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Internal Flow Behaviors in Containment

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1. Introduction

During a Loss of Coolant Accident (LOCA), high temperature and high pressure water and steam from the coolant system pressurize and heat up the atmosphere of the containment. The discharged steam is condensed either at the containment wall, at the heat exchangers of the passive Containment Cooling System, or by the coolant from the Containment Spray System. This study was proposed to develop a new passive Containment Cooling System. As the condensation capability of the cooling system depends on the distribution of the steam in the containment, the location of the heat exchangers and the characteristics of the internal flow of containment should be considered in the design of the heat transfer system

2. Numerical Model

To analyze the flow distribution of the containment, a simplified reactor system model was established (Fig. 1). This model simulates the external shapes of the reactor vessel and steam generators, and other shapes such as the cranes, pipes, and structures, etc., were excluded. In addition, an external atmosphere of the containment was modeled to consider the cooling effect between the containment and external atmosphere.

Fig. 2 shows the initial and boundary conditions for the analysis of the internal flow in the containment. In the calculation, the temperature and pressure of the external air outside the containment were assumed to be 15 ^{o}C and atmospheric pressure, respectively. The initial temperature of the containment was set to 50 ^{o}C. The initial containment was assumed to be full of ideal gas, and the pressure and temperature were 1 bar and 50 ^{o}C, respectively.

In the calculation, it was assumed that 133 ^{o}C steam at the RCS cold leg (D = 0.76 m) is initially ejected vertically upward into the upper atmosphere of the containment at a speed of 50 m/s at 0 s, and 10m/s at 10,000 s. The speed of the steam was assumed to linearly decrease by considering the initial and late phase core decay heats.

For the calculation, commercial CFX Code Version 14 was used. The total number of element is 288 million; 182 million elements for the containment internal, 5 million elements for the concrete structure, and 100 million elements for the external atmosphere.

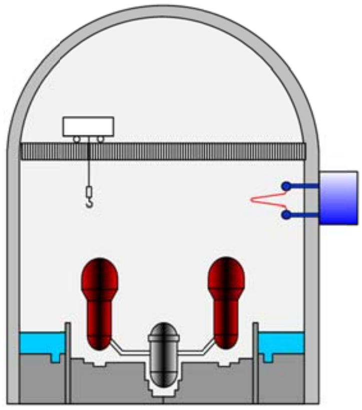

Fig. 1 Schematic of Containment Internal Shape

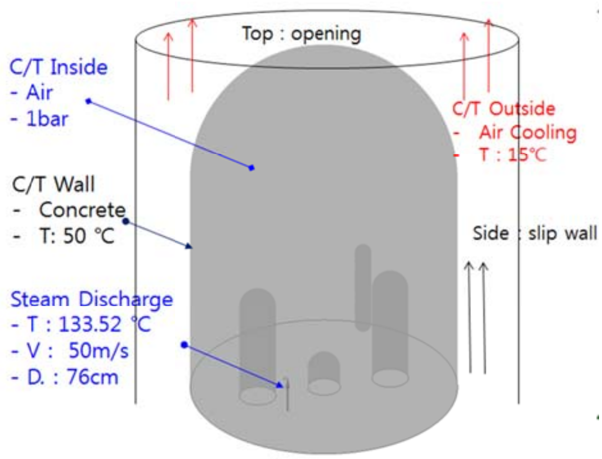

Fig. 2 Initial and Boundary Conditions

3. Calculation Results

Figs 3 and 4 show the temperature and velocity distributions of the steam inside and outside of the containment at 1,020 and 6,000 s, respectively. Fig. 5 shows the stream line distribution of the steam inside and outside of the containment at 1,020 and 6,000 s, respectively. The flow field of steam in the containment is well described in the figure.

The steam flow distributions at the inside region of the containment dome is an eddy type flow. The air flow distribution outside of the containment dome is also a recirculation eddy type flow. Therefore, these regions are not adequate for the location of the heat exchangers. Fig. 6 shows the distribution of steam condensation. The condensation mainly occurs at the containment wall, as the spray system was not operated.

