Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Development of Automation Module for Spent Nuclear Fuel Safety Information

Seok Geun Cho*, Seung Uk Yoo, Kyoon Ho Cha, Change Je Park
Nuclear Engineering Dept., Sejong Univ., 209 Neungdong-ro, Gwangjin-gu, Seoul 143-747, Korea
**Corresponding author: sgcho@sju.ac.kr*

1. Introduction

As the first Nuclear Power Plant (NPP) had operated in Korea, a lot of Spent Nuclear Fuels (SNFs) have been produced. SNFs are required to be transported when the NPP is on progress of decommission. In addition, transporting SNF is a crucial step in the nuclear fuel cycle, and it requires thorough safety measures and information. Thus, it is important to check whole SNF information which required to be transported to other site and it is so called “Safety Information” in this paper. [1]

The safety information which has been received by SNF productor requires to be validated for SNF receivers to check whether the information has been given properly or not. One of the validation methods is to compare the results with validated simulation code. Thus, in this paper, the automized SNF safety information checking module has been developed, and it has check lists for making simulation code input to validate with the safety information. In addition, the reference code input for criticality calculation has been given for example in this paper. The Monte Carlo simulation code MCNP6.2 and KENO-VI in SCALE 6.2.4 have shown for the reference in this paper. [2, 3]

2. Methodology and Conditions

To develop the automation module, it is necessary to use the safety information and its form. However, due to the SNF safety information is confidential, the sample dataset has been developed with reference data. [4, 5] In addition, the SNF information in sample dataset has been developed with reference data. [6] The sample dataset has been developed as **Figure 1**.

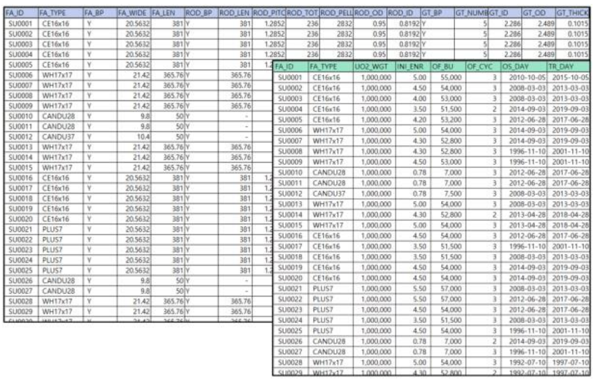

Figure 1. Sample of SNF Safety Information

When the safety information has given to automation module that developed in this paper, it is required to check all information and the check list will be given as **Figure 2** which has referred the document of Nuclear Energy Institute. [7]

Subject	Included (YES / NO)	Required (YES / NO)
Design Parameter		
Fuel Assembly		
Length		
Height		
Fuel Rod		
Length		
Height		
Total Number		
Total Pellet Number		
Inner Diameter		
Outer Diameter		
Guide Tube		
Total Number		
Inner Diameter		
Outer Diameter		

Figure 2. Check List of SNF Safety Information

The check list that given in **Figure 2** is a sample list that could be changed in the future. As shown in **Figure 2**, there are “Included” list and “Required” list. The “Included” list is checking whether the information that given safety information has included following parameters or not. The “Required” list is checking the information which is required while making reference code input.

After the information has been checked with automation module, mode selection will be given for the users. As shown in introduction, user requires to choose the code that the reference input to be created. The reference input will be given with the information that checked in the “Required” list. After select the code, the information about which condition will be used (cask condition or spent fuel pool condition) is additionally required to be chosen for reference input. The detailed process and reference input with result are described in the next chapter.

3. Result Analysis

The automation module has been developed with the process described above in python, and it can be visualized with flow chart as **Figure 3**.

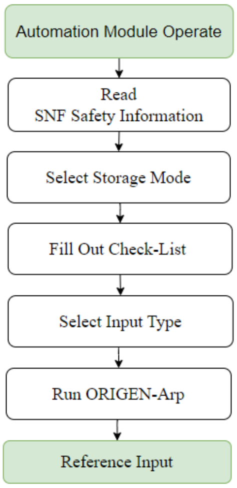

Figure 3. Flow Chart of Automation Module

The module fills out the checklist as the SNF information has been entered. The checklist filled out by automation module as **Figure 4**.

Subject	Included (YES / NO)
Design Parameter	
Fuel Assembly	
Length	YES
Height	YES
Fuel Rod	
Length	YES
Height	YES
Total Number	YES
Total Pellet Number	YES
Inner Diameter	YES
Outer Diameter	YES
Guide Tube	
Total Number	YES
Inner Diameter	YES
Outer Diameter	YES

Figure 4. Check List

After check list is filled out, SNF storage mode is selected. The types of storage modes are "Cask" and "Spent Fuel Pool". This process is to provide the correct reference input. After select storage mode, code type of the reference input is selected. MCNP6.2 and SCALE 6.2.4 may be selected. Upon completion of this process, checklist is filled out as **Figure 5**.

Subject	Included (YES / NO)	Required (YES / NO)
Design Parameter		
Fuel Assembly		
Length	YES	YES
Height	YES	YES
Fuel Rod		
Length	YES	YES
Height	YES	YES
Total Number	YES	YES
Total Pellet Number	YES	NO
Inner Diameter	YES	YES
Outer Diameter	YES	YES
Guide Tube		
Total Number	YES	YES
Inner Diameter	YES	YES
Outer Diameter	YES	YES

Figure 5. Check List

Based on the safety information, the automation module runs the ORIGEN-ARP code to update the SNF nuclide information. The result has been modified for the reference input. After then, the automation module finally provides a reference input. Reference input has been developed through safety information as **Table 1**.

