Preliminary Analysis of Air-Water Two Phase Natural Circulation Flow for K-HERMES-HALF Experiment

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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 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 and AP1000 as an accident management strategy for a severe accident mitigation. Many studies [2, 3] have been performed to evaluate the IVR. As part of an effective reactor vessel insulation design for the external reactor vessel cooling under a severe accident in the APR1400, K-HERMES-HALF experiment (KHNP-Hydraulic Evaluation of Reactor cooling Mechanism by External Self-induced flow-HALF scale) with an air-water two phase natural circulation flow has been performing to verify the coolant circulation flow between the outer reactor vessel and the insulation at KAERI. Preliminary steady-state simulations of this experiment have been performed to predict 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].

2. RELAP5 Input Model

The schematics diagram of the K-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. 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 K-HERMES-HALF experiment. The coolant supplied from an 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 an ambient pressure and no coolant mass flow rate. The coolant level of the water supply tank maintains a constant value by an outer water source.

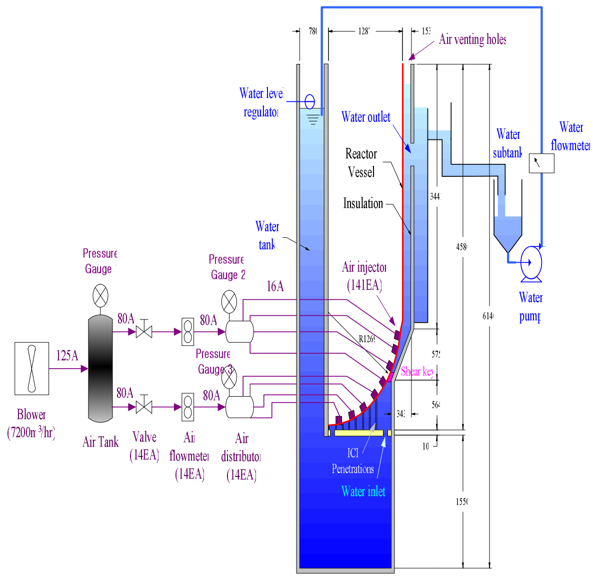

Figure 1. Schematic diagram of the K-HERMES-HALF experimental facility.

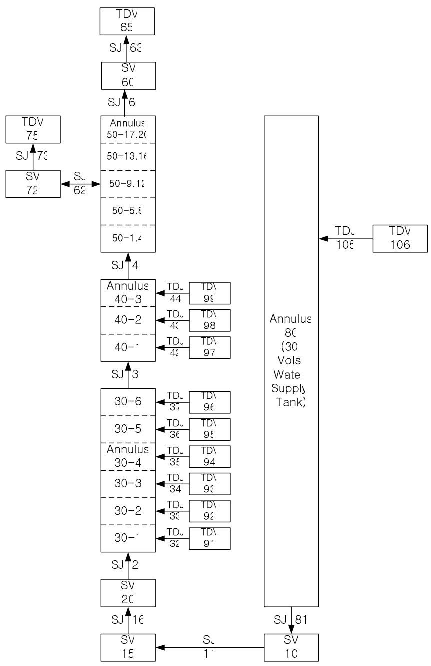

Figure 2. RELAP5 input model for the K-HERMES-HALF experiment.

3. Results and Discussion

Figure 3 shows the preliminary RELAP5/MOD3 results on the water circulation mass flow rate with a time increase. As the time increases, an oscillatory water circulation flow is generated. The average water circulation mass flow rate is approximately 210 kg/s, which means the generation of an effective coolant circulation flow between the outer reactor vessel and the insulation.

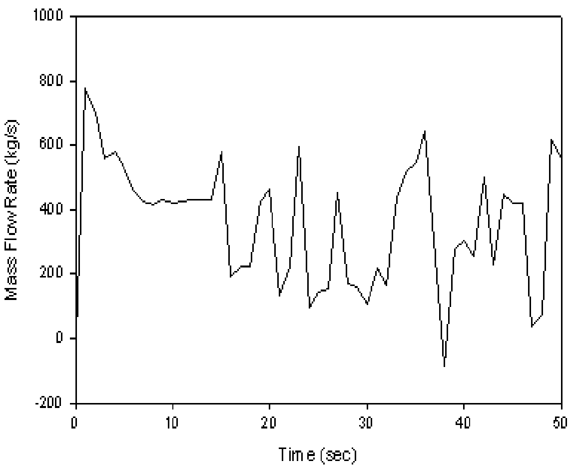

Figure 3. RELAP5 results on the water circulation mass flow rate for K-HERMES-HALF.

Figure 4 shows the preliminary RELAP5/MOD3 results on the local pressure with a height increase. As the height between the outer reactor vessel and the insulation increases, the local pressure decreases.

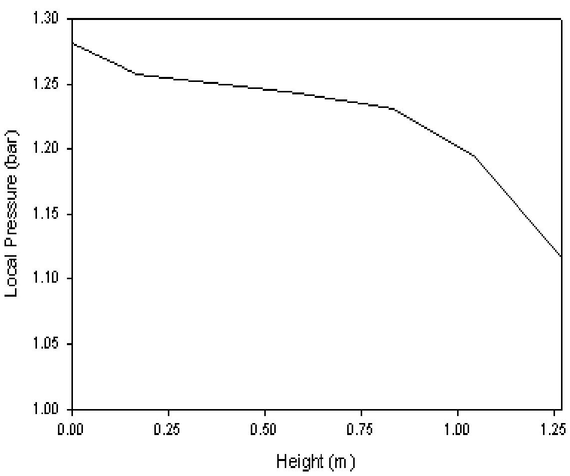

Figure 4. RELAP5 results on the local pressure distribution for K-HERMES-HALF.

Figure 5 shows the preliminary RELAP5/MOD3 results on the local void fraction with a height increase. An oscillatory local void fraction was generated in the upper part of the annular gap between the reactor vessel and the insulation. The average void fraction in the upper part of the gap is maintained at approximately 0.5, which means an annular flow of the air-water two phases. As the height between the outer reactor vessel and the insulation increases, the void fraction increases.

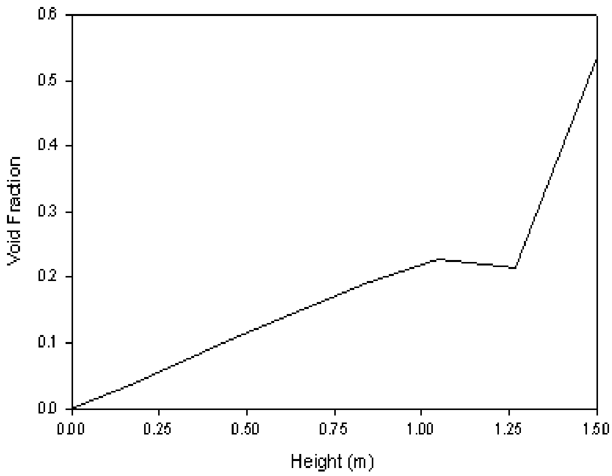

Figure 5. RELAP5 results on the local void fraction distribution for K-HERMES-HALF..

4. Conclusion

Preliminary analysis of the air-water two phase natural circulation flow by using the RELAP5/MOD3 computer has been performed for the HERMES-HALF experiment. The RELAP5/MOD3 results have shown that as the time increases, an oscillatory water circulation flow is generated. An increase in the height leads to an increase in the local void fraction and a decrease in the local pressure. More detailed analysis is necessary to verify the experimental results after the K-HERMES-HALF experiment is performed.

ACKNOWLEDGMENTS

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