Transactions of the Korean Nuclear Society Spring Meeting
Gyeongju, Korea, May 29-30, 2008

Evaluation of Scale Bias Effect in LBLOCA of UPI Plant

Byung Gil Huh*, Young Seok Bang, Deog-Yeon Oh, and Sweng Woong Woo
Korea Institute of Nuclear Safety
*huha@kins.re.kr**

1. Introduction

The Kori Unit 1 is the Westinghous two-loop PWR with the upper plenum injection (UPI) in the emergency core cooling system (ECCS). Generally it is known that the thermal-hydraulic phenomena during LBLOCA of UPI plants are very complicate and show the different characteristics in comparison with the cold leg injection PWRs.

Nowadays, the best estimate methods with the uncertainty evaluation are broadly used worldwide in licensing of NPP. In Kori Unit 1, the LBLOCA analysis using the best-estimate methods to replace the old conservative evaluation method (EM) was performed by the licensee in the Periodic Safety Review (RSR) for the continuous operation [1]. The KINS (Korea Institute of Nuclear Safety) was also conducting the regulatory audit calculation by using the KINS Realistic Evaluation Methodology (KINS-REM) to confirm the validity of licensee's calculation [2].

In KINS-REM, the final peak cladding temperature (PCT_{final}) was obtained as below;

$$PCT_{final} = PCT_{95/95} + B_{SCALE} + B_{IET} + B_{SET} + B_{PLANT} \quad (1)$$

where $PCT_{95/95}$ are the PCT with 95% confidence and 95% probability level. B_{SCALE}, B_{IET}, B_{SET} and B_{PLANT} are the bias due to the scale, the accuracy of code/model for the integral/separate effect tests and the system parameters which was not considered in determination of $PCT_{95/95}$, respectively.

The present study aims to discuss the bias due to the scale. The RELAP5/MOD3.3 was used in this study. From several studies, we can identify that the RELAP5/MOD3.3 has predicted conservatively the experimental results for the ECC bypass and steam binding. However, in order to consider major UPI phenomena, the effect of scale bias should be evaluated for the ECC bypass and the steam binding.

2. Effect of ECC Bypass

In KEPRI Realistic Evaluation Methodology (KREM) [3], the licensee evaluated the ECC bypass by using the experimental data of UPTF 4A. The amount of ECC bypass was determined as 1,000 kg in KREM and it was also used in PSR of Kori Unit 1. It corresponded to 8.9% of total injected flow in Kori Unit 1. Also, the licensee considered additionally the ECC bypass of the accumulator and high head safety injection (HHSI) in the intact loop. The amount of bypass flow was evaluated as about 10% of total injected flow. Therefore, total bypass flow including 1,000 kg, was about 18.9% of total flow injected into the intact loop in Kori Unit 1.

In this study, the ECC bypass was evaluated as following procedures;

2.1 Assumptions

In this study, the PCT occurred at 31 sec and the high/low head safety injection started at 30 sec. Therefore, the effect of safety injection was insignificant for the peak cladding temperature. The accumulator water was injected into the intact loop at 11 sec and then the bypass effect of this water was important to PCT behaviors. In the evaluation of ECC bypass, main assumptions are as below;

- The safety injection in broken loop and the bypass of HHSI in intact loop were not considered.
- One low head safety injection (LHSI) was available and the bypass of LHSI was not considered.
- The bypass of accumulator water in intact loop was only considered.

2.2 Method

The ECC bypass flow was obtained by evaluating the amount of water containing boron in total break flow as the following procedure;

- The boron concentration of accumulator in the intact loop was assumed as 1 and the rest part of the plant has no boron.
- The amount of water containing boron in total break flow was evaluated.
- The boron concentration at the upstream node of break is as follows;

$$C_b = \frac{\rho_b}{\alpha_f \times \rho_f} \quad (2)$$

  where ρ_b, α_f and ρ_f are the boron density, liquid fraction and liquid density respectively.
- The water flow rate containing boron at break

$$\dot{m}_b = \dot{m}_f \times C_b \quad (3)$$

  where $\dot{m}_f$ is the break flow rate at break.

