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Criticality Safety Effect according to Fuel Rod Consolidation

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1. Introduction

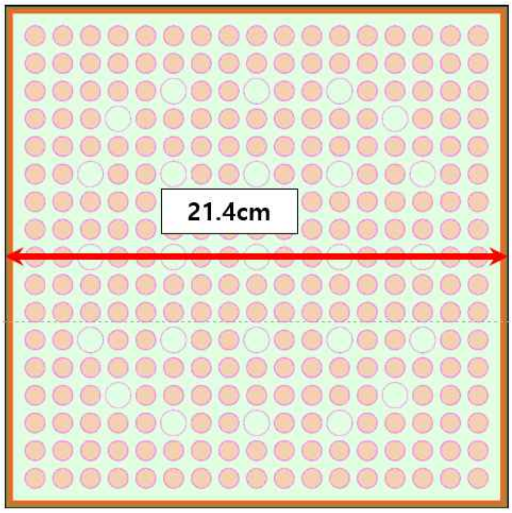
Spent fuels discharged after depletion in the reactor are stored in spent fuel pool (SFP) of domestic nuclear power plant (NPP). KHNP (Korea Hydro. & Nuclear Power Co. Ltd.) has a plan to build a dry storage facility to store spent fuel in a dry storage method within the nuclear power plant site. Currently, the total number of spent nuclear fuel generated in domestic nuclear power plants is more than 20,000 bundles, and large-scale facilities and site areas are expected to be required to store such spent nuclear fuel. Therefore, in this paper, rod consolidation was considered as a volume reduction method for efficiently storing spent nuclear fuel generated on a large scale. What is the rod consolidation method here? It is a method to reduce the volume through re-assembly by taking out only the fuel rods from the fuel assembly. Arithmetically, a volume reduction of about 32% compared to the existing nuclear fuel assembly is expected. In this paper, the re-assembly of the nuclear fuel assembly by the rod consolidation method has analyzed the effect on the critical safety.

2. Methodology and Assumption

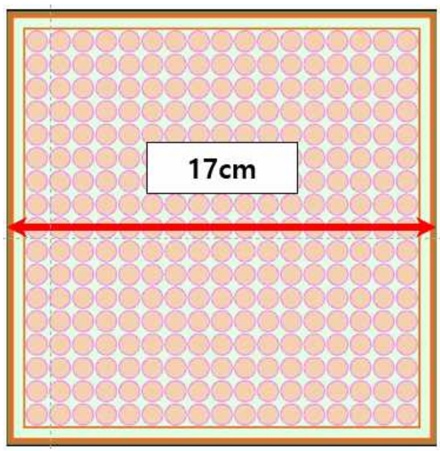
STARBUCKS is used for the criticality safety analysis and it is a module of the SCALE (**S**tandardized **C**omputer **A**nalyses for **L**icensing **E**valuation) [1]. In this analysis, SCALE 6.1.3 and the 238-group ENDF/B-VII cross section library was used. SCALE was originally created under the sponsorship 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 safety analysis was calculated considering the normal fuel assembly model and the rod consolidation model. In case of normal fuel assembly model, V5H fuel assembly with 17x17 array was considered and, in case of rod consolidation model, the fuel rods of the V5H fuel assembly were arranged without gaps and the existing guide tubes were modeled by replacing them with fuel rods. The enrichment of the spent fuel considered in the analysis is 5.0w/o and the burnup is 45,000MWD/MTU [2]. METAMIC neutron absorber (0.0249 B-10g/cm^2) was considered.

Figure 1 shows configurations of the normal fuel assembly model and rod consolidation model. The number of fuel rods is 264 for the normal fuel model and 289 for the rod consolidation model.



(a) Normal Fuel Assembly Model



(b) Rod Consolidation Model

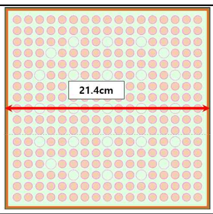
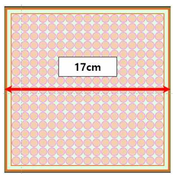
Fig. 1 Configurations of the normal fuel assembly model and rod consolidation model.

The array of the above two models is the same as 17X17, and an infinite arrangement of wet storage conditions was assumed to consider the accident condition.

3. Result and Conclusions

In this paper, rod consolidation was considered as a volume reduction method for efficiently storing spent nuclear fuel generated on a large scale. the re-assembly of the nuclear fuel assembly by the rod consolidation method has analyzed the effect on the critical safety. As the result of the analysis, the case of storage by the rod consolidation method under infinite array conditions showed a higher safety margin in terms of critical safety than the case of storage by the normal fuel assembly model. Table 1 shows the result.

Table 1: k_{eff} according to the normal fuel assembly model and rod consolidation model

Model	Normal Fuel Assembly	Rod Consolidation
		
No. of rods	264	289
k_{eff}	0.9755	0.7795

The reason why the k value of the rod consolidation model is lower is considered to be because the amount of the moderator (h2o) existing between the fuel rods is reduced compared to the normal fuel assembly, reducing the moderating effect of neutrons.

In conclusion, as a methodology for reducing the volume of spent nuclear fuel, the rod consolidation method has an increased safety margin compared to the normal fuel assembly model in terms of critical safety, and has the advantage of obtaining a reduction effect of about 32% in terms of volume. However, it can be said that problems such as damage, working time, and exposure to workers that are concerned in the process of disassembling and reassembling spent nuclear fuel are still problems that remain as homework.

REFERENCES

[1] Scale. A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design, Version 6.1.3, 2015.

[2] NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities", Final Report, U.S. Nuclear Regulatory Commission, 2020.

[3] 10 CFR 72.124 "Criteria for nuclear criticality safety"

[4] NEI 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants", Revision 3, March 2018