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Assessment of Effect on LBLOCA PCT for Change in Upper Head Nodalization

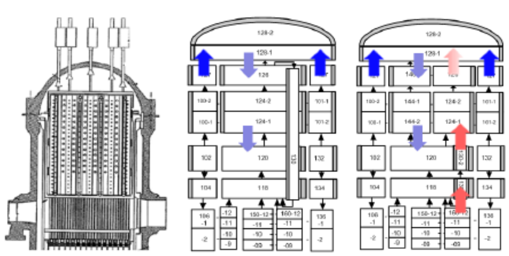
Dong Gu Kang*, Byung Gil Huh, Seung Hun Yoo, Young-Seok Bang, Kwang-Won Seul, Dae-Hyung Cho
Korea Institute of Nuclear Safety, 62 Gwahak-ro Yuseong-gu Daejeon Korea
**Corresponding author:littlewing@kins.re.kr*

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. Up to now, it was assumed that the temperature of the upper dome in OPR-1000 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 best estimate plus uncertainty (BEPU) analysis of LBLOCA for original and modified nodalizations was performed, and the effect on LBLOCA PCT for change in upper head nodalization was assessed.

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 (original) upper head nodalization is shown in Fig. 1 (1). The upper head was composed of three single-volumes and the guide structure was modeled separately from the upper head. Figure 1 (2) 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.



(1) (2)

Fig. 1. Nodalization of Upper Head

3. Application of KINS-REM

The KINS-REM has three elements subdivided by fourteen steps. In this study, MARS-KS 1.3 was used as analysis code, the 95 percentile PCT with 95% confidence level ($PCT_{95/95}$) was determined as comparison variable. The $PCT_{95/95}$ against LBLOCA was calculated according to KINS-REM procedure. The descriptions for procedures not changed were skipped.

1. Specify Scenario: The LBLOCA by 100% double-ended guillotine break at the reactor coolant pump discharge leg which are the limiting break size and location, was selected as accident scenario.

2. Select NPP: The OPR-1000 was chosen to be analyzed.

4. Select Frozen Code: The MARS-KS 1.3 code was selected as a frozen BE code. It has improved reflood model and it can dial uncertainty parameters related to reflood model/correlations.

8. Determine Parameter Ranges: The uncertainty parameters related to reflood model were added to previous uncertainty parameters identified in KINS-REM. Table 1 shows the range and distribution of uncertainty parameters used in this study.

Table 1. Uncertainty Parameter Range and Distribution

No	Models/ Parameters	Dis.	Range	Mean
1	Gap conductance	Uniform	0.4~1.5	0.95
2	Fuel thermal conductivity	Uniform	0.847~1.153	1.0
3	Core power	Normal	0.98~1.02	1.0
4	Decay heat	Normal	0.934~1.066	1.0
5	Groeneveld CHF	Normal	0.17~1.8	0.985
6	Chen nucleate boiling	Normal	0.53~1.46	0.995
7	Chen transition boiling	Normal	0.54~1.46	1.0
8	Dittus-Boelter liquid convection	Normal	0.606~1.39	0.998
9	Dittus-Boelter vapor convection	Normal	0.606~1.39	0.998
10	Bromley film boiling	Normal	0.428~1.58	1.004
11	Zuber CHF correlation	Normal	0.38~1.62	1.0
12	Weismann correlation	Lognormal	0.5~2.0	1.0
13	QF Bromley correlation	Normal	0.75~1.25	1.0
14	F-R correlation (reflood)	Normal	0.5~1.5	1.0
15	Vapor correlation (reflood)	Normal	0.5~1.5	1.0
16	Break CD	Normal	0.729~1.165	0.947
17	RCP 2-phase head m.	Uniform	0~1	0.5
18	RCP 2-phase torque m.	Uniform	0~1	0.5
19	SIT pressure (MPa)	Uniform	4.031~4.459	4.245
20	SIT water inventory (m^3)	Uniform	50.69~54.57	52.63
21	SIT water temp. (K)	Uniform	283.2~322.0	302.6
22	RWST temp. (K)	Uniform	277.6~322.0	299.8

4. Results and Discussion

To determine $PCT_{95/95}$, 124 sets of parameters were generated by random sampling. Figure 2 shows the PCTs of original (1 channel) nodalization for 124 cases, and $PCT_{95/95}$ was estimated to be 1318.88 K. As shown in this figure, most of PCT occur in blowdown phase and blowdown quenching does significantly due to lower upper head temperature in steady state. Figure 3 shows the PCTs of modified (2 channels) nodalization, and estimated $PCT_{95/95}$ of 1333.43 K was higher than original result. Since the upper head temperature calculated using modified nodalization is higher than original one, the blowdown quenching is reduced significantly, and as a result, reflood PCT was predicted to be higher. Final quenching is also delayed.

