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Detailed Analysis of Air-Water Two Phase Natural Circulation Flow using RELAP5/MOD3

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1. Introduction

The IVR (In-Vessel corium Retention) through the ERVC (External Reactor Vessel Cooling) is known to be an effective means for maintaining the integrity of the reactor pressure vessel during a severe accident in a nuclear power plant [1]. This measure has been adopted in some low-power reactors such as the AP600 and the Loviisa nuclear power plants, and in the high-power reactor of the APR (Advanced Power Reactor)1400 as an accident management strategy for severe accident mitigation. Many studies [2] have been performed to evaluate the IVR. As part of a study on two-phase flow in the reactor cavity under external reactor vessel cooling in the APR1400, HERMES-HALF experiment (Hydraulic Evaluation of Reactor cooling Mechanism by External Self-induced flow-HALF scale)[3] with an air-water two phase natural circulation flow as been performing at KAERI. Detailed steady-state simulations of this experiment have been performed to verify the experimental data and to investigate the coolant behavior between the reactor vessel wall and the insulation material using the RELAP5/MOD3 computer code [4] in the present study. The objective of this analysis is to evaluate the experimental results of the water natural circulation mass flow rate and to analyze the effects of the experimental parameters, such as the air injection mass flow rate and water outlet position.

2. RELAP5 Input Model

The schematics diagram of the HERMES-HALF experimental facility is shown in Fig. 1. The facility consists of 3 parts, namely, a main test section, an air supply system, and a water recirculation system. The main test section is a half scaled-down reactor vessel. To simulate the water inlets, there are 23 holes in the central part, and 35 holes in the circumferential part of the water inlet plate. The two phase flow is generated by not a direct heating method but a non-heating method of an air injection. For the non-heating experiment, an equivalent amount of the 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 using the MAAP4 computer code. Figures 2 shows the RELAP5/MOD3 input models for the HERMES-HALF experiment. The coolant supplied from outer water source flows through the water supply tank and gap between the vessel and the insulation to the outer tank. The air was injected through 9 time-dependent junctions into the gap between the spherical reactor vessel and insulation, and vented to the atmosphere. Coolant inlet and two coolant outlets were simulated using three single junctions. In all the simulations, the initial conditions are assumed to be ambient pressure and no coolant mass flow rate. The coolant level of the water supply tank maintains constant value by outer water source.

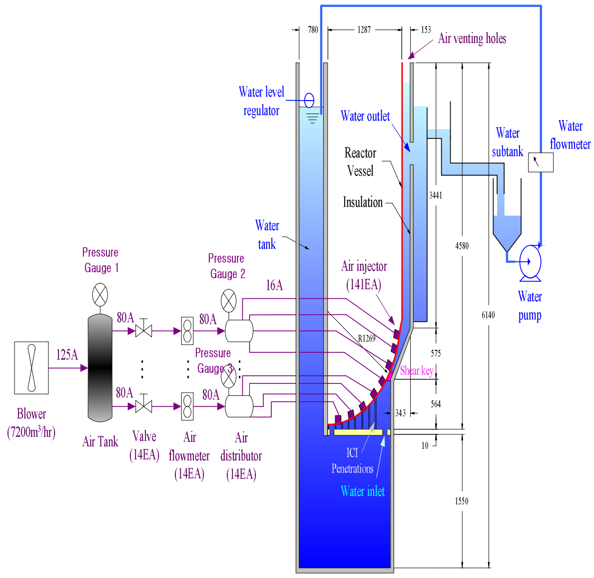

Figure 1. Schematic diagram of the HERMES-HALF experimental facility.

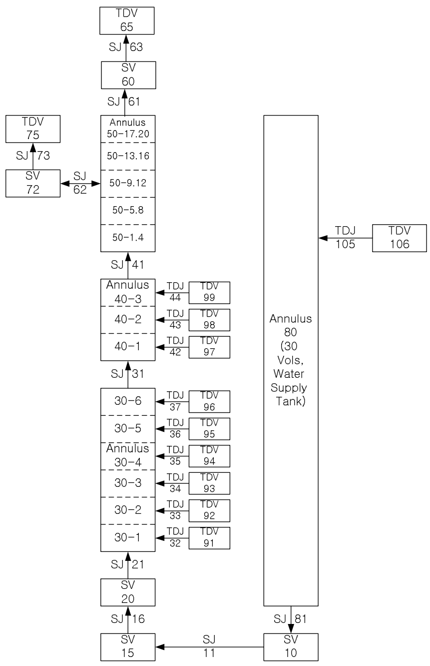

Figure 2. RELAP5 input model for the HERMES-HALF experiment.

