*Transactions of the Korean Nuclear Society Spring Meeting*
*Jeju, Korea, May 7-8, 2015*

# An Overall Investigation of Direct Vessel Injection Line Break Accidents of the ATLAS Facility

Yeon-Sik Kim*, Ki-Yong Choi, Seok Cho and Bok-Deuk Kim

*Thermal Hydraulics Safety Research Division, Korea Atomic Energy Research Institute*
*111, Daedeok-Daero 989 Beon-Gil, Yuseong-Gu, Daejeon, 305-353, Korea*
*[*]Corresponding author: yskim3@kaeri.re.kr*

## 1. Introduction

For parametric evaluations of direct vessel injection (DVI) line break scenarios, the pressurizer (PZR) pressure, core collapsed water level, and peak cladding temperature were investigated between the analyses and tests. The PZR pressure was mainly dependent upon the break flow model, e.g., discharge coefficient of the Henry-Fauske critical model. The core collapsed water level and peak cladding temperature were mainly dependent on the counter-current flow limit (CCFL) option of the fuel alignment plate (FAP). The CCFL option of the cross-over leg (COL) affected the PZR pressure owing to the loop seal clearings and seemed to have little effect on the core collapsed water level. Proper $C_d$ values and applicable CCFL options were summarized. $C_d$ values seemed to be dependent on the sizes of the DVI line break. Although there was little difference for the CCFL options of the COL, Kutateladze(Ku)-option was the preferred one for COLs' CCFL option. The CCFL options of the FAP appeared sensitive to the core collapsed water level and peak cladding temperature. The Ku-option of the FAP tended to negatively exaggerate the core behavior and showed excessively conservative results, especially on the peak cladding temperature. For smaller breaks, e.g., 25%, Not Application(NA)- and Wallis(Wa)-options would be applicable for the FAP. But for larger breaks, e.g., 50%, the Wa-option of the FAP was the preferred one. From comparisons between the tests and analyses for four different DVI line break scenarios with respect to the PZR pressure, downcomer water level, core water level, and clad temperature, the selected $C_d$ and CCFL options showed conservatively good results.

## 2. Methods and Results

### *2.1 Test Scenarios for MARS-KS[1] Analyses*

Four DVI line SBLOCA scenarios were selected, e.g., 5%, 25%, 50%, and 100% of the DVI line breaks, as shown in Table 1. The break nozzle of a test was modeled by a valve component in the MARS analyses. A time-dependent volume was used for the simulation of the containment back pressure in the DVI line break analysis. In the post-test analysis, the measured containment pressures with respect to time were used as the boundary condition of the time-dependent volume. For parametric evaluations, the discharge coefficient, $C_d$, and options of the CCFL model for the FAP and COLs were varied to see their effects on the PZR pressure, core water level, and peak cladding temperature.

Table 1. Summary of DVI line SBLOCA tests

| Test ID | Break Nozzle | | Remark |
|---|---|---|---|
| | Size | *D* | |
| SB-DVI-06 | 5% | 3.41mm (1.9 in.) | |
| **SB-DVI-05** | **25%** | **7.63mm (4.3 in.)** | |
| SB-DVI-09 | 50% | 10.80mm (6.0 in.) | |
| SB-DVI-08 | 100% | 15.13mm (8.5 in.) | DSP-01 |

### *2.2 Parametric study of CCFL options (FAP vs. COLs)*

For a sensitivity study for the application of CCFL option to the FAP, a 25% DVI line break, e.g., SB-DVI-05, was selected for comparisons. Parametric results for three options of the FAP with respect to two options of the COLs are shown in Figs. 1 and 2, respectively. As can be seen in the two figures, NA- and Wa-options for the FAP would have nearly the same effects on the collapsed core water levels under two options for the COLs. However, as the Ku-option for the FAP, the collapsed core water levels tended to be exaggerated, especially during under-shoot behaviors at around 400 s.

The parametric results for three options of the FAP with respect to two options of the COLs are shown in Figs. 3 and 4, respectively. As can be seen in the two figures, NA- and Wa-options for the FAP will have nearly the same effects on the peak cladding temperatures under two options for the COLs. However, for the Ku-option for the FAP, the peak cladding temperatures tended to be largely exaggerated, especially during the first peak behaviors.

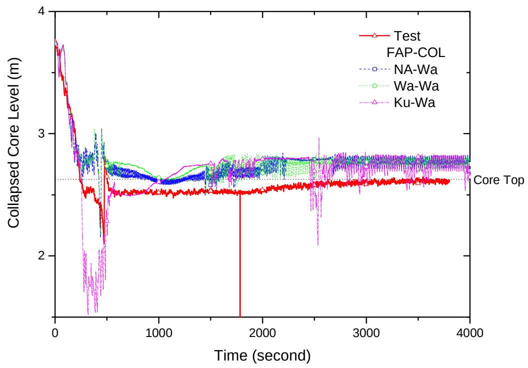


Fig. 1 Core level effects of FAP's options under COL's Wallis-option (25% DVI line break).

