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Evaluation of Criticality for ACE7^{TM} Fueled Fuel Storage Rack in Kori Unit 2

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1. INTRODUCTION

The ACE7^{TM} fuel has been developed for Westinghouse type reactors in Korea and has several outstanding benefits against the existing fuel. For commercial use of ACE7^{TM} fuel, the criticality safety evaluation for fresh and spent fuel storage racks should be performed and licensed by regulatory.

Benchmark calculations of an analysis code system and a cross section library, and criticality safety evaluation of the fuel storage racks in Kori unit 2 were performed in this study.

2. Evaluation of Criticality Safety

2.1 Code System for Modeling

The evaluation of criticality for fuel storage racks was calculated by the code SCALE4.4 [1] (Standardized Computer Analyses for Licensing Evaluation) which provides a comprehensive and integrated package of codes and nuclear data for a wide range of applications in criticality safety, reactor physics, and shielding, isotopic transmutation. The CSAS (criticality safety analysis sequences) module of the code system was used to provide automated, problem-dependent, cross-section processing followed by calculation of the neutron multiplication factor for the system being modeled. These control sequences activate the cross-section processing codes BONAMI and NITAWL-II to provide resonance-corrected cross sections. KENO V.a uses the processed 238 groups ENDF/B-V library cross sections and calculates the k-effective of three dimensional system models. The geometric modeling capabilities available in KENO V.a coupled with the automated cross-section processing within the control sequences allow complex, three-dimensional systems to be easily analyzed.

2.2 Bias and Uncertainty for Code System

Considering the bias and uncertainty of calculation tool, benchmark calculations based on ICSBEP (International Criticality Safety Benchmark Evaluation Project) were performed by the SCALE4.4 code. The 118 benchmark calculations which were experimented for UO_2 fuel were considered from International Handbook of Evaluated Criticality Safety Benchmark Experiments [2]. The results of benchmark calculation were shown as Table 1. In this calculation, bias uncertainty and calculational statics were calculated as equation (1).

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i \quad x_{avg})^2} \qquad (1)$$

where
n :*Number of experiments*
x_i :*Effective multiplication factor for* i_{th} *case*
x_{avg} :*Average multiplication factor for118 cases*

Table 1 The Result of benchmarking calculation

Avg. k-eff	Bias	Bias Uncertainty	Calculational Statics
0.99489	0.00511	±0.003466	±0.00183

2.3 Modeling of Fuel Storage Rack

2.3.1 Assumptions

For conservatism of calculation, several assumptions of modeling storage rack were considered as follows;

- Fresh 5.0w/o enriched uranium fuel without control rods is fueled,
- Water in storage is pure water without boron and 27℃, (just applied for spent fuel)
- Array of assembly is infinite and moderator thickness is 30.48cm axially in top and bottom of assembly,
- In optimized moderating condition, misty Moderator thickness is 230cm axially in top and bottom of assembly,(just applied for fresh fuel)
- All structural material is ignored without guide tube,
- No burnable poison material,
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2.3.2 Spent Fuel Storage Rack

2.3.2.1 Optimum Moderating Condition

Criticality calculation condition which maximize effective multiplication factor should be considered. Therefore sensitivity calculation for water temperature was performed within the operating condition. As result, water temperature which maximize effective multiplication factor was at 48.9℃. But the criticality calculation was performed at 27℃, bias for water temperature was treated in final statistical calculation.

2.3.2.2 Normal and Abnormal Condition

Criticality calculations were performed for normal and abnormal condition. Abnormal conditions were considered for assembly coring and malposition. But abnormal conditions were not happened simultaneously. [3], [4]

2.3.3 Fresh Fuel Storage Rack

Optimum moderation effect was searched by changing the density of moderator. Therefore, optimum moderation condition and flooding condition were calculated. [5], [6]

2.3.4Manufacturing Tolerance for fuel

Commonly manufacturing tolerances uncertainty of fuel also should be considered in the evaluation of criticality for fresh and spent fuel. Therefore, fuel pellet size, enrichment, cladding size, fuel pitch, thickness of GT and IT, and location, and thickness of storage rack were considered for manufacturing tolerances.

2.4 Result of Criticality Calculation

Criticality calculations were performed for fresh and spent fuel storage rack. The results of calculation were introduced in Table 2 and 3. Criticality safety was determined by the value of effective multiplication factor and bias, and uncertainties. Equation (2) shows the final multiplication factor included all conservative conditions.

$$k_{eff} = k_{normal} + k_{bias} + T.U.(\text{Total Uncertainty}) \qquad (2)$$

where
k_{eff} :*Maximum effective multiplication factor*
k_{normal} :*Normal Effective multiplication factor*
k_{bias} :*Computational Model Bias*

$$T.U = \{ (ks)^2_{KENO} + \Sigma(ks)^2_{method} + \Sigma(ks)^2_{mech} \}^{1/2}$$

where
$(ks)^2_{KENO}$: *KENO-V.a Model Uncertainty*
$\Sigma(ks)^2_{method}$:*Monte Carlo Method Uncertainty*
k_{bias} :*Manufacturing Tolerances Uncertainty*

Table 2 Calculation Result of Spent Fuel Storage Rack

Normal K-eff	0.92386
Item	Uncertainty
■ Calculational Bias	0.00511
■ Total Uncertainty	±0.01361
- Bias Uncertainty (95%/95%, 2×σ)	±0.00693
- Calculational Statistics (95%/95%, 2×σ)	±0.00366
- Abnormal and Manufacturing Tolerance	±0.01113

Table 3 Calculation Result of Fresh Fuel Storage Rack

Flooding K-eff	0.86078
Item	Uncertainty
■ Calculational Bias	0.00511
■ Total Uncertainty	±0.01006
- Bias Uncertainty (95%/95%, 2×σ)	±0.00693
- Calculational Statistics (95%/95%, 2×σ)	±0.00631
- Abnormal and Manufacturing Tolerance	±0.00675
Optimum Moderation K-eff	0.94795
■ Calculational Bias	0.00511
■ Total Uncertainty	±0.01034
- Bias Uncertainty (95%/95%, 2×σ)	±0.00693
- Calculational Statistics (95%/95%, 2×σ)	±0.00366
- Abnormal and Manufacturing Tolerance	±0.00675

3. CONCLUSION

In this study, the criticality calculation was performed by using the code SCALE4.4 for the ACE7^{TM} fuel storage racks of Kori Unit 2. The result of criticality calculation of spent fuel storage rack with 5w/o ACE7^{TM} was within the criteria (0.95). Also, the results of criticality calculation of fresh fuel storage rack with 5w/o ACE7^{TM} met the criteria for optimum moderation (0.98) and the criteria for flooding condition (0.95)..

REFERENCES

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