Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2017

Experimental Study on Small Scale Siphon Breaker

Sung-Hoon Kim[a], Dae-Yun Ji[a], Kwon-Yeong Lee[a*]
[a]*Handong Global University(HGU)*
558, Handong-ro, Heunghae-eup, Buk-gu, Pohang, Gyeongbuk, 37554, Republic of Korea
[*]*Corresponding author: kylee@handong.edu*

1. Introduction

A new export-purposed research reactor that is constructed in Jordan uses a plate-type fuel. If a pipe rupture occurs in the reactor, which has a characteristic of core downward flow, the water level of the pool will decrease due to a siphon phenomenon, leading to a leakage of the coolant and an exposure of the core to the air. Consequently, the residual heat of the core will not be removed, causing severe accidents.

Meanwhile, a siphon breaker prevents the occurrence of the loss of coolant accident (LOCA). It blocks an exposure of the core to the air, and cools down the core through a natural convective behavior. There have been several previous researches regarding the siphon breaker to increase the safety of research reactors. Neill and Stephens [1] performed experiments of the siphon breaker using a 4-inch main pipe. Using various orifices, they controlled the pressure and discharge, and depending on the forms of the air sweep-out, they had defined the modes into zero, partial, and full sweep-out. In 2011 and 2013, Kang et al [2,3] performed experiments using a real-scale facility to describe the siphon breaker, which had a 16-inch main pipe, with 16-m height. They continued their experiments by controlling experimental variables such as the size of the siphon breaker line (SBL), size of the pipe rupture (LOCA size), and pipe height (LOCA position). Based on the results of Kang et al [2,3], Lee and Kim [4,5] developed a siphon breaker simulation program (SBSP). In the process of making the program, in order to define the ratio between the air and water discharge, they suggested a C factor. Then, using this, they have provided a correlation formula about Chisholm coefficient B which is required to calculate the two-phase pressure drop. Most recently, Kim et al [6] have designed an experimental facility of the siphon breaker consisting of 1/8 scale – 2-inch main pipe – of the real size by SBSP.

In this study, the experiment was held by altering the SBL and LOCA size through the experimental facility of the siphon breaker, and the results were analyzed using the undershooting height, which is the difference between the end of SBL and the water level

2. Analysis Using Simulation Program

2.1. Experimental Facility

Fig. 1 shows a schematic diagram of a small scale experimental facility of the siphon breaker. Fig. 2 shows the actual small-scale facility. It has been manufactured based on the specifications from the research by Kim et al [6]. The total height of the facility is 2.5-m, and the height disregarding the lower tank is 1.8-m. The designed upper tank has an area of 0.09-m^2, with 0.65-m depth. The undershooting height is measured starting from the end of SBL. The main pipe size is 2-inch, and the size of the experimental facility is designed as 1/8 of the real scale.

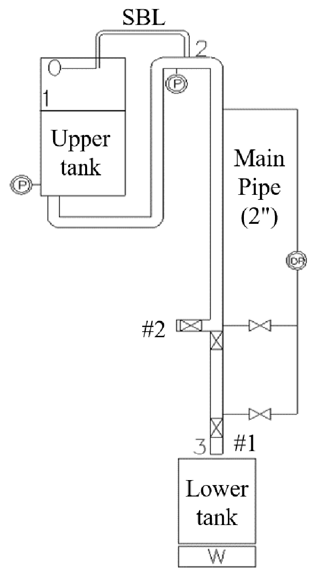

Fig. 1. Schematic diagram of the experimental facility.

Fig. 2. The photograph of the experimental facility.

Table I. Experimental variables

LOCA size (inch)	SBL size (inch)
2	4/8
	3/8
	2/8
1	4/8
	3/8
	2/8

In this study, sensors that were used are based on the specification from the research by Kim et al [6]. A ruler, two absolute-pressure transmitters, a differential-pressure transmitter, and a weighting machine were installed in the experimental facility.

The undershooting height was checked by a ruler with an uncertainty of 1-mm. An absolute-pressure transmitter with ±0.25% accuracy was also installed to assist the ruler at the bottom of upper tank. It monitored the decrease of the water level of the upper tank throughout the experiment in real time. A weighting machine was installed below to record the water weight change of the lower tank. It was installed at the spot where the SBL meets the main pipe. A differential-pressure transmitter with an uncertainty of ±0.3% was placed between point 2 and 3 of the schematic diagram, shown in Fig. 1.

The main variables of this study are LOCA sizes (2 and 1-inch) and SBL sizes (4/8, 3/8, and 2/8-inch). Table I summarizes the variables in this research. Except for 2/8-inch, the experimental range is included within the data of Chisholm coefficient B of Kang et al [2,3].

Whenever the variables are changed, each experiment was named for the ease of understanding. For example, ‘L2S4/8_2’ represents 2-inch LOCA size, 4/8-inch SBL size, and second attempt.

