APR+ PAFS Cooling Performance Analysis using RELAP5

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1. Introduction

To enhance safety and reliability of nuclear power plant in domestic industry, passive safety system design has been introducing. Especially, passive auxiliary feedwater system (PAFS)[1] has been applied to the advanced power reactor plus (APR+). PAFS is a facility that replaces an active auxiliary feedwater system (AFWS) in the existing plant. The system function is to remove the generating heat of primary system during transient and accidents unless main feedwater system is available. PAFS consists of a passive condensate cooling tank (PCCT), a heat exchanger, valves, and pipes as shown in Fig. 1.

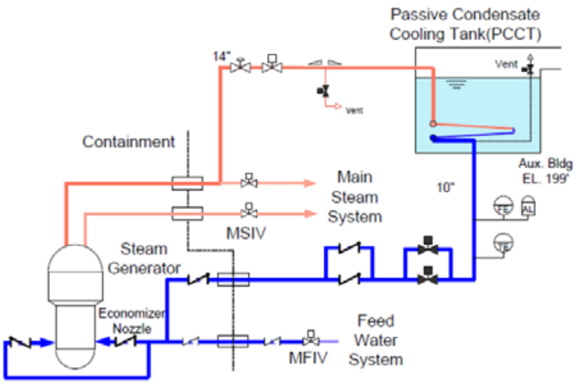


Fig. 1 Design concept of PAFS

PAFS design is considered that its performance ensure the safety function. But it is difficult that the performance of PAFS is determined quantatively unlike AFWS. Because AFWS can be controlled on its flow and enthalpy but PAFS can't be controlled on them. The characteristic of passive safety system can be changed along transient and accident. Therefore some considerations are required about how to determine the PAFS performance and how to find the conservative condition to evaluate it in respect to transient and accidents.

2. Strategy for PAFS Performance Evaluation

Heat transfer is one of the most important factors to determine the performance of PAFS. In the heat exchanger tube, two-phase flow which has a various flow pattern like an annular, wavy, and stratified flows is formed by natural convection and condensation. The performance is affected by various thermal hydraulic parameters of the primary and secondary system according to transient and accidents.

The cooling performance of PAFS is determined by these parameters. But all the parameters are not expected with a consistent tendency according to type of the accidents which require operating of PAFS. Because the auxiliary feedwater flow rate and enthalpy in the existing plant were considered as design parameter to ensure its safety function but the flow rate and enthalpy of PAFS cannot be controlled.

In this study, various sensitivity calculation were carried to find effects of the parameters on the PAFS cooling performance.

3. Analysis and results

PAFS nodalization is shown in Fig. 2 in order to analyze its performance using RELAP5[2]. PAFS is composed of 2 independent trains. They are connected to each steam generators and PCCT respectively. The piping and PCCT of PAFS were modeled. Upper part of PCCT is filled with non-condensable gas.

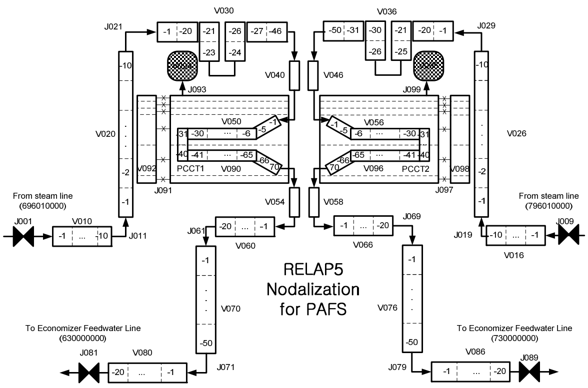


Fig. 2 PAFS nodalization

Table 1 shows the parameters used in sensitivity calculation to evaluate PAFS cooling performance. The range of each parameters were choose with minimum and maximum values for accident analysis in reference to Safety Analysis Report [3]. And inadvertent open of steam generator atmospheric dump valve (IOSGADV) and main steam line break (MSLB) accidents were selected for the calculation. Both accidents are representative cases as a secondary heat removal increase accident.

