A Measurement of the Break Flow Rates in the ATLAS

Hyun-Sik Park, Ki-Yong Choi, Seok Cho, Kyoung-Ho Kang, Nam-Hyun Choi, Dae-Hun Kim, Byong-Jo Yun, and Yeon-Sik Kim
Thermal Hydraulics Safety Research Division, Korea Atomic Energy Research Institute
1045 Daedeokdaero, Yuseong, Daejeon, 305-600, Korea
**Corresponding author: hspark@kaeri.re.kr*

1. Introduction

A thermal-hydraulic integral effect test facility, ATLAS (Advanced Thermal-hydraulic Test Loop for Accident Simulation), is being operated at KAERI (Korea Atomic Energy Research Institute) [1]. Several integral tests for the reflood phase of a LBLOCA (Large Break Loss of COolant Accident) and the DVI line break have been performed with the ATLAS. The ATLAS has a BS (Break Simulator) to simulate the break condition and a CS (Containment Simulator) to measure the break flow rate during the test. The measurement of the break flow rates will be explained based on a LBLOCA reflood test, LB-CL-15 [2].

2. Description of ATLAS BS and CS

2.1 ATLAS Break Simulator

The ATLAS break simulator consists of a quick opening valve, a break nozzle, a case holding the break nozzle, and a few instruments. When a large break LOCA occurs, a choking is expected to occur at the break location in an earlier blowdown phase of a LBLOCA. However, no choking occurs in the late reflood phase of a LBLOCA. Therefore the break area is scaled down to match the pressure drop through the break line. The inner diameter of the break nozzle is determined to be 53.4 mm which corresponds to 1/203.6 of a 30 inch break area. The break nozzle has a well-rounded entrance and its length is fixed to be 650.8 mm including the entrance region to comply with the long pipe requirement that the length to diameter ratio should be above 12. For the chosen nozzle, the scaling ratio of the loss coefficient should be 1.0 and the friction loss coefficient should also be 1.0. The actual friction loss between the break point to the separator in the ATLAS was about 1.13 and thus the pressure drop through the break system is about 13% higher in the ATLAS than that in the APR1400.

2.2 Containment Simulator

The break flow is discharged to a containment simulator, which consists of separating vessels and measuring vessels. Overall configuration of the containment simulator is shown in Figure 1.

The ATLAS has two separating vessels. One is named SV-01 and the other, SV-02. The SV-01 is designed to be used for separating a two-phase break flow of which the flow rate is relatively small. It will be used for most test cases except for the LBLOCA which results in a large break flow rate. In case of the double-ended guillotine LBLOCA, both separating vessels are designed to be used simultaneously. The SV-01 and SV-02 are used for separating the break flow from the reactor pressure vessel side and the RCP side, respectively. In the LBLOCA reflood test, both SV-01 and SV-02 are used because both break points of the cold leg from the reactor coolant pump and reactor pressure vessel sides should be simulated. The steam, which is separated in two separating vessels, was discharged through a silencer to the atmosphere. The steam flow rate is measured by a vortex-type flow meter at the discharge line. The water, which is separated into two separating vessels, is drained to one of the five measuring vessels. A load cell is installed on the bottom of each measuring vessel to weigh the water mass. In the LBLOCA reflood test, five measuring vessels, MV-01 through MV-05 are used to weigh the mass of the drained water. The water from SV-01 is accumulated in MV-01, MV-02 and MV-03, and the water from SV-02, MV-04 and MV-05. First the separated water is introduced to MV-01. When MV-01 is full of water, the flow direction is switched from MV-01 to MV-02 by a 3-way valve. While MV-02 is used to measure the water mass, MV-01 is drained for the next usage and vice versa. The separating vessel is also designed to simulate a containment back-pressure by controlling its pressure by using a pressure control valve.

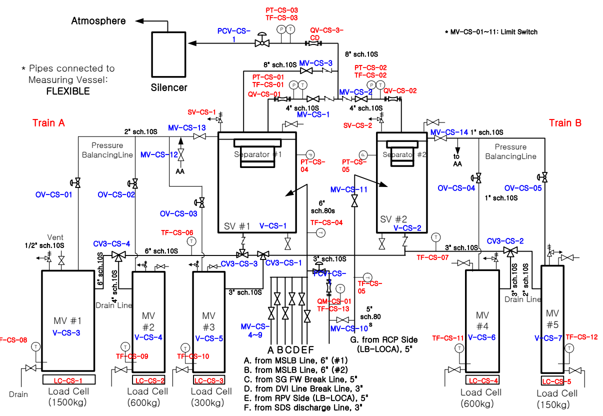

Fig. 1. Schematics of the ATLAS containment simulator

3. Characterization Tests of the ATLAS CS

A set of characterization tests was performed for the containment simulator to validate its capability to measure break flow rates during a LBLOCA simulation. For a characterization test a known flow rate was injected into the CS through a makeup water injection line by using a makeup pump. As the containment simulator is connected to the break simulator with a pipe, the measuring time is delayed a little. In the present test the delay time is estimated to be 7 seconds. The mass difference was about 1.6% at the end of the test, which is quite a reasonable value.

