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Preliminary Sensitivity Study of Upper Head Nodalization for LBLOCA in APR-1400

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1. Introduction

In the best estimate (BE) method with the uncertainty evaluation, the system nodalization is determined by the comparative studies of the experimental data and it could influence the prediction accuracy for specific phenomena such as ECC bypass and blowdown quenching. Up to now, it was assumed that the temperature of the upper dome in APR-1400 was close to that of the cold leg. However, it was found that the temperature of the upper head/dome might be a little lower than or similar to that of the hot leg through the evaluation of the detailed design data. Since the higher upper head temperature affects blowdown quenching and peak cladding temperature in the reflood phase, the nodalization for upper head should be modified. In this study, the preliminary sensitivity study of original and modified nodalization for LBLOCA was performed, and the effect of upper head nodalization and temperature was evaluated qualitatively.

2. Nodalization of Upper Head

The upper head was generally defined as the region above the upper guide structure assembly as shown in Fig. 1 (a). The upper head consists of the upper guide structure assembly and the CEA shroud assembly. There are many holes in these assemblies to exchange the flow between the inner- and the outer-region. The conventional (original) upper head nodalization is shown in Fig. 1 (b). The upper head was composed of four single-volumes and the guide structure was modeled separately from the upper head. In this nodalization, the flow circulation between the upper plenum and the upper head/dome was not considered significantly since it was assumed that the circulation rate was much smaller than the primary coolant flow rate. However, there are actually the upward and downward flows in the upper head and this circulation flow can transfer the heat of the upper plenum to the upper dome. Figure 1 (c) shows modified nodalization reflecting design data. The upper head was separated into 2 axial volumes to simulate the actual circulation flow, and two axial volumes were connected each other with the cross flow junctions. In this study, these two nodalizations were considered for the sensitivity study.

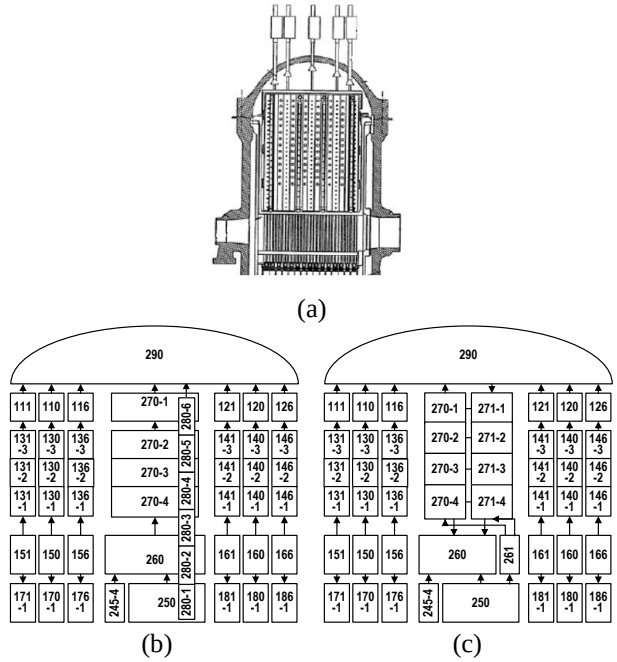

Fig. 1. Nodalization of Upper Head

3. Results and Discussion

The steady state calculation was performed to obtain initial conditions for LBLOCA transient analysis by MARS-KS code. The upper head temperature was generally determined by the bypass rate (the key-ways bypass) from the downcomer into the upper head and CEA guide flow rate. In this study, the key-way bypass was determined to be ~ 0.3 %. The larger the key-ways bypass makes the upper head/dome temperature colder. Figure 2 shows the upper head temperature according to the upper head nodalization. The upper head volume number was plotted along the X axis and the volume number of 290 represented the upper dome. For original (1 channel) nodalization, the temperature of upper dome (node no. 128) and upper head (node no. 270) is relatively low and closer to that of cold leg. In Case of modified (2 channel) nodalization, the flow circulates between the upper plenum and the upper dome, so the temperature of upper head is relatively high and closer to that of hot leg. However, the upper head temperature of 2 CH nodalization is much higher than design value. Therefore, the adjustment should be needed in further study.

