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Long Term Cooling Performance Evaluation of a Passive Air Cooling System

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1. Introduction

In the station black out (SBO) condition, the Long-term cooling applicability of an passive air cooling heat exchanger system is very beneficial for improving the safety of nuclear power plants [1,2,3]. This is because the cooling time can be extended unlimitedly. The cooling of the air-cooled or air-water cooled, water-cooled driven residual heat removal system can be performed without limitation of the cooling tank capacity. Thus, it is a technology that can infinitely extend the cooling time. In this paper, the cooling performance of the air-cooled heat exchanger composed of the triangular array of finned tubes was evaluated. The maximum cooling performance was evaluated for the feedwater line break, The Over-cooling prevention performance was evaluated for the loss of condenser vacuum accident (LOCV). MARS code was used for performance evaluation of nuclear power system.

2. Analysis Model

The dimensions of the heat transfer fin tube used in the evaluation are as follows [4]. Fig. 1 shows the pin tube array configuration. Fig. 2 shows the configuration of the air-cooled heat exchanger system. Table 1 summarizes the tube specifications of the air-cooling system and the design specifications of the air-cooling system.

The nuclear power plant used for the analysis is a 1200 MWe capacity Virtual Innovative PWR 1200 (VIP1200). The performance evaluation of FLB and LOCV was performed using MARS code. Among the main conditions, the steam generator pressure was assumed to be equal to APR +, and the Hybrid SIT was modeled as a passive safety injection system.

Fig. 3 shows the System Node used for MARS analysis.

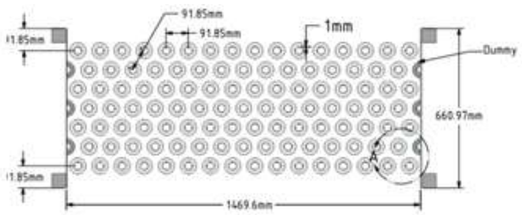


Fig. 1 Fin Tube Array and Shape

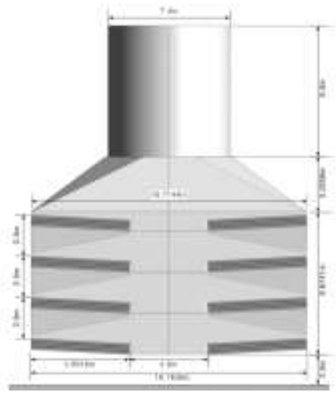


Fig. 2 Air Cooler Shape

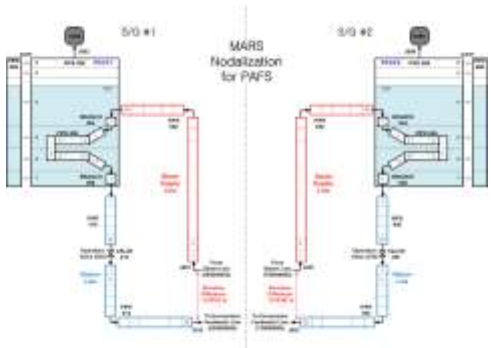


Fig.3 System Node for MARS Analysis

Table 1 Design Specification

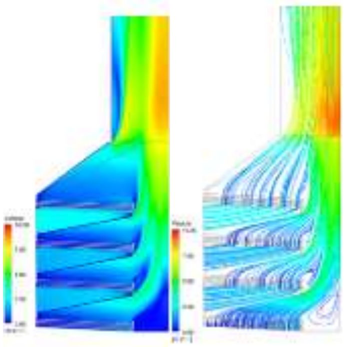
Design Item	Value
No. of Tubes per Unit	109
Outer Dia.[mm]	33.4
Thickness [mm]	1
Inner Dia.[mm]	31.4
Length[m]	6
Fin Thickness[mm]	1
Fin Height[mm]	16.7
Fin Pitch[mm]	5.8
Incline Angle[deg.]	3
Total Units	48
Layer	4
Stack Inner Dia.[m]	7.4

3. Results

Fig. 4 shows the results of the CFD analysis for the velocity field and streamline of the air-cooled heat exchanger. The heat exchanger Bundle is configured in four stages. The cooling air flows into the lower part of the heat exchanger and the left and right side surfaces and is discharged upward.

In order to evaluate the performance under the minimum cooling rate condition, only the heat exchange conditions by the Natural Circulation were considered.

Figure 5 shows the cooling capacity of a water-cooled-air-cooled heat exchanger consisting of 4360 tubes for FLB accidents. The water level of the PAFS cooling water tank is maintained for 72 hours.



(a) Velocity (b) Stream line

Fig.4 CFD analysis result

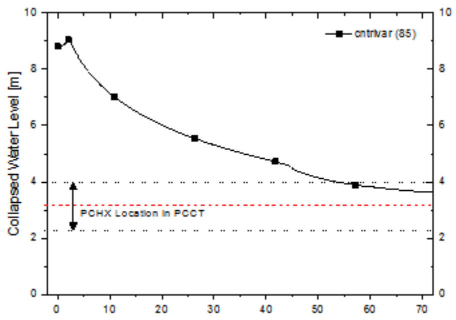


Fig.5 Cooling water level of PAFS for FLB

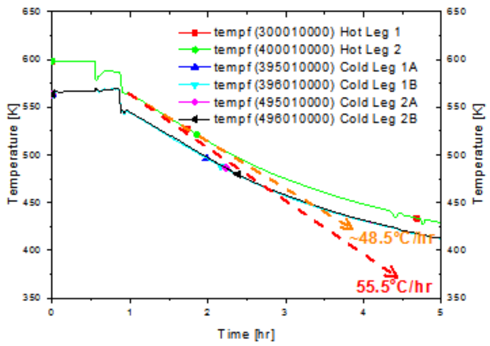


Fig.6 RCS water Temperature for LOCV

Fig. 6 shows the RCS water temperature for the LOCV of an air-cooled heat exchanger composed of 3488 tubes. The RCS cooling rate is under the cooling limit of 55.5 ° C / hr.

The results of the above two analyzes indicate that the maximum cooling performance and the anti-over-cooling prevention design conditions are completed.

4. Conclusions

The cooling performance of the passive cooling residual heat removal system for the VIP1200 virtual reactor was calculated using the MARS code. The cooling performance of the passive air cooling system with maximum cooling capacity and over-cooling accident prevention capability based on FLB and LOCV was evaluated. The results show that it is possible to design an air cooling system having the capability of a long-term cooling over 72 hours.

Acknowledgement

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