9–1 Small Nuclear Reactor for Multiple Heat Applications with Attractive Safety Features

— Conceptual Design of Small High-Temperature Gas Cooled Reactor for Developing Countries —

Design targets and results

Design items	Design target	Criteria	Results	Feasibility
①Core	Reduce the number of uranium enrichments	< 6 (HTTR: 12)	3	○
	Increase core power density	3.5 MW/m³ (HTTR: 2.5 MW/m³)	3.5 MW/ m³	○
	Increase refueling interval	730 d (HTTR: 660 d)	730 d	○
②Component	Increase thermal duty of IHX	20 MW (HTTR: 10 MW)	20 MW	○
③System	Satisfy the user requirements for multiple heat applications	Heat supply for district heating network: 0 MW～25 MW (50% partial load operation of steam turbine)	0 MW～25 MW	○
		Demonstration test of gas turbine electricity generation and hydrogen production can be performed	Demonstration test can be performed using IHX	○
④Safety	Design of the engineered safety features of the residual heat removal system (i.e., VCS) as passive methods	Biological shielding concrete temp. at normal operation: <65 ℃	64.8 ℃	○
		Satisfy the acceptance criteria for accidents in safety analysis	All criteria are satisfied	○

Other design results

Design items	Results
Thermal power	50 MW
Reactor inlet temperature	325 ℃
Reactor outlet temperature	750 ℃, 900 ℃※
Primary pressure	4 MPa
Reactor pressure vessel material	Mn-Mo steel

※ demonstration of the gas turbine and hydrogen production

Example of system configuration

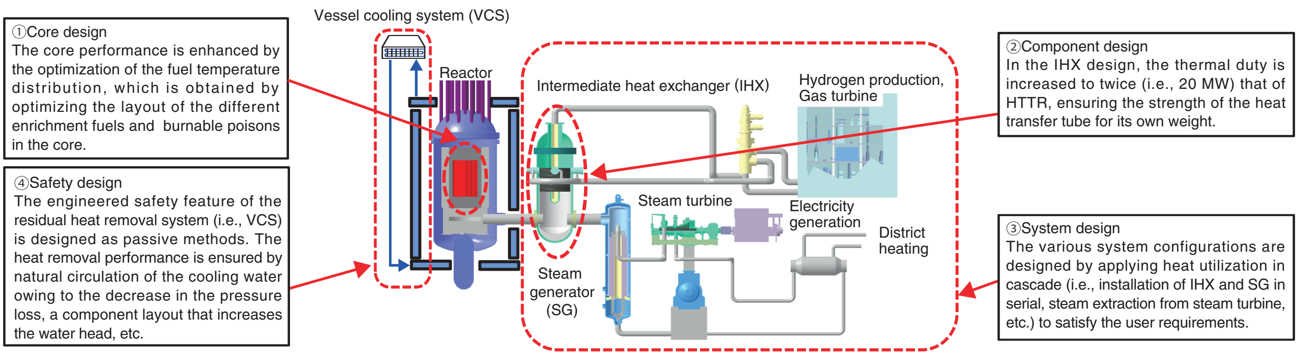

Fig.9-2 Design targets and results of small HTGR system design
The conceptual design of a 50 MWt small HTGR system was completed. It can satisfy the user requirements for multiple heat applications, and its performance is superior to that of the HTTR. The technical feasibility was confirmed by the results of the core, component, and system design, and a safety analysis in the event of representative accidents.

We tested the High-Temperature engineering Test Reactor (HTTR) to establish the high-temperature gas cooled reactor (HTGR) fundamental technologies and to obtain the data required for commercial HTGR design. Since 2010, we also developed the conceptual design for a 50 MWt small HTGR system that can satisfy the user requirements, aiming at construction of a demonstration plant in a developing country in the 2020s. Its performance was improved over that of the HTTR without significant research and development, using the knowledge obtained from HTTR design and operation (Fig.9-2).

In the core design, the number of uranium enrichments was reduced to three (i.e., one-quarter that of the HTTR), and the average core power density was increased to 3.5 MW/m³ (i.e., 1.4 times that of the HTTR), satisfying the maximum fuel temperature criterion throughout the burnup period of 730 d. In the component design, the thermal duty of the intermediate heat exchanger (IHX) was increased to twice (i.e., 20 MW) that of the HTTR; the strength of the heat transfer tube for its own weight was ensured by increasing the tube diameter to decrease the stress and by increasing the flow rate to increase the heat transfer performance. The system configurations were determined so as to use the nuclear heat for district heating and process heat based on a steam turbine system, and to demonstrate a helium gas turbine and hydrogen production to satisfy the user requirements. In the safety design, the residual heat removal system (the vessel cooling system) was designed as a passive system. The safety was confirmed by a safety analysis of representative accidents.

The Republic of Kazakhstan initiated a development program for the nuclear industry in that country in June 2011, which includes a construction plan for the Kazakhstan high-temperature gas-cooled reactor (KHTR) based on this small HTGR system.

Reference
Ohashi, H. et al., Conceptual Design of Small-Sized HTGR System (IV) –Plant Design and Technical Feasibility–, JAEA-Technology 2013-016, 2013, 176p. (in Japanese).