Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Experimental Study on Natural Circulation in REX-10 Test Facility

Byeong-ill Jang[a*], Hyeong-Min Joo[a], Sun-Do Choi[a], Gyoo-Dong Jeun[a], Moo-Hwan Kim[b]
[a]*Department of Nuclear Engineering, Hanyang University, 17,Haengdang-dong, Seongdong-Gu, Seoul, 133-791, Republic of Korea*
[b]*Mechanical Engineering Department, POSTECH, Pohang, 790-784, Republic of Korea*
[*]*Corresponding author: jbi@thlab.hanyang.ac.kr*

1. Introduction

A new concept of energy supply system for nuclear district heating and electricity generation with dispersed power grid by small and medium nuclear power reactor is introduced. What is most important in district heating reactor is to guarantee the safety without helping the power or activity devices. Therefore, we adopt the natural circulation system without pumps because natural circulation ensures passive safety and reliability. To evaluate the natural circulation capability of REX-10, we design the test facility using Ishii' scaling law. We conduct at various powers in order to test the behavior of natural circulation of RTF.

2. Experiments

2.1. Experimental facility

RTF(REX-10 Test Facility) is designed to study the characteristics of natural circulation in REX-10. The experimental facility is composed of a primary loop and a secondary loop. The schematic diagram of the facility is shown in Fig. 1. The sizes of RTF are determined from REX-10 using Ishii' scaling law [1].

The primary loop consists of electric heaters, hot legs, a heat exchanger and a pressurizer. First, electric heaters, which are 12 mm in diameter and 1 m in height, are located in a lower part of the facility. Electric heaters generate 200kW maximum. Secondly, hot legs, which are between a riser and a heat exchanger, are designed to measure a primary flow rate. A flowmeter is installed in a vertical tube of the hot leg. Thirdly, a heat exchanger consists of 12 helical coils. Each helical tube is 3/8 inch in diameter and about 4 m in length. Finally, a pressurizer is located in the highest part of the facility. Electric heaters of the pressurizer generate 20 kW maximum. All parts of RTF are insulated in order to minimize the surface heat loss. The surface heat loss, evaluated on the heat transfer correlations, was less than 1~2% of the heat input. The secondary loop is composed of chillers and helical coils. The secondary coolant flows in helical coils. The secondary flow rate is controlled by the float meters.

In this experiment, 32 K-type thermocouples are used to obtain the temperature in the ambient, primary loop and secondary loop. To calculate the heat removal rate from the secondary loop, the inlet and outlet temperatures of the helical coils are measured. And to evaluate a surface heat loss, the ambient temperature is

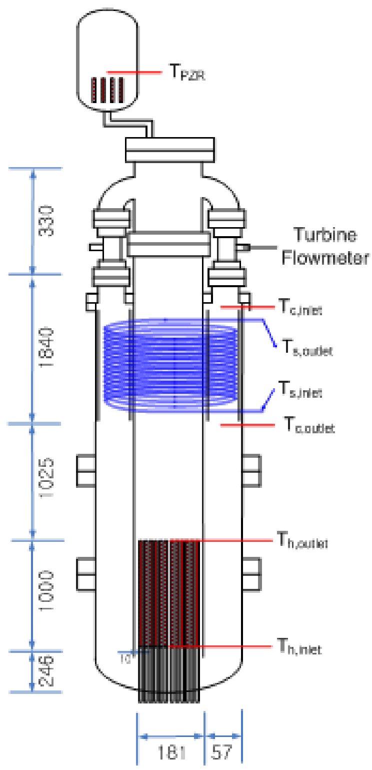

Fig. 1 Schematic diagram of experimental facility

measured. All temperature data are collected by the Data Acquisition System (DAS). Flow rates are measured both a primary and a secondary loop. The turbine flowmeter is installed in a primary loop which measures range from 0.0 liter/min to 33.0 liter/min with maximum error of 0.8%.

