Analysis of the Natural Circulation Behavior in Regional Energy rX-10MW$_{th}$

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1. Introduction

Recently there has been a renewal of interest in the Small- and Medium-sized nuclear Reactor (SMR)[1-2] such as NHR-200 (China), CAREM (Argentina), IRIS (USA), PSRD-100 (Japan) and SMART (Korea). The SMR has two significant redeeming features – various applications and enhanced safety. Firstly, the SMR is used for desalination, district heating, ship propulsion and small-scale power generation. Secondly, in the case of the SMR as the main pipes in the reactor pressure vessel are eliminated and have a simple design, it can avoid a large break loss of coolant accident (LBLOCA). A Regional Energy Research Institute for Next Generation (RERI) is designing a new conceptual nuclear reactor, a Regional Energy rX-10MW$_{th}$ (REX-10)[3] as references of various SMRs. To increase reactor safety, the REX-10 adopts the cooling mode of natural circulation. To evaluate the natural circulation behavior of the REX-10, an experimental facility, NACTER, was designed by scaling down the REX-10. The detailed descriptions of NACTER are in section 2. The main purpose of this article is to evaluate the natural circulation behavior of the REX-10 by the experiment.

2. Experimental Facility

2.1. Experimental facility

NACTER (NAtural Circulation TEst Reactor) was designed on the basis of the scaling law[4-5] in order to study the natural circulation behavior under the steady-state conditions. The scaling ratio of REX-10 to NACTER is summarized in Table I. The schematic diagram of NACTER is shown in Fig. 1. The overall height and diameter are about 3.5 m and 0.22 m, respectively.

Table I. Scaling Ratio between REX-10 and NACTER

Parameters	Scaling Ratio	Parameters	Scaling Ratio
Pressure	1/1	Mass Flow Rate	1/500
Core ΔT	1/1	Flow Area	1/288.7
Height	1/3	Heater Power	1/500

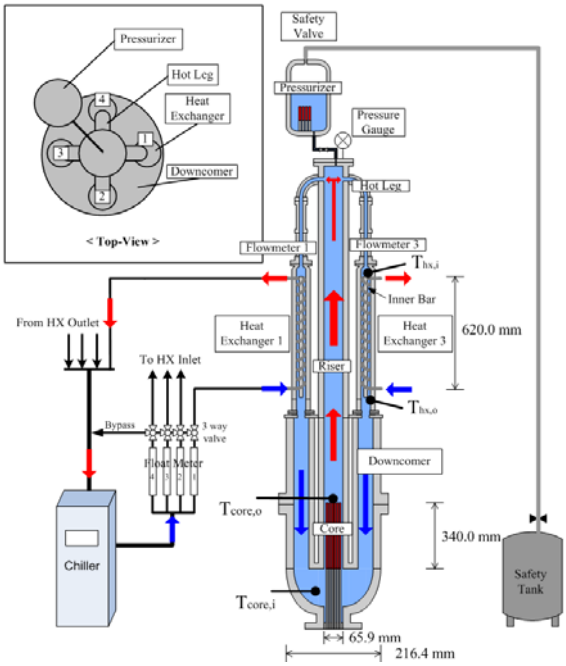

Fig. 1. Schematic Diagram of NACTER

The core serves as a heat source and generates the maximum 20 kW$_{th}$. The core consists of 7 electric heaters with a 10.0 mm in diameter and 20.0 mm in pitch. The experimental facility has four hot legs which are installed to measure the mass flow rate in the primary loop. The NACTER has 4 once-through helical-coiled heat exchangers. Inside each heat exchanger, there is one helical coil which is 4.572 mm in diameter and about 2.0 m in length. The pressurizer which controls the primary pressure is located in the highest part of the NACTER. The flow paths of the primary and secondary loop are shown by the arrows in Fig. 1 and the measuring points are also shown in Fig. 1.

