Scaling Analysis of Separate Effect Test Facility for PAFS (Passive Auxiliary Feedwater System)

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1. Introduction

PAFS (Passive Auxiliary Feedwater System) is one of the passive cooling systems of APR+ [1]. It can replace the conventional active system for auxiliary feedwater injection to the steam generator. A diagram of PAFS in APR+ is shown in Figure 1. It cools down the secondary system by heat transfer at a horizontal U-tube heat exchanger in PCCT (Passive Condensation Cooling Tank).

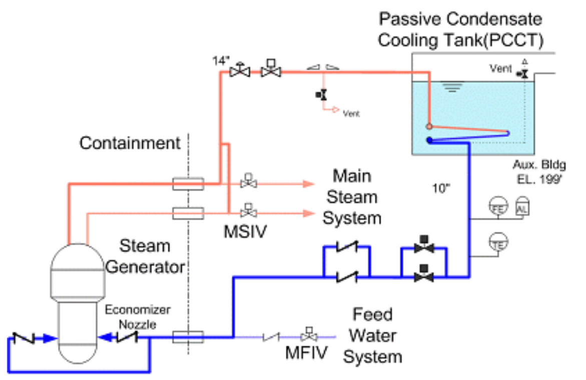

Fig. 1. Schematic diagram of PAFS in APR+

To validate a performance of PAFS, separate effect test loop is being developed, which is named as PASCAL(PAFS Condensing heat removal Assessment Loop).[2] This study aims at analyzing the scaling effect of PASCAL by MARS (Multi-dimensional Analysis for Reactor Safety) code analysis. Transient simulation results for the case of LOCV(Loss of Condenser Vacuum) scenario were compared between PASCAL and prototype.

2. Analysis Results

2.1 Analysis Model

PASCAL facility scales down the PAFS of the prototype with a volume ratio of 1/240 and simulates a single tube of horizontal heat exchanger. Also, the size of PCCT pool was reduced to 1/240 of prototype. In order to conserve the natural convection flow in PCCT, the height of the pool is designed to be same and the length is 6.7m, half of that of prototype. Figure 2 shows the schematic diagram of PASCAL for MARS code nodalization.

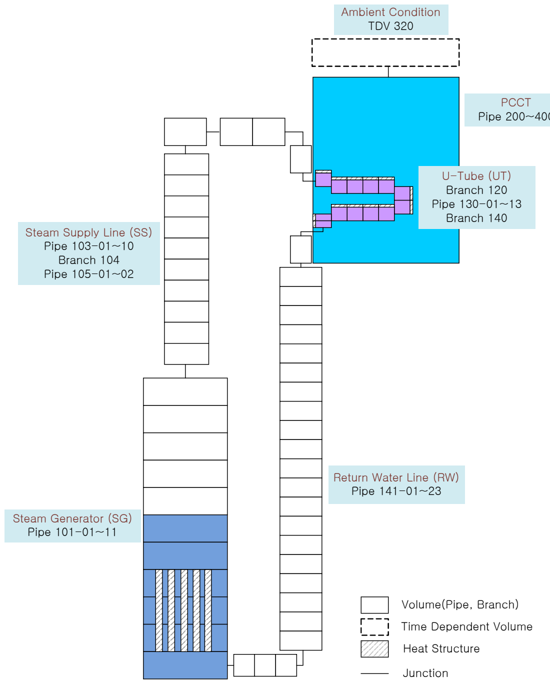

Fig. 2. Nodalization diagram of PASCAL

2.2 Analysis Condition

PASCAL facility was simulated by MARS code for the case of LOCV scenario. The transient simulation result of the prototype in LOCV accident was compared with PASCAL simulation results. The thermal power transient of steam generator of PASCAL facility was determined from RELAP5 /MOD3.3 analysis results for APR1400[3]. The heat transfer rate at the U-tube in the steam generator of the prototype was scaled down to 1/240 and that was given as the boundary condition of the steam generator thermal power in PASCAL facility. Also, the initial condition of PCCT coolant was maintained as the same condition of the prototype, where coolant level is 8.2m and the temperature is 39˚C.