Table 1 Sensitivity parameters

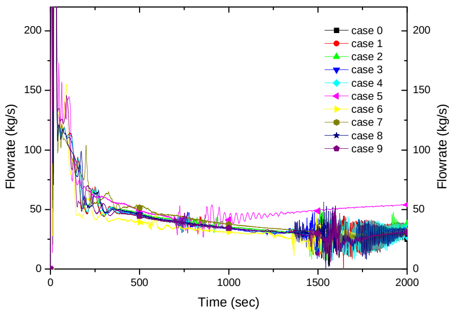
System	Parameter
Primary side	RCS flow rate(1)[*1] PZR level(2) and pressure(4) RCS temperature(3)
Secondary side	Steam Generator (SG) water level(5) PCHX tube plugging(6) and fouling(7) PCCT initial temperature(8)

	PAFS pipe pressure loss(9)

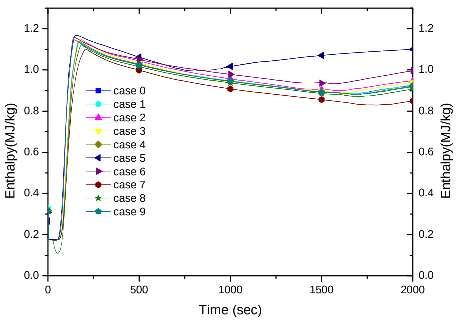
*1: Case number

Fig.3 and 4 show the analysis results for IOSGADV and MSLB accidents respectively. The figures illustrate the behavior of PAFS flow and enthalpy and SG pressure after PAFS operation. The flow increases rapidly at the beginning of accident, and then decreases steadily over time. As shown through the case data, it was found that each parameter made a different flow and enthalpy. But the results on PAFS flow and enthalpy do not show a clear tendency to evaluate the PAFS cooling performance. In other words, PAFS cooling performance is not easy to be determined by PAFS flow and enthalpy.

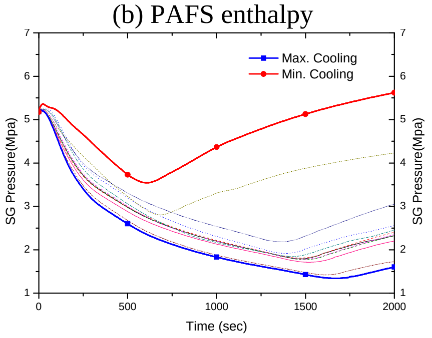
But the SG pressure change vs time had a consistent tendency according to the sensitive parameters in the figure (c). And the results of combination cases (max. and min. cooling) bound the pressures of all the case.



(a) PAFS flow



(b) PAFS enthalpy

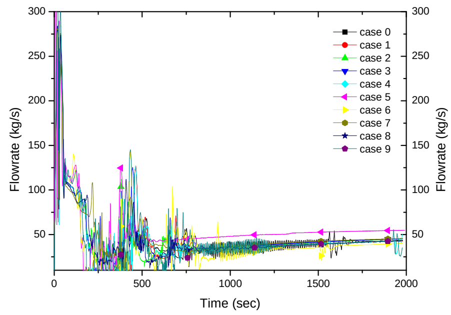


(c) SG pressure

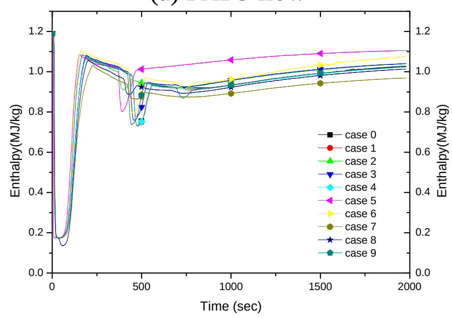
Fig. 3 Analysis results for IOSGADV accident

4. Conclusions

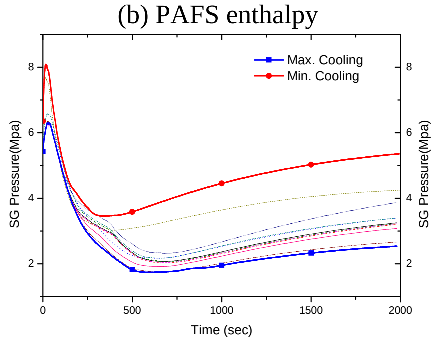
Sensitivity analysis for PAFS with RELAP5 has been carried out to evaluate its cooling performance during transient and accidents. It was found that the performance was affected by various parameters and especially, SG pressure behavior directly related to the performance. In conclusion, it can be used as one of the important measures of PAFS performance evaluation. Further study will be focused on the other effects to PAFS performance.



(a) PAFS flow



(b) PAFS enthalpy



(c) SG pressure

Fig. 4 Analysis results for MSLB accident

5. Acknowledgements

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