MARS Simulation of Air Cooling Heat Exchanger Connected with PAFS

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1. Introduction

After the Fukushima Daiichi nuclear power plant accident, a long term passive cooling capability is a key important design change issue in the nuclear safety concerns. The APR+ system provides the Passive Auxiliary Feed-water System (PAFS) for the passive cooling capability (see Fig. 1). However, the current design requirement for working time for the PAFS is about 8 hours only. Thus, current working time of PAFS cannot meet the required 72 hours cooling capability for the long term Station Black-Out (SBO) situation [1]. Therefore, it is required to improve the design of PAFS for the long term cooling.

In order to ensure the long term cooling of PAFS, the heat exchanger tube should be submerged in the water of the PAFS pool. It can be achieved by condensing the steam vented from the PAFS pool. Based on this concept, KAERI proposed a new passive air-water combined cooling system as shown in Fig. 2 [1]. The Air Cooling Heat Exchanger (ACHX) is installed above the PAFS pool. It is expected that the ACHX condenses the steam vented from the PAFS pool and delays the depletion time of the water in the PCCT. Therefore, this paper introduces the MARS-KS1.4 [2] modeling of the ACHX and the performance analysis results on the PAFS connected with the ACHX.

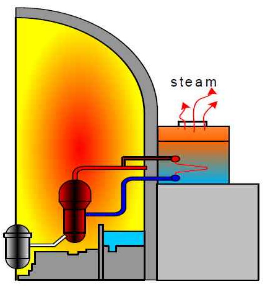

Fig. 1 Conceptual design of PAFS [1]

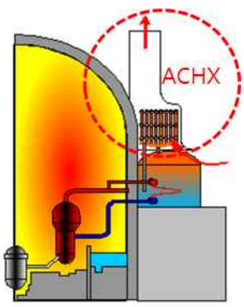

Fig. 2 Conceptual design of combined cooling system [1]

2. MARS modeling of ACHX

Fig. 3 shows the schematic of ACHX. The tube bundle is composed of about 5000 fin-tubes and is located in the large chimney.

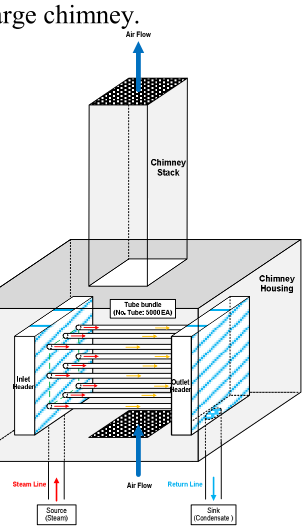

Fig. 3 Conceptual design of ACHX

Fig. 4 shows the MARS nodalization of ACHX. In the chimney(C968), the air heated by the heat exchanger tube bundle(C948/C950/C952/C954/C956) is vented to the atmosphere(C970) due to the buoyancy force. Then, the cold air from C964 as the pressure boundary is injected to the chimney (C966/C968) passively.

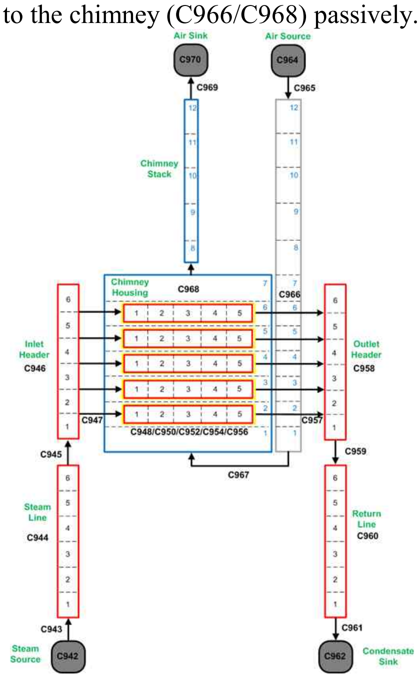

Fig. 4 MARS nodalization of ACHX

3. MARS simulation results of ACHX with PAFS

This study conducted the performance analysis on the PAFS connected with the ACHX by implementing the ACHX input model (see Fig. 4) to the APR+ PAFS input model (see Fig. 5 and Fig. 6).

