Single-tube condensation experiment in Passive Auxiliary Feedwater System of APR1400+

Chang Wook Shin[a], Hee Cheon NO[a*], Bong Yo Yun[a,b], Byong Guk Jeon[a]

[a] *Korea Advanced Institute of Science & Technology, Department of Quantum and Nuclear Engineering, Guseong-dong, Yuseong-gu, 373-1, Daejeon 305-701, Republic of Korea,* [*]*hcno@kaist.ac.kr*

[b] *KNHP Nuclear Engineering & Technology Institute, 508 Keumbyeong-ro, Yuseong-gu, Daejeon, 305-343, Republic of Korea,*

INTRODUCTION

Conventional Korean nuclear power plants, Advanced Power Reactors (APR), are characterized by an active cooling system. However, Active cooling system may not prevent significant damage without any AC power source available for its operation as vividly illustrated through the recent Fukushima incident. In the APR1400+ to be designed, an independent passive cooling system was added in order to overcome the aforementioned shortcomings. In the Passive Auxiliary Feedwater System (PAFS), gravity force and density difference between steam and water are used. The system comprises of 240 condensation tubes to efficiently remove decay heat. Before applying the PAFS to APR1400+, the system's safety and heat removal performance must be verified. The present study experimentally evaluates the heat removal performance of a single tube in the PAFS. The objectives of SCOP (Single-tube Condensation experiment facility Of PAFS) are the evaluation of the heat removal performance in the tube of the PAFS and database construction under various tube designs and test conditions. Reaching these objectives, we developed advanced measurement techniques for the amount of moisture, heat flux, and water film thickness.

METHODS

SCOP is comprised of a 280kW steam generator, an 8.4m condensation-tube, and a 9m^3 condensation tank. Figure 1 shows a schematic diagram of SCOP. A pump was used for circulation instead of gravity. A main test section contains a single condensation tube similarly designed with the PAFS: 2 inch in diameter, 8.4 meter in length, 3 degrees in inclination (Figure 2). Also the figure shows data acquisition points for the

