600~1,800 MWe Sodium Cooled Reactor Core Design for a TRU burning

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1. Introduction

To provide guidance to future R&D directions for an economic burning of TRU and to achieve maximum benefits from the view point of a core size, cores whose powers range from 600 MWe to 1,800 MWe was designed and the performance parameters and reactivity coefficients related to safety analysis were investigated. Instead of the traditional enrichment zoning approach to flatten the power distribution, the design concept of a single fuel enrichment was adopted.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

Core designs used the design constraints related to the current technology database with the TRU enrichment limit (30.0 w/o) and fast neutron irradiation limit (4.0×10^{23} n/cm^2). A single enrichment concept, adopted in the KALIMER-600 breakeven core design[1], was used. As a means to flatten the power distribution, fuel pin designs of different cladding thickness are used in different core regions, while the same cladding outer diameter is adopted throughout the core.

For a consistent comparison, the active core height was adjusted to make the sodium void worth lower than 7.5$ to be 85.0 cm, 73.5 cm and 70 cm for the 600 MWe, 1,200 MWe and 1,800 MWe core. The number of assemblies was adjusted to attain a similar linear power around 180 W/cm so a core radius was increased to conserve the same linear power due to a core height reduction. The fuel pin diameter and the number of fuel pins were fixed at 7 mm and 271, respectively. But, the pitch to diameter of fuel rods is allowed to vary. In order to demonstrate a high TRU consumption rate, a core design is tried to attain TRU enrichment to be 30 w/o. The major design variables to be used in changing the conversion ratio of a given core design are the variation of core height and fuel cladding thickness. A reduction of the fuel volume fraction was used as the primary design variable to increase the enrichment, and a reduction of the core height was used as a secondary so that the reduction range of active core height was restricted within the core height to make the sodium void worth lower than 7.5$. The cladding thickness was increased to decrease the fuel volume fraction. At the same time, the core design was confirmed to have maximum inner cladding temperatures below 650 ℃ and maximum pressure drops below 0.15MPa.

All the nuclear designs and evaluations were performed with the nuclear calculation module packages in the K-CORE System which is an integrated modular program. Global reactivity feedbacks were calculated using a series of neutron flux solution calculations for a hexagonal-z geometry.

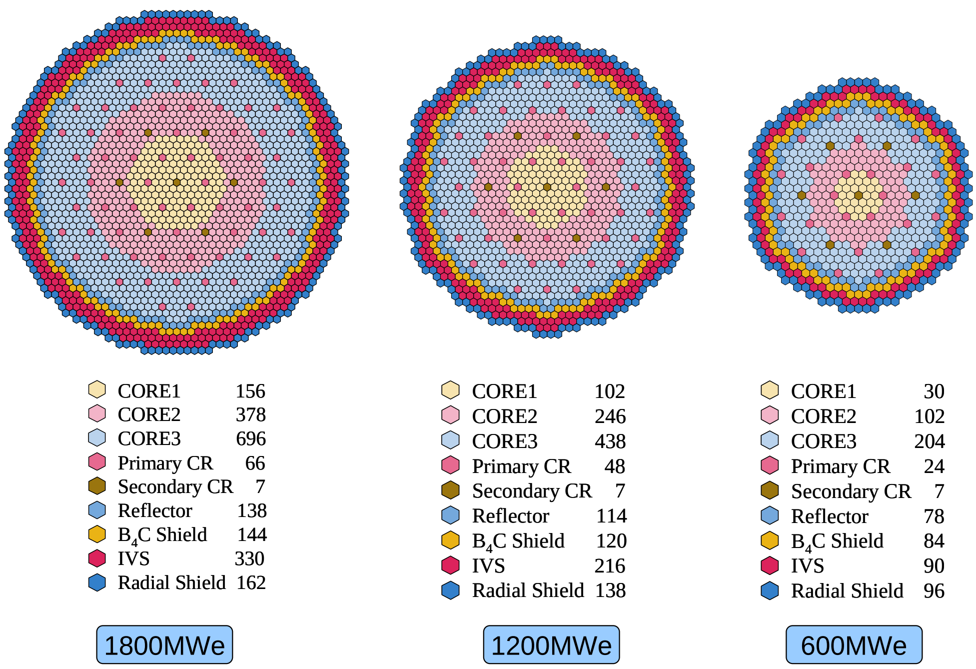

Fig. 1. Core Layout for the Variable-Cladding-Thickness Designs

Table I: Reactivity coefficients

	600MWe		1,200MWe		1,800MWe	
	BOEC	EOEC	BOEC	EOEC	BOEC	EOEC
Doppler coefficient [pcm/ ^{o}C]	-804.5 $T^{-1.113}$	-801.6 $T^{-1.109}$	-819.3 $T^{-1.109}$	-816.6 $T^{-1.106}$	-835.1 $T^{-1.110}$	-834.3 $T^{-1.107}$
Axial expansion coefficient [pcm/ ^{o}C]	-0.160	-0.170	-0.121	-0.127	-0.109	-0.114
Radial expansion coefficient [pcm/ ^{o}C]	-0.707	-0.743	-0.735	-0.771	-0.744	-0.780
Sodium density coefficient [pcm/ ^{o}C]	0.692	0.750	0.702	0.761	0.697	0.761
Control rod worth [pcm/control rod]	-341	-358	-173	-181	-124	-130
Sodium void worth[$]	6.68	7.28	6.91	7.52	6.87	7.55

The numbers of fuel assemblies of the 600, 1200, and 1,800 MWe designs are 336, 786 and 1230, respectively. Fig. 1 shows the radial core configuration.

2.2 Core Performance Analysis and Reactivity Cofficients Results

Performance parameters and reactivity coefficients was calculated. Table 1 shows the results of reactivity coefficients. The REBUS-3[2] equilibrium model with a 25 group cross section was used to perform the core depletion analysis.

The calculation results show that large monolithic sodium cooled fast reactors for TRU burning, of which power range from 600 MWe to 1,800 MWe can be successfully designed, while meeting all the design constraints. The core designs have almost the same TRU burning rate per power and a burnup reactivity swing of ~3,500pcm. The TRU consumption rate is 221 kg/year for the 600 MWe core, 423 kg/year for the 1,200 MWe core, and 626 kg/year for the 1,800 MWe. In all three designs, the sodium void worth upon a core plus fission gas plenum voiding, turned out to be less than 7.5$.

Global reactivity feedback resulting from the Doppler effect, uniform radial expansion, and sodium voidings in the equilibrium core are given in Table 1. The reactivity coefficients estimated at a BOEC and an EOEC for the three cores.

From this table, the following are observed. The core with an increased power rating has almost the same Doppler coefficient, a less negative axial expansion coefficient, a less negative control rod worth per rod and a more negative radial expansion coefficient. Sodium void worth have fixed to be close to 7.5$ for the three cores by reducing the active core height with a increasing of the neutron leakage rate so that almost same positive sodium density coefficient has observed for three cores.

3. **Conclusion**

To investigate the performance parameters and safety implications of reactivity coefficients in large monolithic sodium cooled fast reactors for a TRU burning, cores whose powers range from 600 MWe to 1,800 MWe were designed.

The calculation results show that large monolithic sodium cooled fast reactors for a TRU burning whose power ranges from 600 MWe to 1,800 MWe can be designed satisfactorily. In addition they have almost the same TRU burning rate per power.

Acknowledgement

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