Large-Scale Sodium-Cooled TRU Burners with a Variable Core Height

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1. Introduction

A large monolithic sodium cooled fast reactor for a TRU burning with a power ranging from 1,500 MWt to 3,000 MWt was designed. For a TRU burner core design, a pancake design approach was adopted. Core designs used the design constraints related to the current technology database for a TRU enrichment limit (30.0 w/o) and a fast neutron irradiation limit (4.0×10^{23} n/cm^2).

For the core design concepts, three power levels of 600, 900 and 1,200 MWe were selected to investigate the dependency of the core performance parameters and the reactivity coefficients on the power level.

2. Result and discussion

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 with a different cladding thickness were used in different core regions, while the same cladding outer diameter was adopted throughout the core.

This study focused on a core design which had a maximum TRU enrichment of 30 w/o. 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. 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.

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 by using a series of neutron flux solution calculations for a hexagonal-z geometry.

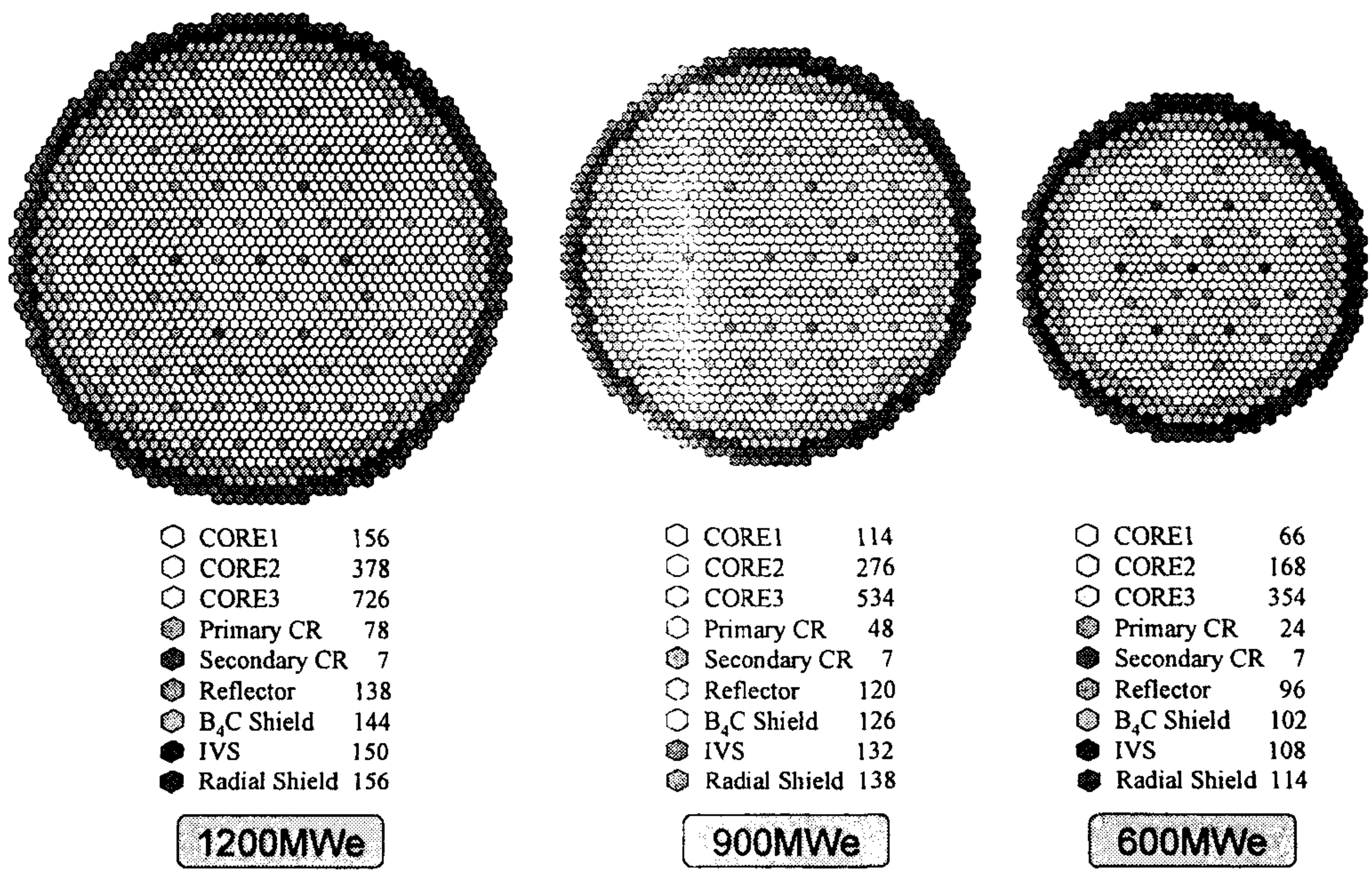

Fig. 1 Core Layout

TABLE 1 Core Performances of Variable-Cladding-Thickness Designs

Design parameter	1,200MWe	900MWe	600MWe
Number of Fuel Assemblies	1260	924	588
Assembly Pitch(cm)	16.3		
Fuel Outer Diameter(mm)	7.0		
P/D Ratio	1.17		
Cladding Thickness(mm)-Inner/Middle/Outer	0.90/0.62/0.55	0.90/0.62/0.55	0.90/0.66/0.55
Charged TRU (w/o)	30.00	30.00	30.00
Conversion Ratio(Fissile/TRU)	0.69/0.50	0.69/0.50	0.69/0.50
Burnup Reactivity Swing(pcm)	3,232	3,204	3,149
Cycle Length(EFPD)	332		
Peak Fast Neutron Fluence(n/cm^2)	3.68	3.63	3.59
Max. Pressure Drop(MPa)	0.06	0.06	0.07
Max. Cladding Inner Wall Temp.(℃)	599.72	597.60	594.58
Average Linear Power(W/cm)	170.15	170.47	170.59
Power Peaking Factor	1.49	1.46	1.43
Active Core Height(cm)	40.05	40.86	42.74
TRU Consumption Rate(kg/year)	514	386	257

Burning characteristics and performance parameters are listed in Table 1 for the three cores. The radial configurations are shown in Figure 1. The REBUS-3[2] equilibrium model with a nine group cross section was used to perform the core depletion analysis.

