Experimental Study on the Passive Containment Cooling System of PWR using Multi-Pod Heat Pipe

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1. Introduction

The main purpose of this experimental study is to effectively remove decay heat from the Multi-pod Heat Pipe (MPHP)[1] when severe accident occurs in the nuclear power plant, for performance test on decreasing pressure inside the containment and maintain the integrity of the containment.[1] For this, experimental proof that heat is removed as much as the Heat Pipe assembly requires is essential.[2]

MPHP is a Two-phase closed Thermo-syphon (TPCT) heat pipe assembly, which experimental studies on TPCT had been performed a lot from the past, and empirical correlation also had been developed greatly. In this experimental study, in the 120psia condition of FLC (Factored Load Category)[2] required for maintaining integrity of containment in APR1400, on the basis of theoretical calculation that TPCT applied Heat transfer correlation[3] is applied for MPHP to remove 1kW of heat per 1m[3], Experimental model was produced and the experiment was proceeded[2]. An experimental device, a scale model of MPHP to be applied to the Nuclear power plant was designed to design and produce 7 MPHP with 7 heat pipes in the form of Hexagonal array, and 7kW was injected to identify the temperature and the pressure to calculate Heat transfer coefficient and Quantity of heat.

2. Design and Method

2.1 MPHP Experimental Design

The experimental device is composed of Boiling tank, Heat Pipe Assembly, and Condensation Tank. The length of Boiling tank and Condensation Tank is 1.5m, and the water to generate steam is filled from the Boiling tank bottom up to 30cm, and during heat supply, a Thermocouple to measure the temperature of the water and the steam is connected.

For the Heat Pipe, as mentioned earlier, the Boiling region and the Condensation region is designed 1m in length and 0.03m in diameter, and adiabatic region is 0.3m in length and 0.2m in diameter.

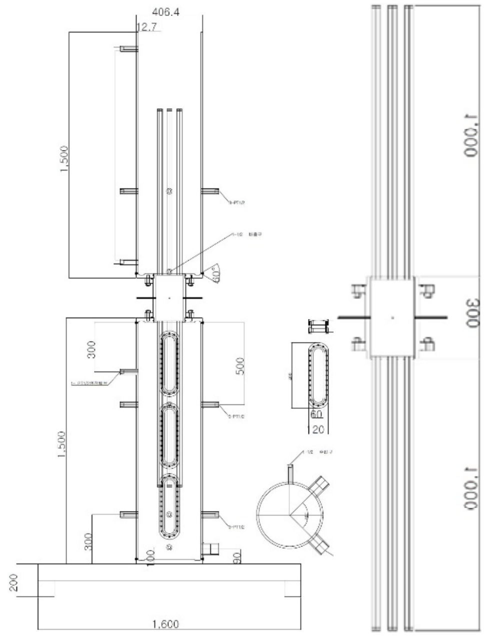

Fig. 1. Experimental device of MPHP

2.2 Measuring facility

According to the purpose of the experimental study, to measure temperature and pressure change of the Boiling tank and the temperature change of the MPHP, measuring facility was connected as followed. First of all, for the Heat Pipe to receive consistent heat, Electrical Heater was installed on the bottom of the Boiling Tank. Sheath heater which is possible for high-power according to the resistance was welded to the Heater, and for 2 Heaters with 5 kW capacity each to put in consistent heat of 90℃, a SCR voltage regulator was connected to maintain power control.

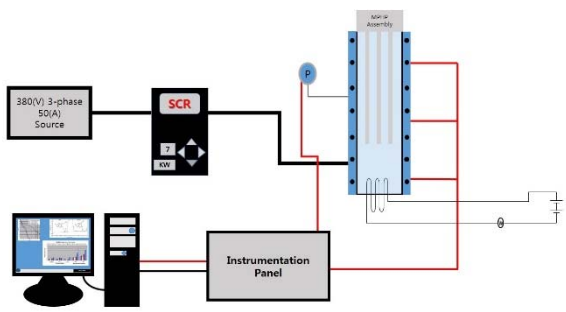

Fig. 2. Schematic Diagram of the MPHP measuring facility

Also, to measure the pressure change of the boiling tank according to the heat removal inside the Boiling tank, a pressure transmitter was installed check the measured value in Multi-function plug-in modules along with the T/C.

