Validation Calculations for Natural Circulation Core Cooling Experiments Simulating Loss of Normal Electric Power in Research Reactors

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1. Introduction

When a loss of normal electrical power (LOEP) accident occurs in research reactors with downward flow cooling the core such as Jordan Research and Training Reactor (JRTR) and Ki-Jang Research Reactor (KJRR), the pump stops and the flow reversal occurs at the beginning of the natural circulation by the decay heat. The phenomena in the LOEP accident are of importance in the safety analysis since the flow in the core is stagnant at the flow reversal.

The natural circulation core cooling experiment is for a simulation of LOEP. The experiment was performed as the progress from the previously introduced study[1].

In order to validate the safety analysis code used in the design of research reactor for LOEP, the calculations have been performed for the natural circulation core cooling experiment. In this paper, validation methods and results are introduced.

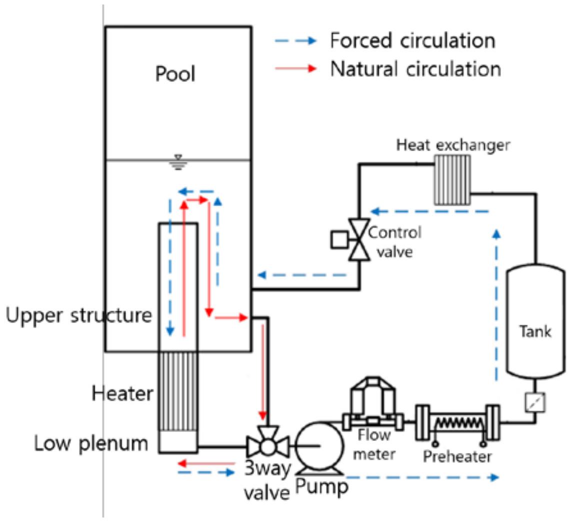

Fig. 1. Schematic diagram of the natural circulation core cooling experimental facility

2. Experimental facility and conditions

2.1. Description of experimental facility

The design of the experimental facility is based on the JRTR applying the scaling law of the natural circulation [2]. The schematic diagram of the experiment facility is shown in Fig. 1.

In the experiment facility, a 3-way valve takes the role of the flap valve. In forced circulation, the 3-way valve provides the flow path from the low plenum to the pool through pump, tank and the heat exchanger (see the blue dashed line in Fig. 1). When the pump flow rate decreases to the setpoint predetermined, the 3-way valve is opened partially connecting the flows from three directions. When the pump flow rate reaches to almost zero, the 3-way valve is opened completely for natural circulation (see the red line in Fig. 1).

The power of a heater can be adjusted by the power controller to simulate the decay power, and the pump flowrate is controlled to simulate the coastdown.

2.2. Experimental conditions

The initial conditions of the experiment are shown in Table I.

Table I. Initial conditions on the calculation

Initial condition	value
Heater power	68 kW
Inlet temperature	38 ~ 40 ℃
Heater flowrate	2.27 kg/s

The heater power and pump flow rate are controlled and adjusted from about 60sec to simulate LOEP accident. Fig. 2 shows the time-dependent behaviors of the heater power and the pump flow rate. There are 3 cases of the pump flowrate with different coastdown characteristics (time constants).

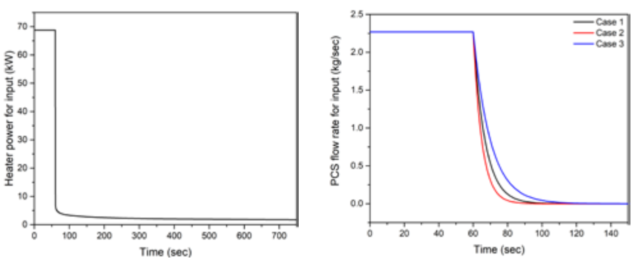

Fig. 2. Time-dependent heater power and pump flow rate

3. Numerical calculation method

The calculations for validation of natural circulation core cooling experiments were performed using RELAP5 code [3].

The node diagram of the model for the experiment facility is shown in Fig. 3. The part of forced circulation is simply modeled using time-dependent junctions and volumes.

