Conceptual Nuclear Design of 10 MW Pool Type Research Reactor with HANARO Fuel Assemblies

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1. Introduction

The proposed 10 MWth reference core has four circular fuel assemblies and nine hexagonal fuel assemblies, and these two kinds of assemblies are the same with HANARO standard fuels. The core size is also almost the same as HANARO and heavy water reflector surrounds it. The core has less number of fuel assemblies than HANARO reference core and the specific power is also about half of HANARO reference core. [1] The specific goal of proposed design was to have a high flux in core region. The reference core is configured as simple as possible for a preliminary state and hence one in-core irradiation site only is included.

Table 1. Design features of the proposed reference core

	Core Design Parameters
Power	▪ 10 MWth
Rx type	▪ Open-tank-in-pool
Fuel (dispersion)	▪ $U3Si_2$-Al (4.8 gU/cc) ▪ Rod type ▪ Discharged burn-up > 50%
Maximum Neutron flux	▪ > $1.0x10^{14}$ $n/cm^2/s$ (core) ▪ > $1.0x10^{14}$ $n/cm^2/s$ (reflector)
Fuel cycle	▪ 30 days
Core Safety	▪ Inherent safety characteristics: Negative Reactivity Coefficient ▪ Passive Cooling System (Flap valve, check valve-modification)
Coolant & Core cooling	▪ H_2O, Upward ▪ Natural circulation: by pool water ▪ Water purification system (WPS)
Reflector	▪ D_2O
Reactor shutdown system	▪ Digital technology ▪ Drop by gravity (CAR & SOR) ▪ Independent 2nd shutdown system (D_2O drainage)
Reactor pool	▪ Power/Pool volume (~70 kW/m^3) ▪ Hot water layer system ▪ Monitor for pool leakage ▪ Spent fuel storage: 20 years
Experimental holes	▪ In-core irradiation site: 1

The flow tubes are used instead of the Al block which was proposed in ref.[1]. Therefore light water behaves as coolant as well as moderator. However, uranium density of the fuel meat and the inner shell along the fuel channel is like as HANARO. Furthermore loading more fuel assemblies in the core is avoided since the neutron flux in the reflector may decrease. The features of the proposed reference core are listed in Table 1. [2]

2. Methodology

2.1 Assembly Calculation

The assembly calculations for quarter part of both hexagonal fuel assembly and circular fuel assembly as shown in figure 1 were carried out. The calculation tool is HELIOS. The neutron groups are considered as two-group and thermal energy range is the band upto 0.625 eV. Geometrical buckling is also taken into account.

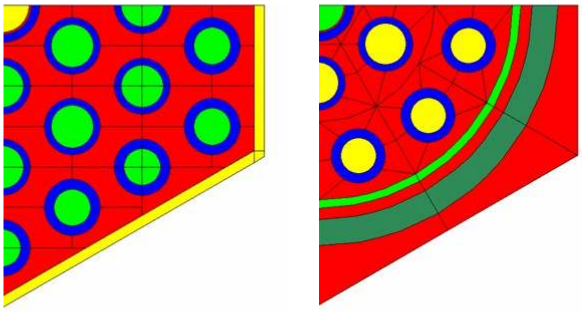

Figure 1. Geometries of ¼ fuel assemblies
(a) ¼ of hexagonal assembly (b) ¼ of circular assembly

2.2 Core Calculation

Quadrant core including reflector region as shown in figure 2 was investigated to evaluate the neutron flux distribution as well as its flux level. The number of vertical irradiation hole and horizontal beam tubes, and their location at the core region as well as reflector region will be decided latter to meet special requirements for future potential user. The classification of neutron group and consideration of geometrical buckling are the same as in assembly calculations. In this core, one in-core irradiation site is used and it is inner two rings in hexagonal fuel assembly located at core center. In the inner two rings in that assembly, there are 18 places for fuel pins and those will be replaced with sample material for production of radioisotope. However, outermost ring having 18 places is used with fuel pins. In this study, the production of P-32 radioisotopes is considered.