2.2. Operation Procedure

The very first procedure to take is to check the data acquisition system to verify whether the sensors work accurately. Except for the valve that supplies the water to the upper tank, all the other valves must be closed. Then, set the variables: SBL size and LOCA size. After these procedures are taken, start suppling water, remove the air within the main pipe and SBL, and fill the water to the upper tank. Before starting the experiment, run and verify the data acquisition system. Open the valve of the LOCA position and run an experiment. If the movement of the water stops, save the data, and measure the undershooting height of the upper tank. If there is another experiment afterward, return the water of the lower tank to the upper tank through a pump.

3. Experimental Results

This study processed experiments by changing SBL size accordingly to Table I. The flow rate, undershooting height, and pressure data of the upper tank and the apex of the main pipe were measured.

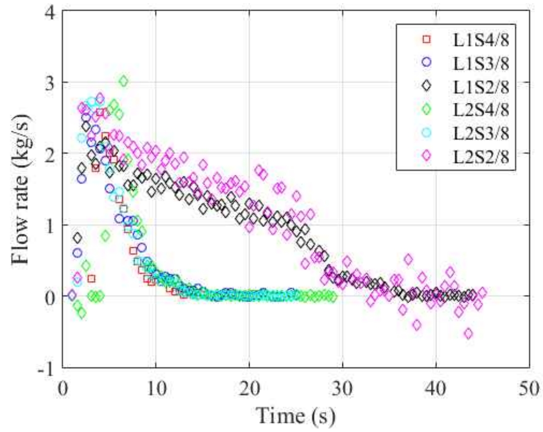

Fig. 3. The results of transient flow rate.

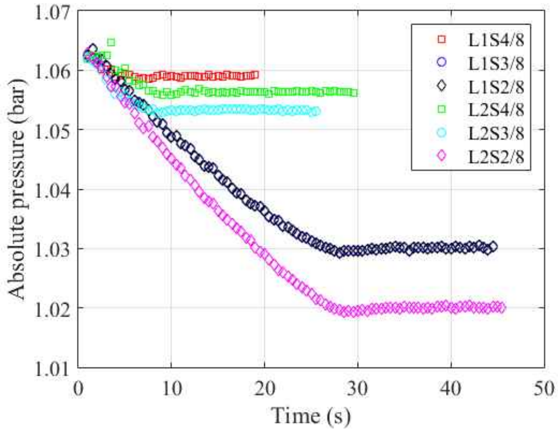

Fig. 4. The results of transient absolute pressure in the upper tank.

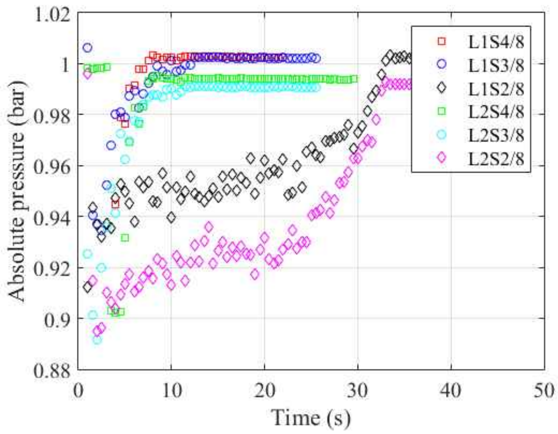

Fig. 5. The results of transient absolute pressure in the apex of the main pipe.

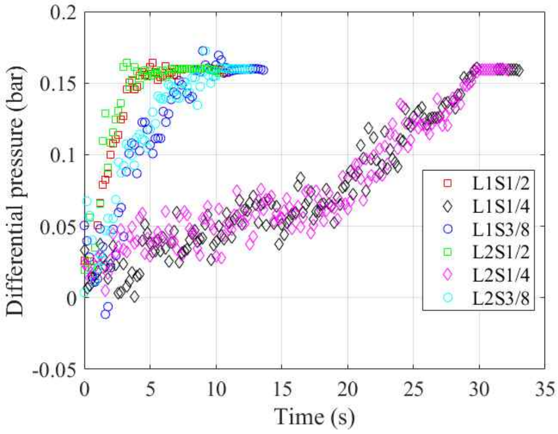

Fig. 6. The results of transient differential pressure.

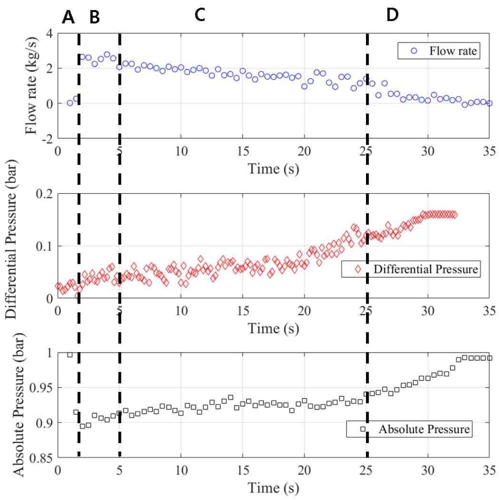

Fig. 7. The results of 'L2S2/8'

Fig. 3 to Fig. 5 show the data of every 0.5 seconds and Fig. 6 shows the data of every 0.2 seconds. Fig. 3 shows the flow rate per time gotten by measuring the water through a weighting machine. Fig. 4 shows the water level that is measured every 0.5 seconds by the absolute-pressure transmitter which is installed in the upper tank. The transmitter supports the attachable ruler that measures the undershooting height and shows how siphon breakers are effective. Fig. 5 shows the absolute-pressure at the point where the SBL meets the apex of the main pipe. Fig. 6 shows the results of the differential pressure, which can be used in analyzing the change of the sweep-out mode, which alters by the increase of air during the siphon breaking. These experiments were repeated by three or more times, providing stable results.

