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Evaluation for Effect of Upper Head Nodalization in OPR1000 Plant

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1. Introduction

Nowadays, the best estimate method with the uncertainty evaluation has been broadly used worldwide in licensing of NPP. In Korea, the LBLOCA analysis using the best-estimate (BE) methods to replace the old conservative evaluation method (EM) was performed by the licensee in several plants such as WH type Units, OPR1000 and APR1400. In the BE method, the nodalization for base calculation was defined from the comparative study of the experimental data and it could influence the accuracy of code for specific phenomena such as ECC bypass and blowdown quenching.

The nodalization of upper head for OPR1000 and APR1400 was generally composed of axial several single volumes and the flow recirculation between the upper plenum and the upper head/dome was not considered significantly since the recirculation 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 recirculation flow can transfer the heat of the upper plenum to the upper dome. Up to now, it was assumed that the temperature of the upper dome was close to that of the cold leg in most LOCA analyses to consider the effect of bypass flow from the downcomer to the upper dome. However, it was recently found that the temperature of the upper dome might be larger than that of the cold leg according to the heat exchange due to the recirculation flow and the detailed design data. Therefore, the high upper dome temperature can influence the modification of nodalization for upper head and the blowdown quenching behavior.

In this study, the LBLOCA in OPR1000 was evaluated to identify the effect of upper head nodalization.

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. 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 upper head nodalization is shown in Fig. 1 (a). The upper head was composed of three single-volumes and the guide structure was modeled separately from the upper head. In this study, two nodalization methods were considered for the sensitivity study. As shown in Fig. 1 (b), the guide structure was modeled as 5 single volumes and the single junction was connected from the upper guide structure to the upper head for more easily exchanging flow. In Fig. 1 (c), the upper head was separated into 2 axial volumes to simulate the actual recirculation flow. Two axial volumes were connected each other with the cross flow junctions.

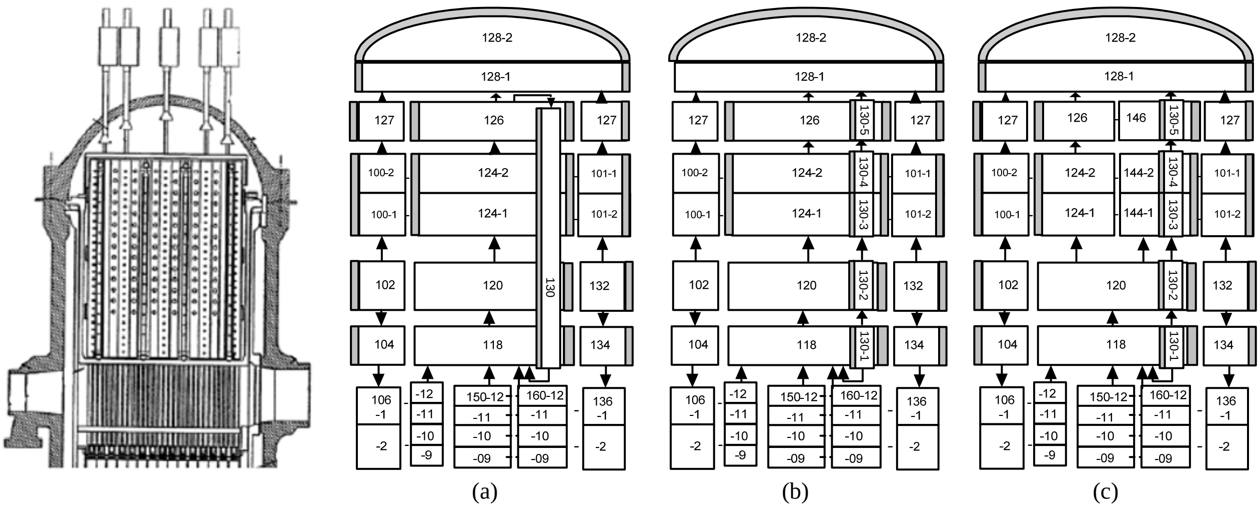

Fig 1. Nodalization of Upper Head

3. Analysis Results

The initial conditions for LBLOCA analysis were obtained from the steady state calculation of MARS code [1]. The input for OPR1000 considered the increment of linear heat generation rate and the reduction of RCS flow according to the recent licensing experiences and the calculated initial conditions show a good agreement to the plant actual values for the major parameter such as a core power, pressurizer pressure and hot & cold leg flow rates.

