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Effect of Uncertainty Parameters in Blowdown and Reflood Models for OPR1000 LBLOCA Analysis

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1. Introduction

In Korea, the best-estimate plus uncertainty (BEPU) methods instead of the conservative evaluation method (EM) were applied to the LBLOCA analysis of several plants by the licensee. KINS(Korea Institute of Nuclear Safety) has also performed the audit calculation with the KINS Realistic Evaluation Methodology(KINS-REM) to confirm the validity of licensee's calculation[1]. In the BEPU method, it is very important to quantify the code and model uncertainty. It is referred in the following requirement: BE calculations in Regulatory Guide 1.157 – "*the code and models used are acceptable and applicable to the specific facility over the intended operating range and must quantify the uncertainty in the specific application*". In general, the uncertainty of model/code should be obtained through the data comparison with relevant integral- and separate-effect tests at different scales. However, it is not easy to determine these kinds of uncertainty because of the difficulty for evaluating accurately various experiments. Therefore, the expert judgment has been used in many cases even with the limitation that the uncertainty range of important parameters can be wide and inaccurate.

In the KINS-REM, six heat transfer parameters in the blowdown phase have been used to consider the uncertainty of models. Recently, MARS-KS[2] code was modified to consider the uncertainty of the five heat transfer parameters in the reflood phase[3]. Accordingly, it is required that the uncertainty range for parameters of reflood models is determined and the effect of these ranges is evaluated. In this study, the large break LOCA (LBLOCA) analysis for OPR1000 was performed to identify the effect of uncertainty parameters in blowdown and reflood models.

2. Uncertainty Parameters

Table 1 show the uncertainty range and distribution for the blowdwon and reflood models. In MARS-KS, the sampled value was multiplied by the calculated value for these 11 separate models, respectively. The uncertainty range in Table 1 was determined conservatively by the expert judgment considering the reports for experiments.

3. Analysis Results

The upper head nodalization was changed to consider the high upper dome temperature of OPR1000. As shown in Fig. 1, the upper head was separated into 2 axial volumes to simulate the actual recirculation flow. Two axial volumes were connected with the cross flow junctions. The important input parameters and initial conditions for the emergency core cooling system (ECCS) were determined as the nominal values in BE methodology of FSAR[4]. The calculated initial conditions showed a good agreement to the plant actual values for the major operating parameters.

Table 1. Uncertainty Range and Distribution

Models/parameters	**Range and Distribution**
Blowdown model	
Groeneveld-CHF	0.17~1.8 (N)
Chen-nucleate boiling HT	0.53~1.46 (N)
Transition Boiling Criteria	0.54~1.46 (N)
Dittus-Boelter (liquid)	0.606~1.39 (N)
Dittus-Boelter (vapor)	0.606~1.39 (N)
Bromley film boiling	0.428~1.58 (N)
Reflood model	
Zuber Pool boiling CHF	0.38~1.62 (N)
Modified Weismann	0.5~2.0 (L)
Modified Bromley	0.75~1.25 (N)
Forslund-Rohsenow	0.5~1.5 (N)
Vapor correlation	0.5~1.5 (N)

* Distribution (L : Log-Normal, N : Normal)

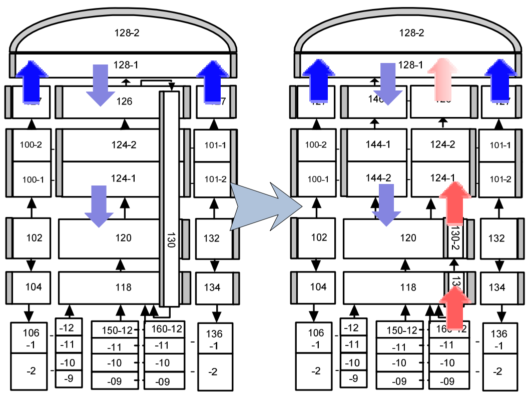

Fig. 1 Upper head nodalization of OPR1000

Fig. 2 and Fig. 3 show the variation of blowdown PCT (Peak Cladding Temperature) and final quenching time. The minimum and maximum uncertainty values were applied to compare the reference base calculation. In general, the blowdown temperature could be affected by the internal stored energy of the fuel and the heat transfer rate in the blowdown phase. If the minimum uncertainty value was used at the separate blowdown model, the heat transfer rate was reduced and then the blowdown PCT could increase. As shown in Fig. 2 and 3, the blowdown PCT increase and the quenching time delay occurred at the minimum uncertainty value. The Dittus Boelter correlation for vapor and the Groeneveld CHF correlation had a large impact on the blowdown PCT. As soon as the initiation of accident, the abrupt flashing and boiling occurred because of the rapid depressurization. Therefore, the blowdown heat transfer could be more significantly influenced by the above two correlations.

