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Criticality Evaluation of Storage Rack with or without Neutron Absorber

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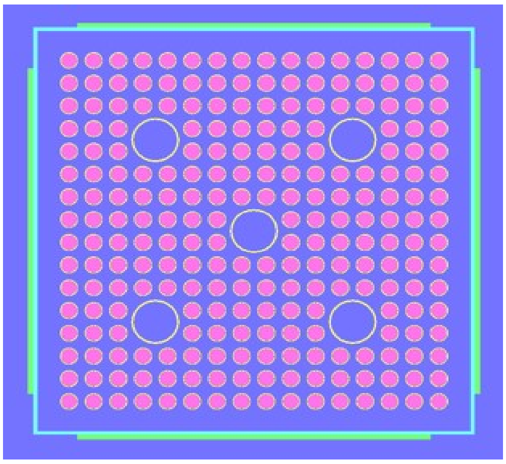
1. Introduction

All of fresh or spent nuclear fuel assemblies must remain under sub-criticality in wet or dry storage facility. According to KINS/RG-N10.0 and 10CFR50.68, if optimum moderation of fresh fuel in the storage racks occurs, the k-effective corresponding to this optimum moderation must not exceed 0.98 at 95 percent probability, 95 percent confidence [1,2]. The criticality analysis was performed under the condition that fresh fuel assemblies are stored in Region 1 rack of spent fuel pool according to water densities. Also, criticality validation was performed depending on whether neutron absorber is installed or not on the storage rack.

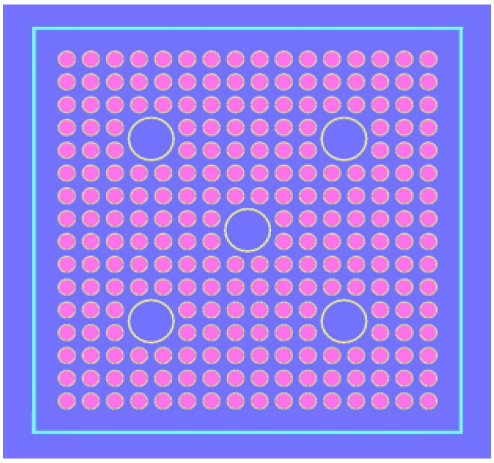
2. Methods and Assumption

SCALE(**S**tandardized **C**omputer **A**nalyses for **L**icensing **E**valuation) is used for the criticality evaluation. The SCALE computer software system developed at Oak Ridge National Laboratory is widely used and accepted around the world for criticality safety analysis [3]. The well-known KENO-VI three-dimensional Monte Carlo criticality computer code is one of the primary criticality safety analysis tools in SCALE. Scale was originally created under the sponsorship of the U.S. Nuclear Regulatory Commission (NRC), and it continues to be supported by the NRC, as well as the U.S. Department of Energy (DOE).

The criticality analysis is performed to determine the k-effective according to the various water densities for the normal condition without any uncertainty and bias calculation. This paper considered PLUS7 fuel assembly with 16x16 array. 5.0wt% fresh fuel assemblies are fully loaded in Region 1 rack at the circumstance temperature of 20℃. The Region I SCALE model of figure 1(a) consists of a single rack cell (rack cell wall, neutron absorber Metamic^{TM}, sheathing and water gap) with reflective boundary conditions through the centerline of the water gaps, thus simulating an infinite array of Region 1 storage racks. Figure 1(b) is the model without neutron absorber.



(a) With neutron absorber



(b) Without neutron absorber

Fig. 1 Geometric mechanical models depending on whether neutron absorber is installed or not on the storage rack

3. Analysis Result

Criticality validation was evaluated depending on whether neutron absorber is installed or not on the storage rack.

Figure 2 shows k-effective according to water densities in case that neutron absorber was installed on the storage rack. As shown in Figure 2, k-effective was maintained in the range of 0.55 to 0.6 between 0.0 and 0.2g/cc water density, and gradually increased at the water density of 0.2 and higher.

Figure 3 shows k-effective according to water densities in case that neutron absorber wasn't installed on the storage rack. As shown in Figure 3, maximum k-effective occurred at 0.06g/cc water density. This means that optimum moderation is 0.06g/cc water density.

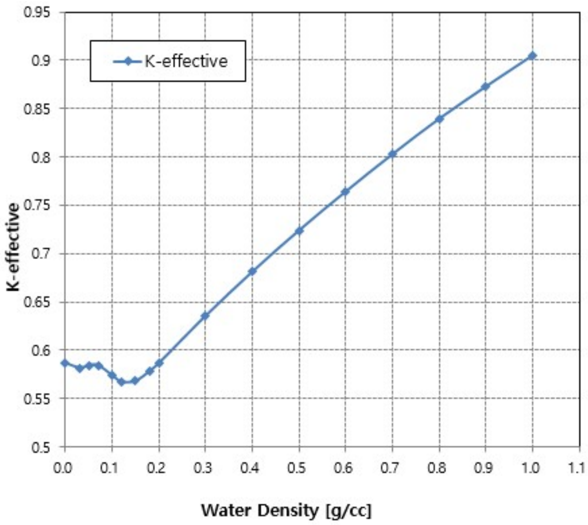


Fig. 2 k-effective according to water densities
(With neutron absorber)

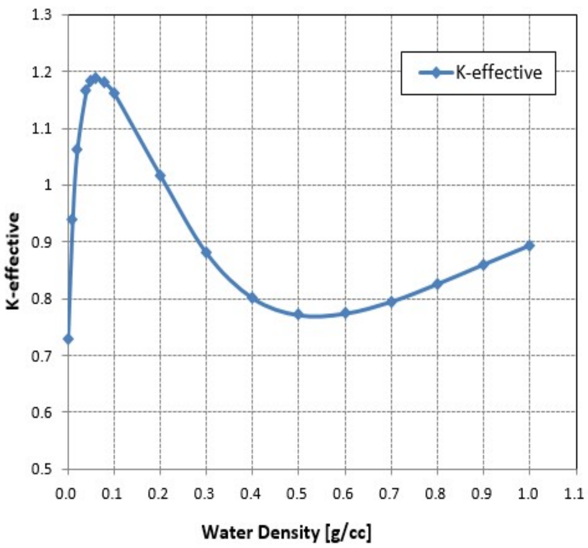


Fig.3 k-effective according to water densities
(Without neutron absorber)

In this result, we can see that optimum moderation occurs at low water density in case that neutron absorber wasn't installed on the storage rack, but the higher the water density, the higher the k-effective in case that neutron absorber was installed on the storage rack. The reason is why the thermal neutrons that increase the reactivity are not absorbed and decelerate to optimum conditions, affecting the reactivity of the adjacent nuclear fuel in case without neutron absorber.

4. Conclusions

Criticality analysis was performed to evaluate criticality validation depending on whether neutron absorber is installed or not on the storage rack. As the result, we can see that optimum moderation occurs at low water density in case without neutron absorber, but the higher the higher water density, the higher the k-effective in case with neutron absorber. This means that we don't need to assess the optimum moderation conditions if neutron absorber is installed on the storage rack.

REFERENCES

[1] 10CFR50.68 Criticality accident requirements, NRC
[2] 경수로형 원자력발전소 규제기준 및 규제지침, KINS, KINS/RG-N10.01, 2015
[3] Scale: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design, ORNL/TM-2005/39, Version 6.1, June 2011. Available from Radiation Safety Information Computational Center at ORNL as CCC-785.