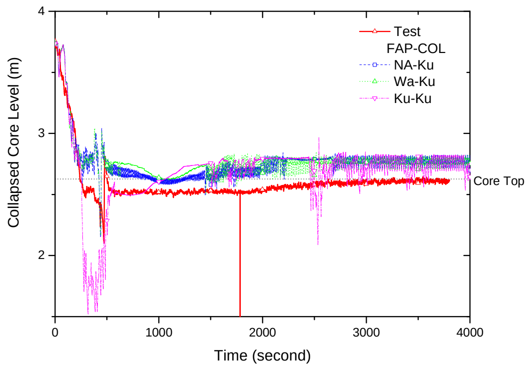


Fig. 2 Core level effects of FAP's options under COL's Kotateladze-option (25% DVI line break).

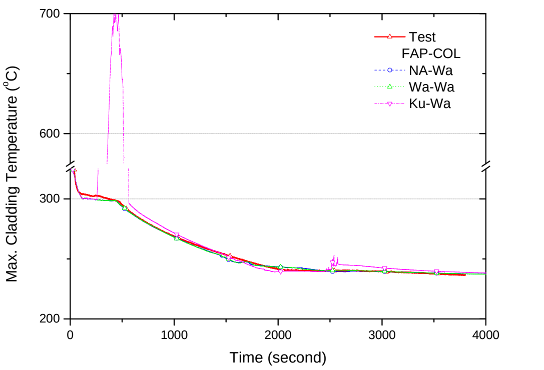


Fig. 3 PCT effects of FAP's options under COL's Wallis-option (25% DVI line break)

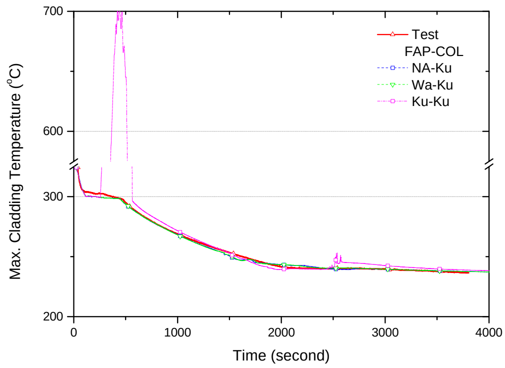


Fig. 4 PCT effects of FAP's options under COL's Kutateladze-option (25% DVI line break)

### *2.3 Summary of parametric studies*

Parametric evaluations were conducted for all DVI line break scenarios like in the above sections. Although omitted in the previous section, proper $C_d$ values were selected by comparison of the PZR pressure between tests and analyses for each DVI line breaks. From the parametric evaluations, applicable CCFL options can be identified from the viewpoint of adjustments of the collapsed core levels and peak cladding temperatures between tests and analyses. The proper $C_d$ values and applicable CCFL options for four DVI line SBLOCA tests are summarized in Table 2.

Table 2. Summary of proper $C_d$ values and applicable CCFL options for DVI line SBLOCA tests

| Test ID | Break Size | $C_d$ | Applicable CCFL Options | |
|---|---|---|---|---|
| | | | FAP | COL |
| SB-DVI-06 | 5% | 0.55 | NA,Wa | Wa,Ku |
| SB-DVI-05 | 25% | 0.79 | NA,Wa | Wa,Ku |
| SB-DVI-09 | 50% | 0.77 | Wa | Wa,Ku |
| SB-DVI-08 | 100% | 0.71 | Wa | Wa,Ku |

From the parametric evaluations, recommendable Cd values and CCFL options for the FAP and COLs are also shown in Table 4, i.e., the underlined options. It appears that $C_d$ values are dependent upon the size of the DVI line break. From the table, it can be concluded that the application of the NA- or Wa-option for the FAP would not affect the collapsed core level and peak cladding temperature in the cases of smaller DVI line breaks. However, for larger DVI line breaks, Wa-option for the FAP would be recommended. In any break size, the collapsed core level and peak cladding temperature were very sensitive to the Ku-option of the FAP and showed largely conservative results. For the options of the COLs, there was little difference between the Wa- and Ku-options.

Comparisons between the tests and analyses are shown in Figs. 5-8 for four different DVI line break scenarios, respectively. The selected Cd values and CCFL options, as the underlined descriptions in Table 2, were used for the analyses. From Figs. 5-8, it can be concluded that the selected Cd values and CCFL options showed conservatively good results.