2.3 Analysis Results

Figures 3 to 6 compare the analysis result of PASCAL and APR1400 in the transient of LOCV, where the mass flow rate of PASCAL facility is scaled according the volumetric scaling ratio, 1/240. As the heat removal at condenser tubes in PCCT occurs, the system pressure of steam generator is decreasing as shown in Fig. 3. Also, Fig. 4 indicates that auxiliary feedwater can be supplied by a natural convection in PAFS. From the transient of steam pressure and mass flow rate, it is concluded that PASCAL facility shows a reasonable agreement with the transient of the pressure and flow rate in the prototype.

The collapsed level of PCCT coolant is presented in Fig. 5. During the initial period of the transient, the coolant level is increased due to an expansion by the increased coolant temperature. After the temperature condition of coolant reached the saturation, the decrease of the level starts around 6000 sec. Figure 6 compares the fluid temperature at the return water line. As shown in the figure, the condensate water temperature was decreased according to the reduced pressure and saturation temperature condition. PASCAL design showed a good capability to predict the PCCT coolant level and the temperature distribution at a return water line.

From the above result, the design of PASCAL facility has been confirmed to have a good scale-up capability in simulating the transient with the activation of PAFS.

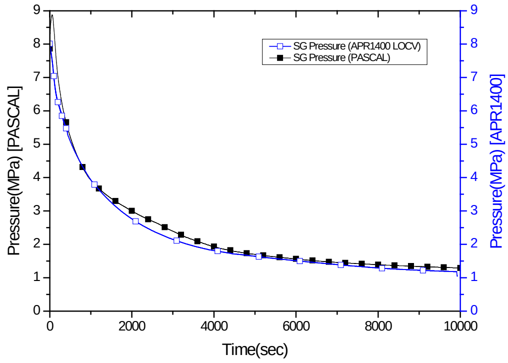

Fig. 3. Steam Generator Pressure Transient in LOCV

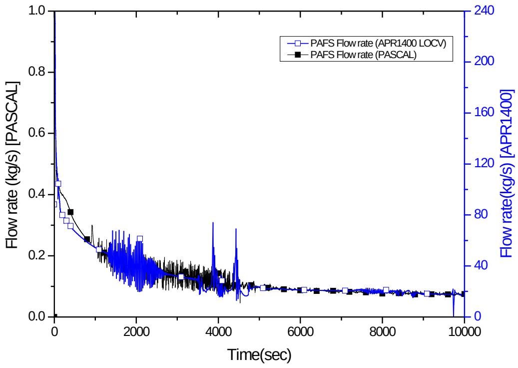

Fig. 4. Flow Rate of PAFS in LOCV

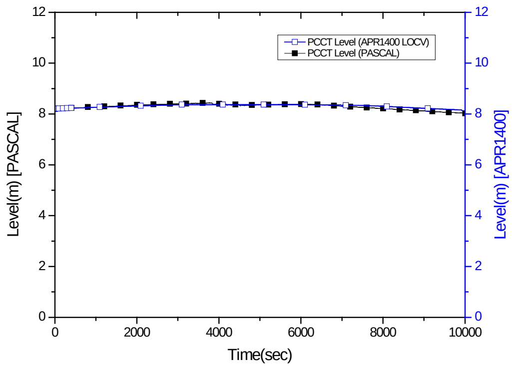

Fig. 5. PCCT Coolant Level in LOCV

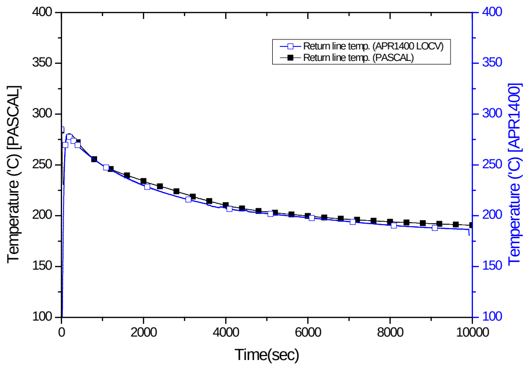

Fig. 6. Return Water Line Temperature in LOCV

3. Conclusions

To evaluate a scaling effect of the separate effect test for PAFS, PASCAL facility was simulated for LOCV scenario and compared with the result of APR1400. Transient simulation of PASCAL facility showed a good agreement with the thermal hydraulic behavior in prototype, where the natural convection in PAFS removed the decay heat of the primary system. From the results, the separate effect test facility for PAFS is proved to have a scale-up capability to validate the cooling performance of PAFS in prototype.

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