The cycle was reduced to 332 EFPD because of the increased burnup reactivity swing originating from the reduced core height which should be maintained at around 3,000 pcm. The number of batches was increased to 5 to increase the discharge burnup. TRU enrichment was maintained at around 30 w/o. The conversion ratios were almost the same because of the fixed TRU enrichment. The consumption rate was also increased at the same rate as the increased power, so it seems to have no preference at any power level.

The core with an increased power rating has a less negative axial expansion coefficient, a less positive sodium density coefficient, a less negative control rod worth per rod and a more negative radial expansion coefficient. As the power rating increases, the core size increases and accordingly, the neutron leakage rate decreases. The reduced leakage rate increases the chance for fission, so it reduces the TRU enrichment necessary for a criticality, but in this case the TRU enrichment is fixed at a maximum enrichment, 30 w/o. Instead of reducing the enrichment, the core height has been reduced.

3. Conclusion

To achieve a core power level as high as possible without penalizing a core safety, a large monolithic sodium cooled fast reactor for a TRU burning with a power ranging from 1,500 MWt to 3,000 MWt was designed. For a TRU burner core design, the design approach of a variable core height was investigated. Core designs used the design constraints related to the current technology database for a TRU enrichment limit (30.0 w/o) and a fast neutron irradiation limit (4.0×10^{23} n/cm^2). A single enrichment concept was adopted to flatten the power distribution and fuel pin designs of a different cladding thicknesses were used for different core regions. For the core design concepts, three power levels of 600, 900 and 1,200 MWe were selected.

The calculation results show that the burnup reactivity swing can be maintained at around 3,000 pcm and the consumption rate is increased at almost the same rate as the increased power, so it seems to have no preference at any power level with the same TRU enrichment.

REFERENCES

[1] Ser Gi Hong et al., "The KALIMER-600 Reactor Core Design Concept with Varying Fuel Cladding Thickness", Proceedings of the Korean Nuclear Society Autumn Meeting(2006).

[2] B. J. TOPPEL, "A User's Guide for the REBUS-3 Fuel Cycle Analysis Capability," ANL Report, Argonne National Laboratory 83-2, March (1983).