Geometry and Material Scaling on Two Phase Natural Circulation Flow for K-HERMES-HALF Experiment

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1. Introduction

As part of a study on two-phase natural circulation mass flow rate between the outer reactor vessel and vessel insulation in the reactor cavity under the IVR (In-Vessel corium retention) through the ERVC (External Reactor Vessel Cooling) in APR1400, K-HERMES-HALF experiment (Hydraulic Evaluation of Reactor cooling Mechanism by External Self-induced flow) had performed at KAERI. This large-scale experiment using a half-height and half-sector model of the APR1400 uses the non-heating method of the air injection. For this reason, it is necessary to evaluate the geometry scaling on full height & full sector and a material scaling between air-water and steam-water two phase natural circulation flow for an application of the experimental results to an actual APR1400. In the geometry scaling, two cases, such as a half height & half sector and a full height & full sector, had performed by using RELAP5/MOD3 computer code [1]. In the material scaling, two cases, such as an air injection and a steam injection, had performed to compare the air injection experimental results with the steam injection case.

2. RELAP5 Input Models

Fig. 1 shows the RELAP5 input models for the K-HERMES-HALF experiment. In the RELAP5 input model, the water supplied from the outer water source, which is simulated by Time Dependent Volume No. 106, flows through the water supply tank, which is simulated by Annulus No. 100, and the gap between the outer reactor vessel and the vessel insulation, which is simulated by Annulus No. 30, 40, and 50, to the outer tank, which is simulated by Time Dependent Volume No. 66. The air or the steam was injected through 9 Time Dependent Junctions. A water inlet, an air outlet and a water outlet were simulated by using three Single Junctions of No. 16, 63, and 93, respectively. The air source was simulated by using 9 Time Dependent Volumes of No. 191-199. A cylindrical gap was simulated by Annulus No. 60, 70. The heat flux from the spherical reactor vessel to the outer coolant was simulated by the steam and air injection mass flow rates.

In all the simulations, the initial conditions are assumed to be an ambient pressure and no water mass flow rate, and the supplied water temperature is maintained at 25 °C.

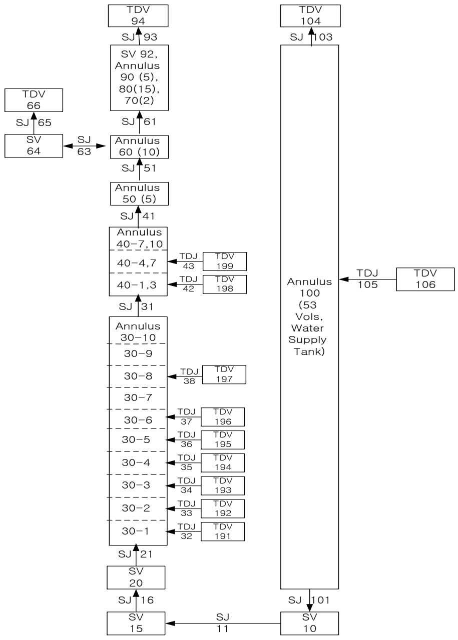

Fig. 1. RELAP5 input model for the K-HERMES-HALF experiment.

3. Results and Discussion

As shown in Table I, the water circulation mass flow rate of the full height & half sector case is 3.8-4.0 times higher than that of the K-HERMEL-HALF case, because of the height increases. The water circulation mass flow rate of the full height & full sector case is approximately 7.6 times higher than that of the K-HERMEL-HALF case, because of the height and the sector increase. As shown in Table II, the water circulation mass flow rate of the air injection case is 20-50 % higher than that of the steam injection case at the 20 % of the injection rate, because of steam condensation and the density difference between the air and the steam. The density of the air is two times higher than that of the steam. The steam is condensed by supplied sub-cooling water in the steam injection case, but not in the air injection case. However, the water circulation mass flow rate of the steam injection case is higher than that of the air injection case at the 100 % of the injection rate, because of oscillatory flow in the air injection case.