2.2. Experimental parameters

There are many parameters that affect the behavior of natural circulation. But geometric factors – especially, the distance between the center of the core and heat exchanger is very important factor in natural circulation – are fixed in the current experiments. So we select the three parameters – primary pressure, electric heaters power, secondary flow rate – in order to evaluate the capability of natural circulation. To examine the natural circulation behavior of various powers, we vary the power between 50 kW and 150 kW, but the pressure and secondary flow rates are fixed in 10 bar and 2.5 liter/min, respectively.

3. Results and Discussion

The overview of the experimental data is shown in Fig. 2-4. Fig. 2, 3 and 4 shows the temperature difference, maximum temperature and flowrate for four input power levels respectively, while keeping the same primary pressure and the secondary flowrate. There are steep rise in the temperature or flowrates for all experiments, which is a point where the heaters are turned on. After several minutes, we observe the steady-state. These experimental results lead to conclusion that the temperature difference, maximum temperature and flowrate increase with increase in heater power.

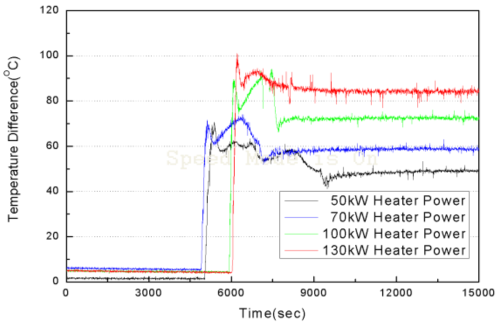

Fig. 2 Temperatures difference at various heater power

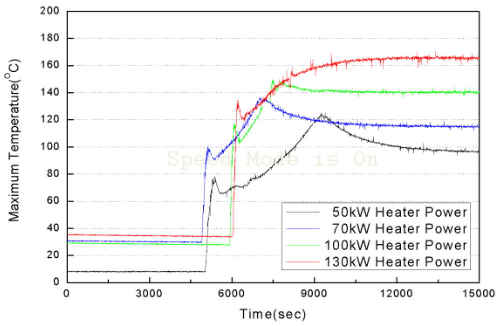

Fig. 3 Maximum temperature at various heater power

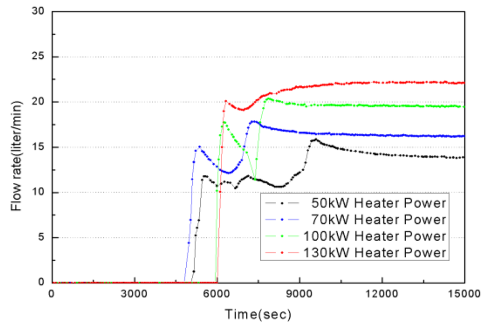

Fig. 4 Flowrates at various heater power

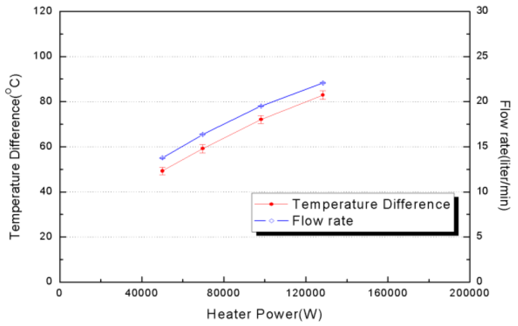

Fig. 5 Steady-state data of the temp. diff. and flowrate

4. Conclusion

The natural circulation experiments with various heater powers, pressures, secondary flowrates are performed. The results of the experiments are that the heater powers have significant influence on the natural circulation. The steady-state temperature difference and flowrate of the natural circulation increase with increasing input power with a relationship of $\triangle T$, $\dot{m} \sim Q^{1/3}$ as Zvirin(1981)[2] supposed.

In near future, we performed the experiments at various pressures and secondary flowrates. It is important to consider the natural circulation behavior of various pressures because the district heating reactor is to guarantee the safety in normal or emergency situations. So, we plan to experiment at 5, 10, 15 and 30 bar. Secondly, we make experiments at various secondary flowrates so as to find out the characteristics of the heat transfer of helical coils. We vary the flowrates between 0.5 and 4.0 liter/min.

Finally the experimental results are compared with the numerical analysis.

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