Containment PT Analysis in case of installation of PCCS using CAP Code

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1. Introduction

For improvement of the reliability of an engineered safety feature (ESF) related system, the application of passive feature in the advance reactor type, which replacing the active system, is a great tide. One of these passive features is the passive containment cooling system (PCCS). PCCS relies on the natural driving force such as gravity and natural circulation. Recently, in last year, a PCCS development project had been lunched under the leading of KHNP in Korea, in collaboration with KEPCO-ENC, KAERI, FNC and academic circles. The goal of this project is developing of the conceptual design of containment passive cooling system, including PMCCS (Passive Molten Core Cooling System) and furthermore, applying to APR+ and iPOWER reactor finally.

Advanced researches on PCCS were carried out by global nuclear industrial companies and the several types of reactor, such as AP1000, ESBWR and VVER, were introduced. Using the different way, these reactor types, however, are devised to mitigate the consequence of LOCA accident and remove the long-term decay heat. To confirm the reliability of PCCS function during an accident progress, experimental proofs and computational evaluations are vital. As a preliminary test, therefore, this research shows the containment pressure and temperature analysis results using CAP code in case of installation of PCCS in containment with rough dimension, capacity and design available at this time.

2. CAP Input Model

CAP (Containment Analysis Package) code has been developed to simulate the pressure and temperature behavior during the DBA. It uses the lumped parameter or multi-dimensional approaches to compose the compartments in containment and has various components and physical models to simulate the thermal-hydraulic phenomena occurred in containment.

2.1 Accident Condition

For this preliminary evaluation on PCCS performance, author choose the accident of ShinKori 3/4 DEDLSB (Double-End Discharge Line Small Break) with maximum ECCS. Not only the containment design specification and passive heat sink information, but the amount of mass and energy release and is same as APR1400 conditions.

2.2 Condensation Model

Condensation phenomenon plays the key role in the estimation of PCCS performance. Typically, Uchida and Tagami condensation model, which are recognized as conservative, has been used to calculate the condensational heat transfer rate on passive heat skins such as containment outer wall, metal structure and etc. Unlike these containment structures, PCCS heat exchange tube has the different heat removal mechanism and there may be necessary to choose the more PCCS specific one.

In this research, Dehbi's and Uchida condensation model are tested for PCCS. Dehbi's condensation correlation is expressed as:

$$\overline{h}_L = \frac{L^{0.05}\left\{\left(3.7+28.7P\right)-\left(2438+458.3P\right)Log\left(W\right)\right\}}{\left(\overline{T}_\infty-\overline{T}_W\right)^{0.25}}$$

Which can be applicable for 0.3m < L < 3.5m, 1.5 atm < P < 4.5 atm and 10 ^{o}C < $\overline{T}_\infty-\overline{T}_W$ < 50 ^{o}C.

Dehbi's experiments were conducted in similar configuration with PCCS type considered in the project; subcooled coolant heat transfer inside tube and condensation heat transfer outside tube.

2.3 Input Model and Nodalization

In other to place the PCCS, some modification from the base input model is conducted; removing the spray system and replacing with PCCS. Single containment and single PCCS system are considered for simplicity and all input parameters of PCCS heat exchanger tube, related with heat transfer, are exactly same as that of single tube. Heat transfer area and PCCT volume are equivalent to whole quantity of PCCS. Figure 1 describes the schematic diagram of input model.

Initial conditions and some geometrical information are as follows:

- Containment
  - Volume: 8.875E+4 m^3
  - Pressure: 115.52 kPa
  - Temperature and Humidity: 326.5 K and 50 %

- PCCS
  - PCCS heat transfer area: 7115.63 m^2
  - PCCT volume: 5736.7 m^3
  - PCCT temperature: 322.05 K

3. Calculation results

Figure 2 shows the pressure behavior of containment during DEDLSB accident. Symbol marks indicate the containment pressure of CONTEMPT-LT calculation for Shinkori 3/4, while lines of CAP calculations under activation of spray system. CAP result shows the very similar trend with the Shinkori 3/4,

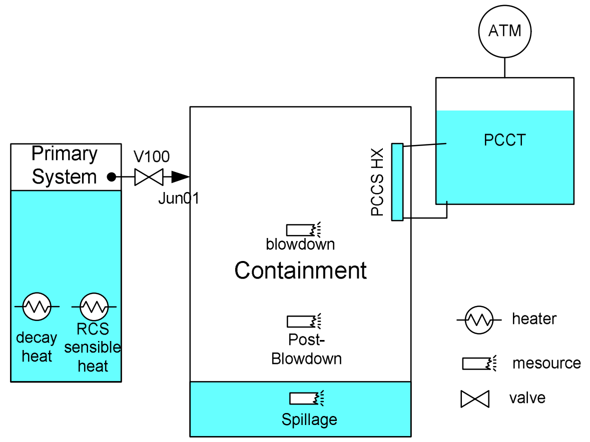

Fig. 1. Nodalization of PCCS

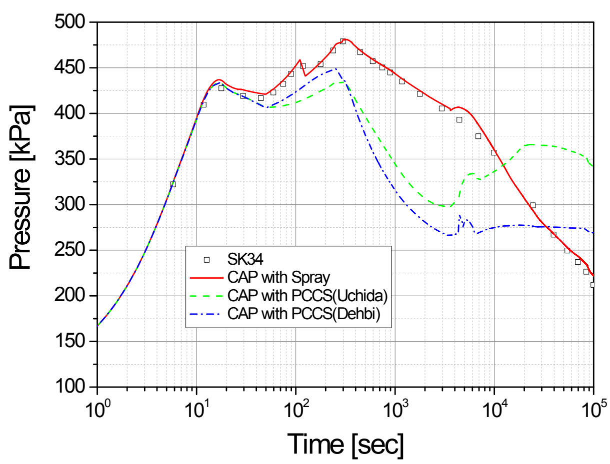

Fig. 2. Containment Pressure Behavior with PCCS

while, with PCCS, better suppression ability of the containment pressure is observed until the EOB (end-of-blowdown). After the EOB, however, containment re-pressurization is observed because of the reduction of heat removal rate of PCCS heat exchanger. It results from the increment of PCCT coolant temperature and decrement of heat removal rate through the PCCS heat exchanger. In the case of using Dehbi's correlation rather than Uchida model, more pressure suppression effect is observed. It may be an inevitable consequence allowing for Uchida's conservative application.

3. Conclusions

To evaluate the PCCS performance, CAP code simulation is preliminarily conducted on the ShinKori 3/4 DEDLSB accident. Two condensation models, Uchida and Dehbi's correlation, are tested for the condensation model applied on PCCS condensation tube outside surface. As compared with the existing spray system, it revealed the good performance in terms of containment pressure reduction. On the other hand, re-pressurization with the start of PCCT coolant temperature increment is observed also.

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