Sensitivity Analysis for the Effect of Pipe Pressure Loss on PAFS Performance

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1. Introduction

Advanced Power Reactor 1000 (APR1000) is currently under development for the export strategy in South Korea. In APR1000, a Passive Auxiliary Feedwater System (PAFS) is adopted as an improved safety design feature (see Fig. 1); and then there have been many efforts to develop the PAFS completely. To perform the safety analysis of APR1000, it is required to develop the reliable PAFS input model for the system analysis code such as SPACE and RELAP5. In the code, the heat removal performance of the PAFS is governed by the heat transfer model inside/outside the heat exchanger tube and the pressure drop in the piping. It is important to secure the technology on the PAFS heat transfer model and the piping modeling. The PAFS heat transfer model was investigated by Jeon et al. [1]. Therefore, this study investigated the effect of piping pressure loss on PAFS performance using SPACE 3.22.

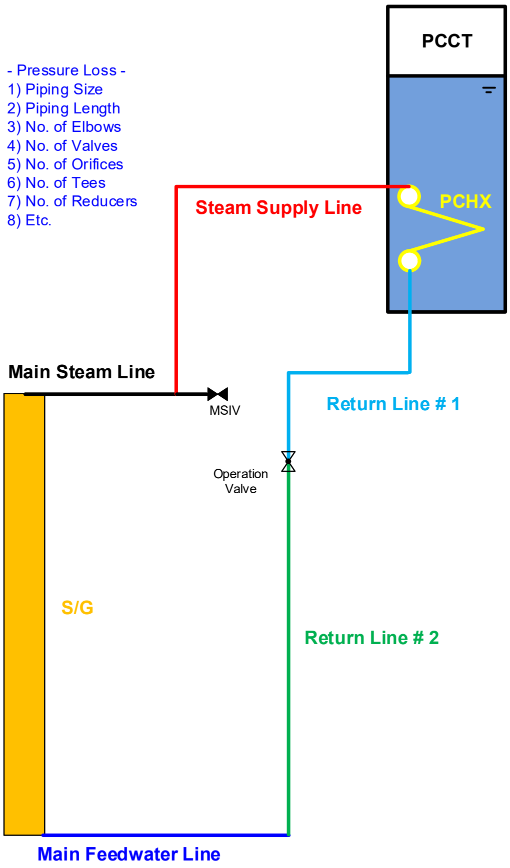

Fig. 1. Schematic of PAFS

2. SPACE Modeling of PASCAL

To investigate the effect of piping pressure loss on PAFS performance, we used the data of PASCAL (PAFS Condensing Heat Removal Assessment Loop) in KAERI (Korea Atomic Energy Research Institute). Figure 2 shows the SPACE nodalization for PASCAL test facility. All systems were modeled including the steam generator. Using this nodalization, SPACE code simulations were performed.

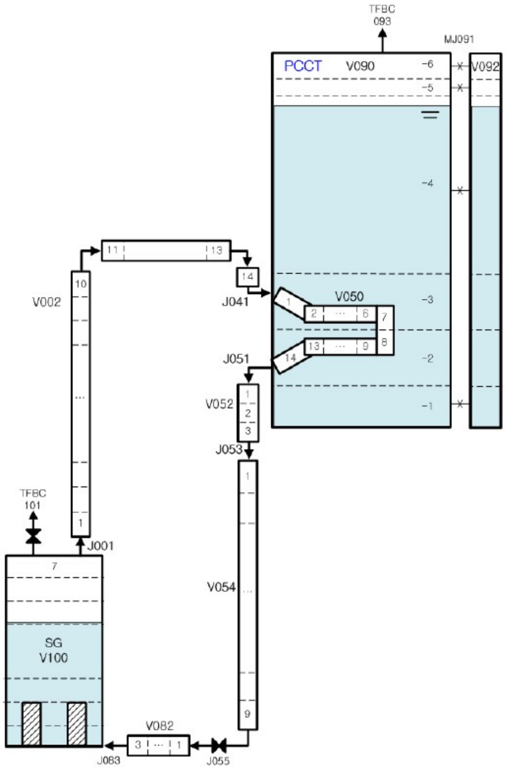

Fig. 2. SPACE nodalization for PASCAL

3. Simulation Results of Reference Input Model

Firstly, we develop the PASCAL reference input model for test case SS/PL-540-P1. To match the simulation results with the experimental data, the dialing factor for the heat transfer model are applied and the piping loss coefficients are adjusted. Figures 3 to 5 show the simulation results. For key parameters, the SPACE 3.22 code shows good agreement with the target value. Sensitivity analyses for the effect of piping pressure loss on PAFS heat removal performance were performed using this input model.

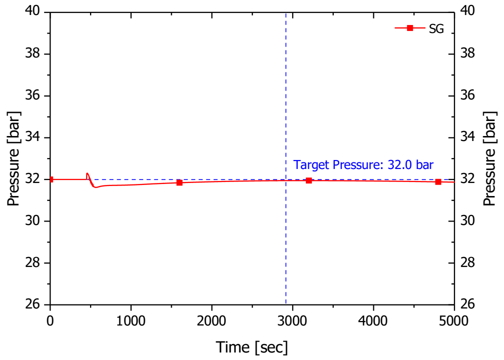

Fig. 3. System pressure (SS/PL-540-P1)