3. Result

As a result of experimenting within the Heater capacity range, maximum steam temperature in Boiling tank increased to 117℃ in 7kW, and identified to become steady state in 112℃ by the heat exchange of the Heat Pipe.

From near 40~45℃ of operating temperature for MPHP, the temperature change of the boiling region changed rapidly for the Heat Pipe to operate. The time took until then was about 40mins.

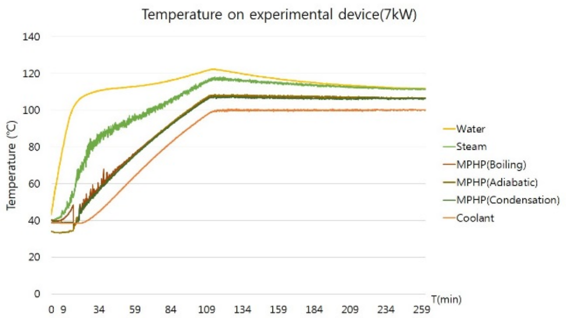

Fig. 3. Variation of Temperature at 7kW

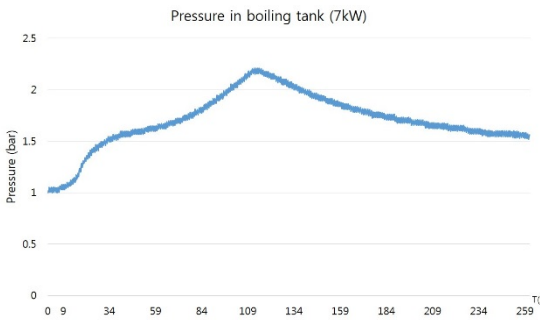

Fig. 4. Variation of Pressure at 7kW

4. Conclusions

As a result of the experimental study, seeing that the pressure inside the boiling tank decreased steadily, it is judged that MPHP's heat transfer performance shows over 100% efficiency. Also, the air-weight fraction in the Boiling Tank showed about 0.02(w/o), Uchida correlation applied Heat transfer coefficient was about 5619($W/m^2 \cdot$℃), and Tagami correlation applied Heat transfer coefficient showed about 13333($W/m^2 \cdot$℃). In severe accident condition, this is a figure short of air-weight fraction inside the containment 0.2 (w/o)[3], and the Heat transfer coefficient is much higher than the estimated heat transfer coefficient($= 1002\, W/m^2 \cdot$℃), which is a result of better heat transfer than the FLC condition.[3]

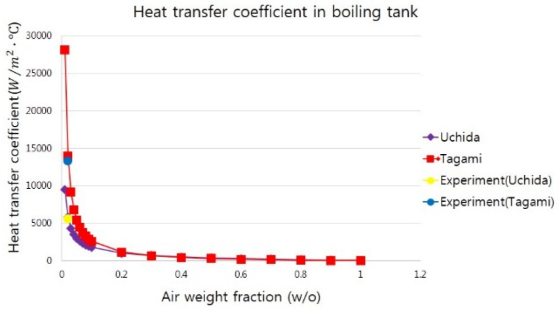

Fig. 5. Heat transfer coefficient in boiling tank at 7kW

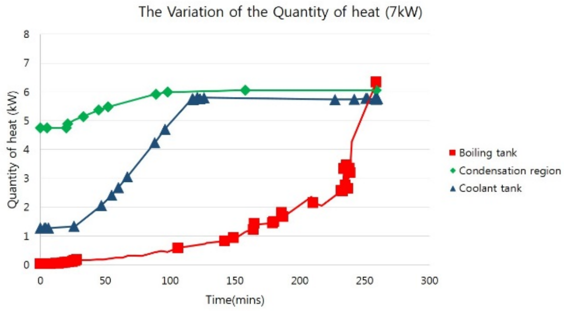

Fig. 6. The Variation of the quantity of heat at 7kW

In further studies, to precisely prove the MPHP performance to be applied to the nuclear power plant, experimenting by putting in air pressure and setting the air-weight fraction correctly is essential.

NOMENCLATURE

SCR: Silicon Controlled Rectifier
T/C: Thermo Couple

ACKNOWLEDGEMENT

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