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Core Thermal-Hydraulic Conceptual Design for the Advanced SFR Design Concepts

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1. Introduction

The Korea Atomic Energy Research Institute (KAERI) has developed the advanced SFR design concepts from 2007 to 2009 under the National long-term Nuclear R&D Program[1]. Two types of core designs, 1,200 MWe breakeven and 600 MWe TRU burner core have been proposed and evaluated whether they meet the design requirements for the Gen IV technology goals of sustainability, safety and reliability, economics, proliferation resistance, and physical protection.

In generally, the core thermal hydraulic design is performed during the conceptual design phase to efficiently extract the core thermal power by distributing the appropriate sodium coolant flow according to the power of each assembly because the conventional SFR core is composed of hundreds of ducted assemblies with hundreds of fuel rods. In carrying out the thermal and hydraulic design, special attention has to be paid to several performance parameters in order to assure proper performance and safety of fuel and core; the coolant boiling, fuel melting, structural integrity of the components, fuel-cladding eutectic melting, etc.

The overall conceptual design procedure for core thermal and hydraulic conceptual design, i.e., flow grouping and peak pin temperature calculations, pressure drop calculations, steady-state and detailed sub-channel analysis is shown Figure 1.

In the conceptual design phase, results of core thermal-hydraulic design for advanced design concepts, the core flow grouping, peak pin cladding mid-wall temperature, and pressure drop calculations, are summarized in this study.

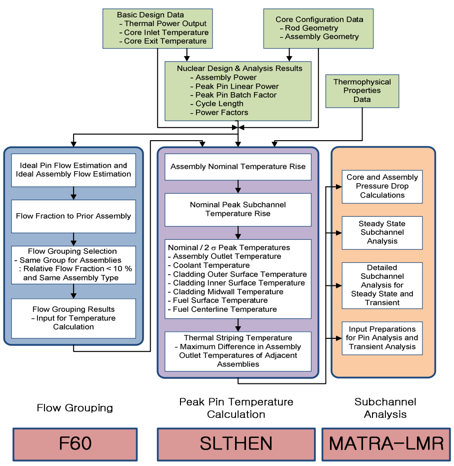


Figure 1 Core thermal-hydraulic design and analysis procedure

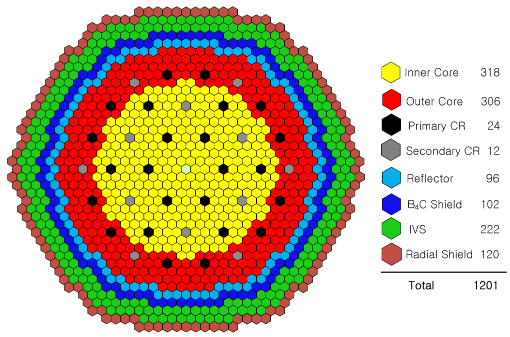
2. Core Configurations

1,200 MWe SFR breakeven core and 600 MWe TRU burner cores meeting the mission of Gen-IV SFR were designed based on the KALIMER-600 breakeven core which was developed under the national long-term nuclear R&D Program[2].

Each reactor core eliminated blanket assemblies to to enhance the proliferation resistance. The 1,200 MWe breakeven core is determined as a homogeneous core of 2 regions with the different fuel enrichment relying on well proven technology in fuel fabrication and fuel performance. In the case of 600 MWe TRU Burner core, the core is determined as a homogeneous core of 2 regions with fuel smeared density to maximize the TRU burning capability.

Figure 2 and Figure 3 show the configuration of the 1,200 MWe SFR breakeven core and the 600 MWe TRU burner core, respectively.

Table 1 shows the basic design data and operation condition of the 1,200 MWe SFR breakeven core and the 600 MWe TRU burner core.



* Another structural assembly instead of control rod was installed at the core centre

Figure 2 Configuration of the 1200 MWe SFR breakeven core.

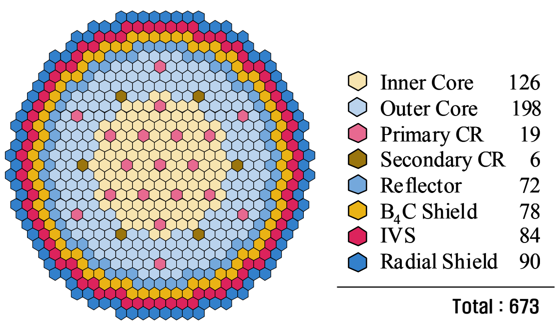


Figure 3 Configuration of the 600 MWe TRU burner core.

