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GOTHIC Multi-Dimensional Analysis for Containment Implemented with Passive Containment Cooling System (PCCS)

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1. Introduction

In order to develop the next generation nuclear power plant (NPP) for the export, South Korea has started to develop an 'IPower (Innovative Power)' which is followed by APR1400 and APR +. In order to raise competitiveness of the IPower in the world market, it is necessary to develop the original technology for the improved technology, economics, and safety features. For this purpose, a Passive Containment Cooling System (PCCS) was adopted as an improved safety design concept of IPower; and there have been many efforts to develop the PCCS.

Fig. 1 shows the schematic of the PCCS. The PCCS can completely replace the active Containment Spray System (CSS) of the previous NPPs in terms of the heat removal functions. When the design basis accidents (DBAs) such as the loss of coolant accident (LOCA), the main steam line break accident (MSLB), and the main feedwater line break (MFLB) occur, the PCCS can cool down the containment atmosphere and prevent the containment pressure and temperature (P/T) from exceeding the containment design P/T.

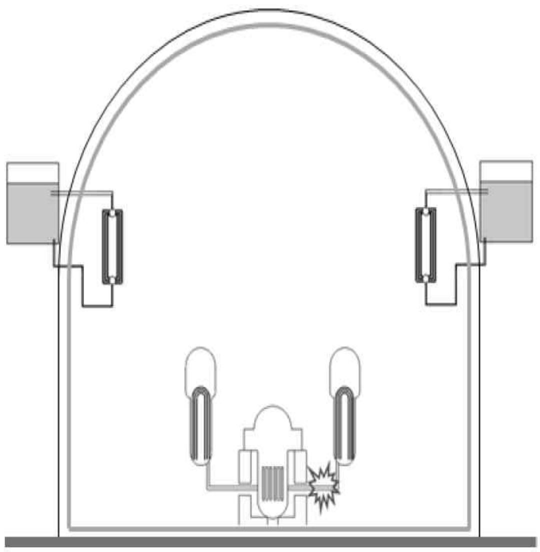

Fig. 1 Schematic of PCCS[1]

In order to design the PCCS reliably, it is necessary to evaluate the PCCS heat removal capacity by the containment P/T analysis. For this reason, authors have developed the APR1400-PCCS input model using the containment thermal hydraulic analysis code, GOTHIC (Version 8.2) code[2], and performed the containment P/T analysis for the LBLOCA M/E release situation.

The heat removal capacity of the PCCS is governed by the condensation heat transfer on the PCCS heat exchanger tube. Since the condensation heat transfer is affected by the flow field of the containment atmosphere, the containment modeling is important to confirm the PCCS performance. Therefore, in this paper, we tries to compare the results from 1) the single volume modeling of the containment, 2) the multi-compartment modeling, and 3) the multi-dimensional modeling and discuss the inspiration obtained from the comparison.

Unfortunately, the modeling of the containment and calculations were not completed. All results and important findings will be presented in the conference. Instead, this paper focuses on the modeling of GOTHIC input model.

2. GOTHIC Input Model

Fig. 2 shows the nodalization of the single volume model of containment. The reactor coolant system is not modeled. Instead, the mass and energy (M/E) for the postulated LBLOCA is injected to the containment volume as a boundary condition. Passive heat sinks in the containment are modeled as 18 heat structures. They remove the heat energy injected to the containment atmosphere passively. For the condensation model, the diffusion layer model (DLM) was used. For the PCCS, the DLM-FM was used as a condensation model outside the tube surface.

Initial conditions and some geometrical information are as follows:

- Containment
  - Volume: 8.8575E+4 m^3
  - Pressure: 101 kPa
  - Temperature and Humidity: 322 K and 0 %

- PCCS
  - PCCS heat transfer area: 5445.3 m^2
  - PCCT volume: 7225.4 m^3
  - PCCT temperature: 322 K

Fig. 3 shows the nodalization of multi-compartment model of the containment. The containment building is divided to 28 volumes. Heat structures are also divided and distributed to each compartment.

Fig. 4 shows the nodalization of multi-dimensional model of the containment. The subdivided volume option is applied to the containment dome and cylinder space (volume no. 17) above the operating floor to simulate the multi-dimensional flow field.

