GOTHIC Simulation of Passive Containment Cooling System

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1. Introduction

One of main features of Advanced Light Water Reactors (ALWRs) such as AP1000, ESBWR, and AES-2006 is to use passive system as a containment cooling function, which provides long-term decay heat removal from the containment using natural forces. The PCCSs (Passive Containment Cooling Systems) of AP1000, ESBWR, and AES-2006 are as follows respectively. (1) AP1000: During a design-basis accident (DBA), heat is removed by externally cooled steel containment. Also, it is designed to maintain containment pressure below the design limit for 72 hours without operator action. (2) ESBWR: it is also capable of sustaining containment cooling for 72 hours. The performance of this system depends on the condensation of steam moving downward inside externally cooled vertical tubes. (3) AES-2006: During a DBA, heat is removed by internally cooled vertical tubes, which are located in containment. We are currently developing the conceptual design of Innovative PWR, which is will be equipped with various passive safety features, including PCCS. We have plan to use internal heat exchanger (HX) type PCCS with concrete containment. In this case, the elevation of HXs is important to ensure the heat removal during accidents. In general, steam is lighter than air mixture in containment. So, steam may be collected at the upper side of containment. It means that higher elevation of HXs, larger heat removal efficiency of those. So, the aim of the present paper is to give preliminary study on variation of heat removal performance according to elevation of HXs. With reference to the design specification of the current reactors including APR+, we had determined conceptual design of PCCS. Using it, we developed a GOTHIC model of the APR1400 containment was adopted PCCS. This calculation model is described herein and representative results of calculation are presented.

2. Calculation methodology

In this section some of the input parameters used to model APR1400 containment are described. The containment model includes control volumes, flow paths, and passive heat sinks.

2.1 Calculation case

For calculation, some conditions were assumed. LBLOCA event happened and all active components were disabled. Containment was initially filled with air. After the accident, PCCS was activated immediately. Model was calculated until 3600s after the accident.

2.2 Containment calculation model

2.2.1 Computer code

The containment thermal-hydraulic phenomena were calculated using the GOTHIC Version 8.0 computer code. GOTHIC code calculates the thermal-hydraulic behavior of a containment response from design basis accidents and severe accident sequences. GOTHIC code provides detailed thermal-hydraulic information in various containment areas.

2.2.2 Initial and Boundary condition

Containment initial conditions are summarized below:

Containment
- Temperature : 321.65K
- Pressure : 97.36 kPa
- Relative humidity : 90%

PCCS pool
- Temperature : 321.65K
- Pressure : 97.36 kPa

Mass and energy release data were used as boundary conditions for the GOTHIC calculation. In this paper, LBLOCA calculation results in the Standard Safety Analysis Report of APR+, which has higher reactor power than APR 1400, were used for conservative approach.

2.2.3 Containment model

A calculation model was composed of 31 control volumes and 142 flow paths for the containment and 36 volumes and 112 flow paths for PCCS. The volume of dome region was about 56000m^3, which was divided into 125 subdivided volumes.

2.2.4 PCCS model

The PCCS was composed of 32 passive containment cooling heat exchangers (PCCXs). In the calculation model, 4 small PCCXs were merged into 1 large PCCX. The 251 PCCX tubes were divided into 6 groups. Each group represents 42 tubes of equal length. Each tube group was divided into three subdivided volumes of equal length in the vertical direction. Each heat structure representing the tube walls had multiplicity of 42 in order to model the 42 identical tubes.

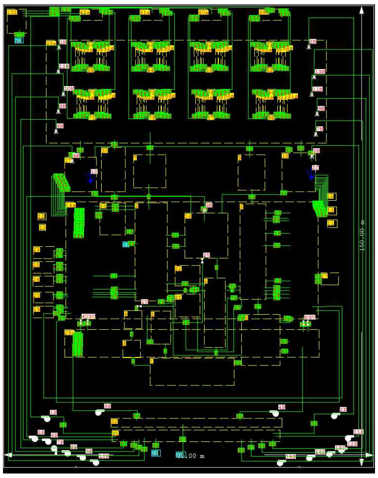

Fig. 1. GOTHIC model of containment.

3. Calculation results

Calculation was carried out by changing the installation elevation of PCCXs. The response of the containment pressure is presented in Fig. 2. As seen from the figure, it can be confirmed that PCCS is working properly. It is found that the pressure difference due to installation elevation of PCCXs is negligible, although there is slight difference at the beginning of accident.

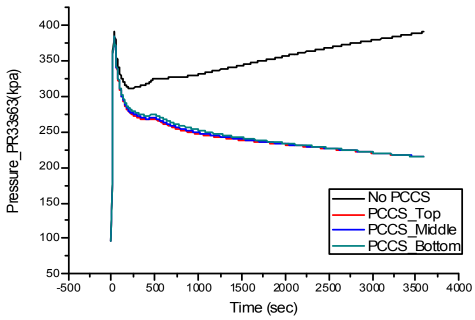

Fig. 2. Containment pressure response to LBLOCA.

Fig. 3 shows the response of the containment temperature. Similar to the pressure response, the difference according to the installation elevation of PCCXs is small.

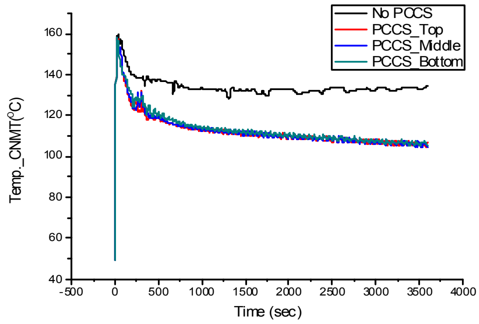

Fig. 3. Containment temperature response to LBLOCA.

Table I: PCC installation height

Index	Elevation(ft)
Top	276.73
Middle	224.67
Bottom	191.86

4. Conclusions and Further Studies

APR 1400 GOTHIC model was developed for PCCS performance calculation and sensitivity test according to installation elevation of PCCXs. Calculation results confirm that PCCS is working properly. It is found that the difference due to the installation elevation of PCCXs is insignificant at this preliminary analysis, however, further studies should be performed to confirm final performance of PCCS according to the installation elevation. These insights are important for developing the PCCS of Innovative PWR.

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