An Analytical Investigation of Loop Seal Clearings for the SBLOCA Tests

Y.S. Kim*, K.Y.Choi, S.Cho., H.S.Park, K.H.Kang, N.H.Choi, B.D.Kim, K.H.Min

Korea Atomic Energy Research Institute
1045 Daedeokdaero, Yuseong-gu, Daejeon, 305-353, Korea
** Corresponding author: yskim3@kaeri.re.kr*

1. Introduction

An analytical investigation of the LSC in the SBLOCA for the DVI line and CL breaks was performed using the MARS code. The experiments show that the loop seal clearing (LSC) behavior appears to be closely related to the break location and break size. In general, a loop seal in the break loop was cleared first, and the number of loop seal clearings was dependent on the break size. The larger the break size was, the more the loop seals that were cleared.

In the analyses, the reference plant was also included to compare with the ATLAS test and analyses. The arrangements of the reactor coolant system were similar between the real and model plants. For an understanding of nodalization and modeling in the MARS analyses, the terminologies for main pipes and safety injection nozzles should be coincident between the real and model plants. Fig. 1 shows a typical arrangement for the main loop pipes and safety injection nozzles used in this paper.

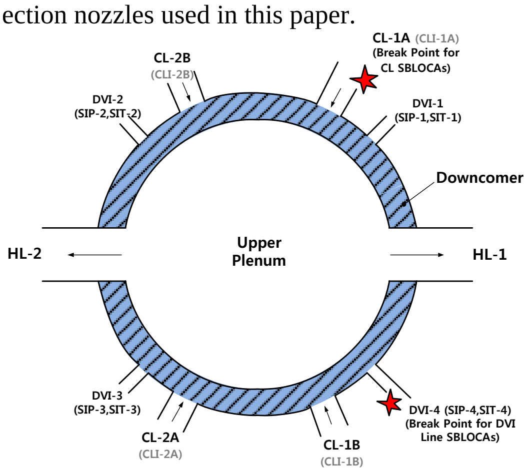

Fig. 1 Planar arrangements for the main loop pipes and safety injection nozzles

2. Analyses Conditions

The rated steady-state conditions between the APR1400 and ATLAS for the analyses are summarized in Table 1. ATLAS has the same two-loop features as the APR1400 and was designed to simulate various test scenarios as realistically as possible. It is a half-height, 1/288-volume scaled test facility with respect to the APR1400. According to the scaling law, the reduced-height scaling has time-reducing results in the model. For a one-half-height facility, the time for the scaled model is $\sqrt{2}$ times faster than the prototypical time. Table 1 compares the rated steady-state conditions between the APR1400 and ATLAS for the analyses.

Table 2. Initial conditions for the analyses

Design Parameters	APR1400 (P)	ATLAS (M)	Ratio (P/M)
Reactor vessel			
Normal power, MWt	3,983.00	1.56	2,553.21
Core exit temp, °C	324.20	324.20	1.00
Core inlet temp, °C	291.30	290.70	1.00
Temperature rise, °C	32.90	33.50	0.98
Core flow, kg/s	20,275.00	7.99	2,537.55
Pressurizer pressure, MPa	15.50	15.50	1.00
Steam generator			
Steam flow rate, kg/s (SG-1)	1,152.40	0.44	2,619.09
Steam flow rate, kg/s (SG-2)	1,152.40	0.44	2,619.09
Saturated steam pressure, MPa	6.90	7.83	0.88
Steam temp., °C	284.90	293.50	0.97
Primary piping			
Hot leg flow, kg/s	10,496.00	3.99	2,630.58
Cold leg flow, kg/s	5,540.10	1.99	2,783.97
Hot leg temp., °C	323.30	323.80	1.00
Cold leg temp., °C	291.30	289.60	1.01

3. Analyses Results

3.1 Loop seal behaviors

Counter-part analyses for typical SBLOCA tests for the DVI line and CL breaks investigated in the previous work [1] were performed with respect to the ATLAS and APR1400 using the MARS-KS code. Occurrences of the loop seal clearing and/or loop seal refilling (LSC/LSR) for the tests and analyses are summarized in Table 2. Kim and Cho [1] noted that an LSC occurs first in the broken loop, and the number of LSCs is dependent on the break sizes in the ATLAS SBLOCA tests. Analyses results for ATLAS and APR1400 also show similar trends with respect to the ATLAS tests. Although general trends were shown between the test and analyses, the specific locations and numbers of LSC/LSR differed. For example, the locations of the LSCs of the SB-DVI-09 test were COL-1B,-1A and -2B. The locations of the counter-part analyses for ATLAS and APR1400 were COL-1B,-1A and -2A, and all COLs, respectively. LSCs occurred first in the broken loop, e.g., COL-1B and -1A, and the remaining LSC(s) were different from each other, e.g., COL-2B for the ATLAS test; COL-2A for the ATLAS MARS; and COL-2A and -2B for the APR1400 MARS. Although, the test results showed a consistency in the LSC occurrence, analyses using MARS showed a different trend in LSC occurrence, which may have been caused from the MARS modeling of the primary and secondary systems. It is noteworthy that LSC behaviors of the ATLAS test and analyses showed quite a similar trend to each other, but those of the APR1400 analyses, differed from the others.

