Proceedings of the Korean Nuclear Society Autumn Meeting

Taejon, Korea, October 1996

Analysis of LOFT LP-02-6 Experiment Using RELAP5/MOD3.2

Tong Soo Choi, Jae Hoon Lee, Byung Suh Park, and Chang Sok Cho

Korea Nuclear Fuel Company

Abstract

LOFT LBLOCA test, LP-02-6 was analyzed using RELAP5/MOD3.2. It has a distinguished thermal-hydraulic phenomenon of a positive bottom-up core flow in the blowdown phase. A modified nodalization which is based on that used in LP-LB-1 calculation by Lübbesmeyer was used in the calculation. RELAP5/MOD3.2 predicted overall system hydraulic behavior relatively well. However, the bottom-up quenching in the middle part of the core was not predicted sufficiently. It was demonstrated also that the peak cladding temperature can be predicted well by adjusting a discharge coefficient. But more improvements are needed in order to apply this code to actual plants with less user dependency.

I. Introduction

The experiment LP-02-6 was the first large break LOCA simulation which was designed to represent the design basis accident conditions. The distinguished thermal-hydraulic phenomenon of the experiment LP-02-6 is a positive bottom-up core flow due to long-term pump coast down, which resulted in bottom-up quench of central fuel assembly during the blowdown period,

LP-02-6 experiment was analyzed using RELAP5/MOD2 Cy 36-02 by Lübbesmeyer [1}. He concluded that the code could not predict the bottom-up core flow properly. In 1995, researchers of KAERI and KEPRI analyzed LP-02-6 experiment using a modified version of the RELAP5/MOD3.1 computer code [2] for the development of LBLOCA Realistic Evaluation Methodology. It was said that bottom-up quenching of the fuel rods during blowdown was calculated well with the code. They used discharge coefficients of 0.89, 1.07, and 1.0 for subcooled, saturated, and superheated discharge conditions, respectively and arbitrary loss coefficient for the cross flow junctions between split downcomer volumes.

The objective of this study is to identify any improvement or deficiency of RELAP5/MOD3.2 in predicting thermal-hydraulic phenomena specific to the experiment LP-02-6 such as bottom-up quenching. To find out the influence of discharge coefficients on the overall thermal-hydraulic behavior in the system, discharge coefficient sensitivity study was carried out. In addition, a calculation using RELAP5/MOD3.2.1.2 with a modified form of Henry-Fauske critical flow model was performed to get knowledge of the effects of the new critical flow model.

II. Description of the Base Case Modeling

The nodalization used to simulate LP-02-6 experiment is shown in Figure 1. This nodalization and input deck are based on those used to analyze the LP-LB-1 experiment with RELAP5/MOD2 by Lübbesmeyer [3]. Slight modifications of the input deck were done to accommodate the modeling changes implemented in RELAP5/MOD3.2 such as heat structure, volume control flag, junction control flag, and ECCMIX component modeling and the test conditions specific to LP-02-6 experiment. The nodalization and geometry data of reactor vessel internals were refined according to reference 4 to get rid of a level checking error.

To obtain the initial conditions appropriate to the test conditions over the whole system, a steady state calculation was performed. The results from the steady-state run agree reasonably with the experimental conditions [5]. Based on the experiment data, the reactor power history, suppression tank pressure and feedwater flow rate after scram were given as time dependent tables. Performance curves for HPSI and LPSI flow rate as function of cold leg pressure were provided in the input deck. The pump speed after trip was simulated by time dependent speed table. Discharge coefficients at the break valves are set to be 1.0 for all three phases of discharge.