4. Discussion

4.1. Process of Siphon Breaking

Fig. 7 shows the results of 'L2S2/8': the transient pressure and flow rate. This test was selected, since it took the longest time among all the experiments and

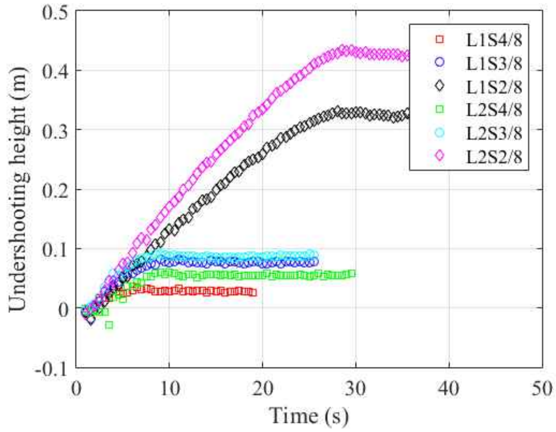

Fig. 8. Graph of undershooting height.

demonstrated the most obvious transient data. In reference to Kang et al [2,3], Fig. 7 splits the data into four stages. In stage A, the water level started to drop to the end of SBL. However, the siphon breaking did not happen since the end of SBL was placed in the water. At the start of stage B, as SBL got exposed to the air, the highest amount of flow rate was shown. The blocking of the water flow by the air and an increase of the absolute pressure were followed afterward. the differential pressure also increased slightly. In stage C, while the water flow decreased gradually, the differential pressure increased. the absolute pressure remained in between 0.94 and 0.96. Last but not least, during stage D, at the end of siphon breaking, flow rate reached 0. differential pressure showed the difference between point 2 and 3 of the schematic diagram. the absolute pressure increased rapidly, and arrived 1-bar.

4.2. Undershooting Height

Fig. 8 shows the undershooting height of each experiment in real time. While the undershooting height was less than 10-cm for 4/8 and 3/8 SBL size, it was above 30-cm no matter the size of LOCA for 2/8 SBL size. These 30-cm-or-above values for 2/8 SBL size had a trend of a steep increase of the undershooting height. As a result, water level dropped below the core and the core was exposed to the air. Since the important role of siphon breaker is to protect the core within the water, if the water does not stop immediately, the siphon breaker will not guarantee the safety. Therefore, 2/8 SBL size is not valid for the actual design.

5. Conclusion

This study was carried out in order to make a small scale experimental facility for the siphon breaker and to evaluate the experimental results through the undershooting height.

The experiment was held for the SBL size of 4/8 and 3/8, which are within the range of Kang et al [2,3], and for 2/8-inch, which is out of the range, while changing the LOCA size. Regardless of LOCA sizes, the results showed that 4/8-inch and 3/8-inch sizes went through immediate siphon breaking, thus having low undershooting heights. However, in the case of 2/8-inch, the undershooting height increased dramatically. Nonetheless, since 2/8-inch is out of the experimental range, it is considered to be unnecessary in designing the actual research reactor.

REFERENCES

[1] D. T. Neill, and A. G. Stephens, Siphon Breaker Design Requirements – Final Report, USA DOE/ER/128020-T1, 1993.
[2] S. H. Kang, M. H. Kim, K. W. Seo, K. Y. Lee, and D. Y. Chi, Final report of experimental studies on siphon breaker, Korea Atomic Energy Research Institute, 2011.
[3] S. H. Kang, K. C. Lee, M. H. Kim, K. Y. Lee, K. W. Seo, S. H. Kim, and J. H. Yoon, Experimental Study of Siphon breaker, Korea Atomic Energy Research Institute, 2013.
[4] K. Y. Lee and W. S. Kim, Theoretical study on loss of coolant accident of a research reactor, Nuclear Engineering and Design, Volume 309, pp 151-160, 2016.
[5] K. Y., Lee and W. S., Kim, Development of siphon breaker simulation program for investing loss of coolant accident of a research reactor, Annals of Nuclear Energy, Volume 101, pp 49-57, 2017.
[6] S. H. Kim., J. H. Kim, D. Y. Ji, and K. Y. Lee, Application of siphon breaker simulation program for small scale siphon breaker, Transactions of the Korean Nuclear Society Spring Meeting, May.17-19, 2017.