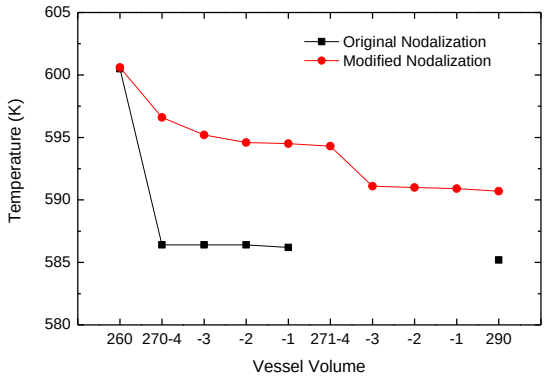

Fig. 2. Upper Head Temperature in Steady State Condition

Figure 3 shows the void fraction of upper plenum (node no. 260) according to the nodalization. Since the upper head temperature of 2 CH nodalization is much higher than that of 1 CH nodalization, the water in the upper head changes to the vapor due to flashing easier; that means water inventory resulting in blowdown quenching become smaller.

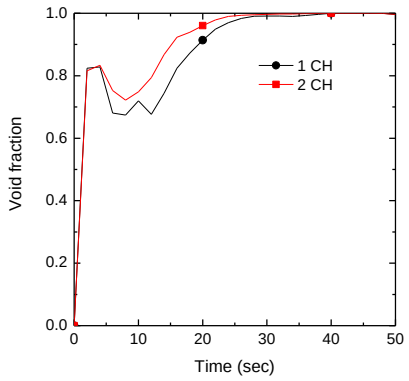

Fig. 3 Void Fraction of Upper Plenum

Figure 4 compares the cladding temperature of 1 CH and 2 CH nodalization. As mentioned before, the upper head temperature of 2 CH nodalization is much higher than design value. Therefore, this result shows the effect of upper head temperature on the LBLOCA PCT qualitatively. For 1 CH nodalization, the PCT occur in blowdown phase and blowdown quenching does significantly due to lower upper head temperature in steady state. For 2 CH nodalization, the blowdown PCT is similar to 1 CH result. However, the blowdown quenching is reduced significantly, and as a result, the reflood PCT was predicted to be higher than the blowdown PCT. The final quenching is also delayed. This result is caused by very conservative upper head temperature determination. In the future work, quantitative comparison of PCT according to upper head nodalization will be made.

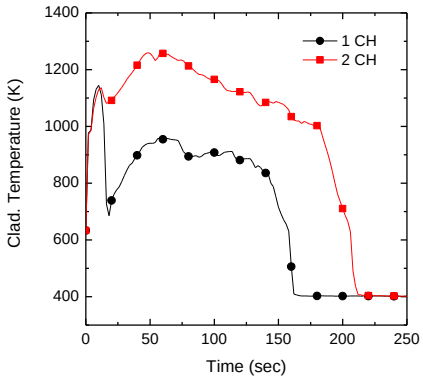

Fig. 4. Cladding Temperature
(Higher UH temp. than design for 2 CH nodalization)

4. Conclusion

In this study, the preliminary sensitivity study of original and modified nodalization for upper head in APR-1400 was performed, and the effect of upper head nodalization and temperature on LBLOCA PCT was evaluated qualitatively. In this study, the key-way bypass was determined to be ~ 0.3 %. The steady state condition which is the initial condition for LBLOCA was obtained by MARS-KS calculation. However, the upper head temperature of 2 CH nodalization was much higher than design value. Through the transient calculation, it was confirmed that the upper head temperature affects the water inventory in the upper head at the early stage of LBLOCA so it does the blowdown quenching and following reflood PCT significantly. The results in this study were caused by very conservative upper head temperature determination. In the future work, the adjustment of input deck to reflect the design appropriately and quantitative comparison of PCT according to upper head nodalization will be made.

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