# Investigation of siphon breaker simulation program through small scale siphon breaker experiment

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**Abstract**. When a research reactor which has a characteristic of the core down flow is designed, some important components like pump are located at a lower height than the core is. It is because of siphon phenomenon. It happens through a pipe when the main pipe of the primary cooling system is ruptured. As coolant leaks from the reactor pool, the water level of the pool gets lower as much as the coolant leaks. Thus, a core is exposed to air and this can lead to dangerous situations. To prevent it, siphon breaker is developed. However, as it is difficult to predict the results, a siphon breaker simulation program(SBSP) was designed by Lee et al.[7]. In this study, by using the SBSP, a small scales siphon breaker was designed to verify the SBSP. Range of experiments included previous experimental range by Kang et al.[4][5], and expended to improve the SBSP. The results of experiments follow the SBSP's one except for the extrapolation range. As a result, the SBSP is a good estimate for designing general siphon breakers, but it requires the model improvement for satisfying the wider range.

## 1. Introduction

A research reactor which has a characteristic of the core down flow locates some important components like pump at a lower height than the core is. If an accident, a pipe rupture, occurs under the cores, the water which cools the cores is leaked from the pool through a siphon phenomenon. As a result, the cores exposed to air will not remove the residual heat, causing serious accidents. A siphon breaker blocks the occurrence of the loss of coolant accident(LOCA). When LOCA occurs in the reactor, it prevents a siphon phenomenon by a siphon breaker line(SBL) using the air. Consequently, the cores are protected in the pool by siphon breaker.

There have been several studies about the siphon breaker which improves the safety of research reactors. In 1958, McDonald et al.[1] carried out an experiment to block the reverse flow of sodium on a sodium graphite reactor. In 1993, Neil et al.[2] designed a siphon breaker facility with a 4-inch main pipe. They controlled flow rates and pressures varied by orifices, and defined the air sweep-out modes which classify into the zero, partial, and full sweep-out modes. In 1999, Sakurai et al.[3] proposed a model to analyze the siphon breaking. While the results of their model showed experimental data, only two experiments were conducted. Kang et al.[4][5] constructed experiment facility like a real-scale research reactor with 16-inch main pipe. They did tests, varying LOCA size and position, SBL size and orifice for making situations like accidents. The results through experiments were applied to the design of real siphon breaker. Lee et al.[6][7] developed the siphon breaker simulation program(SBSP) in order to help analyze and builds about siphon breaking phenomenon. The SBSP was able to analyze siphon breakings and transient pressures and flow rates on real-time. However, it need to check validity the results correspond to experimental results. This study introduces the small-scale siphon breaker facility designed, and experimented varying LOCA size and SBL size. In addition, the results were analyzed with SBSP.

