600 MWe TRU Burner Core Designs with Core Height Variations

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1. Introduction

Core design study has been performed to develop the optimum core designs. The role of the advanced burner reactor is to transmute the TRU elements as much as it can. But to have a high TRU consumption rate, it is desirable to have a low conversion ratio. However, a low conversion ratio requires a high TRU enrichment but currently there is limited irradiation experience with plutonium-based fast reactor fuel. The TRU enrichment can not be higher than 30 w/o, which is the current irradiation experience.

Hence, this study focused to a core design which has a maximum TRU enrichment of 30 w/o and a power level of 600 MWe. After finding the core having the maximum TRU enrichment, the core height was increased to find the relation between the core performance parameter and the core height.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

First a core which has a maximum TRU enrichment limit of 30 w/o was designed. For the core design, a single fuel enrichment concept, adopted in the KALIMER-600 breakeven core design[1], was used. A different cladding thickness is used to control the power distribution. Usually for a burner core design the cladding thickness is increased in order to reduce the conversion ratio through an increased enrichment. But it degrades the neutron economy. In this core design we adopted a strategy where the minimum cladding thickness which is only necessary for controlling the power distribution is used. The only option for reducing the conversion ratio is shortening the core height. A reduction of the core height increased the neutron leakage. Increased neutron leakage also increases the TRU enrichment necessary for a criticality because of the reduced chance for fission. The core height was reduced until the TRU enrichment was 30 w/o, while the number of fuel rod assemblies was increased to conserve the same linear power density of 170 W/cm.

The final adopted burner core, CH-50, having a maximum allowed TRU enrichment, is shown in Figure 1. The core layout consists of 504 driver fuel assemblies, 90 reflector assemblies, 24 primary control rods, 7 secondary control rods, 204 shield assemblies, and 102 in-vessel storages(IVSs). The inner(CORE1), middle(CORE2) and outer(CORE3) cores are composed of 156, 126 and 222 driver assemblies. The cladding thickness is 0.09 cm, 0.073 cm and 0.55 cm for the inner, middle, and outer core regions, respectively.