Fig. 1 shows the calculated PCT for the upper head nodalization. In case for Fig. 1 (a), the temperature of upper dome has a similar value with the cold leg. After a LBLOCA, the blowdown quenching occurs significantly due to relatively low temperature of upper dome. In cases for Fig. 1 (b) and (c), the upper dome has the temperature running 10 K to 15 K above that of Fig. 1 (a) because of the flow exchange and this influences the behavior of blowdown quenching. After break, the blowdown temperature increases rapidly due to the sudden coolant loss, which is the similar for all cases. After that, the blowdown quenching results from the rewet due to the coolant flow in core and the high temperature of upper dome reduces the depth of blowdown quenching as shown in Fig. 2. Also, the relative low blowdown quenching generates a higher reflood temperature.

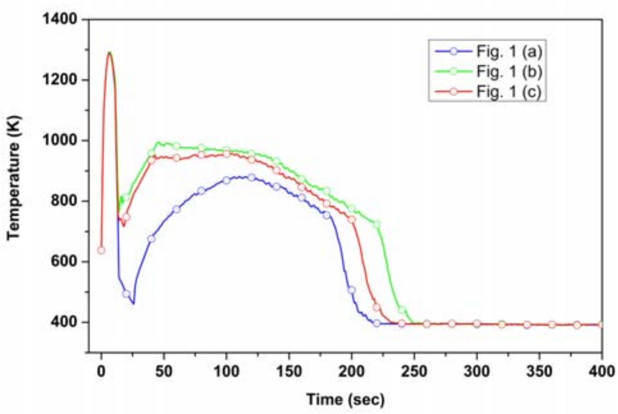

Fig. 2 Cladding Temperature according to Nodalization of Upper Head

The KINS (Korea Institute of Nuclear Safety) has also conducted the regulatory audit calculation by using the KINS Realistic Evaluation Methodology (KINS-REM) to confirm the validity of licensee's calculation. The 22 uncertainty parameters were considered in KINS-REM evaluation for OPR1000 and the nodalization of Fig. 1 (a) was used at that time [2]. In this study, the effect of nodalization change was evaluated in KINS-REM. The 9 cases, which have a high reflood temperature, were selected as the evaluation targets. The nodalization of upper head of Fig.1 (c) was applied to this calculation. Fig. 3 shows the cladding temperature behaviors for the nodalization of Fig.1 (c). As shown Fig. 3, the blowdown quenching doesn't occur significantly and the reflood peak temperature doesn't increase as much as expected. Many uncertainty parameters can affect the behaviors of blowdown quenching and reflood PCT and the effect of nodalization of upper head cannot be shown significantly in this calculation. However, we can identify that the blowdown quenching was finished at the higher temperature and the reflood PCT was increased to a certain degree. The average increment of reflood PCT is ~ 20 K in comparison with the results for the nodalziation of Fig. 1 (a).

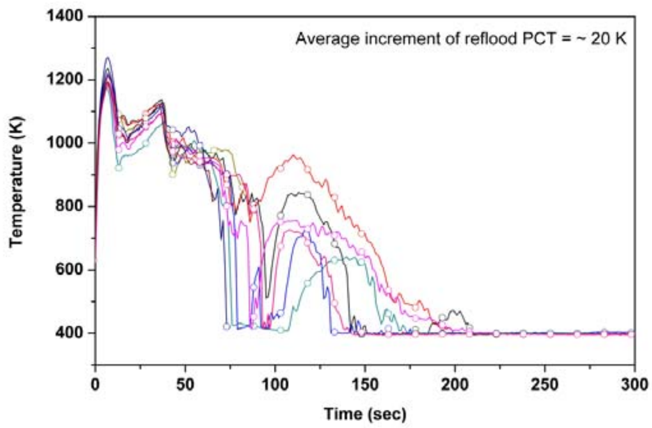

Fig. 3 Cladding Temperature in KINS-REM for OPR1000

4. Conclusion

The LBLOCA calculation for OPR1000 was performed to identify the effect of the upper head nodalization. If the nodalization is changed to exchange the flow between the upper plenum and the upper head/dome, the temperature of the upper dome increases and the blowdown quenching happens at the higher temperature. Also, the modification of nodalization influences the BE method with the uncertainty and the PCT behavior can be changed. The more detailed analysis for the effect of nodalization would be needed to consider the temperature distribution in the core appropriately.

REFERENCES

[1] KAERI, MARS Code Manual, KAERI/TR-3402, 2005.

[2] KINS, Audit Calculation for the LOCA Methodology for KSNP, KINS/HR-766, 2006.