Table 1. Design Parameters of SNF Assembly

Design Parameters	Specification
Fuel Type	CE 16x16
Density of Fuel (g/cc)	10.44
Initial Enrichment (wt%)	5.0
Burnup (MWD/MTU)	55000
Power Density (MW/MTU)	45
Number of Cycles	3
Cooling Time (year)	5
Fuel Pellet Radius (cm)	0.4096
Cladding Outer Radius (cm)	0.475
Guide Tube Inner Radius (cm)	1.143
Guide Tube Outer Radius (cm)	1.2445
Assembly Length (cm)	20.5632
Assembly Height (cm)	381

The composition of SNF has been calculated with ORIGEN-ARP code which included in SCALE 6.2.4. After the SNF composition calculated, the reference cask input has been modified with the calculated composition. The reference input has been visualized with KENO-VI. The visualization has shown as **Figure 6**. [8, 9]

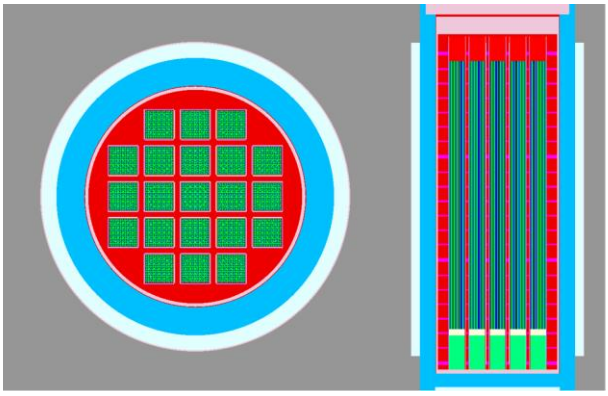

Figure 6. X-Y and Y-Z Cross-sectional View of Reference Input

In addition, the calculation for three cases which are less depleted than normal conditions from sample dataset have been performed. The special cases have following fuel conditions. [6]

Table 2. SNF conditions for each case

Cases	Initial Enrichment (wt%)	Burnup (GWd/MTU)	Cooling Time (year)
Case 1	3.0	10	10
Case 2	4.0	20	10
Case 3	5.0	30	10

The criticality calculation has been performed with KENO-VI of SCALE 6.2.4 with the reference input as shown in **Figure 6**. The criticality calculation has been performed with water flooded condition in cask with ENDF/B.VII.1 cross-section library, and the result has shown as following table.

Table 3. Calculation Result

Cases	k_{eff}	std
Case 1	0.76331	0.00087
Case 2	0.76828	0.00098
Case 3	0.77585	0.00090

As each condition are less depleted conditions than normal SNF, it has been expected to show high k_{eff} for water flooded condition. However, as the results have shown less than 0.8, the normal SNF in sample dataset would show sub-critical in water flooded condition.

4. Conclusion

To handle the SNF information safely, a serious attention is required for SNF producer and receiver. In this paper, an automated module for checking safety information of SNFs has been developed, with the sample dataset and a check list for validation. The automation module has been visualized with a flow chart as shown above. In addition, as the module can provide reference input for given information, the expected results have been calculated automatically with the module. As the criticality calculation has been performed with less depleted cases, the criticality results have shown sub-critical in these cases. For the future work, reference inputs will be added for various calculation modules, and the module will be modified to be available for any information.

Acknowledgement

This work was supported by Nuclear Safety Research Specialist Training Project through the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2020M2C7A1A0207823522) and Technology Development Project for safe operation of nuclear power plants through the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MTIE) (No. 2021040101002D).

REFERENCES

[1] IAEA, Data Requirements and Maintenance of Records for Spent Fuel Management: A Review, IAEA-TECDOC-1519, 2006.

[2] S.M. Bowman and I.C. Gauld, Origen Arp Primer, How to Perform Isotopic Depletion and Decay Calculations with SCALE/ORIGEN, ORNL/TM-2010/43, Oak Ridge National Laboratory, April 2010.

[3] C. J. Werner, "MCNP Users Manual – Code Version 6.2", LA-UR-17-29981, 2017.

[4] C. E. Sanders and J, C, Wagner, Study of the Effect of Integral Burnable Absorbers for PWR Burnup Credit, NUREG/CR-6760, ORNL, 2002.

[5] V. Krasnorutskyy, Fuel Rod Performance Evaluation of CE 16x16 LTA Operated At Steady State Using Transuranus and Pad Codes, KHARKOV, 2009.

[6] D. E. Mueller, et al., Bias Estimates Used in Lieu of Validation of Fission Products and Minor Actinides in MCNP Keff Calculations for PWR Burnup Credit Casks, NUREG/CR-7205, 2015.

[7] Nuclear Energy Institute, Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants, NEI 12-16, 2019.

[8] Jong-Il Yoon, et al., Center for Spent Nuclear Fuel and Radioactive Waste Safety Research, R&D/1505032-0517-CG100, Nuclear Safety and Security Commission (Korea), Korea Advanced Institute of Science and Technology (KAIST, Korea), 2018.

[9] Kyoung-Sik Bang, Seung-Hwan Yu, Sang-Hoon Lee, Ju-Chan Lee, Ki-Seog Seo, Experimental investigation of heat removal performance of a concrete storage cask, Annals of Nuclear Energy 85 (2015) 679-686