III. Results

Figures 2 to 5 show the results from the base case calculation. The calculated system pressure in the intact loop hot leg is plotted with corresponding measured data in Figure 2. It is found that the system pressure was underpredicted than the measured data during overall transient. This underestimation of system pressure is due to the overprediction of break flow during the blowdown. The mass flow rates in the broken loop cold leg and in the intact loop cold leg are shown in Figure 3. The mass flow rate in the broken loop cold leg was predicted to be saturated at ~2.2 secs and to become smaller than that in the intact loop cold leg. Lower mass flow rate in the broken loop cold leg than that in the intact loop cold leg means that the core is filled with fluid from the intact loop cold leg. The liquid level in the core was calculated to decrease rapidly after initiation of break and the core was completely emptied at ~2 secs until bottom-up core flow was initiated as presented in Figure 4. The filling of the core with the bottom up flow was predicted to make the lower part of the core rewet. And then, the liquid level fell again below the bottom of core until the ECC water reached the bottom of core at ~36 secs. The complete recovery of core was calculated to occur at ~54 secs which is ~5 secs earlier than the experiment. The calculated peak cladding temperature is presented with the measured data at corresponding elevation in Figure 5. The blowdown heat up was predicted relatively well, but it was calculated to occur a little bit earlier than the measured data and the blowdown peak cladding temperature was overestimated by ~30K. The early bottom-up quenching was predicted to occur slightly earlier and less than the measured data. The earlier and less bottom up quenching was resulted from the overestimated mass flow rate in the broken loop cold leg. The calculated peak cladding temperature during reflood phase was approximately 861 K while it was 831 K in the experiment. Such an overestimation is mainly due to the deficiency of RELAP5/MOD3.2 not to be able to predict the early bottom-up quenching in the middle part of the core.

In Figures 6 to 8, the results from the calculation with various discharge coefficients are presented. The calculated pressure in the intact loop hot leg is shown in Figure 6. It shows that the system pressure in the base case calculation increases with lower discharge coefficient. Figure 7 shows the calculated mass flow rate in the broken loop cold leg. As shown in the figure, lower discharge coefficient leads to less break flow. The relationship between the discharge coefficient and the bottom-up quenching can be seen in Figure 8. The more break flow rate is estimated in the blowdown phase, the less bottom-up quenching is predicted.

RELAP5/MOD3.2.1.2 calculation with default values for Henry-Fauske critical flow model was done also. RELAP5/MOD3.2.1.2 predicted more break flow and less bottom-up core flow than RELAP5/MOD3.2. The resultant cladding temperature behavior at 5th hot core node is shown in Figure 9.

V. Conclusions

The important findings are summarized as follows:

1) RELAP5/MOD3.2 predicted overall system hydraulic behavior relatively well, but the mass flow rates in the broken loop cold leg and hot leg during the subcooled blowdown were largely overestimated. It predicted reasonably the blowdown heat up of the core. However, the bottom-up quenching in the middle part of core was not predicted sufficiently. Therefore, the peak cladding temperature during the reflood phase was overestimated.

2) It was demonstrated that the peak cladding temperature can be predicted well by adjusting the discharge coefficient. But the appropriate discharge coefficient can be varied case by case. Therefore, more improvements are needed in order to apply this code to actual plants.

REFERENCES

[1] D. Lübbesmeyer, “Post-Test-Analysis and Nodalization Studies of OECD LOFT Experiment LP-02-6 with RELAP5/MOD2 cy 36-02”, Draft to NUREG Report.

[2] KAERI and KEPRI, “Large Break LOCA Realistic Evaluation Methodology, Vol. 1 Model Description and Validation”, Draft for Comment, December 1995.

[3] D. Lübbesmeyer, “Post-Test-Analysis and Nodalization Studies of OECD LOFT Experiment LP-LB-1 with RELAP5/MOD2 cy 36-02”, NUREG/IA-0089, October 1992.

[4] J.C.Birchley, “LOFT Input Dataset Reference Document for RELAP5 Validation Studies”, NUREG/IA-0072, April 1992.

[5] J.P.Adams, K.G.Condie, and D.L.Blatt, “Quick-Look Report on OECD LOFT Experiment LP-02-6”, OECD LOFT-T-3404, October 1993.

[6] INEL, “RELAP5/MOD3 code manual”, NUREG/CR-5535, August 1995.

[7] P.Coddington and C.Gill, “TRAC-PF1/MOD1 Calculation of LOFT Experiment LP-02-6”, NUREG/IA-0027, April 1992.

[8] Reeder, D.G., “LOFT System and Test Description”, NUREG/CR-0247, Tree-1208, 1978.