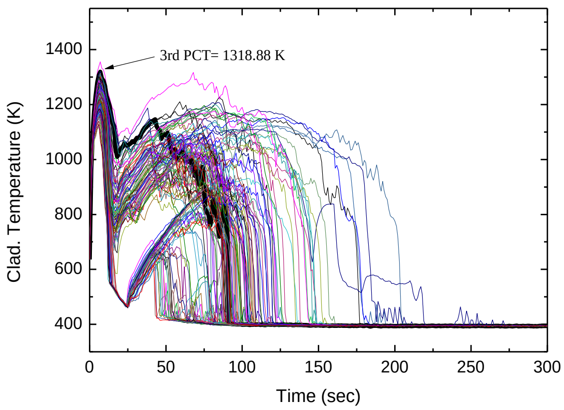


Fig. 2. PCTs for 124 cases (1 channel)

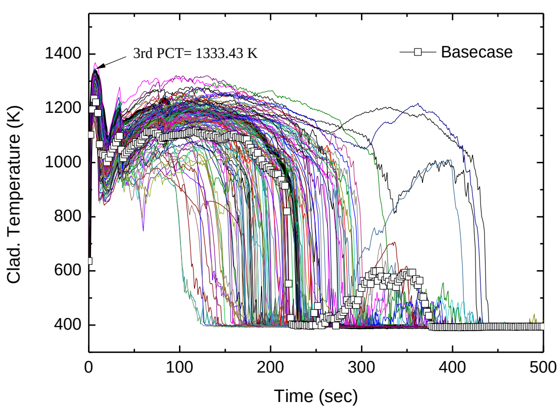


Fig. 3. PCTs for 124 cases and base case (2 channels)

The distributions of blowdown PCT are quite similar to each other. However, it was shown that the distributions of reflood PCT have big difference according to upper head nodalization as shown in Fig. 4 and 5. While the distribution of reflood PCT for 1 channel upper head nodalization is widely distributed as shown in Fig. 4, that for 2 channels model is narrowly distributed and PCTs were much higher than those for 1 channel model as shown in Fig. 5.

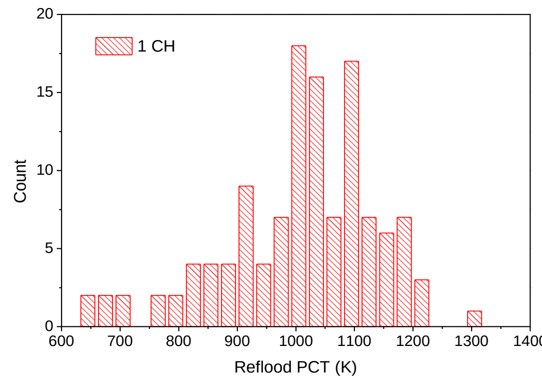


Fig. 4. Reflood PCT Distribution (1 channel)

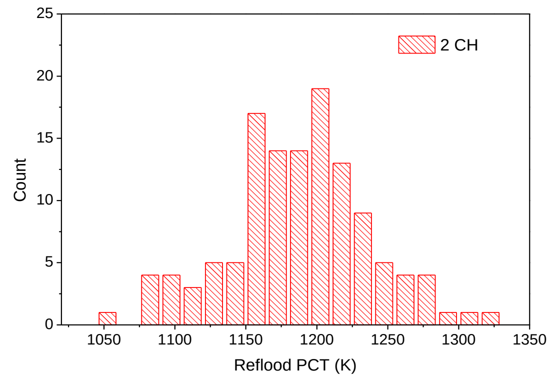


Fig. 5. Reflood PCT Distribution (2 channel)

5. Conclusion

In this study, the best estimate plus uncertainty (BEPU) analysis of LBLOCA for original and modified nodalizations was performed, and the effect on LBLOCA PCT for change in upper head nodalization was assessed. It is confirmed that modification of upper head nodalization influences PCT behavior, especially in the reflood phase. In conclusions, the modification of nodalization to reflect design characteristic of upper head temperature should be done to predict PCT behavior accurately in LBLOCA analysis.

REFERENCES

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