Table 1 Basic design data and operation condition of an advanced SFR design concepts

Core Electric Power (MWe)	1200	600
Coolant Inlet Temp. (℃)	390	
Coolant Outlet Temp. (℃)	545	
Fuel Type	U-TRU-10%Zr	U-TRU-15%Zr
Feed Fuel Enrichment(%)	13.19/16.83	30
Fuel Smeared Density(%)	70	60/69.5
Duct Wall Thickness (mm)	4.0	3.70
Duct Inner Flat to Flat (mm)	172.46	142.47
Number of Pins per Assembly	271	
Fuel Element Length (cm)	355.27	358.28
Active Length (cm)	80.0	89.07
Pin Outer Diameter (mm)	8.7	7.0
Cladding Thickness (mm)	0.595	0.56
Pin Pitch (mm)	10.30	8.50
Pin P/D ratio	1.184	1.214
Wire Wrap Diameter (mm)	1.40	1.50
Wire Wrap Pitch (cm)	20.49	

3. Thermal-Hydraulic Design

The 1,200 MWe SFR breakeven core and 600 MWe TRU burner core has 14 flow groups as shown in Figure 2 and 13 flow groups as shown in Figure 5, respectively.

Table 2 and Table 3 show the flow rate per flow group and the maximum cladding mid-wall temperature with 2σ uncertainty at each flow group of each core.

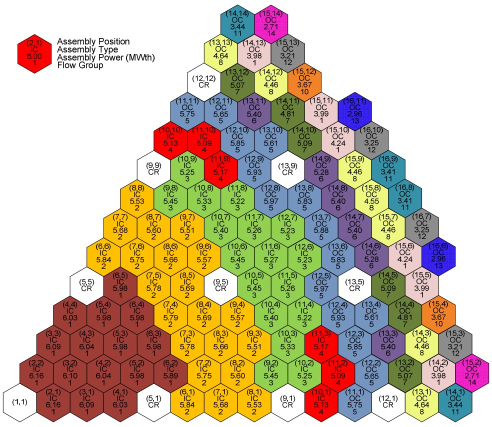


Figure 4 Flow group of 1200 MWe SFR breakeven core

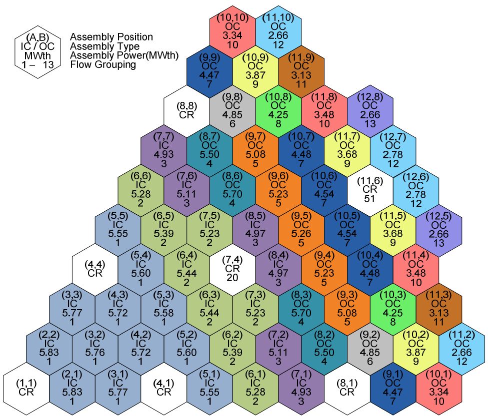


Figure 5 Flow group of 1200 MWe SFR breakeven core

Table 2 Flow rate per flow groups and cladding mid-wall temperature of 1,200MWe SFR breakeven core

Flow Group No.	Assy Type	Assy Flow rate (kg/s)	Assy. No.	Group Flow rate (kg/s)	Fraction (%)	Cladding Midwall (2σ)(°C)
1	IC	28.1	78	2191	53.5%	650
2	IC	26.5	108	2862		650
3	IC	24.6	102	2509		650
4	IC	23.3	30	699		649
5	OC	27.1	84	2276	42.0%	650
6	OC	24.4	36	878		649
7	OC	22.9	36	824		648
8	OC	20.6	36	741		649
9	OC	18.7	36	673		649
10	OC	16.0	12	192		649
11	OC	15.0	18	270		648
12	OC	14.1	24	338		649
13	OC	12.8	12	153		648
14	OC	11.6	12	139		649

Table 3 Flow rate per flow groups and cladding mid-wall temperature of 600 MWe TRU burner core

Flow Group No.	Assy Type	Assy Flow rate (kg/s)	Assy. No.	Group Flow rate (kg/s)	Fraction (%)	Cladding Midwall (2σ)(°C)
1	IC	25.9	54	1399	39.8%	650
2	IC	24.0	48	1008		650
3	IC	22.4	24	672		649
4	OC	25.2	24	605		650
5	OC	23.1	30	693	46.6%	649
6	OC	21.2	12	254		648
7	OC	19.7	30	591		649
8	OC	18.4	12	221		649
9	OC	16.6	24	398		649
10	OC	14.9	18	268		648
11	OC	13.3	12	160		649
12	OC	11.8	24	283		648
13	OC	10.8	12	130		649

4. Conclusion

The maximum cladding mid-wall temperature with 2σ uncertainty is estimated to be 650℃. It does not exceed the limit value for the Mod.HT9 cladding which is expected to be greater than 650℃.

The results show that the conceptual design for advanced SFR design concepts satisfy the design requirement.

ACKNOWLEDGEMENT

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REFERENCES

[1] Yeong-il KIM and Dohee HAHN, Advanced SFR Concept Design Studies at KAERI, International Conference on Fast Reactors and Related Fuel Cycles (FR09), Kyoto, Japan, 7-11 December 2009.

[2] D. H. Hahn et al., KALIMER-600 Conceptual Design Report, KAERI/TR-3381/2007.