Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

A Criticality Analysis of Fresh Fuel Storage Rack for Research Reactor

Chang Je Park*, Tae Young Han, Gyuhong Roh, and Byungchul Lee
Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: cjpark@kaeri.re.kr*

1. Introduction

In a research reactor, plate type fuel assembly is widely used due to a high power density and a marginal safety margin. It should be ensured that the fresh fuel assembly is stored in a safe place satisfying the criticality limit.

In order to evaluate the criticality safety of a plate type fresh fuel storage rack for research reactor, a permissible pitch size should be determined based on the upper subcritical limit (USL) analysis. The upper subcritical limit is estimated by both the regulatory guide [1] and the uncertainty of criticality calculation.

In this paper, criticality calculations for a fresh fuel storage rack are carried out under various pitches, four different fuel meat sizes, and water densities. The calculation uncertainty is also evaluated by using the results of the previous study.[2]

2. Criticality Calculation of Storage Rack

The fresh fuels of a research reactor are usually stored in the dry storage rack. The criticality test of fresh fuel storage rack for wet condition is taken into consideration the following conservative conditions which are based on the reference [1] about fresh fuel storage rack.

- All fuel stored in storage rack are fresh. (19.75 wt% enriched U-235, U_3Si_2 in Al matrix, Al Clad)
- Nominal subcritical limit for fresh fuel in research reactor is 0.9.[1]
- All the structures such as cell tube, storage lattice, and frame are ignored.
- The fuel assemblies are arranged reflectively in both horizontal and axial directions.
- Fuel meat size change (thickness, length) : M1(0.61, 620 mm), M2(0.51, 620 mm), M3(0.61, 640 mm), M4(0.51, 640 mm)
- Water density change : 0.0001 ~ 1.0 g/cc

All calculations are performed using MCNP5[3] code with ENDF/B-VII library. The number of source particles is 1,500,000 with 50 inactive cycles and 100 active cycles, and the standard deviations of the results are about 0.00022 ~ 0.00024. Figure 1 depicts the configuration of the MCNP model for the plate type fuel assembly.

2.1 Pitch size of a storage rack

The water temperature is assumed to be 40 °C. The square pitch sizes are adjusted from 20 ~ 22 cm for various fuel meat sizes. For the purpose of an efficient and conservative calculation, only one fuel assembly with a reflective boundary condition is modeled. Table 1 summaries the criticality for various pitches and four different fuel meat sizes. Base on the nominal critical limit of 0.9, the pitch size of 22 cm provides satisfactory subcritical requirements. However, if the thickness of fuel meat increases, the keff approaches around 0.88, which is very doubtful whether the criticality limit is satisfied or not when a calculation uncertainty is taken into consideration.

2.2 Water density effect

A dry condition of the fresh fuel storage rack may be changed depending on the outer environmental condition. Thus, the criticality of the fresh fuel assembly is tested considering the humidity and the smeared water inside the storage rack. By varying the water density from 0.0001 g/cc to 1.0 g/cc, the criticality of the storage rack is estimated. In this analysis, the pitch size of fuel assembly is fixed as 22 cm. Two different fuel meat sizes are considered and their results are provided in Figure 2. In the case of the fuel meat of M4(0.51, 640 mm), the upper criticality is obtained about 0.855, which satisfies the subcritical limit of 0.9. From the tests, it is found that the criticality of a water density around 0.2 provides the maximum k_{eff}, which is a combined effect of both the positive reactivity due to the moderation effect and the negative reactivity from the absorption of water. Unlike the spent fuel storage rack, a lower density of water coolant plays a key role in design of the fresh fuel storage rack.[4]

3. Uncertainty Analysis

In order to provide the upper subcritical limit, the previous results are used including the following uncertainty factors,[2][4]

- Cross section library
- Statistical error
- Manufacture error.

