| 24.75 | | | 0.01130 | 0.01038 |
| 33.75 | | | | 0.01399 |

The uncertainty due to fuel depletion based on Kopp's memo increases with burnup. The reason of this trend is clear because the reactivity difference is increasing as burnup increases.

### *2.2 Uncertainty Provided in NUREG/CR-7108*

NUREG/CR-7108 addresses the validation of depletion calculations which is performed by comparing calculated nuclide concentrations to available measurements of nuclide concentrations, and provides reference $k_{eff}$ bias and bias uncertainty results as shown in Table 2. The uncertainty in Table

2 was evaluated for the representative PWR cask model, GBC-32, using SCALE6.1/TRITON and ENDF/B-VII.

Table 2. Uncertainty Provided in NUREG/CR-7108

| Burnup (gwd/mtu) | The uncertainty (Δk) due to depletion | | | |
|---|---|---|---|---|
| | 2.0wt% | 3.0wt% | 4.0wt% | 5.0wt% |
| 2.25 | 0.01500 | 0.01500 | | |
| 9.00 | | 0.01480 | | |
| 15.75 | | | 0.01570 | |
| 24.75 | | | 0.01540 | 0.01540 |
| 33.75 | | | | 0.01630 |

As shown in this table, the uncertainties due to fuel depletion in NUREG/CR-7108 are almost same for all combinations of burnup-enrichment. The reason described in NUREG/CR-7108 is that the uncertainties in the calculated U-235 & Pu-239 concentrations contribute about 90% of the $k_{eff}$ bias uncertainty, while the uncertainty in the calculated fission product concentrations is small (<3% of the $k_{eff}$ bias uncertainty).

*2.3 Comparison of Results*

The computer program and cross section library used for the fuel depletion calculation in the *subsection 2.1* (SCALE6.0/TRITON, ENDF/B-VII) are same as those used in *subsection 2.2* (SCALE6.1/TRITON, ENDF/B-VII) because the difference between SCALE6.0 and SCALE6.1 is negligible. The OASIS-32D cask model for *subsection 2.1* is similar to the GBC-32 cask model for *subsection 2.2* because both of them can accommodate 32 PWR assemblies, and use Boral panels containing B-10 as a fixed neutron poison. Also, the burnup credit in *subsection 2.1* is limited to the specific 28 actinide and fission product nuclides listed in NUREG/CR-7108. Therefore, the two sets of uncertainties are comparable.

Table 3 shows the comparison of the uncertainty due to fuel depletion according to Kopp's memo and NUREG/CR-7108

Table 3. Comparison of Uncertainties

| Burnup (gwd/mtu) | (Kopp's memo) / (NUREG/CR-7108) | | | |
|---|---|---|---|---|
| | 2.0wt% | 3.0wt% | 4.0wt% | 5.0wt% |
| 2.25 | 7% | 9% | | |
| 9.00 | | 32% | | |
| 15.75 | | | 47% | |
| 24.75 | | | 73% | 67% |
| 33.75 | | | | 86% |

As shown in this table, the uncertainty due to depletion provided in NUREG/CR-7108 is higher than that calculated according to Kopp's memo.

## 3. Conclusion

The results showed that the uncertainty due to depletion provided in NUREG/CR-7108 is higher than that calculated according to Kopp's memo over the whole evaluated burnup range for OASIS-32D.

The uniform uncertainty regardless of burnup provided in NUREG/CR-7108 shows that the uncertainty contribution from the fission products takes small portion while the contribution from the other nuclides takes great portion.

So, the uncertainty of NUREG/CR-7108 is applied to the criticality analysis of OASIS-32D.

## REFERENCES


[1] Memorandum from L. Kopp to T. Collins, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants," U.S. NRC, August 19, 1998.

[2] G. Radulescu, I. C. Gauld, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Isotopic Composition Predictions," NUREG/CR-7108 (ORNL/TM-2011/509), U.S. NRC, Oak Ridge National Laboratory, April 2012.