Down Selection of the Design Options for a Advanced Gen IV SFR Concept

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1. Introduction

A conceptual design of KALIMER-600, which is a pool-type SFR (Sodium-cooled Fast Reactor) rated at 600MWe, has been developed by KAERI (Korea Atomic Energy Research Institute).

The core of KALIMER-600 is loaded with metal fuels of U-TRU-Zr. The safety systems are based on a passive design concept that does not require any active components in case of design basis accidents [1].

Recently, our efforts for developing advanced Gen IV SFR concept are focused on the R&D activities for the down selection of design options as follows:

- Reactor power and core type
- Cladding and barrier material
- S/G tube, No. of loops and system components.

In this paper, the technical issues and viabilities of the design options to develop a advanced Gen IV SFR concept under investigation are addressed.

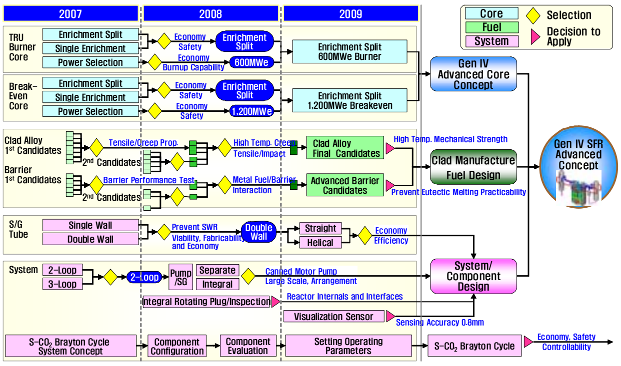

Fig.1. Down Selection of Design Options

2. Review on the Technical Viability of the Design Options

2.1 Reactor Core Type

Two core concepts, the core with an enrichment split fuel and the core with a single enrichment fuel with a region-wise varying fuel volume fraction, have been examined for the breakeven core of the 1,200MWe SFR.

The purpose of using the concepts of an enrichment split or a single enrichment fuel with varying clad thickness or non-fuel rods is to flatten the power distribution over the core by adjusting the fuel inventory for each core region [2].

Comparing the fuel utilization factors such as a fissile plutonium inventory and a discharge burnup, the enrichment split fueled core shows more attractive aspects for an economic potential. The power distribution of the core with the single enrichment fuel does not vary much with the burnup.

Even though the power distribution over the enrichment split core with the burnup state reveals a large difference between BOEC and EOEC, the clad temperature limit has been satisfied with a grouping of the coolant flow distribution. Therefore, the enrichment split core would be adopted as a candidate core concept for the break even core of the 1,200MWe-rated SFR [3].

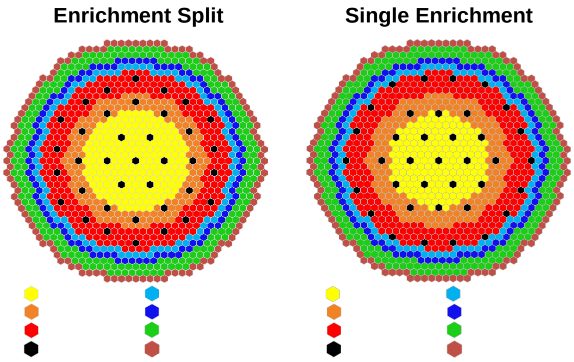

Fig. 2. Breakeven Core Design

2.2 Cladding and Barrier Material

New cladding material which can be used for high burnup and high temperature fuel is being developed. By optimizing alloy compositions and cladding manufacturing processes, several candidates of FMS (ferritic-martensitic steel) cladding alloys having adequate mechanical strength above 650℃ were derived [4]. Further verification such as sodium compatibility, tube manufacturability and irradiation tests will be performed.

Barriers such as Cr and V which can prevent a eutectic interaction between fuel metal and cladding at the temperature above 700℃ were selected through a series of diffusion couple tests [5]. A practical application process of the barrier during fuel fabrication is being investigated.

Application of high performance cladding and a barrier under development will enable the fuel to reach high burnup above 20 at. %.

2.3 Steam Generator, Number of Loops and System Components

The two loop system has some advantages like as a compact building size because the number of component is relatively less, and the total piping length is short. But the main obstacle is the fabricability of large size components, pipes and elbows, and large coaxial piping structures.

The three loop system has a technical feasibility because the component and piping sizes are slightly increased than that of the KALIMER-600 design, so the design experiences can be fully utilized.

A two loop system was selected by a trade-off study, in which the IHTS piping length can be minimized through the properly locating the SG and pump by 126m, being much shortened length compared with other design.

An alternate NSSS arrangement was also studied using an integrated SG-pump design concept, in which the pump is a canned-motor type. This concept can drastically reduce the IHTS piping length, and adopts a maintenance free canned motor pump attached at bottom of SG [6]. But the applicability of the canned motor pump is not verified in a sodium environment.

To achieve a high reliability of a steam generator, a double wall tube steam generator (DWTSG) having two barriers between sodium and water has been developed to minimize steam leaks into sodium, which. There were operating experiences of the SG early in the experimental reactors, EBR-II and so on.

But the heat transfer capability of the double wall tube SGs is about 80% smaller than that of the single wall tube SGs owing to the gas filled region between two tubes. Also the manufacturing cost of double wall tube SGs is about 1.3-2 times greater than that of the single wall tube SGs operated or designed previously. Despite of the economic demerit and the manufacturing difficulties, DWTSG will be adopted in the advanced Gen IV SFR concept to achieve high reliability and availability of SG.

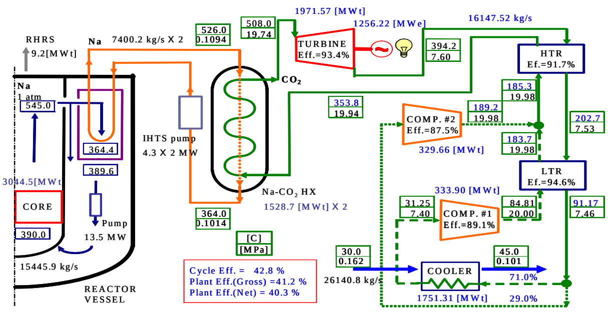

Fig. 3. Heat Balance of S-CO_2 Brayton Cycle

For establishment of Gen IV SFR power conversion system design concept, super heated steam Rankine Cycle and Super critical CO_2 Brayton Cycle [7] were evaluated. The S-CO_2 Brayton Cycle uses very small turbine, compressor and heat exchangers compared with Rankine Cycle. All the components could be combined in a turbine/compressor unit. The combined unit is almost the same size of single steam generator and could be installed in reactor building without turbine and auxiliary building.

Furthermore, the S-CO_2 system has higher system efficiency than the Rankine Cycle at a temperatures than 500℃ at turbine inlet. From the advantages of elimination of turbine building and higher system efficiency, it was estimated that the generation cost is to be reduced by 7%.

However, even though the S-CO_2 Brayton Cycle has lots of advantages, the system needs lots of R&D for the verification of component design and manufacturing, system control. Therefore, Rankine Cycle was selected as the reference system and S-CO_2 Brayton Cycle as the alternatives for the pool type Gen IV SFR system.

4. Conclusion

The enrichment split core, two-loop system, double wall tube steam generator and Rankine Cycle were selected as the reference system for the advanced Gen IV SFR concept and the S-CO_2 Brayton Cycle as an alternatives.

Several FMS cladding alloys and barriers such as Cr and V are adopted as candidates and tests will be performed to verify the viability.

Acknowledgements

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