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Criticality safety analysis of spent fuel pool for TRIGA Puspatti Reactor using MCNP5

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Abstract. Spent fuel pool uses water to temporarily cool spent nuclear fuels before final disposal. The Malaysian Nuclear Agency is recently working on its spent fuel pool facility to store irradiated TRIGA fuel rods. These irradiated fuels still contain significant amount of fissile material which are capable to induce criticality in the fuel storage facility. This study is therefore performed to investigate the safety criticality analysis for the proposed fuel storage rack design of 5x5 arrays. MCNP5 code was used to model the 5x5 array of fuel storage rack in order to determine the optimal fuel pitch distance. The analysis was based on the standard UZrH_{1.6} TRIGA fuel clad with stainless steel used in PUSPATI TRIGA Reactor, which is 19.9% enriched ²³⁵U and 20% weight of Uranium. By varying the pitch distance between 4 cm to 14 cm with no neutron absorber included, the optimum fuel rack design was determined where sub-criticality condition can be maintained.

1. Introduction

PUSPATI TRIGA Reactor (RTP) is a 1MWth research reactor installed in Bangi, Malaysia, which achieved its first criticality in 1982. After many maintenance and upgrade along its safe operation years, RTP is still in service to produce radioisotopes, neutrons for research, education and training activities [1]. Soon enough, the fuel will reach its maximum burnup limit which will be categorized as spent, and thus, the fuel should be removed out from reactor operation.

Spent nuclear fuel is a high-level waste that requires a special designated interim storage facility before being sent to disposal facility of reprocessing facility. Even though it is considered as spent, the spent nuclear fuels are still generate heat from the decay process of actinides and fission products while being stored in interim storage facility. The interim storage facility must be to ensure the facility will always be in subcritical state at any conditions. The goal of this study is to perform the safety criticality analysis of RTP TRIGA fuel rod and determine the optimum 5x5 fuel array rack design, based on the standard and requirements provided by IAEA.

2. Storage rack modelling using Monte Carlo N-Particle (MCNP) code

In this study, MCNP code was used in modelling several designs of the 5x5 array storage rack with varied fuel pitch distances. The fuel data was based on the standard UZrH_{1.6} TRIGA fuel with 19.9% enriched ²³⁵U and composed of 20% weight of Uranium and clad with stainless steel 304 (SS304).



The dimensions of the fuel are as described in Figure 1. Results of interest are infinite (k_{inf}) and effective (k_{eff}) multiplication factors as a function of fuel pitch distances.

