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Design Concept of Transportable Capsular LBE Cooled Fast Reactor, PASCAR

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1. Introduction

A transmutation-purpose fast reactor concept - PEACER (Proliferation-resistant, Environment-friendly, Accident-tolerant, Continual energy producing, and Economical Reactor) has been proposed by Nuclear Transmutation Energy Research Center of Korea as a Gen-IV type actinide burner reactor.[1] A prototype research reactor of PEACER, PASCAR(Proliferation-resistant Accident-tolerant Self-supported, Capsular and Assured Reactor) has been designed to be a test bed of TRU transmutation under a sustainable fast reactor condition with natural circulation mode cooling of LBE.

Purposes of PASCAR are to evaluate transmutation performance of long-lived minor actinides and fission products such as Tc and I, to check the safety viability under operational transient as well as hypothetical accidents. Limiting design goals are to have 1 m active core height for being no grid in the core, to have a 5-year operational cycle without fuel reloading and to take P/D ratio more than 1.20 to have enough natural circulation ability of LBE in 1m active core height.

2. PASCAR core conceptual design

Fuel pins of PASCAR are metal alloy of U-Zr and are of the same size of PEACER-300, arrayed in square lattice structure. Fuel pin will be manufactured by the KAERI technique which was validated for SMART fuels. Eight skeletal bars are located in each fuel assembly and control assembly to hold up the fuel pin array structure as shown in Fig. 1. P/D ratio is changed to 1.3 from 2.2 with the same pin diameter. Even if distance of pin to pin is small, Pb-Bi coolant is satisfied with natural circulation ability. Smeared density is changed to 100% from 70% and fuel enrichment is 18% to satisfy suitable criticality for 5 year cycle length.

The diameter and active core height of the reactor are 3.99m and 1m and reflector of thickness 44.22cm is located around the core. And the reactor core has single batch whereas PEACER-300 has three enrichment zones as shown in Fig. 2.

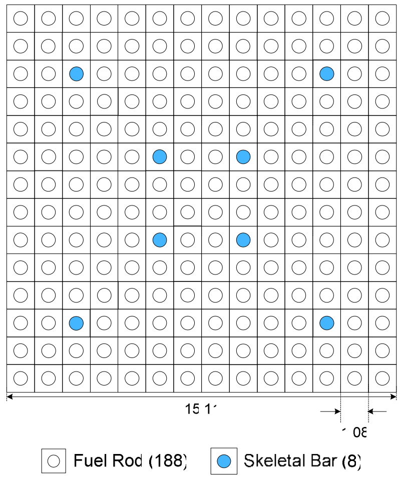

Fig. 1. Fuel Assembly of PASCAR core

Table 1. Core Design Parameters of PASCAR	
Power (MWe/MWt/Efficiency)	35/100/35
Fuel Composition	U-Zr (90.0 - 10.0 w/o)
Fuel Enrichment	18 w/o U-235, Smeared Density : 100%
Fuel Assembly Type	Metallic fuel, Square open
Coolant	Pb(44.5%), Bi(55.5%)
P/D Ratio	1.30
Pin Pitch(cm)	1.079
Core Shape	Cylinder, 100cmH × 399.02cmD
Fuel Assembly	320 /Core
Power Density(Peak)	13.67 W/cm^3 (27.9 W/cm^3)
Averaged Linear Power Density	16.62 W/cm
Average Burnup	5090.42 MWD/T

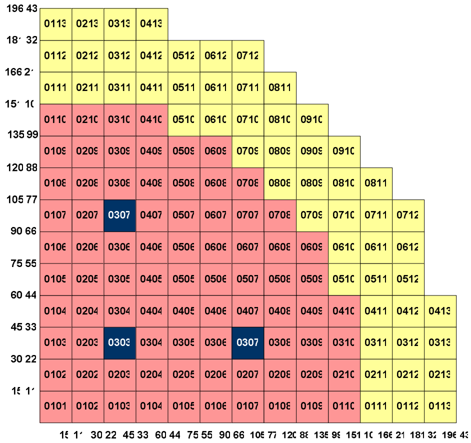

Fig. 2. Horizontal view of 1/4 PASCAR core

In case of U-Zr metal fuel, release rate of fission gas is known to be small but fission gas plenum was installed at the above of active core zone. All fuel pins are fastened at the core bottom plate and free to expand upwards. Average linear power density is lower than PEACER (about 21%) and amount of total fuel volume is comparable to PEACER (about 91%). Calculated rate of fission gas release is about 7.6% of PEACER-300 core.[1]