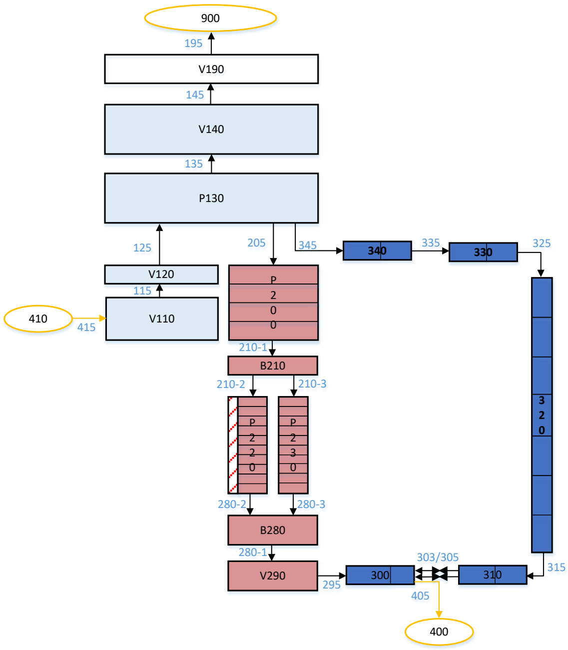

Fig. 3. Node diagram of the experiment facility

4. Result

The calculations for the validation of RELAP5 code were performed with the same initial conditions with the experiments. The calculation results were compared with the experimental data. Since the behaviors of thermal hydraulic phenomena were similar in all the cases of coastdown curves, the results of Case 1 are presented here.

Fig. 4 shows the flowrate in the heater assembly. The calculation result of the flow rate shows good agreement with the experimental result. Table II shows the time values at the point of flow reversal. Since a range of difference between the experimental data and the calculation results for all the cases is 3.4 ~ 8 seconds, there is no significant difference but the RELAP5 code predicts the flow reversal point faster than the experimental results.

Fig. 5 shows the flow rate in the natural circulation pipe. When the 3-way valve is opened partially, the flow rate of the experimental result is larger than the calculation result, and the maximum flow rate of the experimental result is temporarily higher than the calculation result by up to two times. After the 3-way valve fully opened, the flow rate is approximately 10% higher in the calculation result.

Figure 6 shows the axial temperatures of the heater surface. The calculation result shows that the overall temperature behavior is well predicted. But the heater surface temperatures are predicted to be 6 ~ 11% higher than the experimental data.

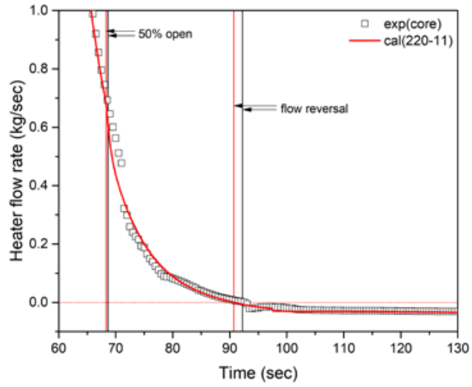

Fig. 4. Flowrate in the heater assembly

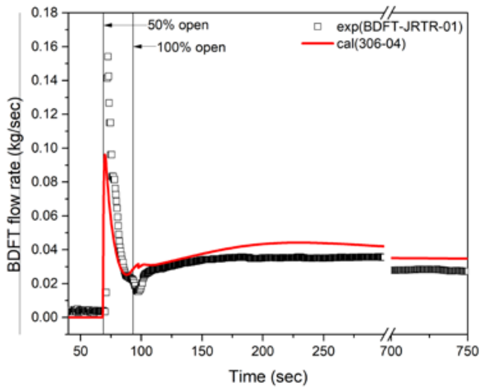

Fig. 5. Flowrate in the natural circulation pipe

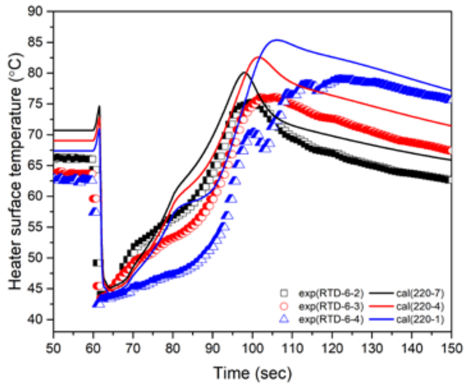

Fig. 6. Axial temperatures of the heater surface

Table II. Time at the point of flow reversal

	Experiment [sec]	REALP [sec]
Case1	92.55	90.72
Case2	84.08	82.53
Case3	107.81	104.07

5. Conclusion

The validation calculations for the natural circulation core cooling experiments were performed using the safety analysis code (RELAP5). As a result of comparing the calculation results with the experimental data, the safety analysis code predicts LOEP accident including the flow reversal phenomenon conservatively.

ACKNOWELGEMENTS

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[1] D. H. Kim et al., Preliminary Calculation of Natural Circulation Core Cooling Experiment Simulating a Loss of Normal Electric Power in Research Reactors, KNS Autumn meeting, 2019

[2] H. Lee et al, “Interim report of natural circulation core cooling experiment for the validation data of safety analysis code for research reactor,” KAERI/CM-2724/2018

[3] RELAP5/MOD3.3 CODE MANUAL VOLUME IV: MODELS AND CORRELATIONS, Division of Systems Research, Office of Nuclear Regulatory Research U. S. Nuclear Regulatory Commission, Information Systems Laboratories, Inc. Rockville, Maryland Idaho Falls, Idaho, 2001.