2.2. Experimental parameters

The parameters that affect the behavior of natural circulation are heater power and the distance (ΔH) between the center of the core and heat exchanger. In this experiment, the geometries of the experimental facility including ΔH are fixed and the heater power is adopted as main parameter. The test matrix is summarized in Table II.

Table II. Test Matrix of the Steady-State Analysis

Case	Heater Power (kW)	Feedwater Flow Rate (LPM)
Effect of Heater Power	4-18	1.4

3. Results and Discussions

The test result of NACTER-15-14 case is shown in Fig. 2. The heater power is 15 kW and feedwater flow rate is 1.4 liter/min. As a result of the test, the temperatures and mass flow rate well maintain steady-state conditions.

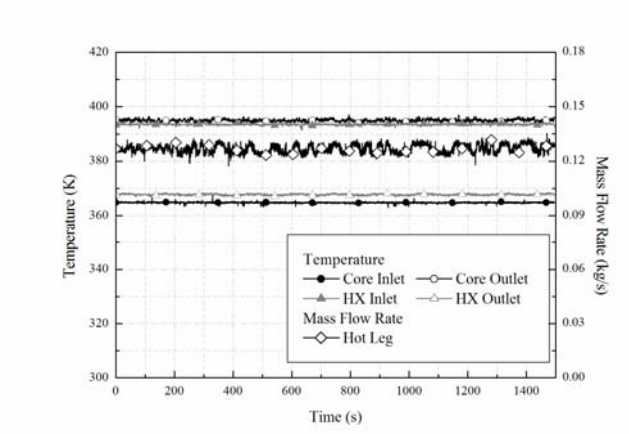

Fig. 2. Experimental Result of NACTER-15-14 test

To evaluate the effect of the heater power, we conducted experiments at various heater powers. The results of NACTER-VHP-14 case are shown in Fig. 3-4. The results show that the heater power has a significant impact on the natural circulation system. The ΔT and mass flow rate increase with increasing the heater power with a relationship of $\dot{m} \sim P^n$ as Zvirin et al[6-7].

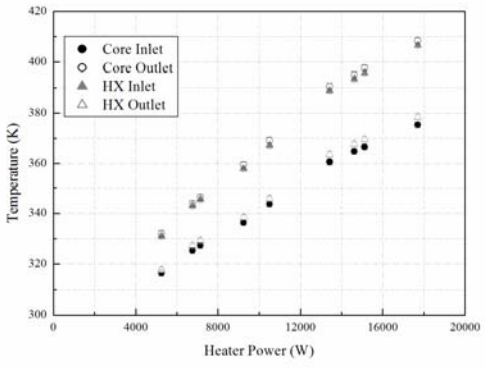

Fig. 3. Temperature Distribution of NACTER-VHP-14

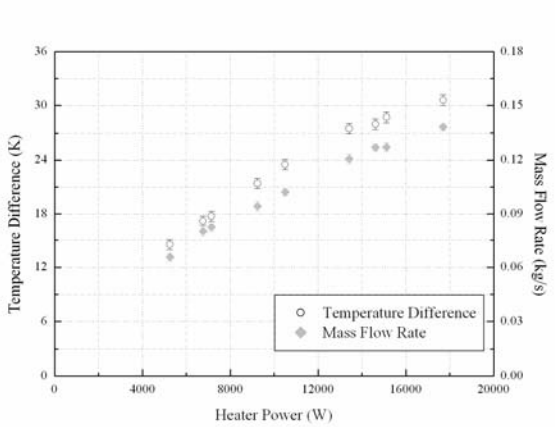

Fig. 4. Temperature Difference and Mass Flow Rate of NACTER-VHP-14

4. Conclusions

The main aim of this article is to evaluate the natural circulation behavior of a new conceptual nuclear reactor, REX-10. In order to conduct the natural circulation experiment, the NACTER was designed by using the scaling law. The heater power was chosen as the experimental parameter. Under all experimental conditions, the NACTER maintained steady-state conditions. In near future, various transient experiments will be performed based on these steady-state tests. Also these results will be used to validate system analysis codes.

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