3. Results and Discussion

Figure 3 shows the RELAP5/MOD3 results on the water circulation mass flow rate as a change of the air injection rate from 5 % to 100 % of the total heat flux distribution at a small water inlet area of 0.0044 m^2. The air injection mass flow rate has no effect on the water circulation mass flow rate when it is greater than 40 % at the small water inlet area. However, an increase in the air injection mass flow rate leads to an increase in the water circulation mass flow rate when the air injection rate is smaller than 40 %. Figure 4 shows the RELAP5/MOD3 results on the water circulation mass flow rate at a large water inlet area of 0.15 m^2. In this case, an increase in the air injection mass flow rate leads to an increase in the water circulation mass flow rate.

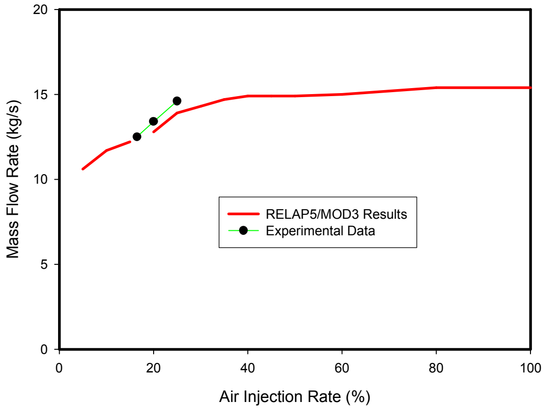

Figure 3. RELAP5 results on the water circulation mass flow rate as a function of air injection rate at small water inlet area.

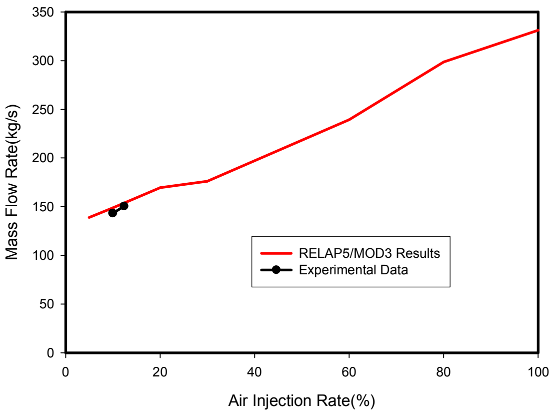

Figure 4. RELAP5 results on the water circulation mass flow rate as a function of air injection rate at large water inlet area.

Figure 5 shows the RELAP5/MOD3 results on the water circulation mass flow rate as a function of the water outlet position from the normal water level. The zero means the normal water level in the reactor cavity. In this condition, the water inlet area, the water outlet area and the air injection mass flow rate are 0.15 m^2, 0.15 $m^2$and 12.4 % of the total air injection mass flow rate, respectively. In the RELAP5 results, the change of the water outlet to a lower position affects the water circulation flow rate. The movement of the water outlet to a lower position leads to an increase in the water circulation mass flow rate. However, it is not effective in the HERMES-HALF experiment. This difference will be investigated in detail.

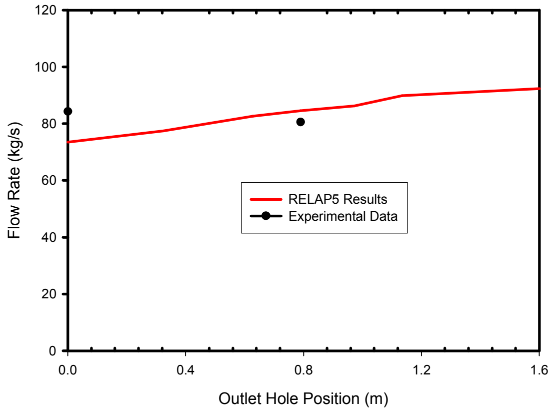

Figure 5. RELAP5 results on the water circulation mass flow rate as a function of water outlet position.

4. Conclusion

The RELAP5/MOD3 results on the HERMES-HALF experiment have shown that the water circulation mass flow rate is very similar to the experimental results, in general. In the small water inlet area condition, the lower value of the air injection mass flow rate have an effect on the water circulation mass flow rate, but the larger values of them have no effect. In the large water inlet area condition, increase in the air injection mass flow rate leads to an increase in the water circulation mass flow rate. The movement of the water outlet to a lower position leads to an increase in the water circulation mass flow rate.

ACKNOWLEDGMENTS

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