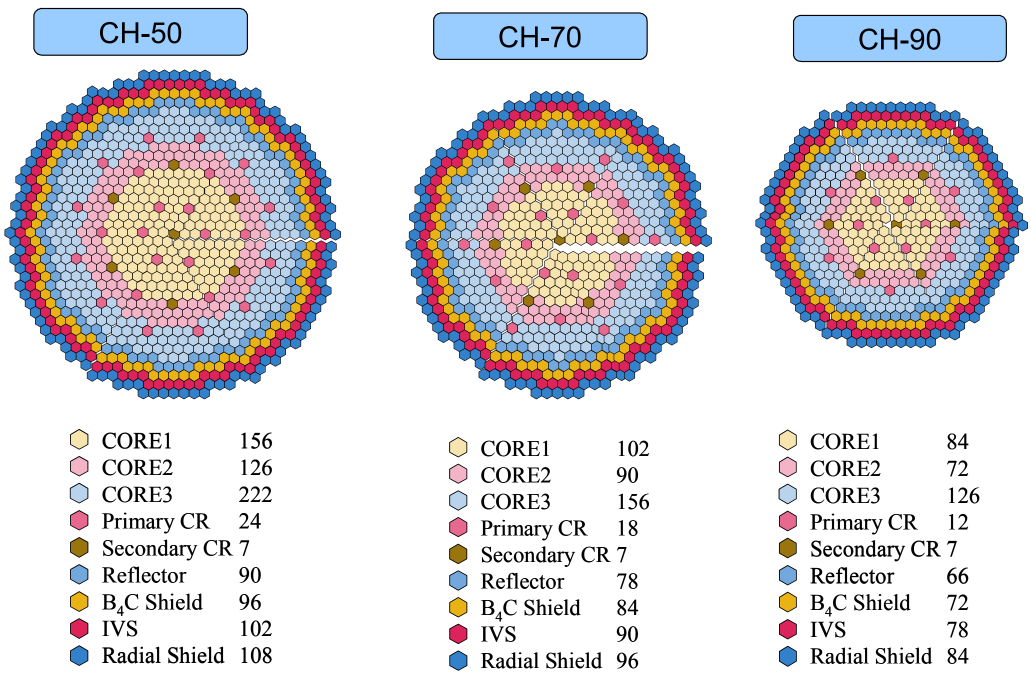

Fig. 1 Core Layout for the Variable-Core-Height Designs

TABLE 1 Core Performances of Variable-Core-Height Designs

	CH-50	CH-60	CH-70	CH-90
Electrical Power [MWe]	600			
Cycle length [EFPD]	332			
Number of batch	5			
Fuel rod outer diameter[cm]	0.7			
Active core height[cm]	49.7	59.6	72.0	88.8
Assembly pitch[cm]	16.3	16.8	17.6	18.5
Eq. diameter[m]	3.95	3.76	3.56	3.37
Charged TRU enrichment [w/o]	29.98	28.61	27.91	27.88
Conversion ratio [fissile/TRU]	0.70/0.52	0.73/0.56	0.76/0.60	0.77/0.62
Peak fast neutron fluence [10^{23} n/cm^2]	3.72	3.75	3.76	3.85
TRU consumption rate [kg/year]	257	226	210	200
Core average power density [W/cc]	244.9	228.3	210.1	188.9
Power peaking factor	1.48	1.44	1.48	1.45
Burnup reactivity swing [pcm]	3,194	3,046	2,896	2,794
Peak linear power [W/cm]	287.51	277.2	282.37	275.21
Average linear power [W/cm]	170.95	170.9	170.93	171.05

After finding the core with the maximum allowed TRU enrichment, the core height was increased to find the relation between the core performance parameter and the core height. When the core height is increased the average linear power is reduced so the number of fuel assemblies should be reduced to conserve the same average linear power. The number of fuel assemblies was reduced in such way that the outermost row of the core fuel region was deleted and the core height was increased to conserve the same average linear power.

Beginning with CH-50, the CH-60, CH-70, and CH-90 cores were selected in a way that the final row of the core fuel region was deleted, as shown in Figure 1.

2.2 Core Performance Analysis Results

Neutronic results and principal nuclear performance parameters for the equilibrium core were obtained from the REBUS-3[2] equilibrium cycle mode calculations. Driver fuel feed enrichment requirements were determined from the flux and burnup calculations to guarantee a hot full power criticality at the end of the equilibrium cycle (EOEC). The nuclear performance parameters for the equilibrium CH-50 burner core, having the maximum TRU enrichment are shown in Table 1. The charged TRU enrichment is 29.98 %. The burnup reactivity swing, i.e., reactivity loss per refueling cycle due to a metallic fuel burnup is 3,194 pcm. The average TRU conversion ratio for the active core over the equilibrium cycle is 0.52.

The results for the cores with core height variations show that the conversion ratio is increased with the core height increase while the burnup swing is decreased. The reactivity coefficients estimated at BOEC and EOEC for the cores with height variation designs show that the core with an increased core height has an increased Doppler coefficient, a more negative axial expansion coefficient, more positive sodium density coefficient and sodium void worth, a more negative control rod worth per rod and a lesser negative radial expansion coefficient.

3. **Conclusion**

To maximize the transmutation of the TRU elements, a core which has a maximum TRU enrichment limit of 30 w/o has been designed, and also to find the relation between the core performance parameter and the core height, the core height was increased starting from this selected core.

The calculation results show that the maximum allowable core which has a TRU enrichment of 30 w/o can be designed with a core height of 50 cm. From these cores with a core height variation, the conversion ratio is increased with the core height increase while the burnup swing is decreased. The core with an increased core height has a more positive sodium density coefficient.

Acknowledgement

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