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# Nuclear Core Design for Small Power Reactor with Thorium Fuel

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## 1. Introduction

A new conceptual core design of a reactor called REX-10 (Regional Energy Reactor, 10 MWth) has been carried out using once-through thorium fuel cycle to accomplish ultra long fuel cycle length with non-proliferation. This reactor core design was aimed to utilize the favorable characteristic of Th-232 and U-233 for environment and safety.

Thorium fuel cycle draws interest due to its natural abundance, high conversion ratio in thermal reactor, non-proliferation and low production of long-life minor actinides. [1-2] However, fuel cycle cost in thorium fuel is higher than that of uranium even for the optimized core design. Therefore, thorium-based core is not easy to satisfy both safety and economic goals. Thorium fuel has only been used at a thermal breeder but the amount used is small. [3]

The use of innovative concepts for burnable poison rod and control rod was suggested in the previous study. [4] In order to maximize the compactness of reactor system, reactor power is controlled by control rod only. Free soluble boron operation leads benefits of system simplification, enhanced safety and reduction of liquid waste generation.

In this study, design optimization was done for maximization of proliferation resistance maintaining the design goal of 20-year cycle length and comparable reactor safety within a boundary limit of economics goal. Core and fuel configuration must be designed as complex geometry for the heterogeneous layout of fuel materials.

## 2. REX-10 Design Goals

### *2.1 Reactor Design Goals*

The reactor design goals of REX-10 are as follows:

1) Small Integral Power Reactor
2) Automatic Control without Operator (possible to Remote Control)
3) Natural Circulation RCS without RCP

### *2.2 Nuclear Core Design Guidelines*

The nuclear core design guidelines would be

1) Small Size Safe Reactor: Rated Thermal Power – 10 MWt
2) Soluble Boron Free Operation
3) Proliferation Resistance Fuel and Core Management

## 3. Fuel Options and Fuel Assembly Options

### *3.1 Fuel Options*

In the previous study, to satisfy the design goals of REX-10, four kinds of fuel options, all UN, all $UO_2$ heterogeneous ($UN+ThO_2$) and heterogeneous ($UO2+ThO_2$) fuel, were investigated as 2x2 array calculations generally using HELIOS. [5] It was found that ($UO2+ThO_2$) fuel option has least production of plutonium isotopes and it is also consistent with the design goal of ultra-long cycle length.

### *3.2 Fuel Assembly Options*

Assembly consists of 11x11 square lattice array that has 112 fuel rods, 8 control rods and 1 instrumental tube. Fuel rod pin has a same configuration as a commercial PWR fuel pin.

