A Study on the Flow Capacity of PAFS using RELAP5/MOD3.3

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1. Introduction

In South Korea, advanced power reactor plus (APR+), as a Korean specific reactor, is currently under development for the export strategy. In order to raise competitiveness of the APR+ in the world market, it is necessary to develop the original technology for the improved technology, economics, and safety features. For this purpose, a passive auxiliary feedwater system (PAFS) was adopted as an improved safety design concept of APR+; and then there have been many efforts to develop the PAFS.

The design concept of PAFS is as follows (see Fig. 1) [1]: 1) PAFS can completely replace the auxiliary feedwater system (AFWS). 2) When the design basis accident (DBA), in which feedwater is not available, occurs, the PAFS can remove the residual heat in the core and then prevent the core damage. 3) PAFS is operated by the natural circulation of the condensed steam due to the condensation and gravity force; and then reduces the operator action for the reactor safety.

In order to confirm whether the PAFS can actually replace the AFWS in various accidents, it is required to carry out the performance analysis of the PAFS. For that, the main purposes of this study are: 1) to develop the RELAP5 input model, 2) to analyze the performance of the PAFS after applying the PAFS model into the RCS input model, 3) to produce the AFW flowrate to be used in the design safety analysis code. Up to earlier this year, 2010, PAFS RELAP5 input model has been developed/improved by using the newly updated design data; nowadays, the performance analyses for various accidents such as loss of condenser vacuum (LOCV), feed line break (FLB), and steam generator tube rupture (SGTR) is ongoing with APR1400 input model. Moreover, in order to produce the minimum AFW flowrate to be used in design safety analysis code, new methodology was developed and tested.

This paper focuses on the new methodology for the production of the minimum AFW flowrate and the sensitivity analyses for the heat source/sink.

2. RELAP5 Modeling

The newest PAFS nodalization is shown in Fig. 2. PAFS is composed of 2 independent trains, and each train covers 100% performance. PAFS line starts from upstream of main steam isolation valves (MSIVs). The steam from the main steam line is condensed in the heat exchanger (Pipe050/056) by the heat transfer to the passive condensate cooling tank (PCCT, Pipe 090/096; 092/ 098). The condensed water is fed into the economizer. This PAFS model is applied into the APR1400 model and used for the performance analysis.

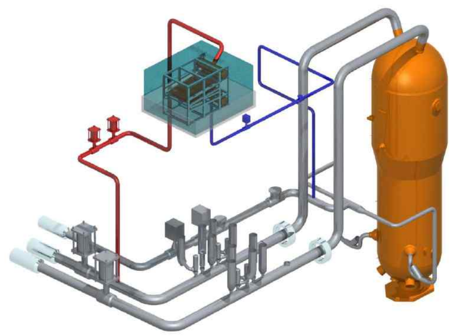

Fig. 1 Outline of PAFS

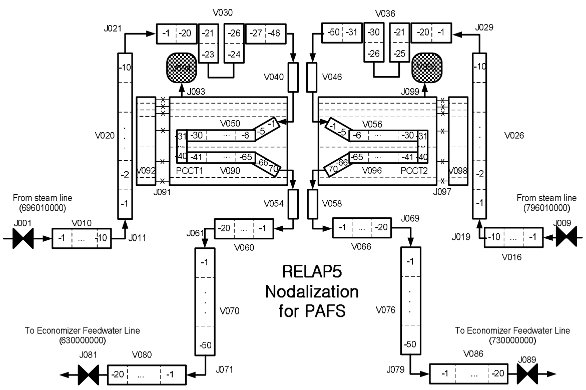

Fig. 2 PAFS nodalization

3. Methodology of Min. AFW Flowrate Production

In PAFS, the natural circulation flowrate of two phase flow is determined by the capacity of the heat source and the capability of the heat exchanger as a heat sink. Since the appropriate flowrate for cooling is prerequisite in the design of PAFS, sensitivity tests for each parameter were performed to produce the minimum AFW flowrate for design safety analysis code.

4.1 Effect of heat source on PAFS flowrate

The effect of the heat source could be analyzed by using time-dependent decay heat after the reactor shutdown. The decay heat decreases as time goes by. If the PAFS operating time is delayed, PAFS flowrate also might be decreased because of the reduced decay heat. The PAFS operating time can be controlled by changing the initial condition setting. Therefore, in this section, the effect of heat source on PAFS was investigated in various initial conditions: core inlet flowrate/ temperature, initial pressurizer level/ pressure, and SG water initial level.

