A Study on the Two-Phase Natural Circulation Flow under ERVC

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1. Introduction

To observe and evaluate the two-phase natural circulation phenomena through the gap between the reactor vessel and the insulation in the APR1400 under the external vessel cooling, the T-HERMES (Thermo-Hydraulic Evaluations of Reactor vessel cooling Mechanisms by External Self-induced flow) program has been performed in KAERI [1]. The HERMES-HALF study [2], which is one of the T-HERMES programs, is a non-heating experimental study on the two-phase natural circulation through the annular gap between the reactor vessel and the insulation. In this paper, the HERMES-HALF experimental results were presented and compared with ones of the numerical analyses using a RELAP5/ MOD3 code.

2. Methods and Results

2.1 HERMES-HALF Experimental Setup [2]

The schematics diagram of the HERMES-HALF experimental facility is shown in figure.1. The facility consists of 3 parts, that is, a main experimental facility, an air supply system and a water recirculation system. The main facility is a half scaled-down reactor vessel and an insulation part which is prepared utilizing the results of a scaling analysis proposed by Cheung [3] to simulate the APR1400 reactor and insulation system. The water inlet pressure condition is controlled by changing the water head level in the reservoir. For maximizing the natural circulation flow, water inlets and outlet ports exist in the insulation. The natural circulation flow is discharged to two outlets in the insulation. Two outlets have rectangular shapes, which are located at a 45, and 135 degrees of longitude on the annular section of the reactor vessel wall. The shape of each outlet is rectangular, that is, the horizontal size is 0.2 and the vertical is 0.375m. The height from the bottom of the reactor vessel to the center of the outlet port is 3.384m.

In the HERMES-HALF experiment, the two phase flow is generated by not a direct heating method but a non-heating method. For the non-heating experiment, an equivalent air is injected through 141 air injectors by the air supply system. The experimental heat distribution for calculating the air injection rate is obtained by the MAAP calculation [4]. The 100% air injection condition is equivalent to 8380m^3/hr total air injection rate.

2.2 Experimental Results

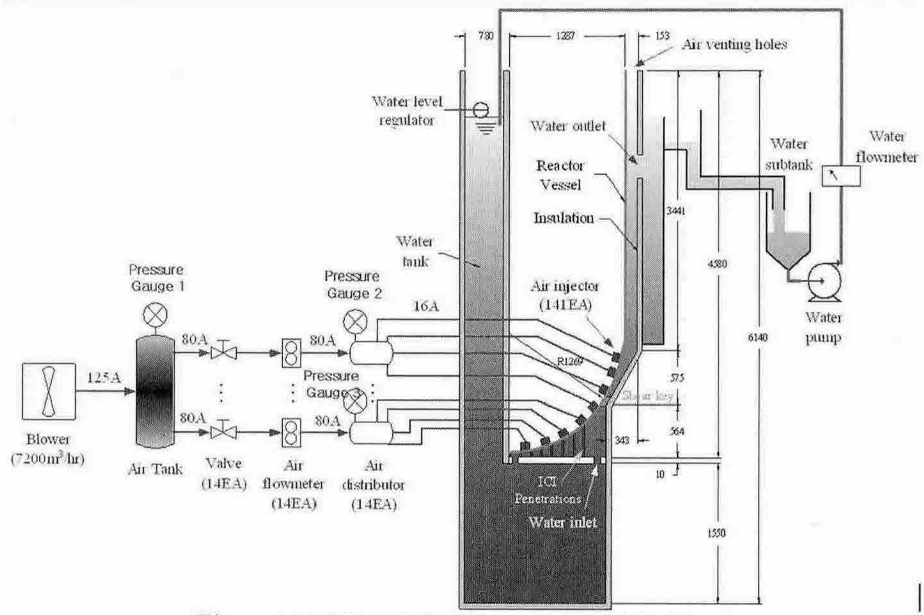
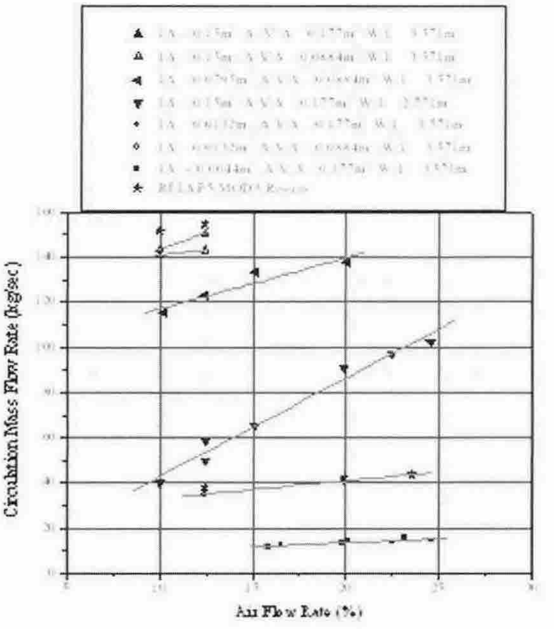
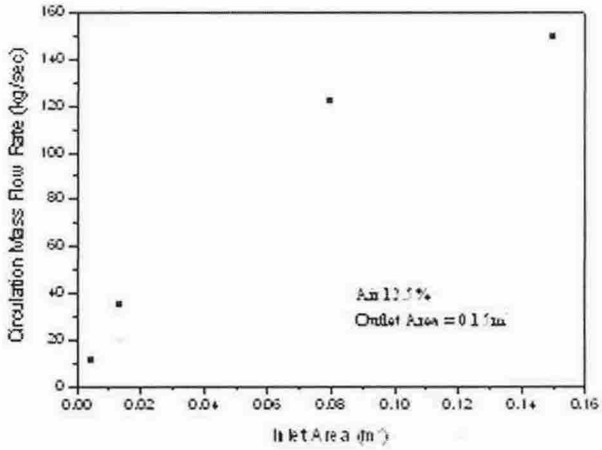


Figure 1. HERMES-HALF experimental facility



(a)



(b)

Figure 2. Experimental Results (I.A. : inlet area, A.V.A. : air venting area, W.L. : water level)

Figure 2 shows the HERMES-HALF experimental results according to the injected air flow rate, inlet area, air venting area, and water head. As shown in figure 2, as the injected air flow rate, inlet area, and water level increase, the circulation water flow rates also increase. Especially, the variations of the inlet area and water level have a lager effect on the circulation flow than the variation of the air flow rate. As shown in figure 2(b), the circulation water flow rate increases non-linearly as the inlet area increases. Therefore, it is expected that, under given outlet area and configuration conditions, minimum inlet area generated the maximal circulation flow should be obtained. A 50% reduction of the air venting area has no influence on the circulation mass flow rate.

Figure 2 also shows the numerical results using the RELAP5/MOD3 code [2]. The RELAP5/MOD3 results coincide with experimental ones within 9.2% error bounds.

3. Conclusion

The two-phase natural circulation mass flow rates through the gap between the reactor vessel and the insulation in the APR1400 under the external vessel cooling have been measured experimentally as variations of the injected air flow rate, inlet area, air venting area, and water head. And the experimental results were compared with ones of the numerical analyses using a RELAP5/ MOD3 code.

The variations of the inlet area and water level had a lager effect on the circulation flow than the variation of the air flow rate. The circulation water flow rate increased non-linearly as the inlet area increased. The RELAP5/ MOD3 analysis estimated the experimental results within 9.2% error bounds.

Acknowledgments

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