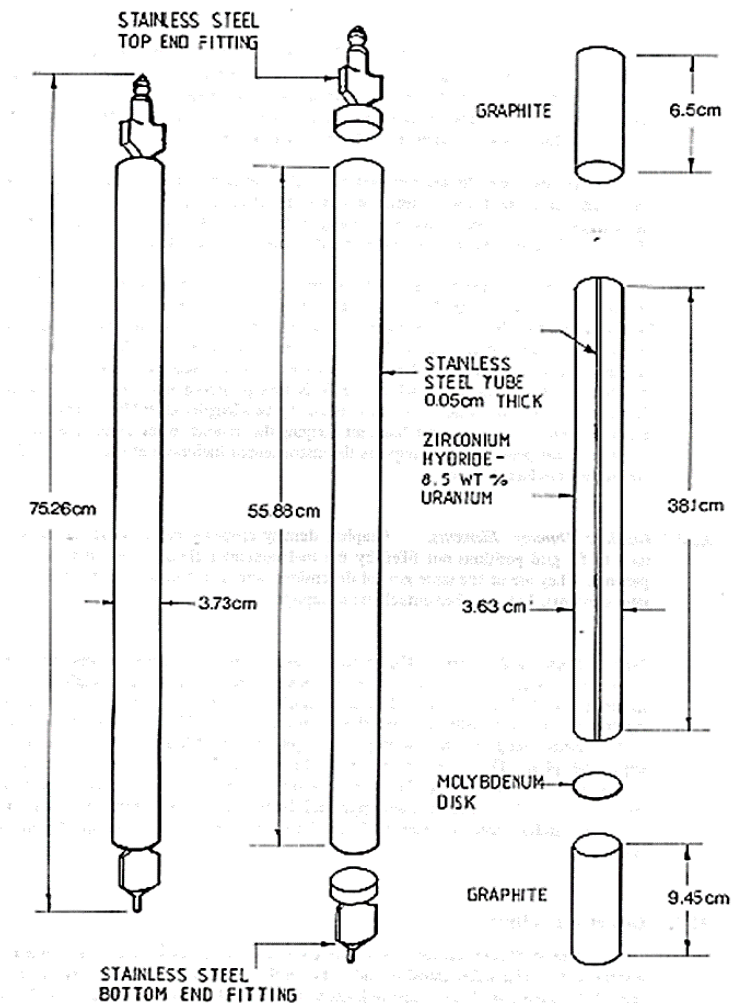


Figure 1. TRIGA fuel dimension [2].

The design of fuel racks with 5x5 array proposed in this study is based on the ability of the coolant to circulate around the fuels in the rack. The configuration of fuel array design should be taken seriously as it could lead to insufficient coolant flow which results in cladding failures and subsequently overheating. These may also lead to critical or supercritical conditions in the fuel storage pool [3].

3. Results and discussions

Figure 3 shows cross section of the MCNP model of the RTP fuel rod, while Figure 4 shows top and side view of 5x5 array of the storage rack. The criticality safety calculation was performed for fuel pitch distances ranging from 4 cm to 14 cm. Conservative and best estimate analysis approach using infinite and finite lattice model respectfully were considered. In infinite lattice model, the rack side boundaries were assumed to be reflective.

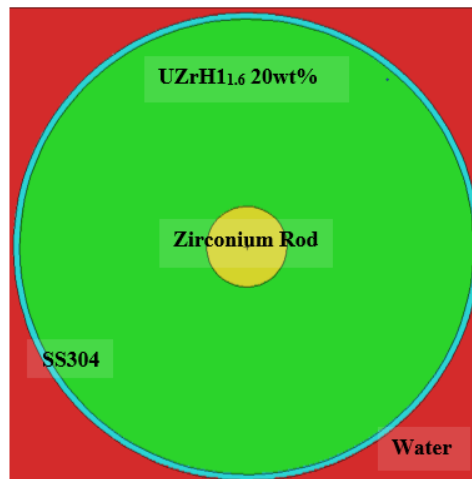


Figure 2. Cross section of RTP fuel rod.

IAEA requires that multiplication factors of the research reactor fuel storage to be lower than 0.80 under normal situations and lower than 0.95 under accidental conditions [4]. These values must be calculated by assuming the worst-case scenarios. Thus it was assumed that; a) the fuel element was all fresh (it has its original enrichment), b) the uranium weight of 20% type is used instead of 12% and 8.5% fuel type in RTP, and c) the geometric cross-sectional configuration is the same. The following is the results of the multiplication factor as a function of fuel pitch distances as calculated using MCNP5 code.

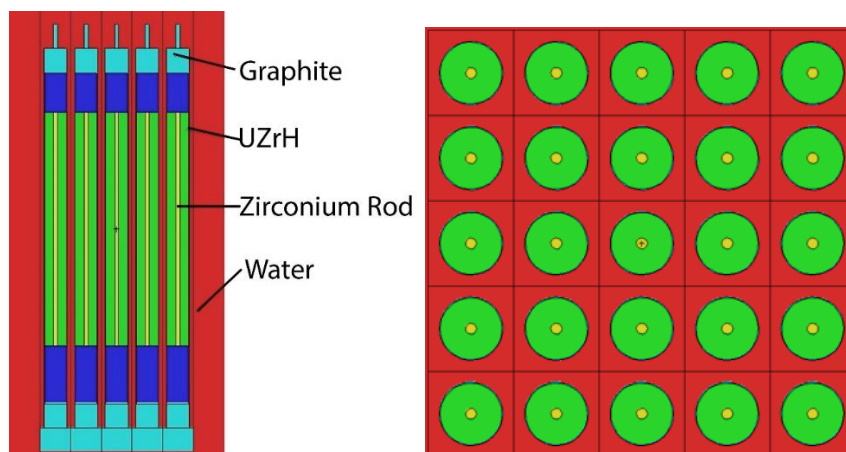


Figure 3. Top and side view of 5x5 array.