Fig. 2 shows the typical trends of the flow rates measured by using a flow meter on the makeup water injection line and estimated from the accumulated mass from load cells. A time interval of 1.0 second was used to estimate the break flow rate from the accumulated mass measured from the load cell and the data was smoothed by using a Savitzky-Golay smoothing filter and the flow rate was calculated by using a moving window averaging method. The characterization test shows that a reasonable flow rate could be acquired to estimate the flow rate for a low injection case if the time delay is considered. However, for the high injection flow rate above 4.0 kg/s, the flow rate was not properly measured until now. There is a need for more characterization tests and some modification of the containment simulator should be considered.

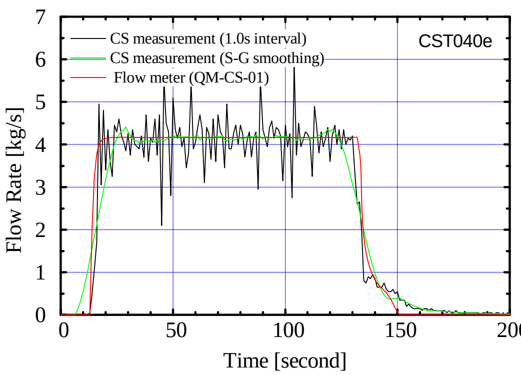

Fig. 2. A typical measurement of a break flow rate during the characterization test

4. Break Flow Rates during LB-CL-15

During the LB-CL-15 test, LC-CS-01 and LC-CS-04 were used to measure the accumulated water masses from separating vessels 1 and 2, respectively. The total break flow rate was also estimated with the RCS inventory change to validate the measured break flow rate by using the CS. The uncertainties of break flow rates measured by using the CS and estimated by using the RCS inventory change are 0.07 and 0.59 kg/s, respectively. The detailed calculation results are summarized in a reference [2].

The accumulated masses measured with the CS and estimated from the RCS inventory change were compared each other during LB-CL-15. There were some difference between them in the initial stage of the test but they were matched in an overall sense. Their final mass difference is 6.4 kg and its error is about 1.6% of the final mass and it could be concluded that the total accumulated mass was measured reasonably well by using the CS.

The mass change rate with respect to the time was converted to a mass flow rate and it is plotted in Figure 3, together with the steam flow rates measured by using a vortex flow meter. QV-CS-02 and QV-CS-03 were used to measure the steam flow rate from separating vessel 2 and the total steam flow rate from both separating vessels, respectively, and thus the steam flow rate from separating vessel 1 is the difference between QV-CS-03 and QV-CS-02. As the CS is installed downstream of the break point and the flow rates of the steam and water were measured with time delays of 10 and 57 seconds, respectively, due to their different flow paths and velocities. The total break flow rate was calculated by a summation of the water and steam flow rates. Accordingly the flow rates of the steam and water were shifted as much as the delayed times and the total break flow rate was also provided. It was concluded that the measured break flow rate is reasonably acquired except for the initial period of 100 seconds, which could be complemented by the flow rate estimated from the RCS inventory change.

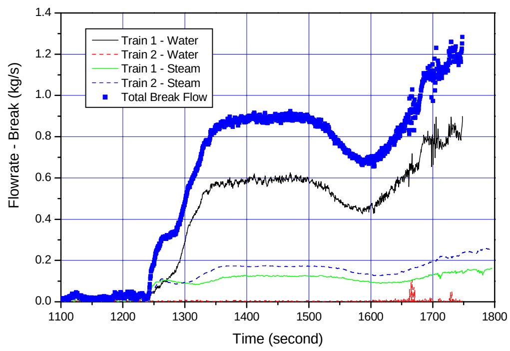

Fig. 3. Variation of the measured break flow rates during LB-CL-15

3. Conclusions

A measurement of break flow rates in the ATLAS was explained based on a LBLOCA reflood test, LB-CL-15. In conclusion the measured break flow rate was reasonably acquired separately for the steam and water flow rates both from the RCP and RPV side breaks. However, as the error seemed to be large for the initial period of 100 seconds, it was complemented by the flow rate estimated from the RCS inventory change.

REFERENCES

[1] Baek, W. P. and Kim, Y.S., "Accident Simulation ATLAS for APWRs," Nuclear Engineering International 53 (646), 21-25, May 2008.

[2] Park, H.S., Choi, K.Y., Cho, S., et al., "Quick-Look Data Report of LB-CL-15," KAERI report, September 2008.