Advanced Design Concepts and R&D Activities for a Gen IV SFR

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1. Introduction

Based upon the experiences gained through the development of KALIMER conceptual designs, KAERI is now developing advanced SFR design concepts that can meet the Gen IV technology goals. In order to verify the viability and to improve the performance of advanced designs, R&D activities are also being performed.

2. Advanced Design Concepts

2.1 Plant Design

Various design concepts have been proposed and evaluated against the design requirements which were established to satisfy the Gen IV technology goals. Table 1 shows the key parameters of the Gen IV SFR being developed at KAERI.

Table I: Design Parameters of Gen IV SFR

Overall		**PHTS**	
Net Plant Power, MWe	1,200.0	Reactor Core I/O Temp., °C	390/545
Core Power, MWt	3,046.4	Total PHTS Flow Rate, kg/s	15,455.4
Gross Plant Efficiency, %	41.9	Primary Pump Type	Centrifugal
Net Plant Efficiency, %	39.4	Number of Primary Pumps	2
Reactor	Pool Type		
Number of IHTS Loops	2	**IHTS**	
Safety Decay Heat Removal	PDRC	IHX I/O Temp., °C	325/528
		IHTS Total Flow Rate, kg/s	11,777.7
Seismic Design	Seismic Isolation Bearing	IHTS Pump Type	Centrifugal
		Total Number of IHXs	4
CORE		**SGS**	
Metal Alloy Fuel Form	U-TRU-10%Zr	Steam Flow Rate, kg/s	1326.6
		Steam Temperature, °C	503.0
Conversion ratio	1.0	Steam Pressure, MPa	16.5
		Number of SGs	2

2.2 Reactor Core Designs

In order to improve the economics, rated power was increased to 1,200 MWe from 600 MWe of the KALIMER-600. Core design with enrichment split fuels was chosen since it showed attractive economics potential in terms of fissile plutonium inventory and discharge burnup.

In order to investigate performance parameters of large scale SFRs for TRU burning, cores of 600~1,200 MWe were designed. A single enrichment fuel concept was selected to increase TRU enrichment and thereby TRU burning. Region-wise variable cladding thicknesses were used to flatten the power distribution. Pancake core geometry enabled sodium void reactivity not to be the safety concern. According to the current study, TRU burner reactors can be developed with a power level of over 1,200 MWe. However, considering 1) the realistic size of SFR demonstration reactor planned to be constructed by 2028 according to the long-term R&D plan, and 2) the availability of KALIMER-600 reactor system designs, a TRU burner of 600 MWe was selected.

A representative performance parameters for the breakeven and burner cores are shown in Table II.

Table II: Core Performance Parameters

	Burner	Breakeven
Electrical Power (MWe)	600	1,200
Cycle length (EFPD)	332	540
Charged TRU enrichment (w/o)	30.0	15.0
Conversion ratio (fissile)	0.74	0.99
Burnup reactivity swing (pcm)	3,685	226
Average discharge burnup (MWD/kg)	127.9	100.1
Sodium void worth ($)	7.43	7.25
Delayed neutron fraction	0.00321	0.00353

2.3 Heat Transport System Designs

The heat transport system consists of a Primary Heat Transport System (PHTS), an Intermediate Heat Transport System (IHTS), a Residual Heat Removal System (RHRS) and a Steam Generating System (SGS). A typical configuration of the heat transport system is shown in Figure 1. Net plant efficiency of the reactor system is 39.4% which is higher than the Gen IV standard requirements of 38%.

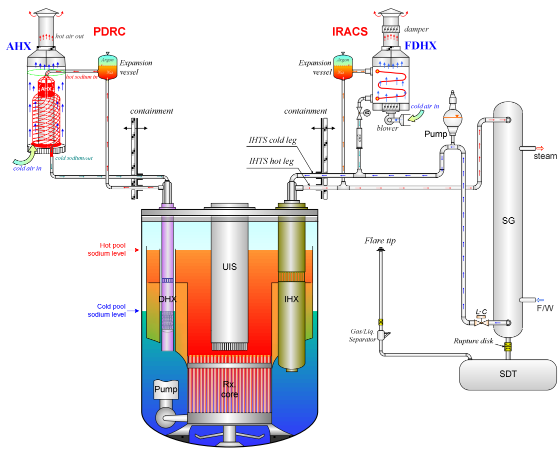

Fig. 1. Configuration of the heat transport system

The Passive Decay-heat Removal Circuit (PDRC) operates by natural circulation of sodium and external air without any active component actuation or operator's action. Under accident conditions, hot and cold pool levels equalize due to PHTS pump trip after the reactor shutdown. Since the normal heat transport path is not available, the hot pool sodium is heated, expanded and overflows to buffer region, which allows enhanced heat removal through the PDRC.