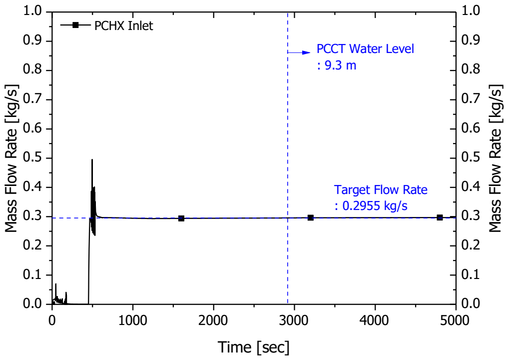

Fig. 4. PASCAL flow rate (SS/PL-540-P1)

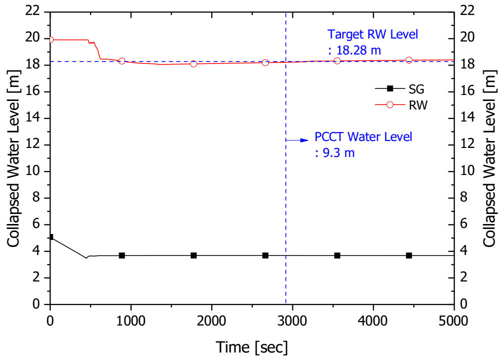

Fig. 5. PASCAL return line water level (SS/PL-540-P1)

4. Sensitivity Analysis for Pipe Pressure Loss

For the given flow condition, the pressure drop in the pipe is governed by followings: 1) pipe size, 2) pipe length, 3) number of elbows, valves, reducers, orifices, tees and etc. If the physical design of the piping is determined, the pipe size and length are clearly known. However, for the elbows, orifices and etc., the number is known but it is difficult to determine the loss coefficients of them. Therefore, this study performed the sensitivity analysis for the pressure loss by adjusting the total loss coefficients (K) in each piping.

Table I shows the test cases. Total Ks are presented as a normalized value. The case 0 indicates a reference case so total K in steam line and return line are 1.0.

Table I: Sensitivity Analysis Case

Total K	Steam Line (SL)	Return Line (RL)
Case 0	1.0	1.0
Case 1	0.5	1.0
Case 2	2.0	1.0
Case 3	1.0	0.5
Case 4	1.0	2.0
Case 5	0.5	0.5
Case 6	2.0	2.0

Figures 6 to 8 show the sensitivity analysis results for pipe pressure loss. Key findings are as follows:
1) If the pressure loss increases, the system pressure and the return line water level increases generally.
2) In cases that the steam is completely condensed, the pressure and the PASCAL flow rate hardly changes even if the piping resistance is reduced (see cases 0, 1, 3 and 5). The effect of resistance in return line is negligible (see cases 3 and 4).
3) When the steam line resistance increases and the return line are fully filled with water, the system pressure increases dramatically. Also PASCAL flow rate decreases and significantly fluctuates (see cases 2 and 6).
4) When the return line is filled with water, increase in the return line resistance degrades the heat exchanger performance (see cases 2 and 6).

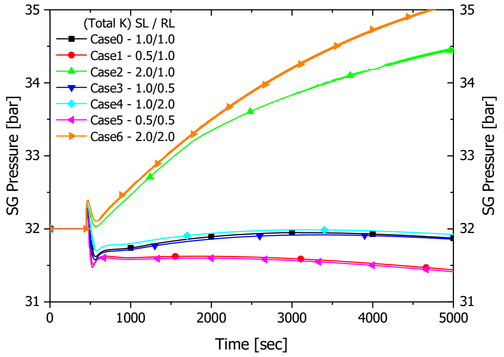

Fig. 6. System pressure (Case 0 – Case 6)

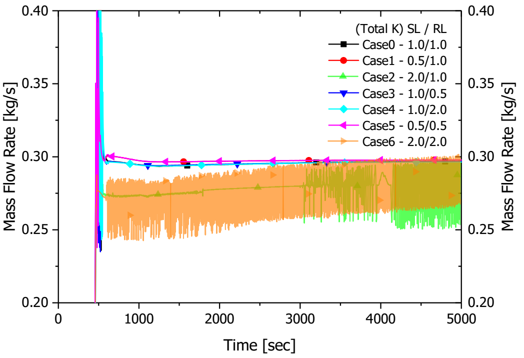

Fig. 7. PASCAL flow rate (Case 0 – Case 6)

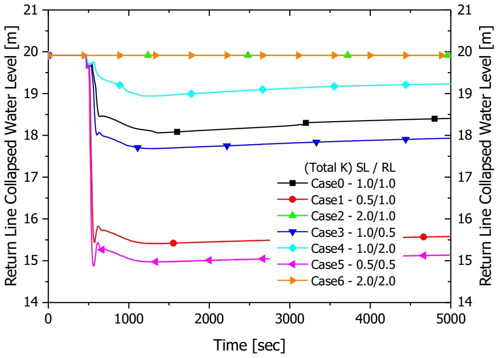

Fig. 8. PASCAL return line water level (Case 0 – Case 6)

5. Conclusions

To investigate the effect of piping pressure loss on PAFS performance, this study performed the sensitivity analysis for the pressure loss using SPACE 3.22. From the calculation results, it is found that the pressure loss in the piping may affect the heat exchanger performance and the system pressure significantly. In order to secure a reliable input model for PAFS, it is confirmed that further research on this is necessary.

REFERENCES

[1] S. S. Jeon, S. J. Hong, H. K. Cho, and G. C. Park, Development of Heat Transfer Model Package for Horizontal U-Shaped Heat Exchanger Submerged in Pool of Passive Safety System, Nuclear Technology, Vol. 196, pp.303~318, 2016.