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Average Natural Convective Heat Transfer of Air-cooled Condensing Heat Exchanger of Emergency Cooldown Tank – Effect of Tube Banks

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1. Introduction

Recently emergency cooldown tank(ECT) is a great concern of passive cooling system for the safety of nuclear reactor. When an accident occurs in nuclear reactor, passive cooling system is operated to cool down a huge amount of steam by naturally circulating water in condensation heat exchanger which is immersed into ECT as shown in Fig. 1 [1]. After the operation of a conventional passive cooling system for an extended period, however, the water level falls as a result of the evaporation from the ECT, as steam is emitted from the open top of the tank. Therefore, Kim *et al.*[1] applied for a Korean patent covering the concept of a long-term passive cooling system for an ECT. The basic idea behind this concept involves the installation of an air-cooled condensing heat exchanger on the top of the ECT, so that the water level can be maintained by collecting the steam from the tank, as shown in Fig. 1.

In this study, the effect of heat transfer area at the air-cooled condensing heat exchanger was investigated by changing 5×5 tube banks into 4×4 and 3×3. Moreover, each of air-side natural convective heat transfer coefficient of tube banks was compared to existing correlations.

2. Experiments

Experimental setup and procedure were explained in detail in the literature Kim *et al.*[2]. They conducted to measure average natural convective heat transfer

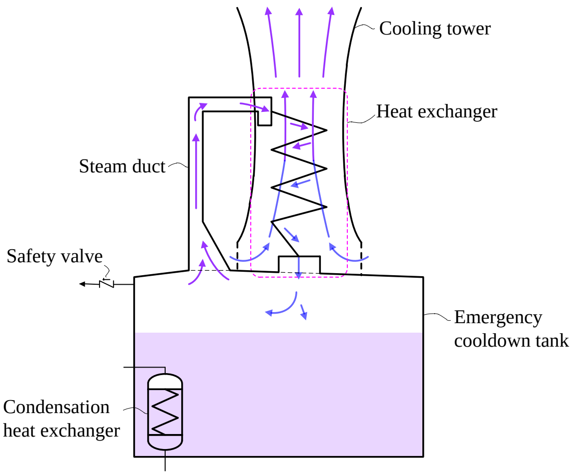

Fig. 1. Schematic of air natural convective cooling system of emergency cooling tank.

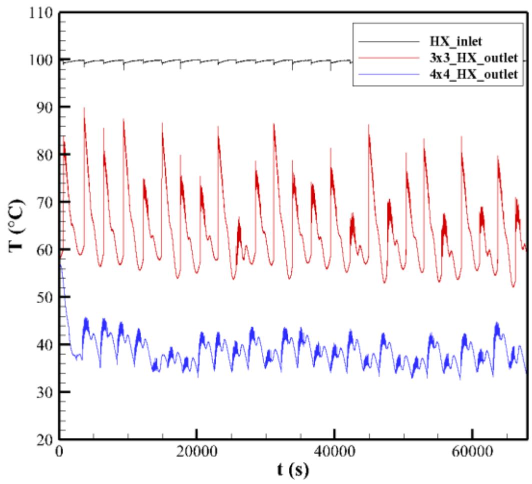

Fig. 2. Temperature of inlet and outlet of air-cooled condensing heat exchanger depending on the heat transfer area.

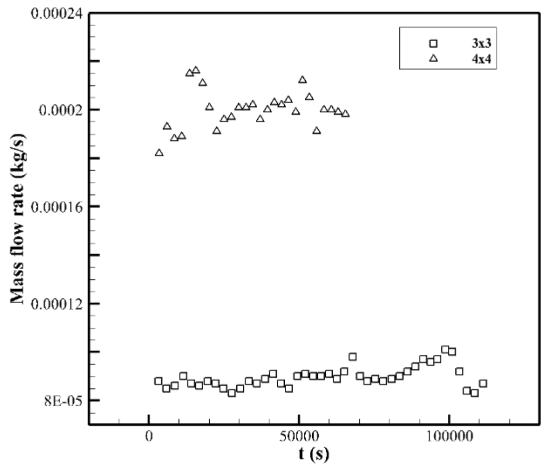

Fig. 3. Condensing flow rate of air-cooled condensing heat exchanger depending on the heat transfer area.

coefficient in the air-cooled condensing heat exchanger consists of 25 half-inch vertical tubes (arranged in a 5 × 5 array), 1.1m in length and spaced 0.05m apart. To investigate the effect of tube banks, the number of tube array was changed to 4×4 and 3×3 array with maintaining tube length and pitch.

3. Results

Fig. 2 shows the temperature of inlet and outlet of air-cooled condensing heat exchanger depending on the

Table I: The average value of natural convective coefficient of vertical cylinder depending on the heat transfer area.

	4×4 tube		3×3 tube	
	Average h (W/m^2/K)	Error (%)	Average h (W/m^2/K)	Error (%)
Experiment	15.30 ± 0.11	-	4.92 ± 0.05	-
Eigenson [3]	5.57	63	5.88	20
McAdams [4]	4.89	67	5.16	7
Churchill and Chu [5]	4.49	70	4.73	6
Al-Arabi and Khamis [6]	8.19	46	8.56	74
Yang [7]	8.28	45	8.63	76

heat transfer area. It was not performed to compare with the 5×5 tube banks since after the 5×5 tube banks experiment, delay timer was broken and replaced into new one but the model that was used was discontinued so that it could not be replaced with the same model. For that reason, it did not satisfy the previous condition. As shown in Fig. 2, the temperature of outlet increases with the decrease of heat transfer area. It means that each tube is provided with more vapor. The average outlet temperature at 4×4 tube banks and 3×3 tube banks were 38.2°C and 61.3°C respectively. Moreover, the heat transfer area of an air-cooled condensing heat exchanger was evaluated to determine the cooling capacity. It was changed from 502 W (4x4 tube banks) to 216 W (3x3 tube banks). The decrease rate was 43%, which is sufficient to demonstrate that the change of heat transfer area affects the cooling capacity.

Fig. 3 shows condensing flow rate of air-cooled condensing heat exchanger depending on the heat transfer area. The average condensing flow rate at the 3×3 tube banks was 0.09 g/s and that of 4×4 tube banks was 0.2 g/s. It can be considered that the decrease of heat transfer area affects the flow rate.

As shown in Table I, the average value of natural convective heat transfer coefficient that was obtained from the 4×4 tube banks experiment was 15.3 W/m^2/K. The air-side natural convective heat transfer coefficient of 4×4 tube tanks was relatively higher than the value under previous experimental condition. On the other hand, the value of 3×3 tube banks was 4.92 W/m^2/K, which was lower than the value at the previous condition. They could be compared to the value of natural convective coefficient from a number of correlation equation of vertical cylinder. The value obtained from the 3×3 tubes is similar to the value obtained from Churchill and Chu [5], which had 6% error. However, the value obtained from 4×4 tubes had at least the error of 46% which was attained from Al-Arabi and Khamis [6].

4. Conclusions

This study presents the effect of heat transfer area at air-cooled condensing heat exchanger. As heat transfer area decreased, the temperature of outlet increased. In other words, the cooling performance got lower with the decrease of heat transfer area. In addition, the average natural convective heat transfer coefficient was 15.3 W/m^2/K from the 4×4 tube banks, and 4.92 W/m^2/K from the 3×3 tube banks, which had quite a large error more than 46% especially with the value of 4×4 tube banks compared to the value from correlation equation. Therefore, according to this result, it is needed to measure the local heat transfer coefficient of vertical cylinder more elaborately in further study.

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