Criticality Analysis for Loading Curve Generation for OASIS-32D Cask With PLUS7 Fuel

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1. Introduction

The OASIS-32D is a dual purpose (storage and transportation) metal cask under development by KEPCO E&C. It is designed to store 32 spent nuclear fuels (SNF). In this study, the depletion and criticality calculations are performed to evaluate criticality safety of the OASIS-32D. The cask is modeled as loaded with 10-year cooled PLUS7 fuel as shown in Figure 1.

The NUREG-1536 [1] subsection 7.4 is applied as the criticality safety design criteria. The acceptance criterion is such that k_{eff} including all biases and uncertainties at 95 percent confidence level should not exceed 0.95 under all credible normal, off-normal, and accident-level conditions.

The loading curves are generated for a target k_{eff} value of 0.95. The biases and uncertainties associated with the calculation methods as well as variations of design parameters are included in k_{eff} calculations.

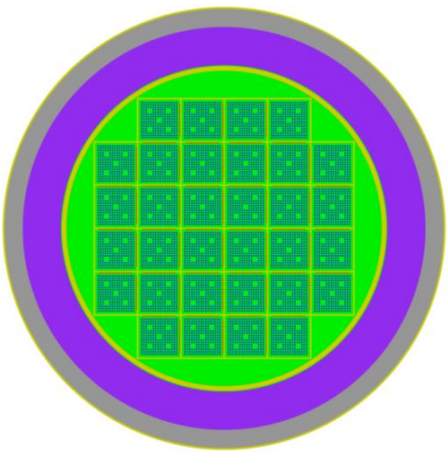

Fig. 1. X-Y cross-section View of OASIS-32D with PLUS7 Fuel.

2. Methods and Results

The SCALE 6.0 code package [2] is used for depletion and criticality calculations. The depletion calculations are performed using the ORIGEN-ARP with cross section libraries which are pre-generated by the TRITON-NEWT for the PLUS fuel depletion. The criticality calculations are performed using the CSAS5/KENO-V.a with the ENDF/B-VII 238-neutron energy-group library.

In order to determine the loading curve, criticality analyses are performed to find the minimum burnup which produces k_{eff} less than 0.95 at each initial enrichment of fuel assemblies.

The biases and uncertainties associated with the calculation methods, variations of design parameters and the depletion calculation are estimated from the following items:

- Biases and bias uncertainties of the criticality calculation method,
- Statistical uncertainty of the Monte Carlo calculation,
- Uncertainty due to tolerances or variations in the design parameters,
- Uncertainty due to eccentric fuel assembly positioning,
- Bias due to axial burnup distribution (end effect),
- Bias due to the fuel temperature in depletion calculation,
- Bias due to minor actinides and fission products,

- Uncertainty due to reactor burnup record, and
- Uncertainty due to the depletion calculation.

All biases are directly added to determine the total bias. Therefore, the total bias is the sum of all the biases due to the methodology, the minor actinides and fission products, the axial power distribution, and the fuel temperature in depletion calculation. etc.

All uncertainty values are statistically combined (the square root of the sum of the squares) to determine the total uncertainty. The uncertainties are due to the methodology, the Monte Carlo calculation, the mechanical tolerance, the reactor burnup record, and the depletion.

The calculated k_{eff} values considering the total bias and uncertainty are summarized in Table 1.

Table 1. k_{eff} with Bias and Uncertainty

Burnup (gwd/mtu)	Final k_{eff} + bias and uncertainty			
	2.0wt%	3.0wt%	4.0wt%	5.0wt%
2.25	0.91294			
6.75	0.89005	0.97341		
11.25		0.93488		
13.50		0.91901		
18.00			0.96666	
20.25			0.95448	
24.75			0.93416	
27.00				0.98024
31.50				0.96248
36.00				0.94543

The loading curve is the minimum burnup which satisfies the target k_{eff} for each initial enrichment. The curve is produced by targeting the k_{eff} less than 0.95 with considering all the biases and uncertainties in this analysis.

The calculated loading curve for OASIS-32D bounds 98.9% of the discharged fuel population as indicated in Figure 2. Discharged fuel population data are from the 2013 Energy Information Administration (EIA) GC-859 Nuclear Fuel Data Survey [3] which is a reliable and relatively recent estimate of the discharged fuel population.

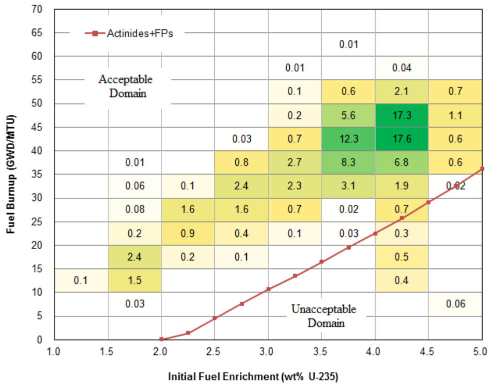

Fig. 2. Loading Curves for the OASIS-32D Superimposed over the GC-859 Data (%).

3. Conclusion

The k_{eff}s for various cases of initial enrichments and burnups of SNF loaded in the OASIS-32D cask are calculated to obtain loading curve in this study. The biases and uncertainties are properly applied for a conservatism in the loading curve. The loading curve for the OASIS-32D cask with PLUS7 fuel has been successfully generated. The loading curve bounds 98.9% the discharged fuel population [3]. Therefore, it is concluded that most of the discharged fuel can be stored in the OASIS-32D cask.

REFERENCES

[1] NUREG-1536, Rev.1, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," U.S. Nuclear Regulatory Commission, July 2010.

[2] "SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations," ORNL/TM-2005/39, Version 6, Vols. I-III, Oak Ridge National Laboratory, Jan. 2009.

[3] GC-859 Nuclear Fuel Data Survey 1968 through June 30, 2013, Energy Information Administration, Washington, D.C.