Role of Thorium as a Shim Control Material in the AMBIDEXTER-NEC

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1. Introduction

The AMBIDEXTER-NEC is an integral-type molten-salt reactor system. This system is having been designed to meet the GEN IV requirements, especially minimizing high-level waste, with a denatured thorium-uranium fuel cycle. The reactor attempts to operate with the uranium-reduced DUPIC fuel under the nominal design condition. However, it has a sudden rise in k_{eff} at the very early stage of reactor operation because fission products, which take high portion of neutron capture in the uranium-reduced DUPIC fuel, have burned out. As a result, it has to be provided with a means of shim control against the excess reactivity.

In this paper thorium-232 has been used as a neutron poison for compensating the excess reactivity during the initial operation. Moreover, thorium can be converted to fissile material U-233 at later time so that the reactor can be operation long even with the neutron poisoning material. It does not cause a sudden neutron density change as well.

2. Methods and Results

The $250MW_{th}$ AMBIDEXTER design [1] is taken as the reference in this study, but fueled with fluorides of U-reduced DUPIC fuel material. Because the DUPIC process does not require any chemical reprocessing, it enhances the property of nuclear transparency.

2.1 *Code System*

The ORIGEN2-HELIOS-AMBIKIN2D code system is used. The ORIGEN2 is used to calculate isotope generation and depletion under continuous feeding and removal conditions. The HELIOS is used to modify the ORIGEN2 library suitable for the AMBIDEXTER and its lattice parameters as well. The AMBIKIN2D is a 2-dimensional, 2-group kinetics code, having developed to be useful for the fluid-fuel reactors.

2.2 *DUPIC-Based Fuel Materials*

In the DUPIC, there is too small portion of fissile material to ensure the criticality of the AMBIDEXTER. Therefore, 95% of uranium contents were decided to be removed by a fluorination process to make Pu-239 and Pu-241 be main contributors to fission, not U-235 as usual. The mole percent differences of important nuclides between DUPIC and R-DUPIC can be seen in Table 1[2].

Isotope	DUPIC (m/o)	R-DUPIC (m/o)
U-235	0.507	0.332
U-236	0.450	0.294
U-238	96.267	63.017
Pu-239	0.524	6.860
Pu-240	0.275	3.605
Pu-241	0.151	1.973
Pu-242	0.078	1.016
MA	0.039	0.507
FPs	1.711	22.398

Table 1 DUPIC and R-DUPIC Compositions [2]

As shown in the table, an unusual feature of R-DUPIC compositions is that fission products take about 22.4 mole percents. As several nuclides (Zr-93, Tc-99, Rh-103, etc) among them are burned out by 100 FPDs after startup, the multiplication factor rapidly rises ~0.15⊿k. This is presented in Fig.1 dotted line.

2.3 *Reactivity Swing With and Without Thorium*

To control reactor safely, thorium is fed for 17days up to 11.6m/o in this study (the solubility limit of thorium is 12m/o). Advantage of using thorium as the shim control material for the AMBIDEXTER is that it does not only captures neutrons but is converted to a fissile, U-233, and that the reactivity swing over the desired period can be minimized. The effect of feeding thorium in the AMBIDEXTER is also shown in Fig 1.

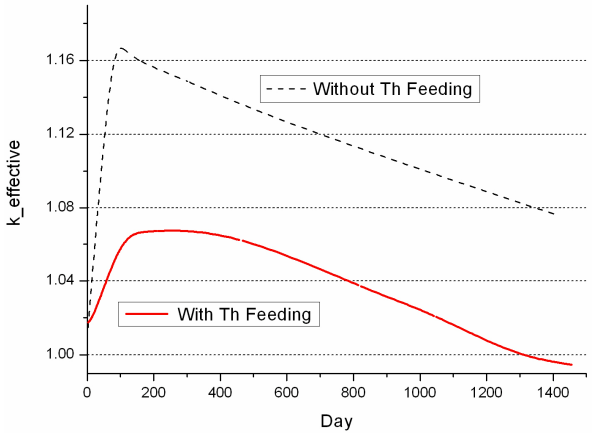

Fig. 2 The effect of feeding Thorium

2.4 *Core Specification*

For the initial core design, simulations were performed to make optimum condition to minimize the reactor core size. The amount of feeing Thorium is 70.5 ton by 17 FPDs for 250MW_{th}AMBIDEXTER. Table 2 represents the general characteristics of the reactor.

General Characteristics Parameters	
Core Height / Radius, cm	241.74 / 119.34
Reflector Thickness, cm	80
Temp. at channel Inlet / outlet, ℃	621 / 704
Salt velocity in fuel channel, cm/s	59

	0 FPDs	120 FPDs	1200 FPDs
Neutron Fluxes	1.484	1.615	1.676
(Fast / Thermal) $\times 10^{15}$nυ	/ 0.228	/0.294	/0.367
Fissile Fraction mole%			
^{233}U	0	0.021	0.115
^{235}U	0.013	0.012	0.008
^{239}Pu	0.274	0.229	0.106
^{241}Pu	0.079	0.112	0.110

Table 2 General Characteristics of the AMBIDEXTER-NEC

3. Conclusion

The molten salt reactor is one of well-known TRU burner. On top of that, the AMBIDEXTER-NEC with uranium-reduced DUPIC demonstrates its excellent performance of reducing HLW by means of fluorination. And feeding thorium is promising the AMBIDEXTER more reliable by suppressing the reactivity not to get to too high and helping sustain reactivity by U-233. At this moment, the maximum cycle-length is estimated around 1300 FPDs, but this would be improved by optimizing the amount of thorium feeding at later work.

REFERENCES

[1] Se Kee Oh, and Kun Mo Chung, AMBEDEXTER nuclear energy complex: a practicable approach for rekindling nuclear energy application, Nucl. Eng. & Dsgn. 207 (2001) 11-19

[2] Y. J. Lee, Designed and Operational Characteristics of the AMBIDEXTER-NEC with Uranium-Reduced DUPIC Fuel Material, ICAPP, 2007.