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Investigation of Thermal Hydraulic Characteristics of PCCS According to the Containment Size

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1. Introduction

In the iPOWER, the Passive Containment Cooling System (PCCS) is installed to cool the Containment Building (CB), as shown in Fig. 1. In this case, the PCCS is operated under low-temperature and low-pressure conditions in the CB. And the thermal hydraulic characteristics of iPOWER PCCS are well known by previous studies.

Recently, there a trend to develop and commercialize Small Modular Reactors (SMRs) worldwide. Therefore, this study attempts to understand how the thermal hydraulic characteristics change when the PCCS is installed in the SMR with a small Containment Vessel (CV) through MARS-KS analysis of the conceptual problem.

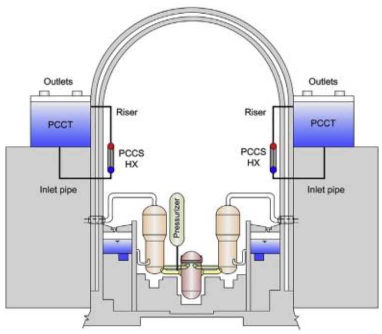
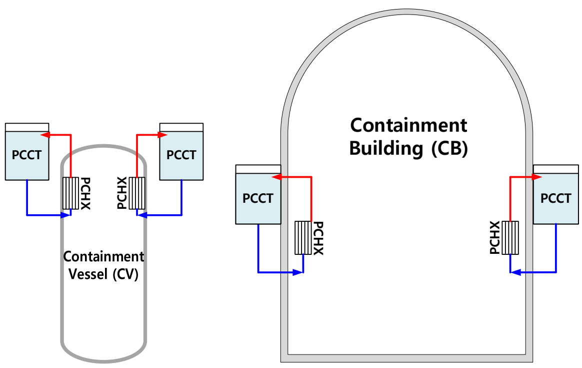


Figure 1. Schematic diagram for iPOWER PCCS [1]

2. Independent model for virtual PCCS and Analysis

An independent model for PCCS was developed using MARS-KS code according to the conceptual diagram shown in Fig 2. Fig 2(a) and (b) show the installation of the PCCS in the CV and CB, respectively. And Table I summarizes the assumed volume of the CV or CB.



(a) CV type (b) CB type
Figure 2. Conceptual diagram of PCCS installation

Table I: Assumed design values for containment

	CV type	CB type
Containment [m^3]	1,000	40,000

Fig. 3 shows the nodalization of the independent model for the virtual PCCS. The Passive Containment Cooling Tank (PCCT) was simulated with TANK component (T400). And using PIPE component for PCCS Heat eXchanger (PCHX) inlet and outlet pipe (C080 / C090 / C092).

Also, tubes of the PCHX were simulated with one PIPE component (C800), and the diameter and thickness of the tube were referred with the iPOWER PCCS design [1]. But the tube length and the number of the tubes were selected with an assumption of 2 m, and 300 EA for each train, respectively. And this number of tube is significantly smaller compared to the actual design of the iPOWER PCCS (2688 per train, [1]).

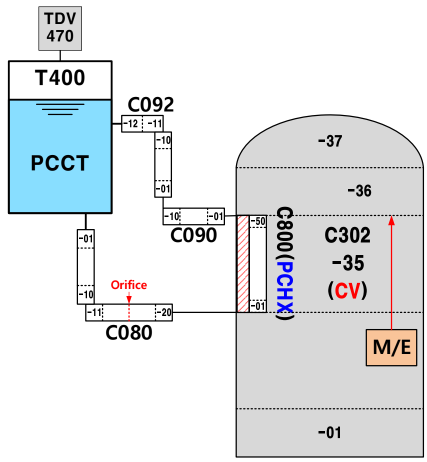
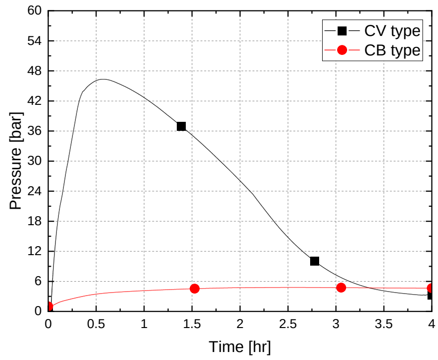