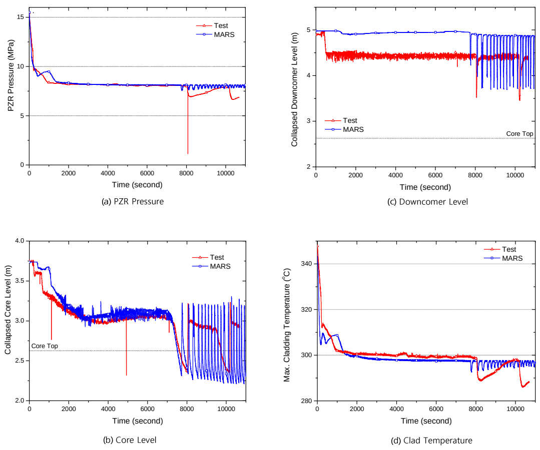


Fig. 5 Comparison between ATLAS test and MARS analysis for 5% DVI line break

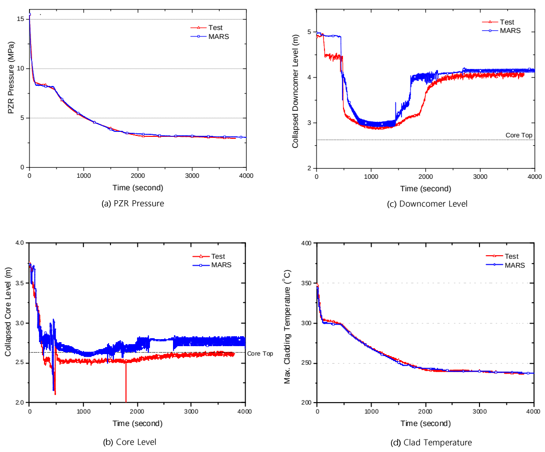


Fig. 6 Comparison between ATLAS test and MARS analysis for 25% DVI line break

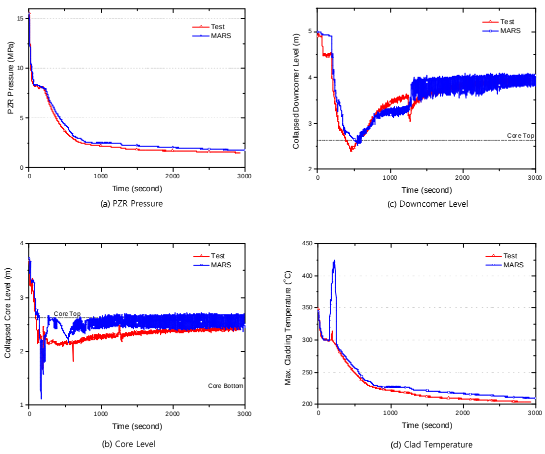


Fig. 7 Comparison between ATLAS test and MARS analysis for 50% DVI line break

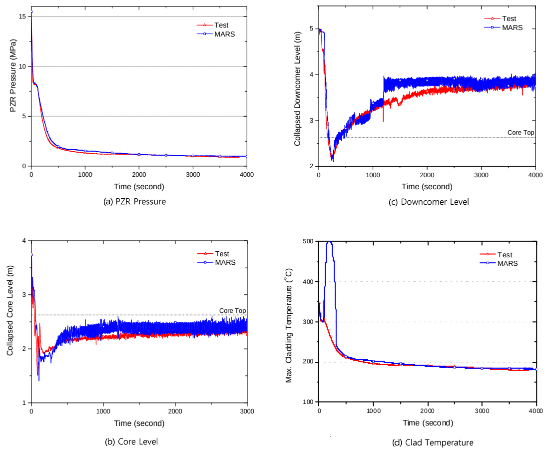


Fig. 8 Comparison between ATLAS test and MARS analysis for 100% DVI line break

## 3. Summary and Conclusions

For an analytical study of DVI line break scenarios, the PZR pressure, core collapsed water level, and peak cladding temperature were investigated between the analyses and tests. The PZR pressure was mainly dependent on the break flow model, e.g., the discharge coefficient of the Henry-Fauske critical model. The core collapsed water level and peak cladding temperature were mainly dependent on the CCFL option of the FAP. The CCFL option of the COL affected the PZR pressure owing to loop seal clearings and seemed to have little effect on the core collapsed water level.

From parametric evaluations, proper $C_d$ values and applicable CCFL options were suggested. The $C_d$ values seemed to be dependent on the sizes of the DVI line break. Although there was little difference in the CCFL options of the COL, the Ku-option was the preferred one for COLs' CCFL option. The CCFL options of the FAP appeared sensitive to the core collapsed water level and peak cladding temperature. The Ku-option of the FAP tended to negatively exaggerate the core behavior and showed excessively conservative results, especially on the peak cladding temperature. For smaller breaks, e.g., 25%, NA- and Wa-options would be applicable for the FAP. However, for larger breaks, e.g., 50%, the Wa-option of the FAP was the preferred one.

Comparisons between the tests and analyses were depicted for four different DVI line break scenarios with respect to the PZR pressure, downcomer water level, core water level, and clad temperature. The selected $C_d$ and CCFL options showed conservatively good results.

**Acknowledgement**

The authors would like to express their sincere thanks to the ATLAS group of KAERI. This paper is prepared utilizing the results of their work. This research has been performed under the nuclear R&D program supported by the Ministry of Science, ICT and Future Planning (MSIP) of the Korean Government.

## REFERENCES

[1] Chung, B.-D. et al., MARS Code Manual, KAERI/TR-2812/2004, Korea Atomic Energy Research Institute, 2010.