Table 2. Summary of LSC/LSR for SBLOCA tests

Test ID	Break Size[a]	ATLAS (Test)		ATLAS
		LSC/LSR[b]	PCT	LSC/LSI
SB-DVI-06	5%	C:1B/R:1B	NA	C:1B;2A/R:1B;2.
SB-DVI-05	25%	C:1B,1A;2B	NA	C:2A,2B
SB-DVI-09	50%	C:1B,1A;2B	X	C:1B,1A;2A
SB-DVI-08	100%	C:1B,1A;2B,2A	X	C:All
SB-CL-07	2”	C:NA	NA	C:1B;2A/R:1B;2.
SB-CL-05	4”	C:1A,2B	NA	C:1A
SB-CL-09	6”	C:1A,2B	NA	C:1A,1B;2A,2B/]
SB-CL-04	8.5”	C:1A;2B,2A	X	C:1A,2A,2B;1B

3.2 Thermal hydraulic behaviors

From the viewpoint of nuclear power plant safety, loop seal behaviors are important to the water level changes of the core and DC, and the core temperature. In this section, comparisons of the major thermal hydraulic parameters, e.g., the core and DC water levels, and the core temperature, were described for the two typical scenarios, e.g., SB-DVI-09 and SB-CL-09.

The core, DC, and COL-1A water levels and clad temperature were compared for the SB-DVI-09, as shown in Fig. 2. The trend of the core water levels between the APR1400 and ATLAS MARS was similar, but the core water level of the ATLAS MARS under-estimated that of the APR1400 analysis. Generally, MARS predicted an over-estimation of the core water levels relative to the ATLAS test. The lowest core levels at the first LSC were similar between the ATLAS test and MARS analysis.

As a result, ATLAS MARS showed a similar behavior in the peak cladding temperature at the first LSC. It is noteworthy that the first PCT occurred owing to the LSC occurrence only. In addition, the ATLAS MARS showed another larger PCT occurrence after the first LSC during the loop seal oscillations for the second LSC in COLs-2A and -2B of the intact loop – finally, COL-2A was only cleared at around 870s, as shown in the Table 3. During the loop seal oscillations for the second LSC, the second PCT started owing to the decreasing in the core level, and reached a peak value just before the SIT injection, e.g., at 375 s. In the second PCT, its peak value was dependent on the SIT injection, but in the first PCT, it was dependent on the LSC itself.

The downcomer water levels showed similar trends with the core water levels and were found to start recovery owing to the SIT injections for all cases.

For the SB-CL-09 scenario, the overall behaviors of the water levels and core temperature were similar to those of SB-DVI-09, as shown in Fig. 8. In the test, there was no PCT occurrence although there were LSC occurrences, as shown in Table 2.

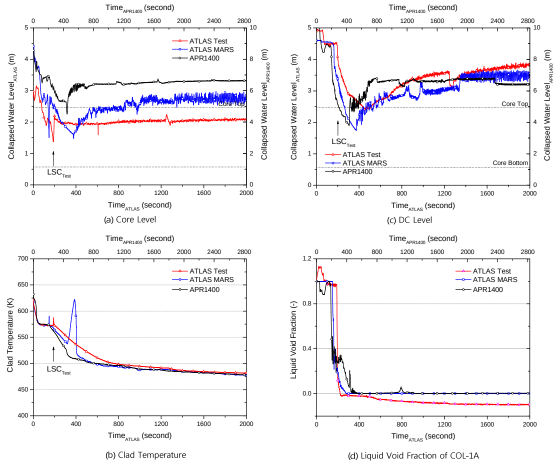

Fig. 2. Comparison of the APR1400 and ATLAS for SB-DVI-09

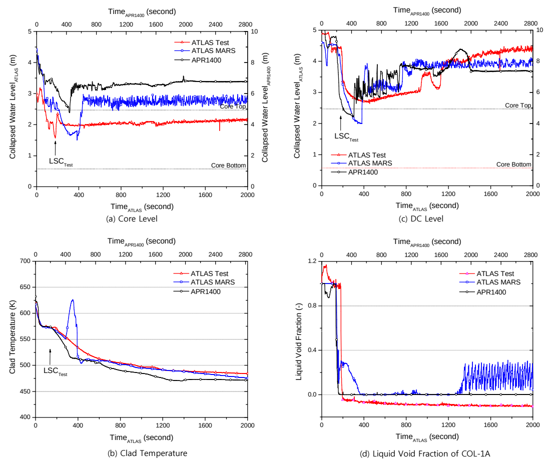

Fig. 3. Comparison of the APR1400 and ATLAS for SB-CL-09

4. Conclusions

Loop seal behaviors were compared between the test and MARS analyses including the effects of the system and component modeling and CCFL option. LSC behaviors of the ATLAS test and analyses showed quite similar trends, but those of the APR1400 analyses differed from the others. In the effect of the modeling, the LSC behaviors showed a strong dependence on the system and component modeling. In the parametric study of the CCFL option, the LSC behaviors showed a weak dependence on the CCFL model options. Thermal hydraulic behaviors important to reactor safety, e.g., the core and downcomer water level, the cladding temperature, and the COL water level, were also evaluated for two typical scenarios, e.g., SB-DVI-09 and SB-CL-09. Most of the thermal hydraulic behaviors were deeply dependent on the system and component modeling of the MARS analyses including the multi-dimensional effect of RV.

REFERENCES

[1] Kim, Y.S. and Cho, S., An Investigation of Loop Seal Clearings for the SBLOCA Tests, Submitted for Publication to Ann. of Nucl. Energy (2013).