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# A Misload Analysis for PLUS7 Fuel Assemblies in the 32 Burnup Credit Cask

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## 1. Introduction

The "Burnup Credit" (BUC) means the concept that takes for the reduction in reactivity because of fuel burnup.[1] As refer to Nuclear Regulatory Commission (NRC) report, the earlier studies only have analyzed on 4 misloading assemblies in the center of Generic Burnup Credit (GBC)-32 cask.[2] And according to recent NRC Interim Staff Guidance (ISG)-8 has suggested that even if multi spent fuel assemblies have been misloaded cask requires to be subcritical.[3]

In this study, extending the previous studies, misloading criticality analyses have been performed for the GBC-32 cask up to 16 misloaded fuel assemblies, which is much higher than other cases. Two types of fuel assemblies are considered such as WH 17x17 and Plus 7 (16x16). The distribution of axial burnup is assumed to be uniform and the composition of fuel assemblies have been obtained from the ORIGEN-ARP [4], one of the modules in SCALE 6.1[5]. The criticality was analyzed with MCNP6.1[6] with the ENDF/B-VII.1[7] Library.

## 2. Conditions

The reference model of GBC-32 cask is introduced in reference 2. The cask model is designed with MCNP6.1, and visualized with Visual Editor 6.1 which is one of the visualization programs of MCNP.[8] The isotopic compositions of spent fuel include actinides and fission products are obtained from ORIGEN-ARP. The list of isotopes is given in Table 1, which follows the ISG8 rev.3 guide.[3]

Table 1. Nuclides Compositions of Spent Fuel

| | | | | | |
|---|---|---|---|---|---|
| Ag-109 | Am-241 | Am-243 | Cs-133 | Eu-151 | Eu-153 |
| Gd-155 | Mo-95 | Nd-143 | Nd-145 | Np-237 | O-16 |
| Pu-238 | Pu-239 | Pu-240 | Pu-241 | Pu-242 | Rh-103 |
| Ru-101 | Sm-147 | Sm-149 | Sm-150 | Sm-151 | Sm-152 |
| Tc-99 | U-234 | U-235 | U-236 | U-238 | |

Various conditions of burnup and enrichment are obtained for the types of Plus 7 and WH 17x17. The applied conditions of burnup and enrichment are chosen based on the loading curve of GBC-32 cask and they are tabulated in Table 2.[2]

Table 2. Enrichment and Burnup Conditions

| Enrichment (wt%) | Burnup (MWD/MTU) | Fresh Fuel Burnup |
|---|---|---|
| 1.80 | 13000 | 0 |
| 2.00 | 18000 | 0 |
| 2.50 | 28000 | 0 |
| 2.70 | 26000 | 0 |
| 3.00 | 33000 | 0 |
| 3.30 | 38000 | 0 |
| 3.50 | 39000 | 0 |
| 4.00 | 45000 | 0 |
| 4.50 | 48000 | 0 |
| 5.00 | 55000 | 0 |

The misloading fuel assemblies are assumed to be fresh state of which composition is U-234, U-235, U-236, U-238 and O-16.[4]

## 3. Analysis

Fig.1 and Fig. 2 depict the analysis model of GBC-32 cask with MCNP6.1. Only fuel configurations are different for both models.

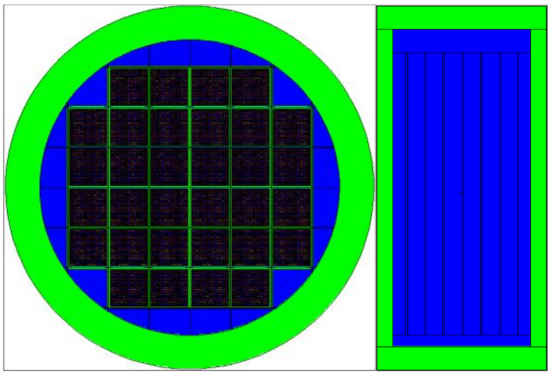

Figure 1. Visualized GBC-32 Cask with WH 17x17 fuel assemblies designed with MCNP 6.1

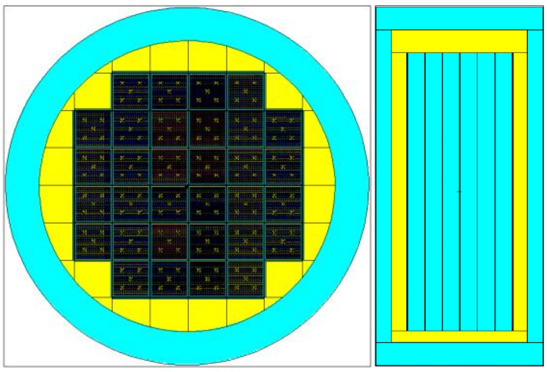

Figure 2. Visualized GBC-32 Cask with Plus 7 fuel assemblies designed with MCNP 6.1

From the previous analysis [9], the most significant misloading cases are provided from almost 140,000 possible misloading cases. The model and analysis are carried out by using KNEO-VI, one of the modules in

SCALE 6.1.[10] As a result, the most significant case of various misloading cases was found as in Fig. 3.