Figure 3. Nodalization of the virtual PCCS

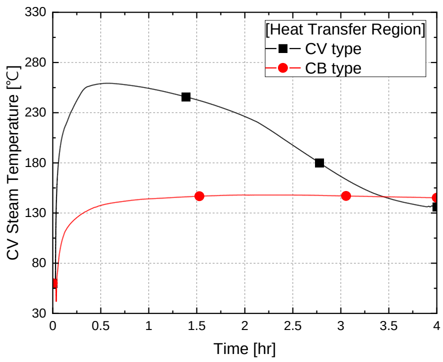
This study analyzed a Loss Of Coolant Accident (LOCA). For simulating the accident, the arbitrary Mass and Energy (M/E) were given as the boundary condition.

3. Analysis Result

Fig. 4 shows the P/T analysis result of the containment. The same PCCS and M/E were applied, but the result was different according to the containment size. When the containment is small, it is under the high-temperature and high-pressure conditions.



(a) Pressure



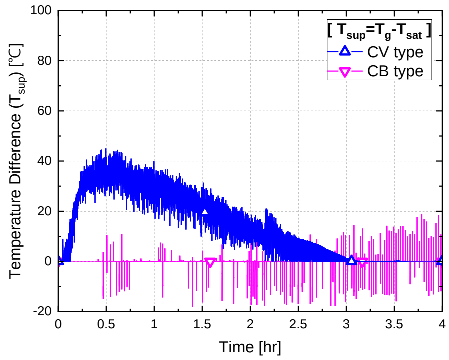
(b) Steam temperature (heat transfer region)

Figure 4. State of the CV and the CB during LOCA

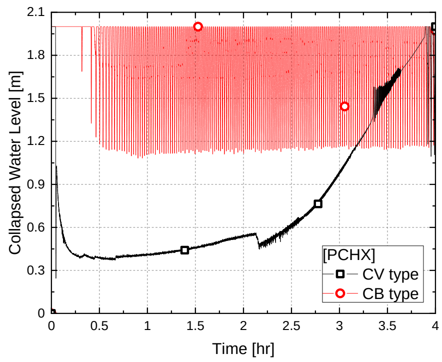
Fig. 5 shows the thermal hydraulic characteristic of the PCHX. The PCHX is exposed to high-temperature and -pressure conditions, when the volume of the containment is small. Accordingly, it can be confirmed that there is a lot of heat transferred to the tube, which quickly reaches saturation, and superheated steam is released through the heat exchanger outlet.

4. Conclusion

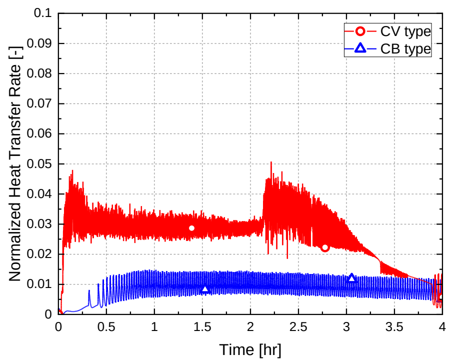
In this study, the thermal hydraulic characteristics of the PCCS were investigated by analysis of the conceptual problem according to the containment size using MARS-KS. As a result, when the PCCS is mounted in a containment building with a small volume, the phase change may occur rapidly due to high-heat flux, and the thermal hydraulic characteristics may be significantly different from those of the PCCS in the large nuclear power plants. When the PCCS is introduced into SMR with a small containment vessel, these characteristics must be well identified for the optimal design of the PCCS.



(a) Superheated temperature



(b) Collapsed water level



(c) Normalized heat transfer rate

Figure 5. State of the PCHX tubes during LOCA

5. Acknowledgements

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[1] S. G. Lim, H. C. No, S. W. Lee, H. G. Kim, J. Cheon, J. M. Kim, and S. M. Ohk, Development of stability maps for flashing-induced instability in a passive containment cooling system for iPOWER, NET, Vol. 52, Issue 1, pp. 37-50, 2020.