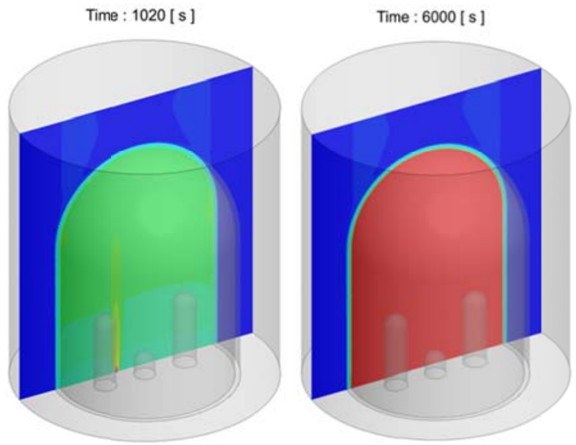

Fig. 3 Temperature Profile in Containment

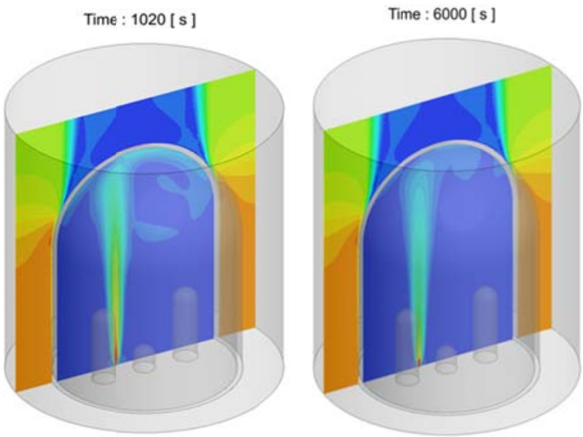

Fig. 4 Velocity Profile in Containment

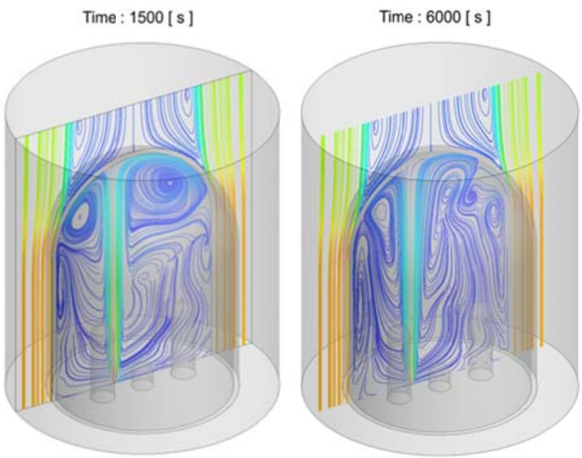

Fig. 5 Stream Lines

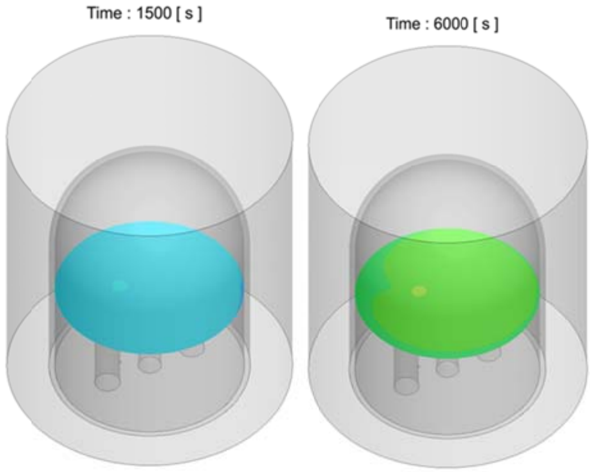

Fig. 6 Steam Condensation Distribution

4. Conclusions

The internal dome region of the containment is not adequate for the installation of the heat exchangers of the passive Containment Cooling System. The external dome region of the containment is also not adequate for the heat exchangers since the stream lines of the air are vertically upward and adequate cooling is not possible without separate air tubes for cooling.

The velocity distribution of air is not uniform and the distributions of air temperature and velocity around the heat exchanger tube are strongly asymmetric. Therefore, the temperatures at the inlet, middle, and outlet regions do not indicate the average temperatures of the corresponding regions, and some difficulties in the derivation of the average tube heat removal rate are expected. In the design of the measurement system of the test facility, the problems mentioned above should be considered.

Acknowledgement

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References

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