Table 1. Results of multiplication factor of 20% wt Uranium content RTP fresh fuel with different assembly pitch.

Assembly Pitch (cm)	K_{inf}	K_{eff}
4	1.235348 ± 0.004797	0.66209 ± 0.008235
6	1.192878 ± 0.004112	0.70123 ± 0.005841
8	1.096726 ± 0.004287	0.701812 ± 0.005292
10	0.97445 ± 0.004485	0.67054 ± 0.004567
12	0.848506 ± 0.004722	0.620182 ± 0.004293
14	0.731256 ± 0.00448	0.562762 ± 0.004108

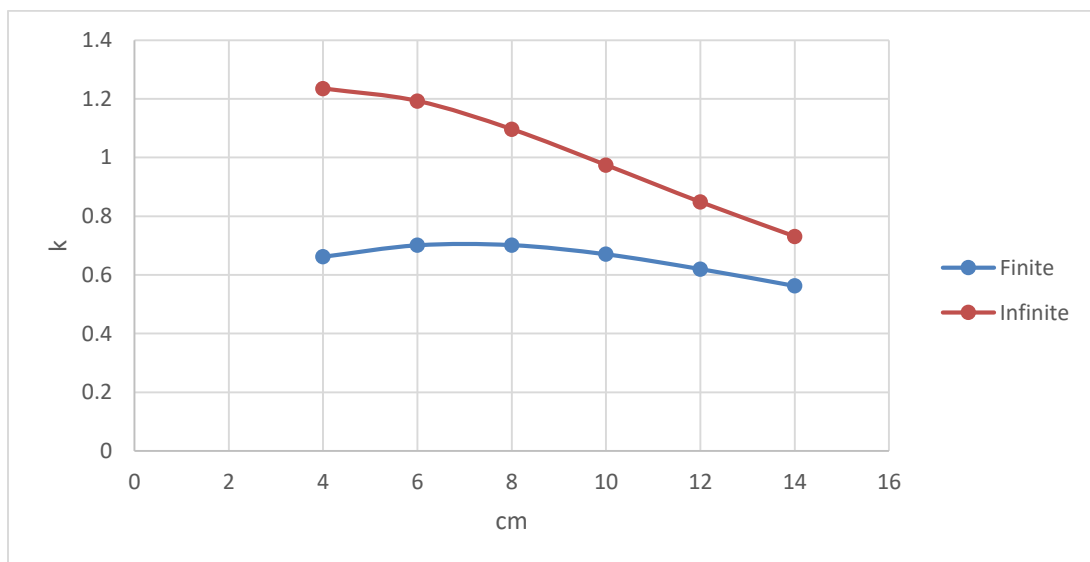
**Figure 4.** Multiplication factor of 20% wt Uranium content RTP fresh fuel with different assembly pitch.

Figure 4 shows the k_{inf} decreases as the assembly pitch increases. The k_{inf} value which indicates the maximum criticality can be achieved at a fuel pitch distance of 4 cm which is the closest distance the fuel rods can get. If the fuel pitch is less than 10 cm, the 5x5 fuel assembly will be supercritical.

The criticality calculation for the finite lattice (for best estimation approach), shows a slightly different trend of k_{eff} as a function of fuel pitch distance. All range of pitch distances for the 5x5 fuel assembly give k_{eff} values below 0.8. This result may be due to the modelling method in which there is empty space outside the 5x5 fuel assembly that leads to significant neutron leakage.

4. Conclusion

The subcritical state with k_{inf} value below 1.0 for the 5x5 array of fuel rods can be achieved at fuel pitch distance of 10 cm and bigger while k_{inf} 0.80 can be achieved at pitch distance of at minimum 13 cm in an infinite lattice model. The k_{eff} however was found to be within the safety margin, where at all pitch distance, the obtained k_{eff} are below 0.8. The safest rack design could thus be based on the conservative analysis.

5. References

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