Core Performance Investigation for Conversion Ratio Changes

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1. Introduction

The core power levels of 600, 1,200 and 1,800 MWe were investigated with a TRU conversion ratio of about 0.6 in previous study[1]. Even at each pre-determined power level, the performance parameters, reactivity coefficients and their implications on the safety analysis can be different when a target TRU conversion ratio changes. In order to address this aspect of a design, a variation study of a TRU conversion ratio change with core power levels is performed in this study and the core performance is investigated at various core powers.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

For a consistent comparison, the active core height was adjusted to make the sodium void worth around 7.5$, and they are 86.8 cm, 73.5 cm and 70.0 cm for the 600 MWe, 1,200 MWe and 1,800 MWe cores, respectively. A clad outer diameter of 7.0 mm is adopted over all the designs and the cladding thicknesses are adjusted to make the TRU enrichment close to 30 w/o. The fuel pitch was allowed to vary in order to cause no more than 0.15 MPa that is the nominal (w/o uncertainty) maximum (among channels) pressure drop across the axial fuel rod section.

All the designs maintain an average linear power of 180 W/cm. The number of assemblies in each region was determined to minimize the peak-to-average power ratio in the core. The total number of control assemblies was determined to maintain the ratio of the fuel assembly area to the control rod area, under the presumption that the burnup reactivity swing would be similar, once the feed TRU enrichment is similar. The numbers of fuel assemblies of the 600, 1,200, and 1,800 MWe designs are 330, 786 and 1230, respectively. The respective numbers of control assemblies are 31, 55 and 73 as shown in Fig. 1.

As a design variable to change the conversion ratio of the given reference core (TRU feed enrichment of 30 w/o), a clad thickness variation with an accompanying change in the fuel volume fraction is chosen. The high conversion ratio and the low conversion ratio core were designed to have feed TRU enrichments of 22 w/o and 38 w/o, respectively with the fixed cycle length of 332 EFPD. Compared to the high conversion ratio core, the resulting fuel volume fraction of the low conversion ratio core, for example, decreased from 28.6% to 19.4% in the inner core region for the 600 MWe core.

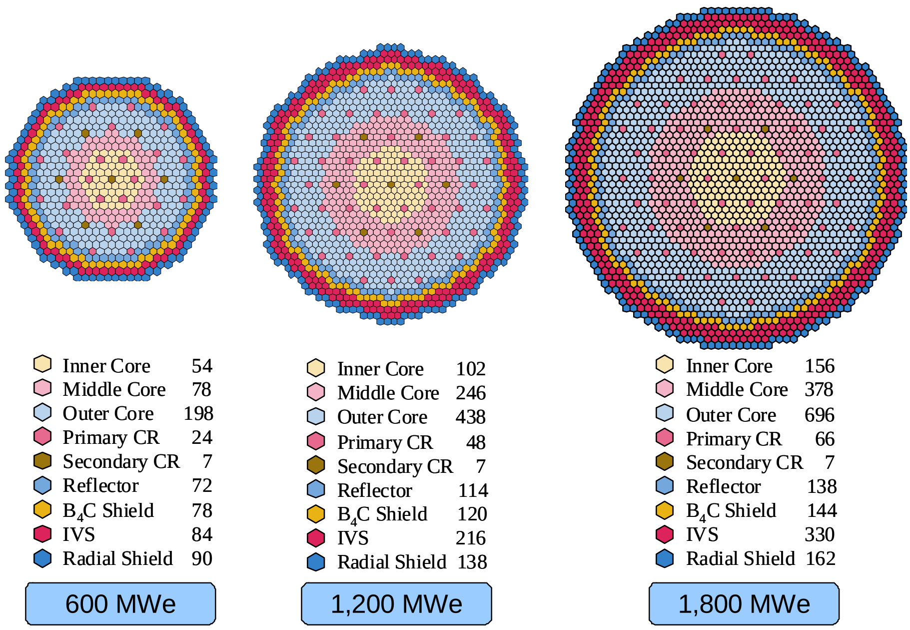

Fig. 1. Core Layout.

Table I: Core Performances

	600 MWe	1,200 MWe	1,800 MWe
Burnup reactivity swing(pcm)	2,145	2,192	2,203
Conversion ratio(fissile/TRU)	0.86/0.75	0.86/0.75	0.86/0.75
Charged TRU (w/o)	22.00	22.00	21.99
Fuel inventory (HM/TRU)[ton]	21.19/4.66	41.31/9.09	61.29/13.48
Average linear power(W/cm)	180	178	179
Power peaking factor	1.55	1.49	1.51
Average assembly discharge burnup(MWd/kg)	106	109	110
Peak fast neutron fluence(n/cm^2)	4.49	4.35	4.35
Cycle length(EFPD)		332	
Max. pressure drop(MPa)	0.15	0.14	0.13
Max. cladding inner wall temp.(℃)	581	565	560
TRU consumption rate(kg/cycle)	113	224	335

2.2 Core performance Analysis

Table I shows the transmutation characteristics and performance parameters in the case of the high conversion ratio core. The REBUS-3[2] equilibrium model with a 25 group cross section was used to perform the core depletion analysis. Representative TRU conversion ratios are 0.75, 0.57, and 0.44 for the high conversion, the reference, and the low conversion ratio core, respectively.

The burnup reactivity swing is strongly dependent on the TRU feed enrichment. The higher burnup reactivity swing is the direct result of removing fertile material from the reactor which is most clearly seen by a drop in a total heavy metal inventory and a relatively small increase in a TRU inventory.

The lower inventory in the low conversion ratio core also causes a maximum utilization of the fuel, which is reflected in the average discharge burnup. Since the same thermal power is produced regardless of the conversion ratio, the average burnup ratio between the low conversion and high conversion ratio cores is approximately inversely proportional to the heavy metal inventory ratio.

The TRU consumption rates at the reference conversion ratio core are 202 kg/cycle for the 600 MWe core, 401 kg/cycle for the 1,200 MWe core, and 602 kg/cycle for the 1,800 MWe. Accordingly, the consumption rate increases by 1.99 times for the 1,200 MWe core and by 2.98 times for the 1,800 MWe core, compared to that of the 600 MWe core.

A lower conversion ratio increases the TRU consumption rate at each power level. The TRU consumption rate increases from ~113 kg/cycle (CR=0.75) to ~270 kg/cycle (CR=0.44) at 600 MWe power level. Because of a much faster burnup reactivity swing at a low conversion core, however, appropriate means for a reactivity compensation must be employed (e.g., shorter cycles with more frequent refuelling or increased number of control assemblies). More importantly, a TRU enrichment of ~38% is required in the low conversion ratio core, which is beyond the currently established irradiation experience for ternary metal fuels.

3. Conclusions

Conceptual fast reactor core designs with a TRU conversion ratio were developed at 600, 1,200 and 1,800 MWe.

The calculation results show that it is feasible to design a TRU burner core to accommodate a wide range of conversion ratios by employing different fuel cladding thicknesses. The TRU consumption rate can be made to be proportional to the core power level without any significant adverse effect in the core performance at higher power levels. A low conversion ratio core has an increased TRU consumption rate and a much faster burnup reactivity swing, which calls for a appropriate means for a reactivity compensation.

Acknowlegement

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