Figs. 2& 3 show the RELAP5/MOD3 results on the local pressure in the K-HERMES-HALF case and full height & full sector case. The local pressure of the full height & full sector case is higher than that of the K-HERMEL-HALF case, because of the water depth.

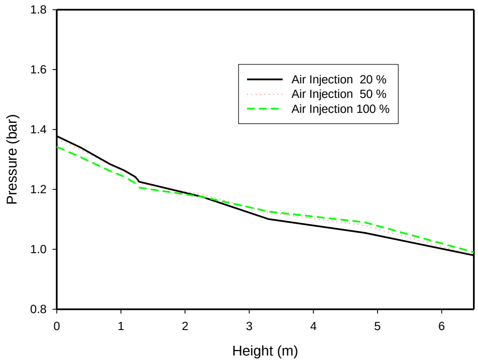

Fig. 2. RELAP5 results on the local pressure in the K-HERMES-HALF case.

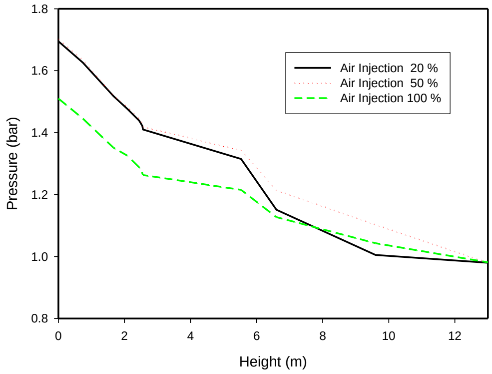

Fig. 3. RELAP5 results on the local pressure in the full height and full sector case.

As shown in Fig. 4, the local void fraction of the air injection case is higher than that of the steam injection case at the upper part of the test section, because of steam condensation.

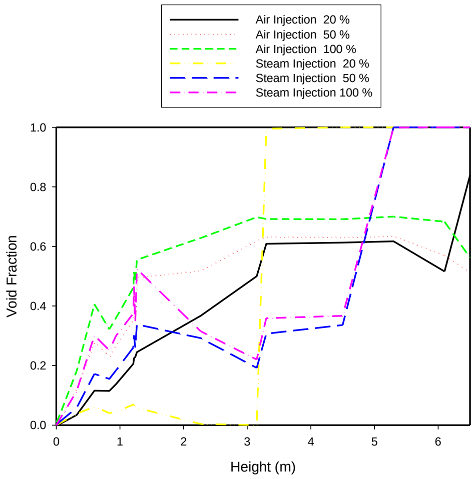

Fig. 4. RELAP5 results on the local void fraction at 20 % of the injection rate.

4. Conclusion

The water circulation mass flow rate of the full height & full sector case is approximately 7.6 times higher than that of the K-HERMEL-HALF case. The water circulation mass flow rate of the air injection case is 20-50 % higher than that of the steam injection case at the 20 % of the injection rate.

ACKNOWLEDGMENTS

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REFERENCES

[1] The RELAP5 Development Team, RELAP5/MOD3 Code Manual, NUREG/CR-5535, INEL95/0174, 1995.

Table I: RELAP5 results on the water circulation mass flow rate in the geometry scaling analysis.

Air Injection Rate	K-HERMES -HALF (kg/s)	Full Height & Half Sector (kg/s)	Full Height & Full Sector(kg/s)
100 %	253.5	940.3	1295.8
50 %	288.0	1120.8	2193.5
20 %	277.7	1110.9	2113.8

Table II: RELAP5 results on the water circulation mass flow rate in the material scaling analysis.

Injection Rate	K-HERMES-HALF (kg/s)		Full Height & Half Sector (kg/s)		Full Height & Full Sector (kg/s)	
	Air	Steam	Air	Steam	Air	Steam
100 %	253.5	273.9	940.3	1050.3	1295.8	2080.4
50 %	288.0	270.7	1120.8	958.7	2193.5	1625.8
20 %	277.7	191.3	1110.9	906.4	2113.8	1595.7