Preliminary Study on Conceptual Design Analysis of PCCS for SMART

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1. Introduction

System-integrated modular advanced reactor (SMART) is an integral reactor. In order to enhance the safety of SMART, the passive containment cooling system (PCCS) is under development. When an accident happens, PCCS cools the hot atmosphere in the containment without any external actuating force.

The hot atmosphere of containment is cooled by the heat exchange between the water in heat exchanger (HX) and atmosphere of containment. The atmosphere of containment forms the accident-induced flow. The velocity of a moving atmosphere influences on the performance of HX. Thus, before designing PCCS, understanding the flow field of zone where HX is installed is important.

CAP[1] code was used in this preliminary study. Upper compartment of operating deck in the SMART containment is modeled with CAP code, and flow field analysis for the upper compartment was performed and compared to the other research results in this study. Also, preliminary analysis of the SMART containment cooling by conceptually designed PCCS was performed under Small-break loss-of-coolant-accident (SBLOCA) accident.

2. Flow Field Analysis

2.1 CAP Input Model

SMART containment consists of three major parts such as a base slab, a cylindrical region and a spherical dome. PCCS is considered to be installed at dome or the lower zone of dome, which is located in the upper region of operation deck (12.6 m). The complex region below operation deck is not considered in the input model, because it is believed to have less influence on the flow field of atmosphere in containment.

Fig. 1 shows CAP input nodalization. The model is comprised of core region (from UP-C1 to DM-C3) and annular region (from UP-A1 to DM-A3). The nodes in cylindrical region locating between bottom of dome and operation deck have the name of ‘UP-XX’, and the nodes in dome region have the name of ‘DM-XX’. In order to simulate the accident-induced natural circulation in containment atmosphere, core and annular regions are connected with each other by horizontal junction. The concrete walls of containment are modeled as heat sinks whose outsides are insulated. PCCS is not considered in this analysis.

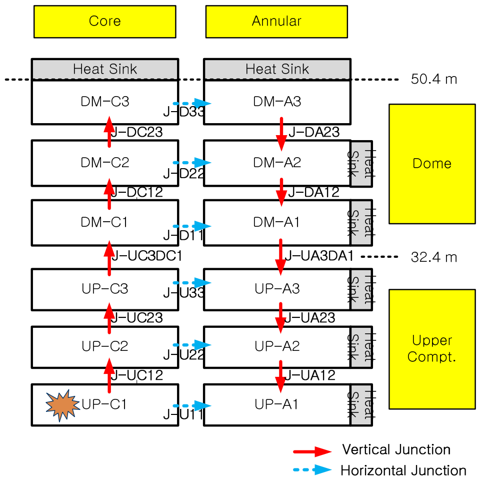

Fig. 1 CAP Input Nodalization Model

2.2 Mass and Energy Release Data

SBLOCA) is the only design basis accident (DBA) which fatally affects the pressure and temperature of containment. In SMART, the bounding SBLOCA is a double-ended-guillotine-break of safety injection line with maximum safety injection. The break location is at UP-C1 node.

2.3 Calculation Results

The flow fields of containment atmosphere were analyzed by using CAP code. The velocities at each vertical and horizontal junction are shown in Fig.2. In these results, the accident-induced flow behavior with the typical velocity direction is maintained except for the very early stage.

The two dimensional flow behaviors of containment atmosphere at various time steps are shown in Fig. 3. There is the natural circulation of atmosphere following upward flow at the UP-C1 and downward flow along the walls of containment. The velocities of flow field exist from 0.5 m/s, slow velocity in dome region, to 2.5 m/s, fast velocity in blowdown region.

According to the earlier study[2], it is expected that occurrences of updraft jet in center region near the break location and descending air current near the walls of containment. Also, as results of the above phenomenon, the natural circulation is predicted with distribution of velocities between 0.3 m/s and 3.0 m/s. And analysis for flow field of containment by other computer code was performed, and its trends of results seem similar with the trends of CAP calculation. In comparison with the results of above study and calculation, results of analysis for flow fields using CAP code are considered reliable.

