Comparison of Nuclide Inventories for Magnox Fuel Obtained by SCALE TRITON and SFCOMPO

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1. Introduction

DPRK has been continuously upgrading its nuclear weapons since its first nuclear test, especially in 2022 when it conducted dozens of missile tests and continued to demonstrate its potential for a seventh nuclear test. Think tank institute have published several contributions on nuclear activities of the DPRK based on satellite images, and it is believed that DPRK has continued its nuclear activities on the 5MWe Yongbyon reactor to produce nuclear materials needed for nuclear weapons. DPRK is known to have 5, 50, and 100 MWe reactors, but only one 5 MWe reactor have been believed to be operate, and it seems to be a means of producing tritium or Pu using the reactors. A quantitative analysis is needed in preparation for identifying the production of nuclear materials for nuclear activities of the DPRK and possible denuclearization in the future. In this study, SCALE TRITON modeling and validation with SF COMPO were performed for plutonium production.

Table 1. DPRK's nuclear activities in 2022

Institute	Date Issued	Title of Report
38 North	22.02.17.	Insights from a Snow-covered Day
38 North	22.03.03.	In Full Swing
38 North	22.05.24.	Upgrades Around the Complex.
38 North	22.07.12.	Plutonium Production Continues Despite Heavy Rains
38 North	22.07.28.	Plutonium Production Continues
38 North	22.10.28.	Ongoing Plutonium Production and New Construction
38 North	22.11.08.	Ongoing Fissile Material Production and Fall Harvest Activity
CSIS BP	22.02.18.	Thermal Imagery Analysis of Continued Activity at Yongbyon
CSIS BP	22.07.11.	Yongbyon Update: New Activity at Building 500 and Rising Waters

2. Analysis Method

The purpose was to verify the feasibility of SCALE TRITON module by comparing the SFCOMPO data and SCALE TRITON module for Hunterston Magnox reactor before using it to analyze the 5MWe Yongbyon reactor. Comparative verification was performed on the measured and derived data of the Hunterston reactor provided by SFCOMPO and the SCALE TRITON analysis values. Since the SCALE 6.2 ORIGEN library MAGNOX model is CALDER HALL and there was no measurement for CALDER HALL in SFCOMPO, validation of TRITON calculations was performed based on Hunterston. The SCALE 6.2 modeling was performed by using reactor operating histories, burnup steps, specific power and specifications provided by SFCOMPO. The fuel rods were calculated by using SCALE TRITON depletion module and the nuclide inventory was compared as the residual amount ratio to the initial uranium.

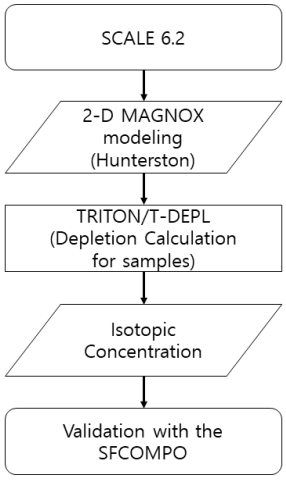

Fig. 1. Work flow for validation of the SCALE TRITON

Table 2. Hunterston reactor operating histories

Reactor	Sample	Burnup (GWd/MTU)	Specific power (w/g)	Depletion Day and Cooling(d)
Hunterston	A	3.271	1.5335	2398
	B	6.576	3.0346	2412
	C	6.902	3.5688	2282

3. Results

Nuclides inventory was verified by comparing error rates and RMS errors for U-235, 238, Pu-239 and Nd-145 and 146. [Case1] When SCALE TRITON and measured data were compared, Nd-145 was the nuclide with the smallest RMSE(Root Mean Square Error) for percentage error, which was approximately 2% and Pu-239 with the largest nuclide was approximately 4%. [Case2] When SCALE TRITON and Derived data were compared, the smallest nuclide was U-238, which was about 2% and the largest was about 4% in U-235. The RMSE of Case 1 was 3.1% and the RMSE of Case 2 was 2.8%. These RMSE validation less than 5% was reliable but additional calculation of various samples and nuclides will be required to be trusted for Magnox fuel analysis and plutonium production assessment.

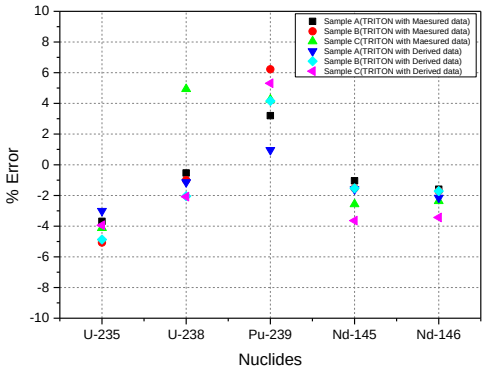

Fig. 2. Percentage error of the sample A, B and C

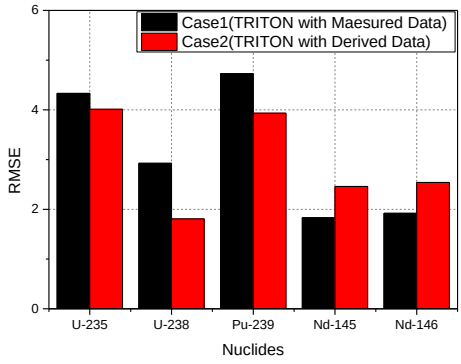

Fig. 3. RMSE of the Case1, Case2 for Nuclides

4. Conclusion

North Korea has been upgrading its nuclear weapons and is being captured continuing to operate the 5MWe reactor at the Yongbyon nuclear research complex. Therefore, as a tool for evaluating plutonium production, the SCALE TRITON module was conducted to verify that the estimated nuclide inventories for the MAGNOX fuel were evaluated at a reliable level. In this study, it can be confirmed by RMSE that the SCALE TRITON module was reasonable for the anlysis of Magnox fuel, but there was a limit to the number of samples provided by SFCOMPO, so additional analysis used MCNP such as Pu isotopes and major actinides will be performed.

ACKNOWLEDGMENTS

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