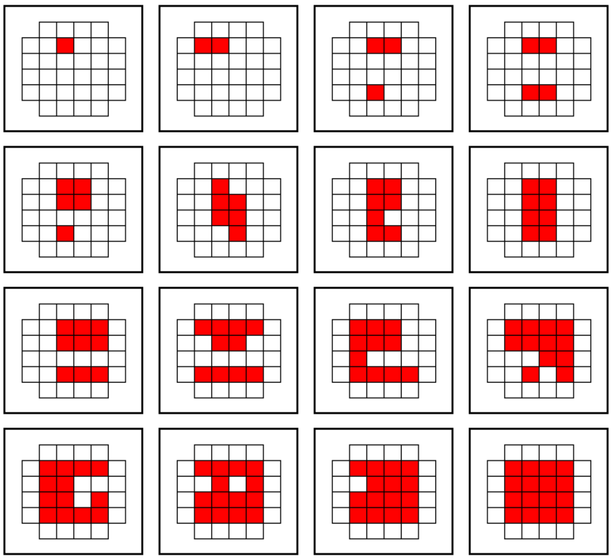

Figure 3. The Most Critical Case of Misloading

In Fig. 3, the misloaded assemblies are colored with red color. Outer 16 fuel assemblies are assumed to be correctly loaded without any mistakes. The calculations of criticality are performed with the various conditions of enrichment, burnup and misloading cases.

## 4. Result

The calculation of criticality was performed with KCODE card with ENDF/B-VII.1 cross section library in MCNP 6.1.[6] In order to compare the results, all k-eff values are depicted in one figure for various misloading cased as shown in Fig. 4 and Fig. 5 which provides k-eff for WH 17x17 and Plus 7 assemblies, respectively.

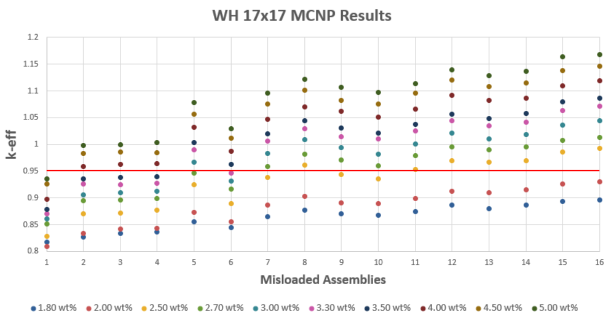


Figure 4. Criticality Results of Misloaded WH 17x17 Fuel Assemblies

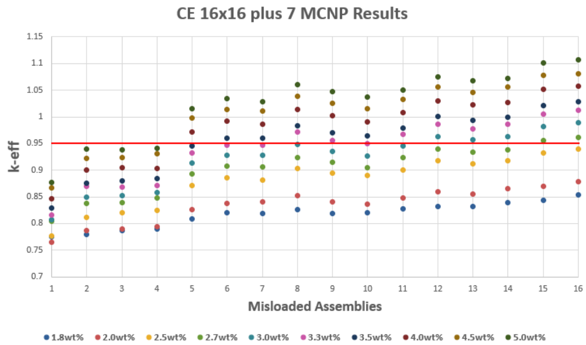


Figure 5. Criticality Results of Misloaded Plus7 Fuel Assemblies

The critical limit is assumed to be 0.95 which only includes administrative margin of criticality.

As shown in figure 4, even though analysis was performed with the most critical state when multiple misloaded assemblies are considered, the only one misloaded case satisfy subcritical safety irrespective of enrichments. When misloaded cases increase, the subcriticality margin is reduced in terms of enrichment. For example, for the 16-misloaded case, only 1.8 wt% and 2.0 wt% are acceptable. However, for Plus 7 type fuel assembly, it is much more marginal than WH 17x17 fuel assembly. From Fig. 5, up to 4 misloaded cases are below the critical limit of 0.95. And for the 16-misloaded case, 2.5 wt% fuel assembly is also satisfactory the misloading analysis. And the reactivity deviation of the 16-misloaded case due to enrichment change, about 0.13 ~ 0.16 $\Delta k$ is obtained for both two fuel assemblies. It is also found that the reactivity deviation of misloading increase as the misloaded fuel assemblies increase.

## 5. Conclusion

The critical analysis for the multiple misloading cases of the GBC-32 cask has been performed with various conditions of enrichment, burnup and the fuel types. The MCNP6.1 code is used for modeling and critical analysis for WH17X17 and Plus 7 fuel assemblies. It is found that even though 16 spent fuel assemblies are misloaded the value of criticality is less than 0.95 when lower enrichment spent fuels are loaded for both fuel assemblies. The reactivity deviation due to enrichment change increases as misloading cases increase.

In order to analyze the misloading analysis correctly, it is necessary consider a real loading curve based on the spent fuel histories. And the enrichment dependent axial burnup distribution is also taken into consideration. It is expected that current approach may provide the basic data to establish safety regulation or guide for the dry spent fuel cask in a near future.

Acknowledgments

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