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Concept Design Evaluation of Passive Containment Pressure and Radioactivity Suppression System with cooling tank for SMR

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1. Introduction

High pressure and temperature vapor released from the reactor in the event of an accident raises the pressure of the containment and cause to explode the containment. For this reason, various methods are required and designed to suppress the pressure rise of containment. 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 can not be operated without electricity, and need to become structural larger due to large upper structures.

The passive containment cooling system is one of several safety systems of reducing pressure, temperature within the containment, and a concentration of radioactive materials. The objective of the paper is to propose and evaluate a design concept for passive containment pressure suppression method with cooling tank inside IRWST (In-containment Refueling Water Storage Tank).[1]

2. Description of the System

Figure 1 shows the conceptual design of passive containment pressure suppression system with passive cooling tank inside IRWST. The systems are contained by containment structure and confinement building. The containment structure includes four Core Make-up Tanks (CMTs), four Safety Injection Tanks (SITs), IRWST and sub-components. Reactor is located inside CPRSS. 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. Passive cooling tank is installed in IRWST and connected to environment. 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 wall of the cooling tank, causing the cooling tank to heat up. The steam boiled from cooling tank is released to environment due to natural convection.

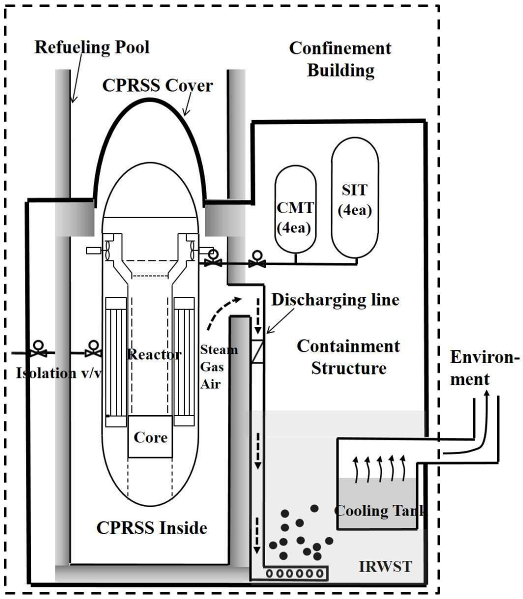

Fig. 1.Coneptual view of Passive Containment Pressure Suppression System for SMR

3. Analysis Method and Results

3.1 Analysis Model and Method

The analysis is performed using MARS-KS1.4. A nodalization for the CPRSS system analysis consist of CPRSS inside volume, discharging line, IRWST, passive cooling tank and containment building volume.

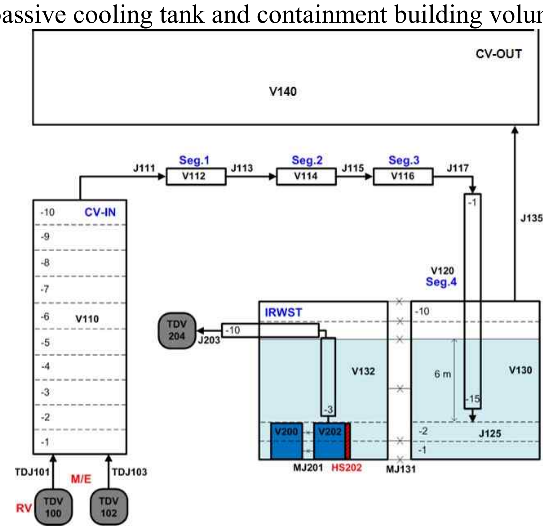

Fig. 2. Temperature behavior in IRWST and passive heat sink (Cooling tank)

In the figure 2, The time-dependent volumes, TDV-100 and TDV-102, and the time-dependent junctions, TDJ-101 and TDJ-103, were used to provide the inlet boundary condition for the Mass/Energy(M/E) which represents the high pressure steam-water two phase flow released from the reactor vessel following LOCA. V110, V202 and 200, V132, V130 and V140 correspond to the CPRSS inside, passive cooling tank, IRWST and containment structure in Figure.1.

