Analysis of the Burner Core Characteristics at Different Power Levels

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1. Introduction

To determine the appropriate power level and conversion ratio for an economic burning of TRU, various design trade-off studies are necessary and for this purpose the core power levels of 600, 1,200 and 1,800 MWe have been investigated[1]. The reactor power should be maintained in pursuit of size of economy.

Hence, this study focused to core designs which have cores whose powers range from 300 MWe to 1,800 MWe and compare the core performance parameters and reactivity coefficients of four cores which have power levels of 300, 600, 1,200 and 1,800 MWe.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

As the core power level increases, the core design with various core size are possible so that core design is limited to the design which satisfy four targets. First, the sodium void worth is fixed to 7.5$ so that active core height was adjusted to make the sodium void worth around 7.5$, and they are 123 cm, 86.8 cm, 73.5 cm and 70.0 cm for the 300 MWe, 600 MWe, 1,200 MWe and 1,800 MWe cores, respectively. Second, 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. Third, all the designs maintain an average linear power of 180 W/cm. Fourth, the cladding thicknesses are adjusted to make the TRU enrichment close to 30 w/o.

A clad outer diameter of 7.0 mm is adopted over all the designs. 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 300, 600, 1,200, and 1,800 MWe designs are 126, 330, 786 and 1230, respectively. The respective numbers of control assemblies are 13, 31, 55 and 73 as shown in Fig. 1.

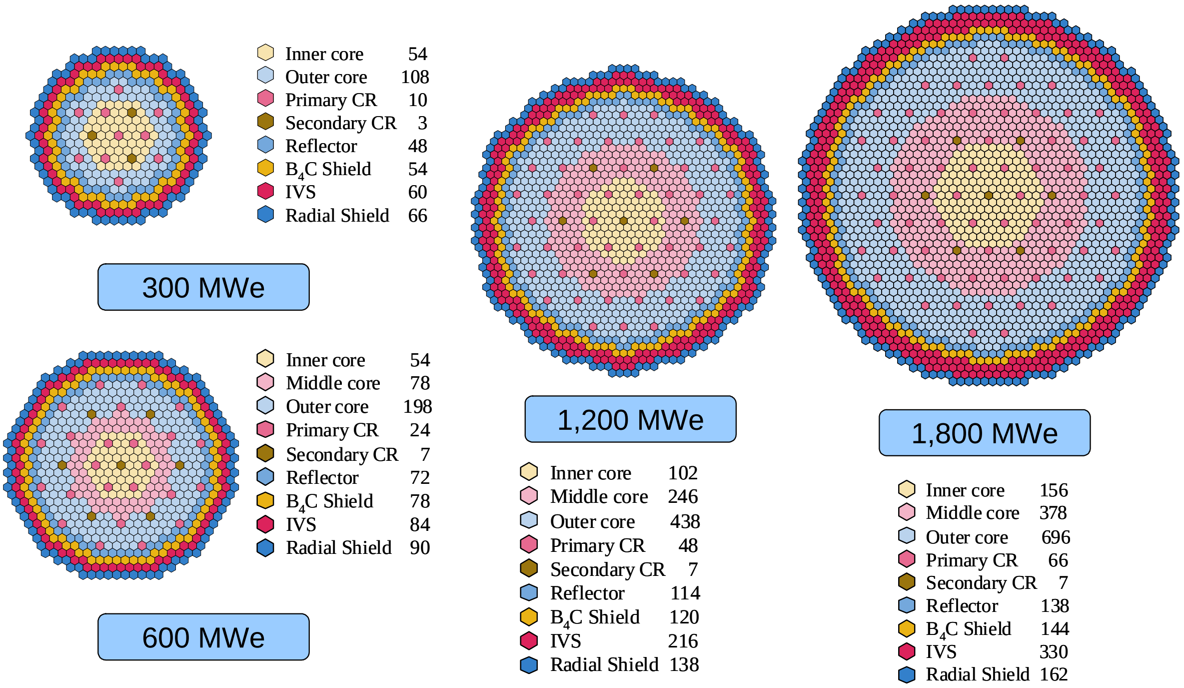

Fig. 1. Core Layout.

2.2 Result and Analysis

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 sodium cooled fast reactors for TRU burning, of which power range form 300 MWe to 1,800 MWe can be successfully designed, while meeting four design targets.

After calculations, various core performance parameters were examined, including the required TRU enrichment, heavy metal and TRU loading, active core height, core equivalence diameter, axial expansion coefficient, radial expansion coefficient, sodium void worth, sodium density coefficient, TRU conversion ratio, burnup reactivity loss, fissile conversion ratio, and TRU consumption rate on the power levels. Among these parameter relations on the power levels, two things such as the inventory and core dimension relations on the power level are noteworthy.

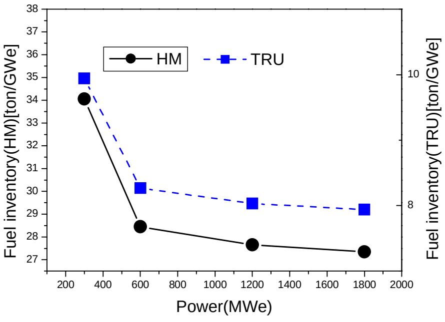

Fig. 2. HM and TRU inventory on power levels

The heavy metal and TRU inventory per GWe are maintained almost constantly from 600 MWe to 1,800 MWe but increased sharply at 300 MWe as shown in Fig 2. This result means that if the core power increases above 600 MWe, the benefit of increasing power level is meaningless so that it is means that the minimum power of the commercial TRU burner is proper to 600 MWe at the economical aspect of the fuel.

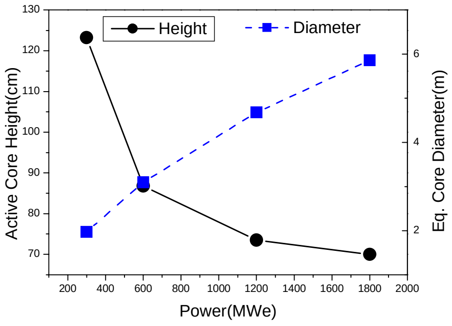

Fig. 3. Axial core height and core equivalence diameter on power levels

The axial core height decreases and core equivalence diameter increases on power levels as shown in Fig 3. The reason for this is that to maintain an equal linear power density in proportion to power levels, the number of fuel assembly loaded in the core should be increased in proportion to power levels so that the core equivalence diameter is increased. Once the core size increases, the neutron leakage rate decreases accordingly. The reduced leakage rate increases the sodium void worth and the core height was decreased to adjust the target value of 7.5$ on the increase of power levels. The reduced core height accompanies the increased liner power density and the number of fuel assembly is added to reduce the increased linear power density so that the core equivalence diameter is increased further.

3. Conclusions

Conceptual fast reactor core designs were developed at power levels of 300, 600, 1200 and 1,800 MWe.

The calculation results show that sodium cooled fast reactors for a TRU burning, of which the power range is from 300 MWe to 1,800 MWe can be successfully designed, while meeting four design targets. Comparsion of the core performance on the power levels shows no clear difference. Two kinds of trends are found which is the decrease in active core height as power level increases, and the decrease of the fuel loading per GWe in proportion to the power levels. It is judged that it may affect the selection of the optimum capacity for a power rating.

Acknowlegement

This study was supported by the Korean Ministry of Education & Science through its National Nuclear Technology Program.

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