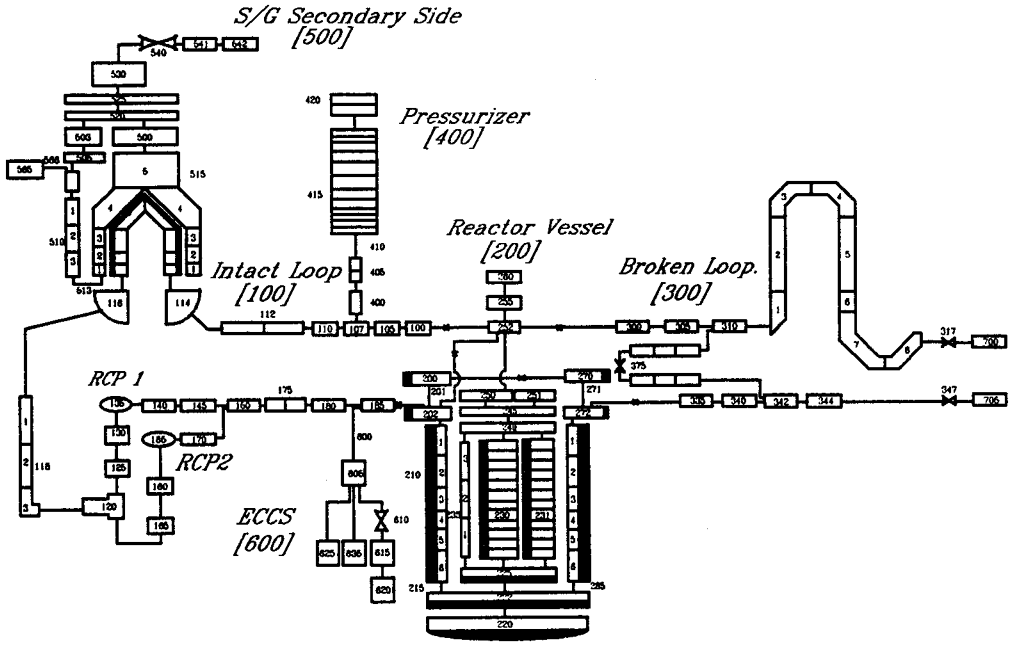

Figure 1. Schematic diagram of nodalization

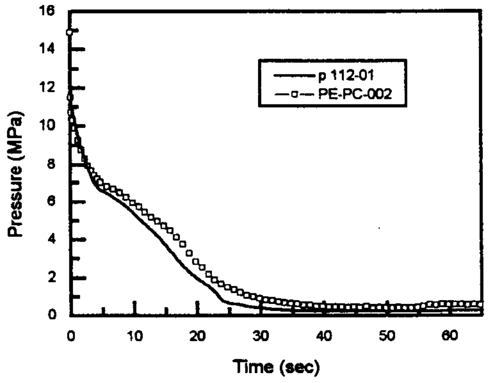

Figure 2. System pressure in the intact loop hot leg

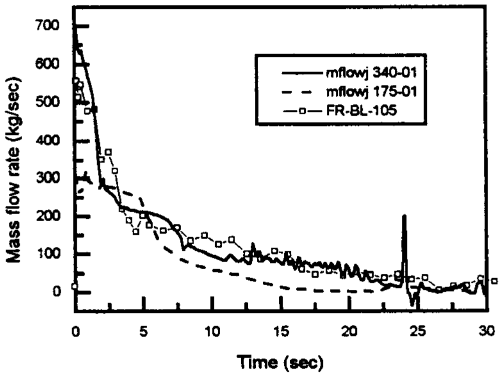

Figure 3. Mass flow rate in the broken loop cold leg

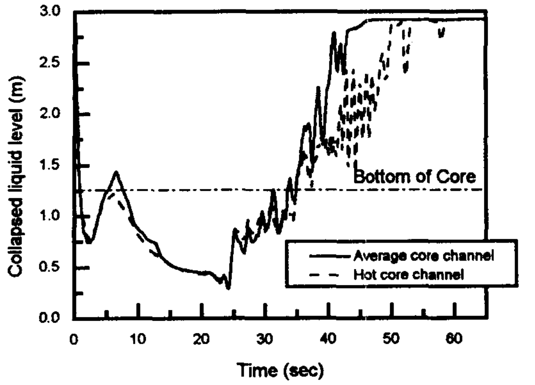

Figure 4. Collapsed liquid level in the core channels

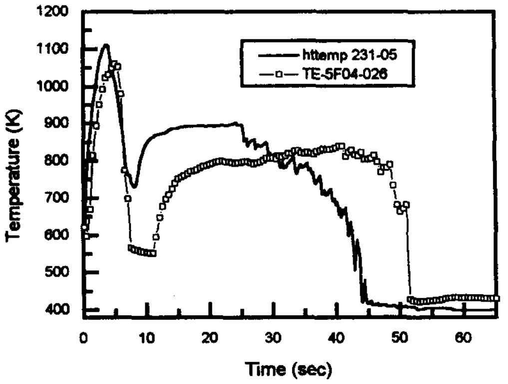

Figure 5. Cladding temperature at hot core node 5