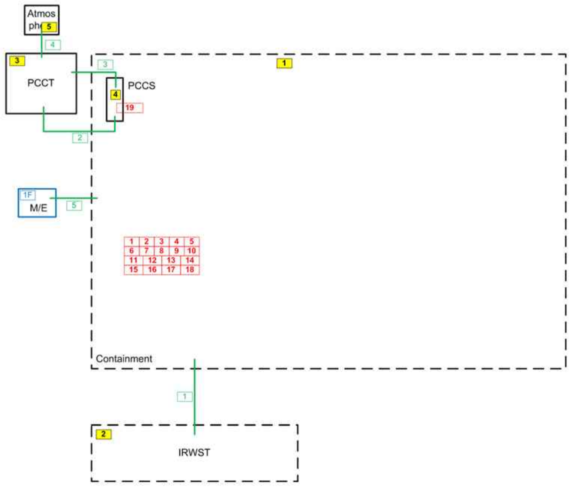

Fig. 2 Single volume model of containment

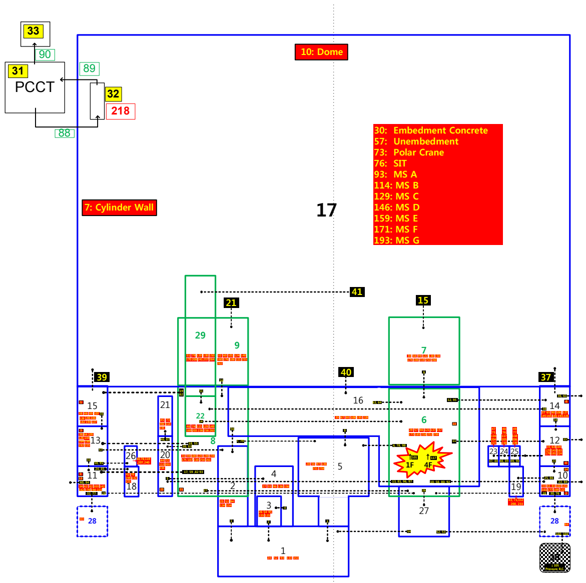

Fig. 3 Multi-compartment model of containment

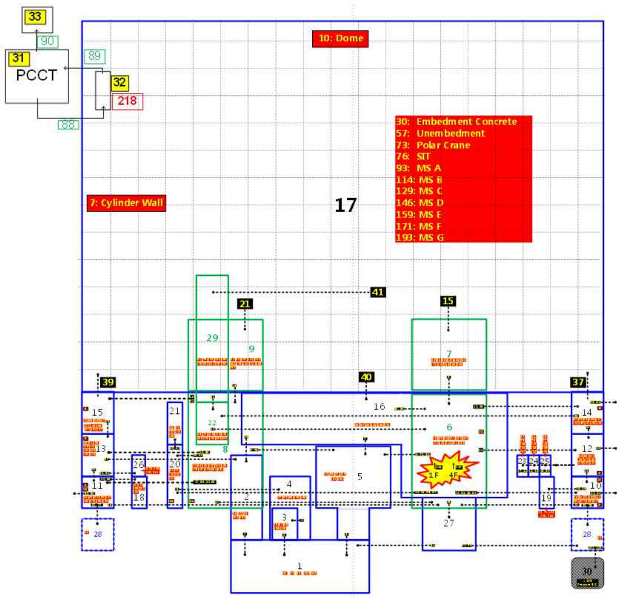

Fig. 4 Multi-dimensional model of containment

3. GOTHIC Simulation Result

When the accident occurs, the passive heat sink removes the significant amount of the heat energy in the initial phase of the accident. Afterwards, the PCCS removes the heat as main heat sink.

Fig. 5 shows the containment pressure behavior. There is a pressure increase region (~10,000s-30,000s) but the containment pressure decreases gradually. Referentially, the pressure increase phenomenon is expected to be solved by the design optimization.

At present, the modeling of the containment and calculations were not completed. All results and important findings will be presented in the conference.

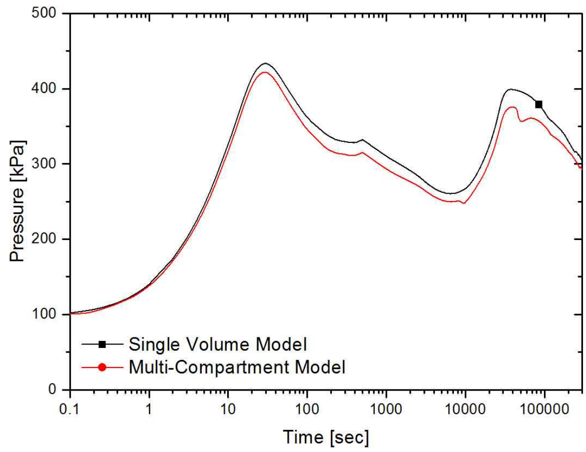

Fig. 5 Containment atmosphere pressure

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REFERENCES

[1] Bae, et al., Preliminary Analysis of the Thermal-Hydraulic Performance of a Passive Containment Cooling System using the MARS-KS1.3 Code, Journal of Energy Engineering, Vol. 24, No. 3, pp.96~108, 2015.

[2] EPRI, GOTHIC THERMAL HYDRAULIC ANALYSIS PACKAGE USER MANUAL (Version 8.2), 2016.