Figure 3 shows the results of the sensitivity analysis for LOCV, as a representative transient accident. For all cases, the initial conditions were different. Contrary to expectations, PAFS flowrate is almost same. From this result, it is found that PAFS flowrate is not significantly affected by the capacity of heat source.

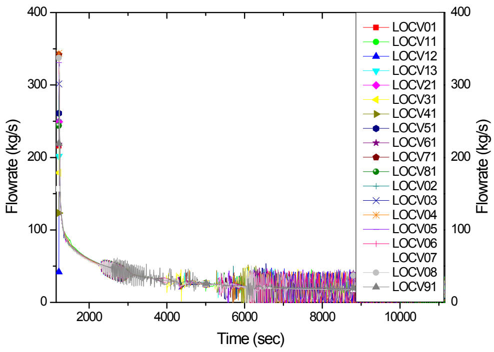

Fig. 3 Sensitivity analysis for heat source (LOCV)

4.2 Effect of heat sink on PAFS flowrate

In order to investigate the effect of the capability of the heat exchanger (HX) on PAFS flowrate, the heat transfer area of HX was modified from 100% to 80%. Figure 4 shows the sensitivity analysis results for LOCV. As the heat transfer area is decreased, PAFS flowrate also decreased. From this figure, it could be found that the PAFS performance is determined by the capability of the heat exchanger than by the capacity of the heat source.

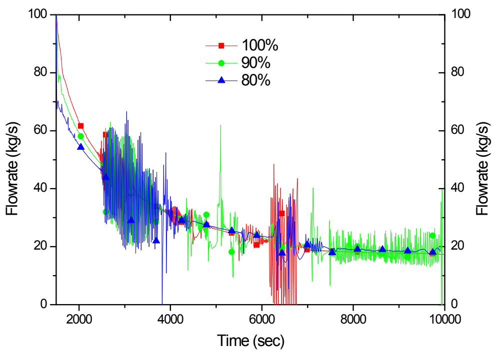

Fig. 4 Sensitivity analysis for heat sink (LOCV)

In addition to LOCV, sensitivity tests for the FLB (see Fig. 5) and SGTR (see Fig.6) were performed by modifying the heat transfer area from 100% to 20%. The AFW flowrates varied with the accidents and was proportional to the heat transfer area. However, as the heat transfer area decreased, the oscillation happened and flowrate got unstable. From the sensitivity analyses, it was found that the capability, or heat transfer amount, of the heat exchanger is the key parameter to describe the PAFS performance.

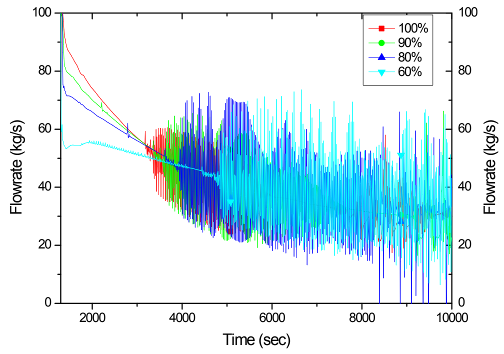

Fig. 5 Sensitivity analysis for heat sink (FLB)

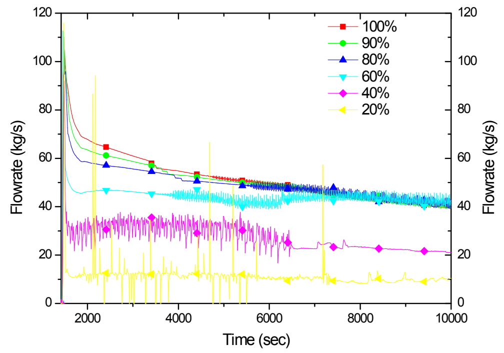

Fig. 6 Sensitivity analysis for heat sink (SGTR)

5. Conclusions

In this study, the methodology of the minimum AFW flowrate production was discussed. From the sensitivity analyses, it was found that the PAFS performance is more dependent on the capability, or heat transfer amount, of the heat exchanger than by the capacity of the heat source. It is expected that the results of this study will be useful tool to assess the PAFS performance and safety.

ACKNOWLEDGMENTS

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