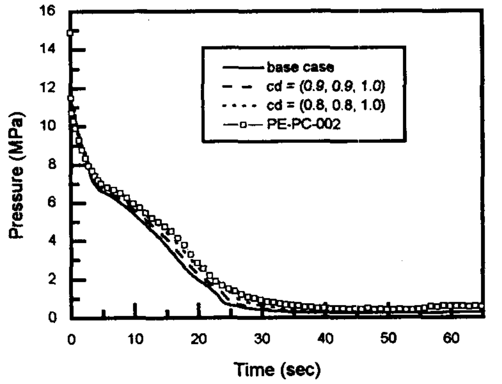

Figure 6. System pressure in the intact loop hot leg for various discharge coefficients

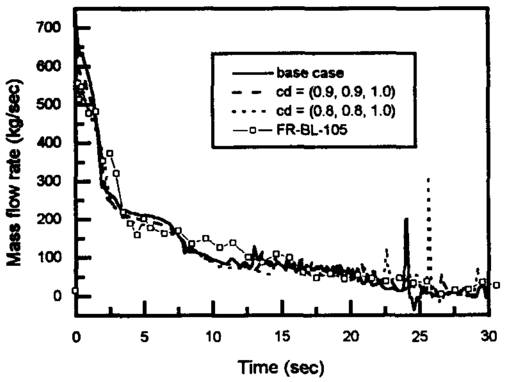

Figure 7. Mass flow rate in the broken loop cold leg for various discharge coefficients

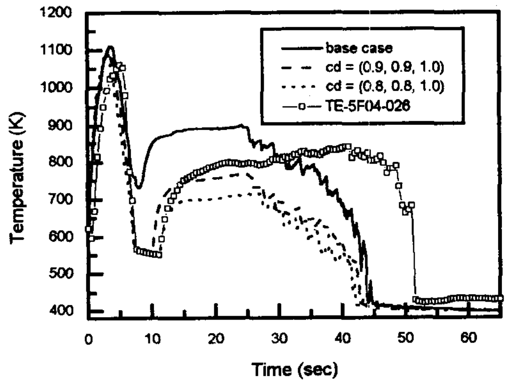

Figure 8. Cladding temperature at hot core node 5 for various discharge coefficients

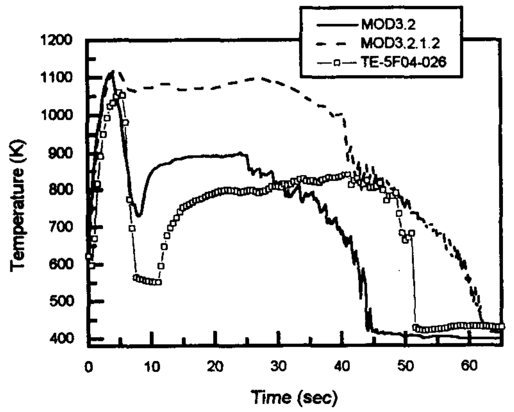

Figure 9. Cladding temperature at hot core node 5 with RELAP5/MOD3.2.1.2