3.2 Analysis Results

Figure 3 indicates the pressure behavior inside CPRSS and containment structure for 10 days after LOCA initiating inside CPRSS. The pressure difference between inside CPRSS and containment structure is static head of the end of the discharging line. The pressure inside CPRSS is the peak just after LOCA initiating, and gradually increased to 2.1 bar after 3 days. And then, the pressure is saturated to 3 bar. In containment structure, pressure trend shows with pressure ascending line.
Figure 4 presents temperature of IRWST and inside cooling tank. The temperature of IRWST is increase because steam is released to IRWST. The temperature of cooling tank for heat sink is gradually increased to 5.4 days along the temperature trend of IRWST. And, water of cooling tank begins to boil away at 5.4 days and steam is generated and released to environment. The temperature of IRWST is convergent to 383 K. Figure 5 shows the cooling capacity of heat sink. In early phase of LOCA, a discharged mass flow rate of steam is large because of high pressure difference between inside CPRSS and in the end of the discharging line. Therefore, the temperature difference between IRWST and cooling tank is large and heat transfer is increased. The heat is removed from IRWST after water boiling because the sensible heat is eliminated by boiling

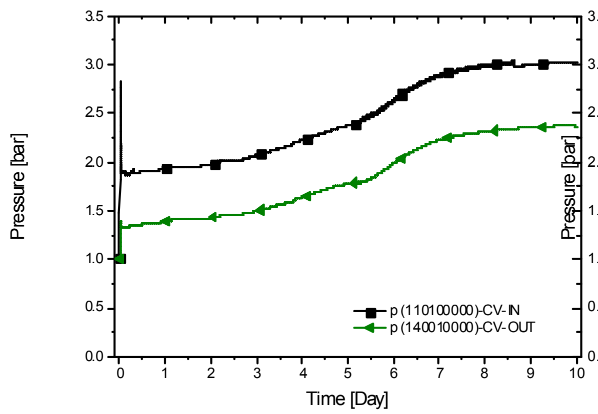

Fig. 3. Pressure behavior inside CPRSS and containment

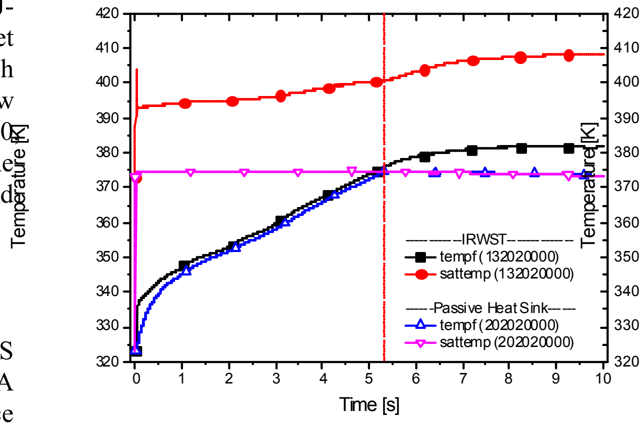

Fig. 4. Temperature behavior in IRWST and passive heat sink (Cooling tank)

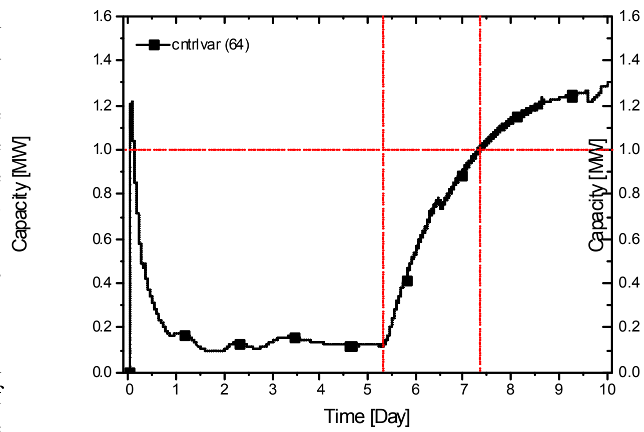

Fig. 5. Heat removal capacity of passive heat sink

4. Conclusions

The preliminary thermal hydraulic evaluation of CPRSS was performed using the analysis code, MARS. From the MARS results, the passive containment pressure and radioactivity suppression system with cooling tank inside IRWST can maintain the pressure of the containment at about 3.0bar during 10 days without any active methods.

REFERENCES

[1] K.J.Kang, Y.I.Kim et al, Radioactive Material Reduction Facility and Nuclear Power Plant having the same, 10-2014-003632, Korea Patent(2014)