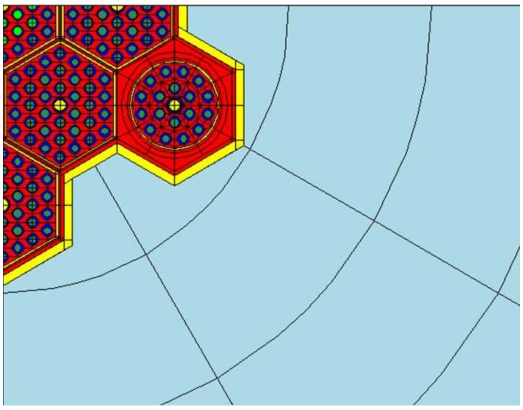

Figure 2. Layout of proposed quadrant Core

3. Results and discussion

3.1 Excess Reactivity and cycle Length

Figure 3 shows that core has excess reactivity with more flat characteristic and longer cycle length by using two kinds of assemblies together rather than the use of individual assemblies.

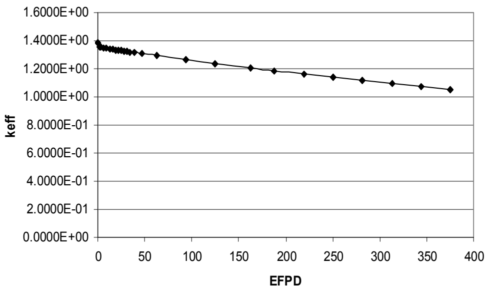

Figure 3. Excess reactivity and cycle length

3.2 Neutron Flux Evaluation

Table 2 shows the maximum values of fast and thermal neutron fluxes at ARO. It can be said that the require flux level is available at in-core irradiation site in core region for production of radioisotopes as well as in reflector region. The reflector region having high flux is up to the radius of 30 cm from core center.

Table 2. Fast and thermal fluxes at ARO

	Core		Reflector	
	Fast	Thermal	Fast	Thermal
BOC	9.4734E+15	1.9631E+14	2.2624E+14	1.4071E+14
EOC	9.3326E+15	1.0031E+15	4.5565E+14	2.1655E+15

3.3 MTC and FTC

Moderator temperature coefficient and fuel temperature coefficient are both negative throughout the cycle length as shown in Fig. 4 and 5.

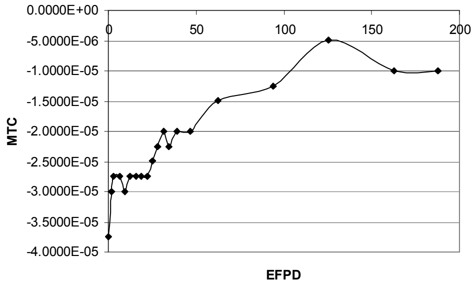

Figure 4. MTC versus cycle length

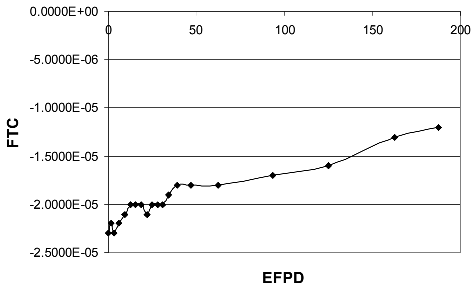

Figure 5. FTC versus cycle length

4. Conclusion

Core has good characteristics from a reactor safety and a fuel economy point of view because of its enough negative values of MTC and FTC and longer cycle length.

It can also have less excess reactivity reduction due to irradiation facility. There was an enough flux level both in core for existence of irradiation-site and in inner reflector region. Therefore several experimental facilities can additionally be placed in both regions. It is aimed to expand for other design goals with those experimental facilities as much as possible as future study.

REFERENCES

[1] Choong Sung Lee et al, “The Equilibrium Core Analysis with a Basic Core for the Development of a New Research Reactor Using Rod Type Fuel”, Transactions of the HANARO Symposium, Annual Meeting, Daejeon, Korea, May 10, 2006

[2] C. Park et al., “Design Approach to the Development of an Advanced HANARO Research Reactor”, Proceeding of the International Symposium on Research Reactor and Neutron Science, In Commemoration of the 10th Anniversary of HANARO, Korea, April 2005