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KALIMER-600 Single Enrichment Core with Dummy Rods

Hoon Song, Young In Kim and Yeong Il Kim
Korea Atomic Energy Research Institute (150-1 Deokjin-Dong), 1045 Daedeokdaero, Yuseong, Daejeon 305-353, Korea, hsong@kaeri.re.kr

1. Introduction

The KALIMER-600 reactor core concept using single enrichment fuel[1] was Recently developed. In this reactor core the single enrichment fuel concept was achieved by using the special fuel assembly designs where non-fuel rods (i.e., $ZrH_{1.8}$, B_4C, and dummy rods) were used to control the power peaking factor caused by a single enrichment. Use of three kinds of non–fuel rods has a weak point of making the fuel assembly inside complex.

In this paper, to make the previous core simpler, the 600MWe KALIMER-600 core of a single enrichment with dummy rods is introduced. In this core concept, only the dummy rods are introduced to reduce the power peaking factor.

2. Core Design Approach

2.1 Nuclear Design Basis and Ground Rules

Core design requirements embracing core design criteria and restraints for metal fuel were made based on the metal fuel database currently available. The following requirements guided the nuclear design basis and ground rules: The reactor power shall be 1525.3 MWt. The capacity factor shall be 85 %. The local fuel burnup limit shall be 150 MWD/kg. The peak fast fluence shall be less than 4.0 x 10^{23} n/cm^2. The breeding ratio should be near 1.00 and the allowable burnup reactivity swing should be around 1000 pcm. The average discharge burnup shall be more than 80 MWD/kg. The operation cycle length shall be more than 18 months.

2.2 Nuclear Design and Analysis Methodology

All the nuclear designs and evaluations were performed with nuclear calculation module packages in the K-CORE System. The evaluation procedure for the nuclear design and analysis consists of three parts: a neutronics cross section generation, a flux solution and the burnup calculation, and reactivity calculation. The nuclear evaluation process was initiated by the generation of regionwise microscopic cross sections, based upon the self-shielding f-factor approach. Composition-dependent, regionwise microscopic cross sections were generated by utilizing the effective cross section generation module composed of the TRANSX[2] and TWODANT[3] codes. Fuel cycle calculations were carried out with the neutron flux and burnup calculation module consisting of the DIF3D and REBUS-3 codes. Various reactivity feedback effects and neutron kinetics parameters were calculated by utilizing the codes.

3. Core Performance Analysis

3.1 Core Description

Started from the reference core[1], shown in Figure 1, three kinds of non fuel rods were replaced with dummy rods, varying the number of dummy rod to find a suitable core meeting the design ground rules. After studying on the suitable number of dummy rods and the fuel rod outer diameter, selected numbers of dummy rods for the inner and middle core regions are 60 and 36. The fuel outer diameter is increased from 8.5mm to 9.0mm in order to design the breakeven core[design-1]. To reduce the peak fast fluence, other core design was investigated where the dummy rod use the HT-9 material inserted inside rod[design-2]. Main design parameters of the core are given in Table 1.

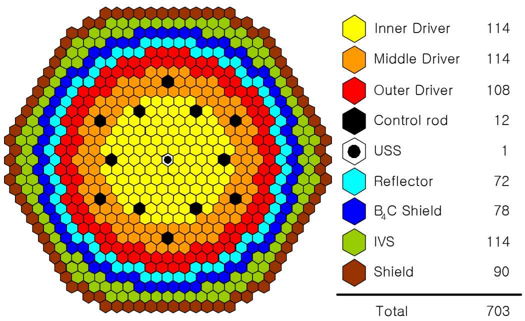

Figure 1. KALIMER-600 Core Layout

3.2 Nuclear Performance Analysis

Neutronic results and principal nuclear performance parameters for the equilibrium core were obtained from the equilibrium cycle mode calculations. It is worthwhile to note that top/bottom cutback zones are applied to the burnable absorbers to reduce the fast neutron fluence, which is a limiting design constraint in the design ground rules in the reference core. The length of cutback is 22 cm from the top of active core and the bottom of active core.

The nuclear performance parameters for the equilibrium core are summarized in Table 2. The design-1 and design-2 cores have a smaller TRU wt% than the reference core because of increased fuel loadings. The design-1 core satisfies the design ground rules except the peak fast fluence. The inserted HT-9 materials inside the dummy rods showed the effect of reducing the peak fast flunce.

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Table 1. Comparisons of the Design Parameters

Design parameter	Reference	Design-1	Design-2
Core height(cm)	100	100	100
Fuel rod outer diameter (mm)	8.50	9.00	0.89
Fuel assembly pitch(cm)	17.88	18.71	18.71
Pin P/D ratio	1.176	1.166	1.166
Material inside the dummy rods	NA	N/A	HT-9
Number of the non fuel rods(B_4C/ZrH_2/dummy rods) Inner/middle/outer core	(12/4/8)/(0/0/15)/(0/0/0)	(0/0/60)/(0/0/36)/(0/0/0)	(0/0/60)/(0/0/36)/(0/0/0)

Table 2. Comparisons of Core Performance

Parameters	Reference	Design-1	Design-II
Cycle length(EFPD)	517	570	570
Fuel management batches	4	4	4
Average discharge burnup(MWD/kg)	81.7	79.6	81.6
Peak discharge burnup(MWD/kg)	123.9	128.5	122.4
Burnup reactivity swing(pcm)	59	148	162
TRU wt%(BOEC/EOEC)	15.2	13.2	14.3
Peaking factors(BOEC/EOEC)	1.45/1.46	1.48/1.48	1.47/1.48
Peak fast neutron fluence(n/cm^2)	3.92	4.33	4.02
Average Breeding ratio	1.005	1.036	1.013

4. Conclusion

In this paper, a 600MWe sodium cooled fast reactor core design study is presented. In this core design concept, the dummy rods are used to achieve power flattening under single enrichment fuel. The core performance analysis results show that KALIMER-600 breakeven core has an average breeding ratio of 1.013 and average discharge burnup of 82 MWD/kg.

Acknowledgments

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REFERENCES

[1] H. Song and Y. I. Kim, "The KALIMER-600 Core Neutronic Design with a Single Enrichment," Proceedings of GLOBAL 2005, Tsukuba, Japan, Oct. 9-13.
[2] R. E. MACFARLANE, "TRANSX 2: A Code for Interfacing MATXS Cross-Section Libraries to Nuclear Transport Codes," LA Report, Los Alamos National Laboratory LA-12312-MS, December (1993)
[3] R. E. ALCOUFFE, et al., "User's Guide for TWODANT: A Code Package for Two-Dimensional, Diffusion-Accelerated, Neutron Transport," LA Report, Los Alamos National Laboratory LA-10049-M, February (1990)