Evaluation of Passive Containment Cooling System using Passive Heat Sink Tank for Small Modular Reactor

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Introduction

◆In the event of a LOCA(Loss Of Coolant Accident) at a small and medium-sized nuclear power plant, high energy steam is released through pipe connected to the reactor and the pressure of the containment building is increased. For this reason, various methods are required and designed to suppress the pressure rise of containment building. Some of these methods are via spray system within the containment, and others are by cooling the containment exterior walls. However, these methods require the use of pumps as an active manner and large upper water storage tanks, which cannot be operated without electricity. The passive containment cooling system with passive heat sink tank is one of several safety systems of reducing pressure, temperature within the containment. The objective of the paper is to propose and evaluate a design concept for passive containment pressure suppression method with passive heat sink cooling tank inside IRWST (In-containment Refueling Water Storage Tank).

◆ Figure 1 shows the conceptual design of passive containment pressure suppression system with passive heat sink tank(PHST) inside IRWST. The systems are contained by containment structure and confinement building. PHST is a steel structure submerged in top-side of IRWST, and there is 200 tons of coolant inside it.

◆At the bottom of the PHST, there is an inlet for external cold air, and at the top, there is an outlet for steam releasing. The steam outlet is located inside the stack installed outside the containment building. The role of the chimney is to breathe air from the outside to the inside the stack when the steam is released to the stack. This air intake allows steam to be released more efficiently. When LOCA occurs inside CPRSS, steam, air and radioactive materials (especially iodine) are released to IRWST through the discharging line by pressure difference between CPRSS inside and the containment structure. The containment structure performs the role of a barrier for preventing the leakage of radioactive materials to an external environment from the reactor coolant system. The steam from the reactor is released into CPRSS inside, and the steam released to IRWST through the discharging line is directly condensed and the water temperature of IRWST increases. The heat from IRWST is transferred through the surface of the PHST, causing the coolant inside PHST to heat up. The steam boiled from PHST is released to environment due to natural convection. As the boiled steam flow out into the outlet by natural convection, outside fresh air enters the lower part of the PHST.

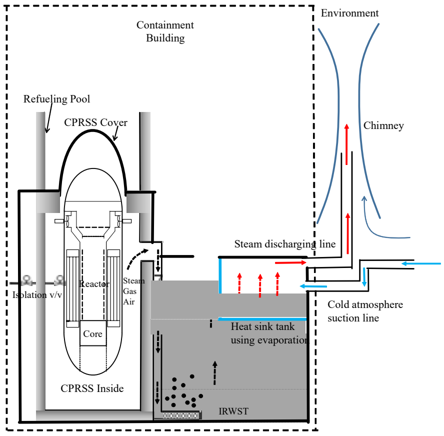

Fig. 1 Schematic of heat sink tank inside IRWST

Analysis Model and Results

◆The MARS code was used to assess the design concept. Figure 2 indicates the pressure behavior inside CPRSS and containment structure for 72 hours after LOCA initiating inside CPRSS. The pressure difference between inside CPRSS and containment building is a static head of the end of the discharging line. The pressure inside CPRSS is the peak just after LOCA initiating, and gradually increased to 2.3 bar. And then, the pressure is saturated to 1.9 bar. The pressure of containment building increased to 1.3 bar.

◆Figure 3 presents temperature of IRWST and inside passive heat sink tank. The temperature of IRWST is increase because steam is released to IRWST. The temperature of PHST is gradually increased to 340 K. along the temperature trend of IRWST. The temperature of IRWST is convergent to 347 K. Figure 4 shows the cooling capacity of PHST. At the beginning of the accident, 1MW of heat was removed by PHST, and after 72 hours it was confirmed that 0.8 MW of heat was removed. The heat is removed from IRWST after water boiling because the sensible heat is eliminated by boiling.

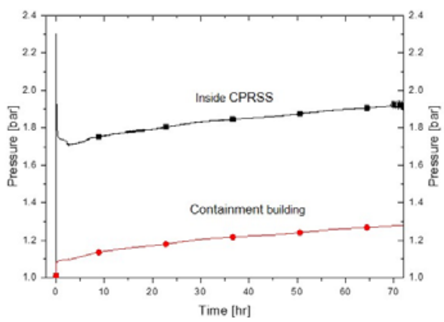

Fig. 2 Pressure inside CPRSS and containment building

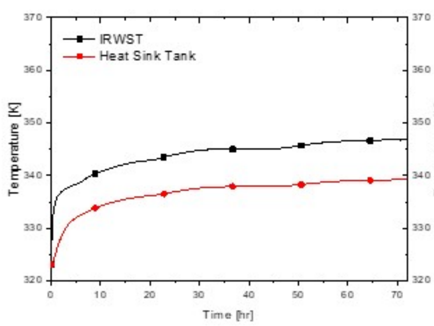

Fig. 3 Temperature inside CPRSS and containment building

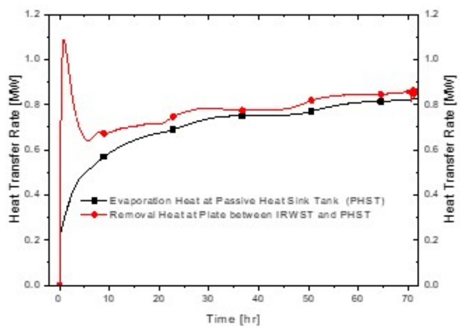

Fig. 4 Heat transfer rate

Summary

◆In this study, the preliminary thermal hydraulic evaluation of passive containment cooling system with passive heat sink tank(PHST) was performed using the analysis code, MARS. From the MARS results, the proposed passive containment cooling system with passive heat sink tank inside IRWST can maintain the pressure of the containment at about 1.3 bar during 72 hours without any active methods.

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