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Criticality Safety Review using WIMS-AECL code in CANDU6 Spent Fuel Pool

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1. Introduction

Criticality safety at CANDU6 power plant is insignificant concern due to using natural uranium fuel and stored in light water spent fuel pool (SFP). But the criticality margin should be quantified to confirm safety. Heat load and heat sink are definitely separated issue with criticality margin [1]. This study reviews reference case, drained case, and optimum moderating condition case according applying safety review guideline of LWR [2].

2. Models and Results

In this section case model used to evaluate the criticality is described. Infinitive multiplication factor (k-inf) is calculated by WIMS-AECL code using CANDU6 lattice model [3].

2.1 Code System for Modeling

The WIMS-AECL code is a multigroup transport code for reactor lattice calculations, including burnup. The code has been developed from the WIMS code which was created at the United Kingdom Atomic Energy Establishment, Winfrith, Dorset. WIMS-AECL performs a detailed calculation for a single lattice cell, providing flux distribution, eigenvalues and reaction rates, as well as providing the usual lattice parameters.

Fuel bundle model of WIMS-IST is given in Fig 1 and Fig 2. Most of the variables used reference fuel bundle are simply the basic reactor data and the nominal operating conditions. However, heavy water moderator was substituted to light water in spent fuel pool. The 89 energy groups in ENDF/B-VI nuclear data library are condensed into 33 groups in WIMS-IST.

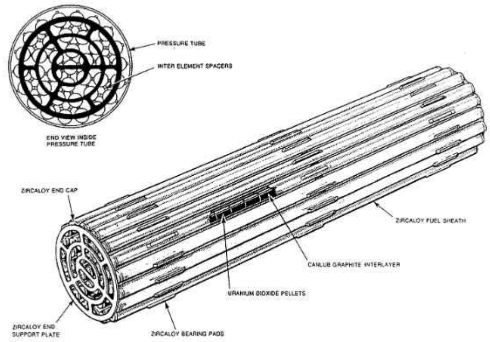

Fig. 1. The CANDU 6 37-Element Fuel Bundle

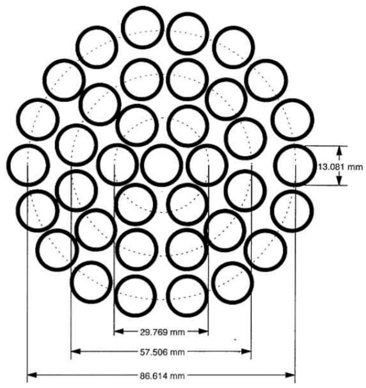

Fig. 2. 37-Element Fuel Geometry

2.2 Modeling of Spent Fuel Pool

2.2.1 Assumptions

For conservatism of calculation, several assumptions of modeling SFP are considered as follows;

- All fuel bundles are fresh fuel
- Water in storage is pure water without boron and absorbers (fuel tray) in spent fuel pool
- All structural material is ignored
- 2-Dimensional reflective infinite array (No Leakage)

2.2.2 Spent Fuel Pool Modeling

Criticality calculations are performed for normal and abnormal condition. Abnormal conditions are considered for fuel bundle malposition such as contacts.

Fuel bundle pitch and water density are varied to find the optimum moderating condition. Pitch size of Fuel bundle is normally 11.734cm when it located in tray cradle strip. If bundles are contacted, then the pitch size will be 10.8cm. Therefore, pitch size was increased from 10.8cm to 57.15cm. Optimum moderating condition calculation are done by changing water density from drained condition (0.1g/cc) to the saturated condition (1.0g/cc). The highest multiplication factor was searched from the calculations results, and it was and reviewed by the requirement [2].

2.3 Results and Review

The results of calculation were introduced in Fig 3 and Fig 4. The trend of multiplication factor by varying bundle pitch size and water density was shown in Fig 3.

Based on the trend analysis, more detailed calculation was performed from 0.01g/cc to 0.2g/cc for water density and from 10.8cm to 57.15cm for pitch size. As a result, when bundle pitch size and water density are 45.72cm and 0.02g/cc, the maximum k-inf. is 0.93390. This value has enough criticality margin than requirement (k-inf.=0.98). Moreover, k-inf. at flooding condition in spent fuel pool is 0.89354. It has also enough criticality margin at normal condition. Table 1 shows the summarized calculation results.

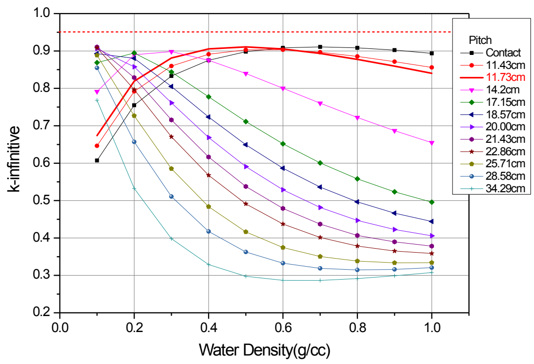

Fig. 3. Trend Analysis of Multiplication Factor by changing Fuel Bundle Pitch Size and Water Density in Spent Fuel Pool

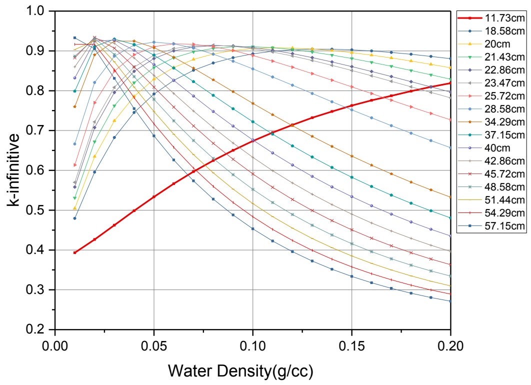

Fig. 4. Detailed Sensitivity Calculation of Multiplication Factor by Fuel Bundle Pitch Size (10.8cm ~ 57.15cm) and Water Density (0.01g/cc ~ 0.2g/cc) in Spent Fuel Pool

Table I: Summary of Results

	Water Filled	Optimum Moderating Condition
Bundle Pitch (cm)	10.8cm (Contacted)	45.72cm
Water Density (g/cc)	1.00g/cc	0.02g/cc
k-inf.	0.89354	0.93390

3. Conclusions

In the analysis presented in this study, two approaches have been followed the review of criticality safety in CANDU 6 spent fuel pool. One approach was the variation of pitch size to find at normal condition. A second was search of optimum moderating condition to make maximize the k-inf., and it was reviewed to have enough criticality margin. In conclusion, it was confirmed that criticality safety at CANDU6 power plant is insignificant concern, and the margin was quantified.

To evaluate bias and uncertainty related to model, manufacturing tolerance, and other sources, criticality calculation using SCALE code will be performed [4].

REFERENCES

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[4] "SCALE 6.2.1 (Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstation and Personal Computers)," ORNL/TM-2005/39, Oak Ridge National Laboratory, 2016.