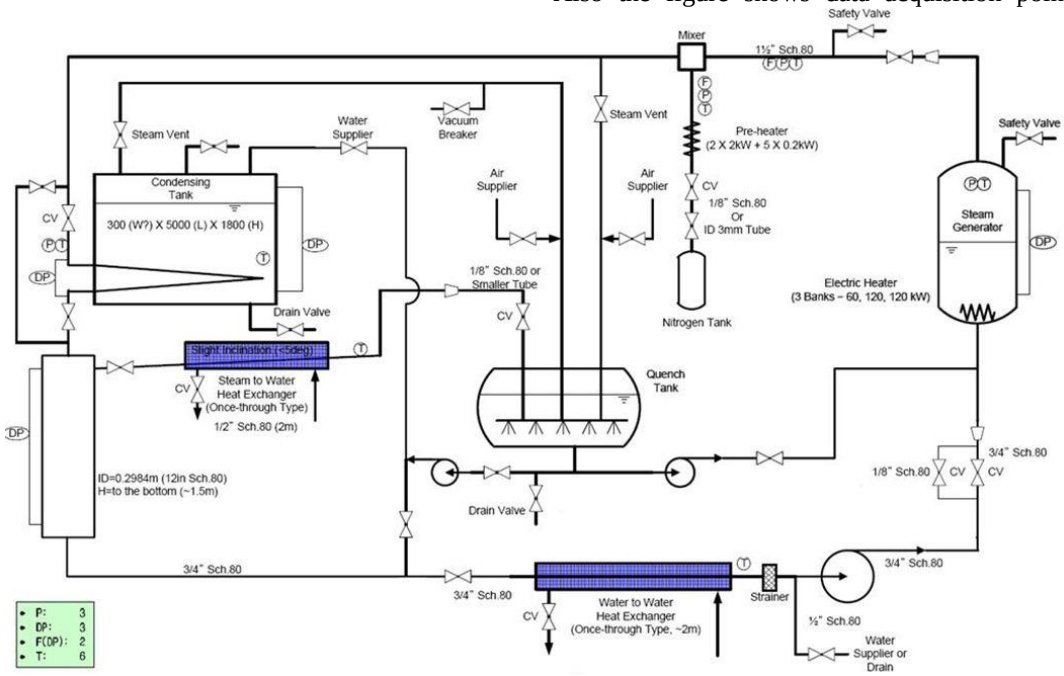

Figure 1 : SCOP test facility diagram

measurement of heat flux

Through SCOP we mainly focus on detecting changes in heat transfer and flow regime based on changes in the inclined tube design. By improving the measurement methodology data accuracy was improved. By using a scanning system of water film measurement, flow regime was assessed at various locations and heat flux data acquisition points were largely increased in number compared to previous studies. In measuring flow regime, it was measured externally using an ultrasonic sensor to minimize flow distortion. Of the 8 sensors used, 4 fixed-types and 4 moving-types each moving by 1.6 meters were installed. These sensors measure the height of water film to derive the flow regime. Ultrasonic sensors are newly developed to be operable under boiling and underwater conditions. In measuring the heat flux, the temperature difference between the inner and outer walls was measured without exposing the thermocouple inside the tube. Several validation tests had been performed for these methods in severe conditions such as high heat flux, high temperature, and boiling conditions.

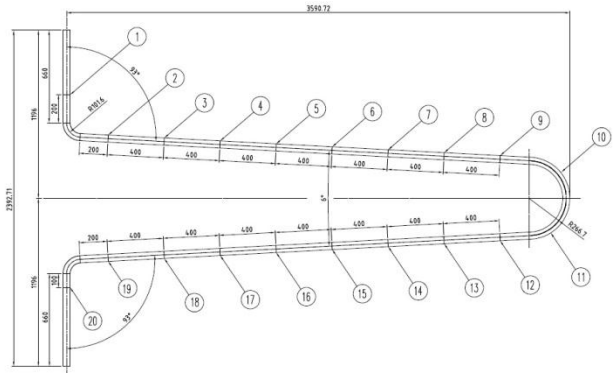

Figure 2 diagram of condensation tube in SCOP

The condensation tube was tested using various inclines and diameters to evaluate various effects according to the tube design: 1) three condensation tube angles (3, 2.5, and 2 degrees) 2) diameters (2 and 1 inch). Also, 3) the non-condensable gas effect (~1%), which significantly deteriorates heat removal capacity in operation, was evaluated by supplying nitrogen. By allowing condensation evaluation under each set of parameters, we obtained various databases as well as confirm safety margin. The results may be greatly useful in deriving new correlations incorporating various parameters.

SCOP steam generator is limited to 300kW, while the design heat removal capacity per tube of the conventional PAFS design is 540kW. In order to compensate such a difference, the diameter was scaled during additional experiments, and transient experiments also were conducted. In the transient experiments, as steam is vented from the lower part of the tube, a pressure difference was created in the condensation tube leading to an increase in the steam flow rate for a certain period.

RESULTS

We performed a transient test in order to confirm that the quasi-state assumption is valid. We checked through the transient test whether the steam flow generated from the current facility reaches that of PAFS and the pressure and steam flow coastdowns are slow enough for the application of quasi-state assumption. We found out that over 10 minutes, the deviations of the pressure, temperature, and flow rate were around 3% at 0.1MPa, around 1%, and around 0.3%, respectively. The average power is 551.8kW with 50kW power reduction over 1000 second at a rate of 3.15kW/min. For an average over 10 minutes, its deviation is around 3% as shown in Figure 3.

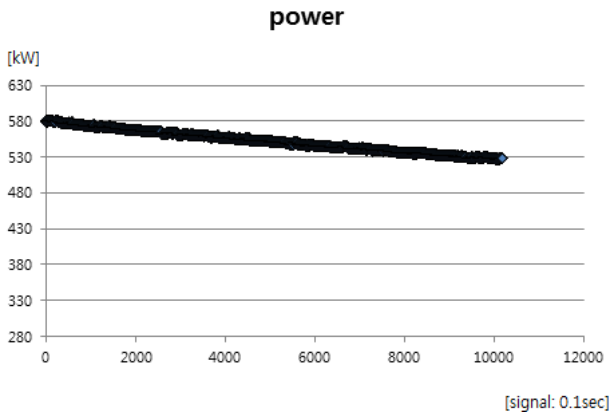

Figure 3: 280kW transient test results in SCOP

ACKNOWLEDGMENTS

The authors gratefully acknowledge that this research was cooperatively performed with KHNP, not only in technical aspects but also in theoretical discussion and financial support.