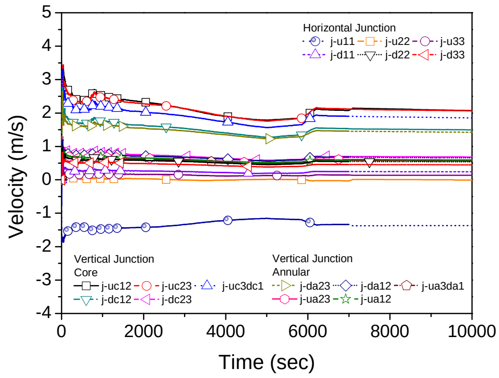

Fig. 2 Velocities in Junction

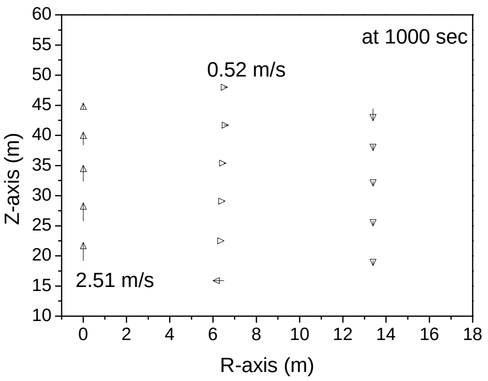

Fig. 3 Flow Fields of Atmosphere in Containment

4. Preliminary Analysis for PCCS Performance

Preliminary analysis for assumed PCCS design was performed by using CAP code whose condensation model is Uchida model. Fig. 4 shows CAP input nodalization model of SMART with PCCS. The containment is modeled as 6 multi compartments. Additionally, single volume model of containment was also considered to perform the node sensitivity study. The external pool is modeled as 4 nodes. The tube-type heat exchanger of PCCS is connected to the outside pool.

The calculation results of preliminary analysis for models with/without spray or PCCS are shown in Fig. 5. To confirm the feasibility, the CAP calculation results for the case with spray and without PCCS were compared with the results of the other computer code before PCCS performance analysis. The calculation results of each code show very similar trends. In the case without PCCS and containment spray, the pressure of containment reaches the peak point approximately at 3,400 sec. But for the case with PCCS and without spray, the pressure peak that was decreased by the PCCS working occurs approximately at 2,800 sec. Also, the peak pressure of multi compartment model is slightly lower than that of single compartment model.

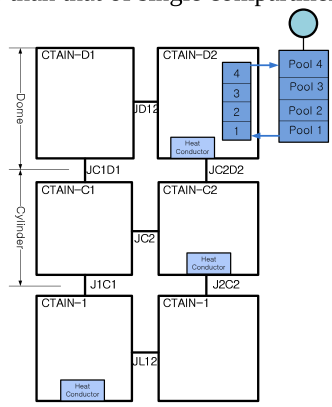

Fig. 4 Nodalization of SMART

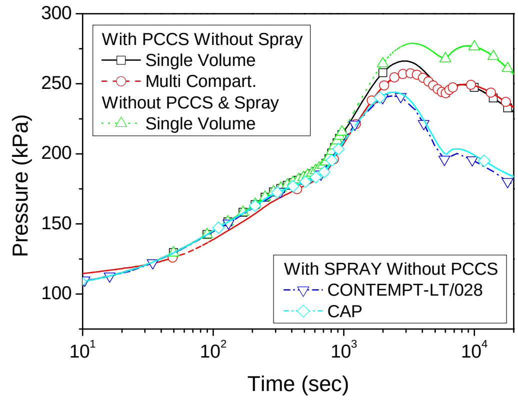

Fig. 5 Results in Preliminary Analysis for PCCS performance

5. Conclusion

Flow field in containment of conventional pressurized power reactor is formed by the accident-induced natural circulation, and it was intensively reviewed through literature surveys. And several calculations using the CAP and the other computer codes were actually carried out to find out the SMART containment flow field during SBLOCA. The calculation results seem well agreed with each other quantitatively and with the assessments in several literatures qualitatively. And, preliminary analyses for the PCCS performance of conceptual design were carried out based on the multi-compartment model using CAP code adopting Uchida model. It shows the feasibility of the CAP usage for the assessment of the PCCS. In further study, additional condensation models which can reflect the effect of containment field velocity are to be implemented.

Acknowledgement

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[2] de la Rosa, J.C., et al., Review on condensation on the containment structures, 2009.