2.3 Results

The ECC bypass of the accumulator was shown in Fig. 1. The safety injection started at 11 sec and then the ECC bypass increased gradually up to 31 sec that the PCT occurred. The bypass ratio was evaluated as 47.8 % of total injected flow. This is larger than 18.9% of Kori Unit 1 PSR. Therefore, the initial and boundary condition in this study was very conservative in respect to available ECC water.

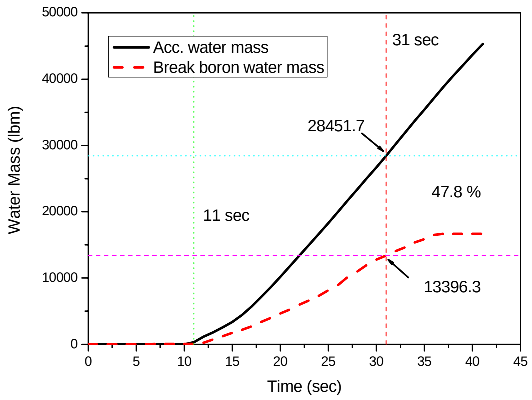

Fig. 1 ECC Bypass of Accumulator in Intact Loop

3. Effect of Steam Binding

The liquid carryover from the core and the deentrainment in the upper plenum should be correctly calculated in order to evaluate steam binding. However, it was difficult to accurately evaluate this phenomenon due to the insufficient experimental data. In KREM, the bias for steam binding could be obtained by evaluating the droplet deentrainment in the upper plenum and the droplet evaporation in the steam generator. In the UPI plant, water pool was formed in the upper plenum and it obstructed the liquid carryover from core to hot leg. In PSR of Kori Unit 1, the bias for droplet deentrainment was replaced with bias in the upper plenum and the bias for droplet evaporation was calculated like KREM.

In this study, the droplet evaporation was evaluated by using the base input applied in KINS-REM. The bias for droplet evaporation was considered by modeling additive heat structure in U-tube of the steam generator of intact loop. The imposed heat at a specific time evaporated the droplet in U-tube. The quality at exit of steam generator was calculated over 0.9 on the basis of the observation of 2D/3D program [4]. First, the heat was imposed to U-tube at 72.4 sec which the injection of accumulator was terminated (Case-01). In Case-02, the heater was operated at the reflood initiating time (39 sec). After the heat was on, the quality at exit of steam generator was increased rapidly over 0.9. As shown in Fig. 2, the droplet evaporation increased the cladding temperature to some degree and the fuel quenching time was slightly late. Consequently, the abnormal increase of the cladding temperature due to the steam binding was not shown and the steam binding didn't influence the PCT which occurred at 31 sec.

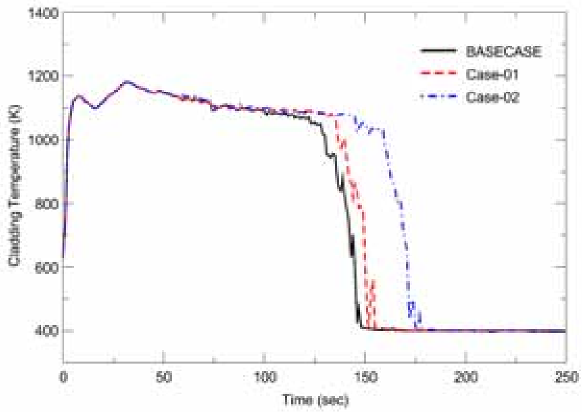

Fig. 2 Fuel Cladding Temperature for droplet evaporation

4. Conclusion

From the present study for Kori Unit 1, it is concluded that the bias for ECC bypass was evaluated conservatively and the steam binding had no effect on the change of PCT.

REFERENCES

[1] KHNP, Periodic Safety Review for Continuous Operation of Kori Unit 1, 2006.
[2] KINS, Evaluation of ECCS Performance of Kori Unit 1 Using KINS Best-Estimate Methodology, KINS/RR-531, 2007.
[3] KHNP, Topical Report for the Realistic Evaluation of Emergency Core Cooling System, TR-KHNP-0002, 2002.
[4] USNRC, Compendium of ECCS Research for Realistic LOCA Analysis, NUREG-1230 R4, 1988.