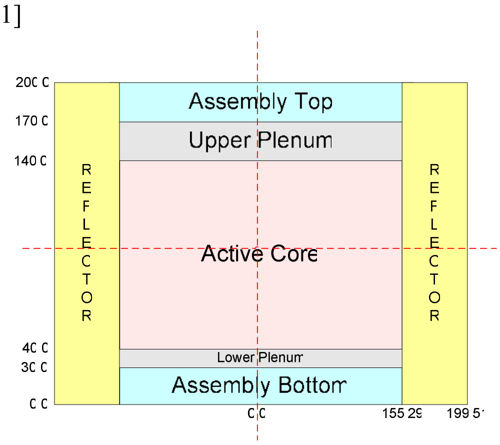

Fig. 3. Vertical view of PASCAR core

As a core design analysis tool, TRANSX, DANTSYS, DIF-3D, REBUS-3 code system was used in this paper. First of all, TRANSX code converts cross-sections of MATXS format to a format for discrete-ordinate code (TWODANT) from modified master library, KAFAX-F22. This XS library is collapsed in 80 neutron groups and 24 gamma groups using JEF-2.2 and NJOY94.[2] An ISOTXS format is considered with self-shielding effect, group collapsing, and region homogenization. DANTSYS (TWODANT) code produces a region flux table for R-Z geometry by S_N method to adjust self-shielding and region homogenization effect. Using the ISOTXS formatted cross-section, DIF3D/REBUS-3 solves a multi-group steady-state neutron diffusion equation in 2-D or 3-D geometries and also performs a fuel cycle analysis.

For a non-equilibrium cycle simulated by REBUS-3, the k-effective was calculated for a cycle as shown in Fig 4. From this calculation, It was known that PASCAR can satisfy a design goal of 3-year operational cycle without refueling.

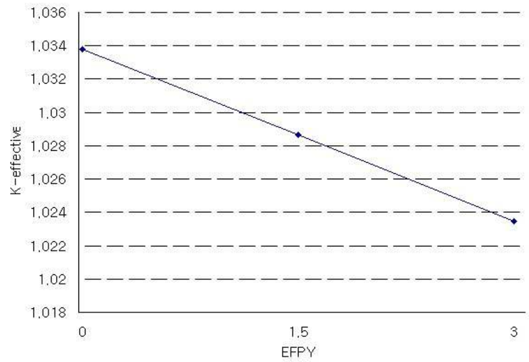

Fig. 4. K-effective letdown curve of PASCAR core

3. Conclusions

Fundamental design concept of PASCAR is the same with PEACER. Fuel pin array is square to allow enough space for natural circulation coolant of Pb-Bi. Fuel pin size is the same with PEACER. Preliminary design was done only for the feasibility test. Detail conceptual design will be followed for fuel assembly structure, core structure, Tc & I target assemblies, control rod assemblies, and reactor structure with reloading machine. Secondary side design will be highly different from PEACER design because of limited period and fund before license application.

REFERENCES

[1] Jae-Yong Lim, Myung-Hyun Kim, "A New LFR Design Concept for Effective TRU Transmutation," *Progress in Nuclear Energy*, 49, No.3, pp.230-245, April 2007.

[2] J.D. Kim, C.S. Gil, and J.H. Chang, "KAFAX-F22 : Development and Benchmark of Multi-group Library for Fast Reactor Using JEF-2.2," KAERI/TR-842/97, KAERI, Daejon, KOREA, 1997.