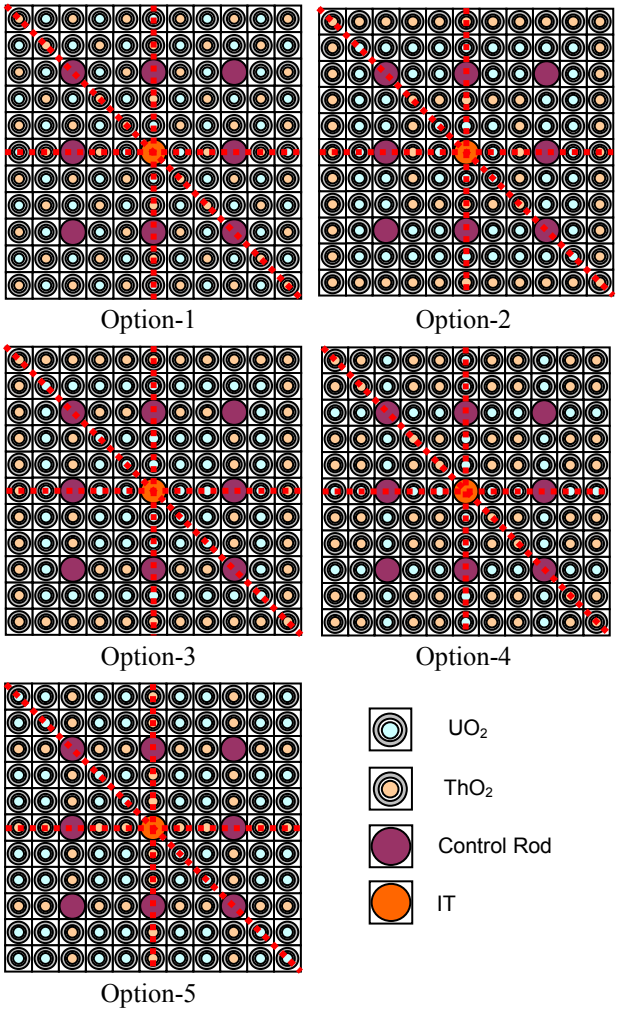


Fig.1 Heterogeneous Fuel Assembly Configurations

In case of fuel rod configuration, five kinds of heterogeneous fuel assembly configurations were considered to select one having least pin power peaking and those are as shown in Fig. 1. In option-1, option-2 and option-3, UO2 fuel and ThO2 fuel are the ratio of 1:1 while option-4 and option-5 are the ratio of 4:3 and 3:4.

## 4. Calculation Results

The value of maximum pin power peaking for five kinds of fuel assembly configurations were evaluated by using HELIOS. Figure 2 shows the comparison of the maximum pin power peaking for five kinds of fuel assembly configurations. Based on the calculation results; Hetero option-2 was selected due to its least pin power peaking among all configurations.

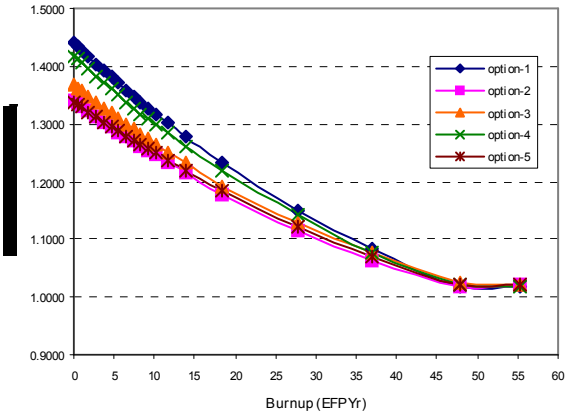


Fig. 2 Maximum Pin Power Peaking versus burnup

## 5. REX-10 Core Design

REX-10 reactor is very smaller core than that of commercial reactor. As shown in figure 3, REX-10 core consists of 52-fuel assembly and the active core height is reduced to 100 cm that is a quarter of PWR. The desired power rate of 10 MWth can be satisfied by simple handy calculation.

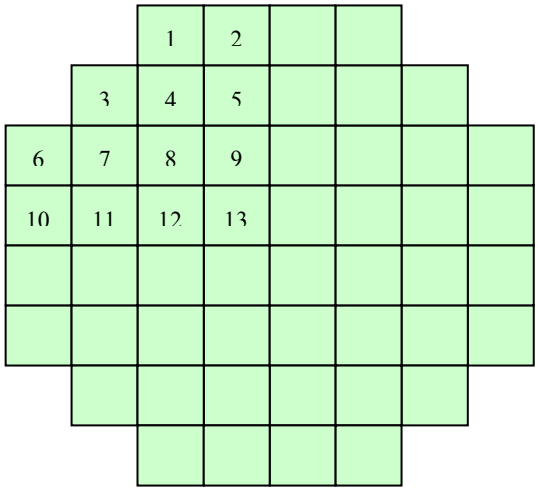


Fig. 3 Conceptual Core Design

## 6. Discussions and Future Work

In order to satisfy ultra long fuel cycle length, one of the goals of REX-10, the use of thorium fuel was suggested. Thorium has good characteristics in proliferation resistance and nuclear properties of U-233 produced by neutron capture of Th-232. The nuclear performance such as fuel cycle length, uranium isotope conversion as well as plutonium isotope production during irradiation time for four kinds of fuel options was investigated in the previous study. In this study, the pin power peaking of the five heterogeneous assembly configurations were additionally evaluated. Option-2, 1:1 ratio of uranium seed fuel and thorium blanket fuel, could be satisfied the design goals.

The candidate core design was proposed using these fuel assembly configurations studies. As a future work, REX-10 core performance will be assessed using MASTER code.

## REFERENCES

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