The criticality bias also occurs by the following causes:

- Cross section library
- Abnormal water temperature rise
- Fuel drop
- Fuel misloading

Table 2 summarizes the uncertainty and bias, which is based on the references [2] and [4]. From the results, the upper subcritical limit is obtained as USL= 0.9 – 0.0267 - 0.0072 = 0.8661.

4. Conclusions

From the uncertainty analysis, the upper subcritical limit of the fresh fuel storage rack is obtained as 0.8661. In the case of the fresh fuel storage rack, the pitch size of 22 cm satisfied for the meat thickness of 0.51 mm provides an enough margin by considering a conservative way of critical evaluation. However if the meat thickness is increased up to 0.61 mm, the pitch size of 22 cm is not fully satisfied in terms of the critical safety.

REFERENCES

[1] NUREG-1537, Part 2, Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria, U.S.NRC (1996).

[2] S.Y. Oh, "A Suggest for Expansion of HANRAO Spent Fuel Storage Rack", Internal Memorandum, KAERI (2005).

[3] MCNP – A General Monte Carlo N-Particle Transport Code, Version 5, X-5 Monte Carlo Team, LA-UR-03-1987, LANL (2003).

[4] T.Y. Han, "Criticality and Its Uncertainty Analysis of Spent Fuel Storage Rack for Research Reactor", Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 27-28, 2011.

Table 1. Criticality of Fresh Fuel Storage Rack for Various Pitches and Meat Sizes

Pitch (cm)	Meat size (thickness, length) (mm)	k_{eff}	standard deviation
20	M1(0.61, 620)	0.94678	0.00075
21	M1(0.61, 620)	0.90766	0.00082
22	M1(0.61, 620)	0.87019	0.00025
20	M2(0.51, 620)	0.92001	0.00024
22	M2(0.51, 620)	0.84341	0.00025
22	M3(0.61, 640)	0.88160	0.00023
22	M4(0.51, 640)	0.85464	0.00025

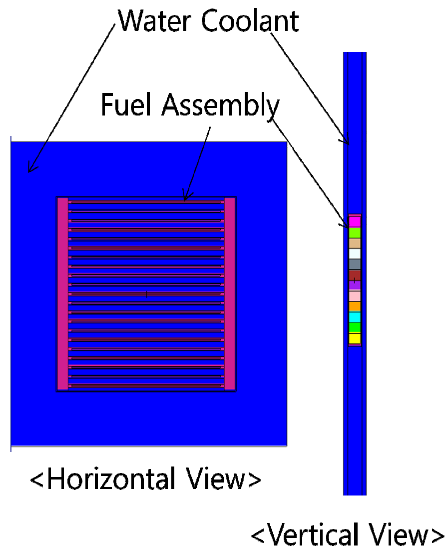

Figure 1. Calculation Model of a Plate Type Fresh Fuel for Criticality Test.

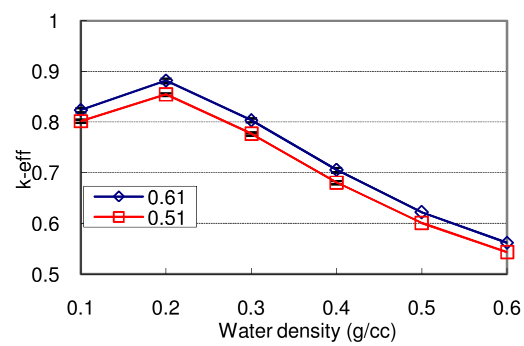

Figure 2. Criticality for Various Water Densities

Table 2. Evaluation of Uncertainty and Bias for the Criticality of the Fresh Fuel Storage Rack

Item	Bias	Uncertainty
MCNP + ENDF7 library	0.0017	0.0005
Standard deviation		0.0050
Manufacturing deviation on the tube thickness		0.0051
Abnormal state – temperature increase	0.018	
Abnormal state – fuel drop	0.005	
Abnormal state – fuel misloading	0.002	
Total	0.0267	0.0072