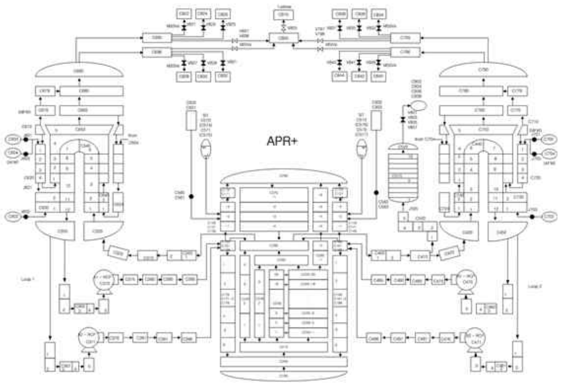

Fig. 5 MARS nodalization of APR+

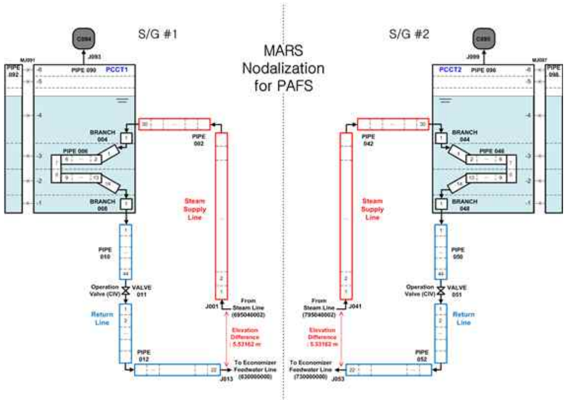

Fig. 6 MARS nodalization of PAFS

For the feed line break analysis, MARS simulation results are as follows (see Fig. 7 to Fig. 9). The long term cooling of the PAFS was achieved by the ACHX (see Fig. 7). The water in the PAFS pool was not exhausted during 72 hours (see Fig. 8). The capacity of ACHX was predicted as about 22 MW continuously (see Fig. 9). The air velocity in the chimney inlet was predicted as about 0.7 m/s continuously.

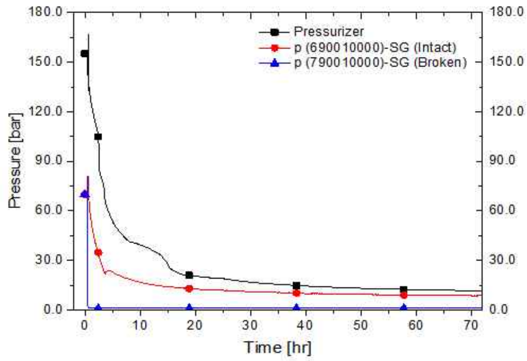

Fig. 7 Pressurizer and steam generator pressure

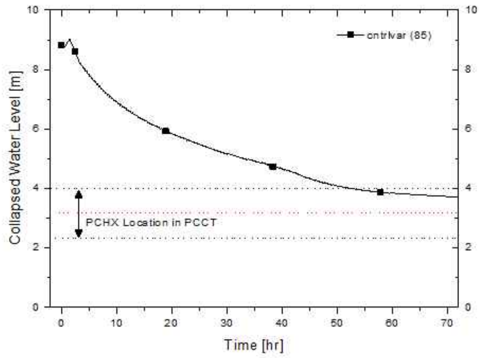

Fig. 8 Water level in PAFS pool

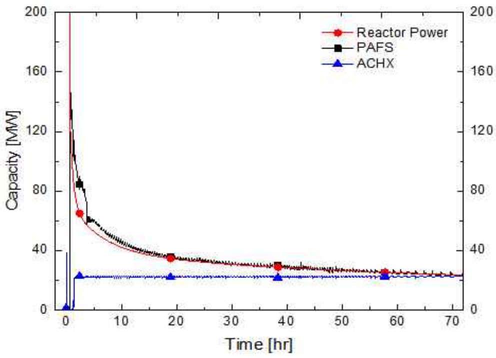

Fig. 9 PAFS and ACHX capacity

4. Conclusions

For the long term cooling with PAFS, KAERI proposed a new passive air-water combined cooling system. In this study, the modeling of the ACHX and the performance analysis on the PAFS connected with the ACHX were carried out with MARS. MARS predicted the behavior of main thermal-hydraulic variables of ACHX reasonably. Then, it was found that the long term cooling of PAFS could be achieved by the installation of the ACHX in which the tube length is 6 m and the number of tubes is 8000. As a future work, for the reliable design of ACHX, the validation study against the experimental data will be performed.

ACKNOWLEDGEMENT

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