3. R&D Activities

Various R&D activities are now being performed in order to support development of advanced concepts. These activities include PDRC experiment, conceptual design of supercritical carbon dioxide (S-CO_2) Brayton cycle system, Na-CO_2 interaction test, under-sodium viewing technique, metal fuels and sodium technologies.

3.1 PDRC Experiment

For the verification of PDRC design concept and assessment of the system performance, a large scale sodium thermal-hydraulic experimental facility as shown in Figure 4 is now under construction with a goal of completion by 2011.

Main test section is composed of a primary heat transport system and PDRC which are scaled-down from the KALIMER-600 design. In order to represent important thermal-hydraulic phenomena in the PDRC as well as the reactor system, the main test section has been designed complying with proper scaling criteria for geometric, hydrodynamic and thermal similarities. Overall scaling of the facility is 1/125 for volume and 1/5 for height. The reactor vessel height and diameter are about 3.6 m and 2.3 m, respectively. The reactor core is simulated by electrical heaters of 1.9 MW capacity which corresponds to a 7 % of the scaled full power. Sodium is used as a working fluid and its inventory inside the main test section is approximately 13 ton. Operating temperatures of the reactor system are preserved in the experiment.

In the test, the natural circulation cool-down capability of the PDRC in conjunction with the reactor system will be investigated for various design basis events.

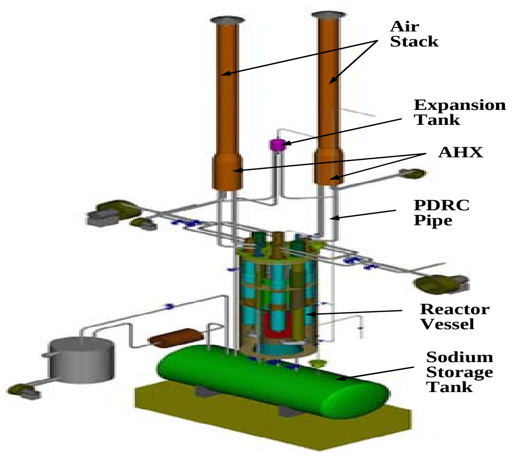

Fig. 4. Configuration of the PDRC Experimental Facility

3.2 Na-CO_2 Interaction Test

The supercritical carbon dioxide (S-CO_2) Brayton cycle system is now being studied for its potential application to SFR. If successful, concerns of sodium water reactions in steam generators can be resolved and capital cost can be drastically reduced. However, there is still a possibility for a potential tube rupture accident due to a high pressure difference between the tube-side CO_2 and shell-side liquid sodium. For this reason, the kinetic behaviors during a Na-CO_2 chemical reaction and its consequences should be clarified or quantified.

Experimental facilities for the Na-CO_2 interaction test have been assembled and the flow diagram of the test rigs is shown in Figure 5.

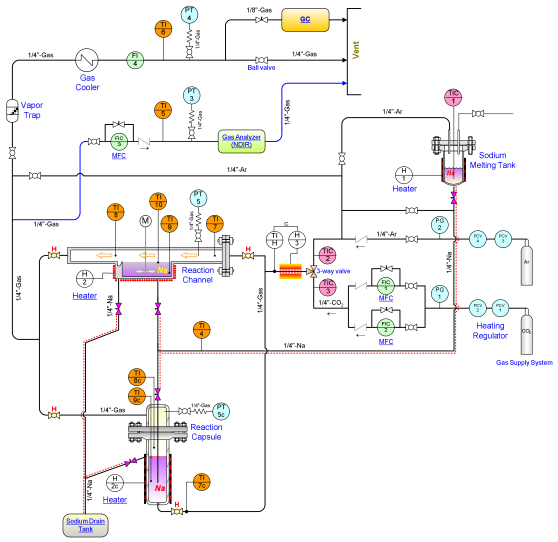

Fig. 5. Flow diagram for the Na-CO_2 interaction test

4. Conclusions

Advanced SFR design concepts have been developed in order to meet the Gen IV technology goals. Preliminary overall plant design has been developed and safety assessment will be performed to finalize the design. In order to support development of advanced design concepts, various R&D activities are being performed as well.

Acknowledgements

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