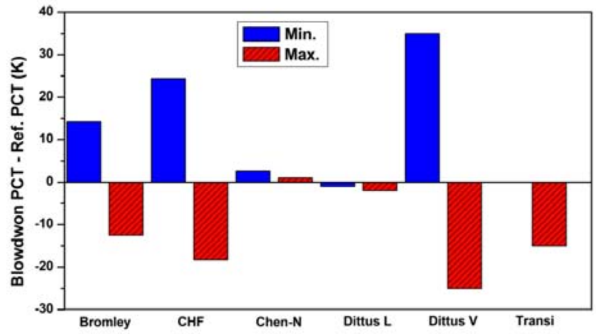

Fig. 2 Blowdown PCT difference for the blowdown models

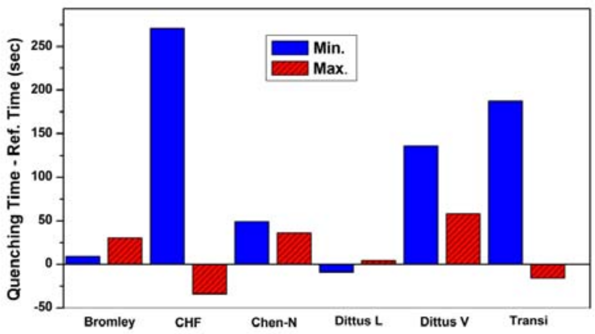

Fig. 3 Quenching Time difference for the blowdown models

Fig. 4 and Fig. 5 show the variation of reflood PCT and final quenching time. For most reflood models, the reflood PCT increased and the final quenching time delayed regardless of the uncertainty values. Especially, for the modified Weismann correlation, the reflood PCT increased greatly even at the maximum uncertainty value. This correlation applied dominantly at the close area from the quenching front. Therefore, as the heat transfer with this correlation increases, the vapor formation may be accelerated and the reflood quenching may be delayed relatively. Also, it may be resulted from the conservative application of the uncertainty range by the expert judgment. In the reflood phase, the core region was filled with the mixture of liquid, vapor and droplet and then various heat transfer mechanisms could be applied to the inner core. Actually, it was difficult to determine accurately the uncertainty range of specific model in the reflood phase.

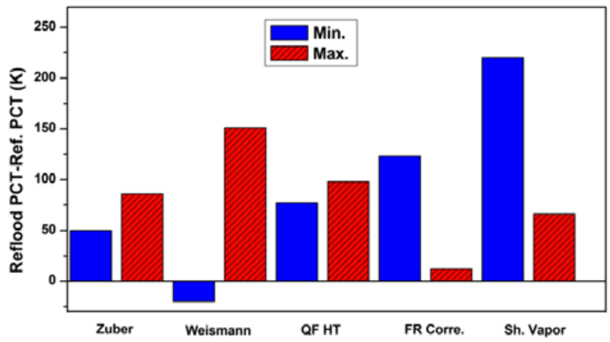

Fig. 4 Reflood PCT difference for the reflood models

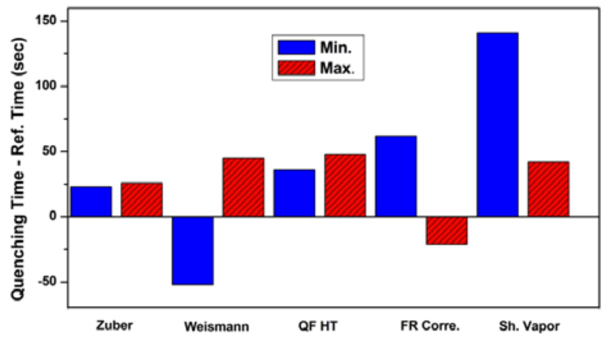

Fig. 5 Quenching time difference for the reflood models

4. Conclusion

The LBLOCA calculation for OPR1000 was performed to evaluate the effect of uncertainty parameters in blowdown and reflood models. The blowdown PCT increased at the minimum uncertainty value as expected. However, the reflood PCT didn't show consistent tendency due to the complicated heat transfer mechanisms. Therefore, in order to obtain the more robust uncertainty range, the generic tool would be needed for quantifying model uncertainties.

REFERENCES

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