300 MWe Burner Core Design with two Enrichment Zoning

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1. Introduction

KAERI has been developing the KALIMER-600[1] core design with a breakeven fissile conversion ratio. The core is loaded with a ternary metallic fuel (TRU-U-10Zr), and the breakeven characteristics are achieved without any blanket assembly. As an alternative plan, a KALIMER-600 burner core design[2] has been also performed. In the early stage of the development of a fast reactor, the main purpose is an economical use of a uranium resource but nowadays in addition to the maximum utilization of a uranium resource, the burning of a high level radioactive waste is taken as an additional interest for the harmony of the environment. In way of constructing the commercial size reactor which has the power level ranging from 800 MWe to 1600 MWe, the demonstration reactor which has the power level ranging from 200 MWe to 600 MWe was usually constructed for the midterm stage to commercial size reactor.

In this paper, a 300 MWe burner core design was performed with purpose of demonstration reactor for KALIMER-600 burner of 600 MWe. As a means to flatten the power distribution, instead of a single fuel enrichment scheme adapted in design of KALIMER-600 burner, the 2 enrichment zoning approach was adapted.

2. Core Design and Performance Analysis

2.1 Description of the Core Design

Instead of a single fuel enrichment, a enrichment zoning approach was used to flatten the power distribution. The hexagonal driver fuel assembly consists of 271 rods within a duct wrapper. The rod outer diameter is 0.7cm and the wire wrap diameter is 0.17mm. Fig. 1 shows the core configuration. The core configuration is a radial homogeneous one that incorporates annular rings with a zone-wise enrichment variation. The active core consists of two driver fuel regions (i.e., inner, outer core regions) and two core regions have 84, 108 fuel assemblies, respectively.

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). The active core height was adjusted to make the sodium void worth to be under 7.5$, and the number of assemblies was adjusted to attain a linear power around 180 W/cm. The pitch to diameter of the fuel rods is allowed to vary. The core design was confirmed in that the maximum inner cladding temperatures are below 650 ℃ and the maximum pressure drops are below 0.15MPa.

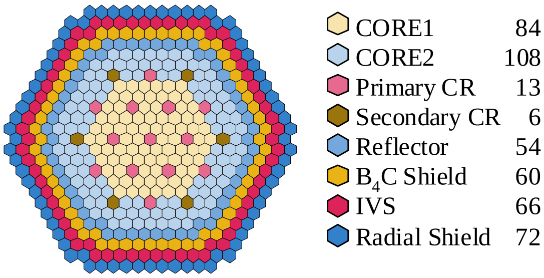

Fig. 1. Core configuration

2.2 Core Performance Analysis Results

The REBUS-3[3] equilibrium model with a 25 group cross section was used to perform the core depletion analysis. Table I shows a summary of the core performance analysis results. The burnup reactivity swing and the TRU conversion ratio over one cycle were estimated to be 2,538 pcm and 0.60, respectively. This relatively large value of burnup reactivity swing is due to the small breeding ratio. To compensate for this large value of burnup reactivity swing, the number of control assemblies is increased. The total number of control rod assemblies is 19. This core can transmute 92 kg/year of TRU. The TRU enrichments for the inner(CORE1)/outer(CORE2) driver fuels are 24/30 %.

For confirming the safe reactivity controls, the shutdown margin was calculated. Table II shows the shutdown margins of the control systems of the final core. For calculating this, the temperature defect from a full power to a refueling state was estimated to be ~0.4$. The reactivity worth of the maximum one stuck assembly of the primary and secondary was estimated to be ~1.6$ and ~1.8$. The reactivity fault was evaluated to be ~0.7$. The reactivity variation from considering a 15% over power was estimated to be ~0.1$. The total uncertainty (RMS) in calculating the shutdown margin was evaluated to be ~4.1$. With these estimations and the assumption, the total reactivity requirements of the primary and secondary control systems were estimated to be ~31.0$ and ~7.6$, respectively. So, the reactivity available of the control systems after considering one stuck control assembly worth are ~29.4$ and ~5.8$, respectively. The shutdown margins of the primary and secondary control systems are estimated to be 15.9$ and 4.6$, respectively. These shutdown margins satisfy the design target on the shutdown margin of the primary control systems.

Table I: Core Performances

Design parameter	300MWe
Core Thermal Power(MWt)	750
Coolant Temperature(℃)'-Inlet/Outlet	390/545
Number of Fuel Assemblies	192
Fuel Outer Diameter(mm)	7.0
Pin Pitch(mm)	8.76
P/D Ratio	1.252
Eq. Core Diameter(m)	2.36
Eq. Reactor Diameter(m)	3.72
Charged TRU wt%	24.07/30.08
Conversion Ratio(Fissile/TRU)	0.76/0.60
Burnup Reactivity Swing(pcm)	2,538
Cycle Length(EFPD)	332
Average discharge burnup(MWD/kg)	107
Peak Fast Neutron Fluence(n/cm^2)	4.28
Max. Pressure Drop(MPa)	0.149
Max. Cladding Inner Wall Temp.(℃)	564
Average Linear Power(W/cm)	178.6
Power Peaking Factor	1.47
Active Core Height(cm)	75

Table II: shutdown margins of the control systems of the final core

	Primary($)	Secondary($)
Reactivity worth of system	30.97	7.64
Worth of 1 stuck assembly	1.59	1.84
Reactivy worth available	29.37	5.80
Maximum requirement	13.511	1.159
Shutdown margin	15.863	4.643

3. **Conclusion**

In this paper, a 300 MWe burner was designed with a average linear power around 180 W/cm, a maximum pressure drop below 0.15MPa and a sodium void worth to be under 7.5$ in which a power flattening is achieved by using a region-wise enrichment variation. After extensive trials and errors by varying the fuel enrichments and zone dimensions of two zones, a final core was selected to satisfy all the design targets. It was also shown from the core design studies that the selected core satisfies the shutdown margin of the control rod system.

Acknowledgement

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

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