## 2. System description of small-scale siphon breaker

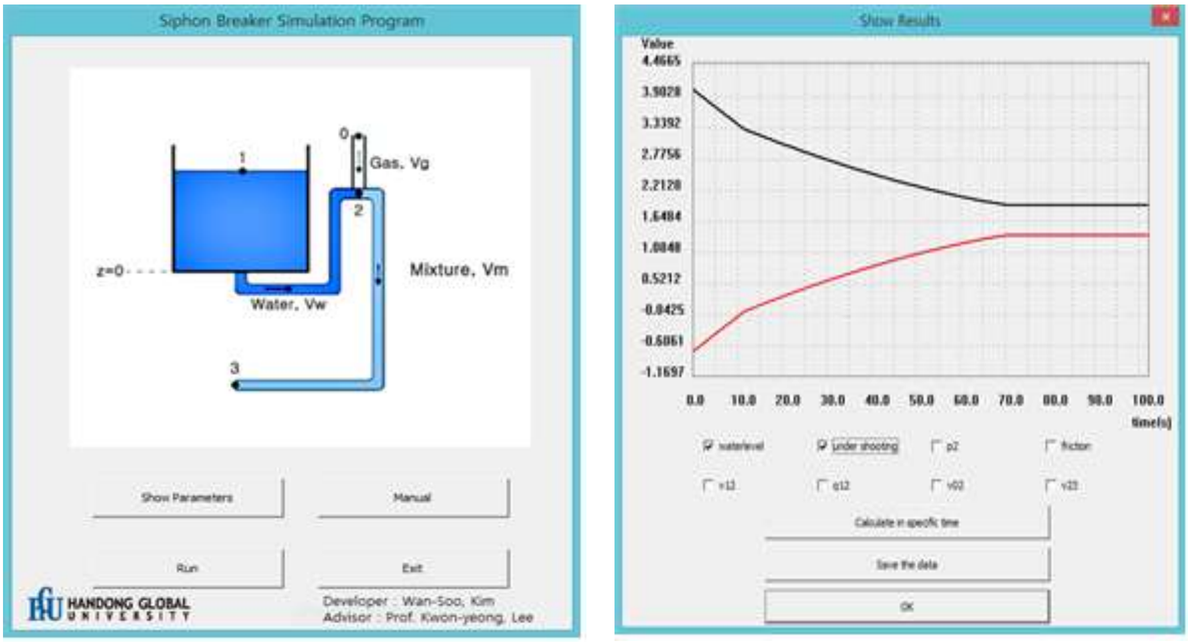
### 2.1 Theoretical modeling

Figure 1(a) and Figure 1(b) show siphon breaker simulation program developed by Lee et al.[7]. The equation (1) to equation (3) are used based on SBSP. An equation (1) is a Chisholm coefficient B model developed by Lee et al.[6]. An equation (2) is C factor rate between air flow and water flow. And an equation (3) is the undershooting height that is difference between the water level and $Z_0$, the end of SBL. Relation between Chisholm coefficient B and C factor is variables to verify the SBSP. Undershooting height can evaluate exposure range of the cores.

$$B = 1.4618 \times 10^{-10} \times C^2 - 2.7856 \times 10^{-5} \times C + 1.831678 \quad (1)$$

$$C\ factor = \frac{Mass\ flow / Area}{\sqrt{Area_{siphonpipe} \times \sqrt{1/K_{02}}}} \quad (2)$$

$$Undershooting\ \ height = waterlevel - Z_0 \quad (3)$$




*(a) Initial screen* *(b) The results of simulation*

*FIG 1. Siphon breaker simulation program(SBSP)*

### 2.2 Experimental facility

Figure 2 and Figure 3 show a schematic diagram of the experimental facility and the small-scale experimental facility. The facility was constructed by reducing the size of real-scale experimental facility[4][5] to 1/8 ratio, and it is consisted of an upper tank, a lower tank, pipes which connect the upper tank and the lower tank, and a pump. The size of upper tank which imitate a pool of the reactor is 0.09-m$^2$ area and 0.65-m height. The lower tank is used to receive the water drained by the siphon effect in the tank. The diameter of the pipes has 2-inch. The pump returns the water from lower tank to upper tank every experiment finishes.
Table 1 shows experimental variables; LOCA sizes and SBL sizes. Kang et al.[4][5] checked that the smaller the diameter of LOCA size, the lower the undershooting height, while the smaller the diameter of SBL size, the higher the undershooting height. In this study, LOCA sizes were used two variables; 1-inch and 2-inch and SBLs were used three variables; 2/8-inch, 3/8-inch, and 4/8-inch.
For experiments, several measuring instruments were used. A tapeline measured undershooting height, and an absolute-pressure transmitter (absolute 1~2-bar, uncertainty 0.25%) are installed in the upper tank. The other absolute-pressure transmitter is installed at the point 2-inch the Figure 2 where the pipes and the end of the SBLs meet. A differential pressure transmitter (0~200-mbar, uncertainty 0.3%) is installed between point 2 of the schematic diagram and point 3. And a weighting machine for measuring flow rate is installed under the lower tank.

*TABLE 1. Experimental variables*

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

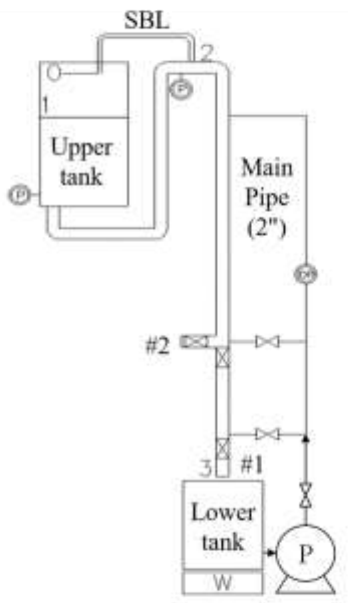
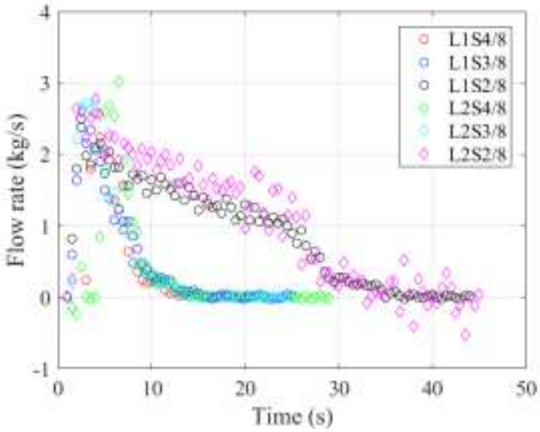
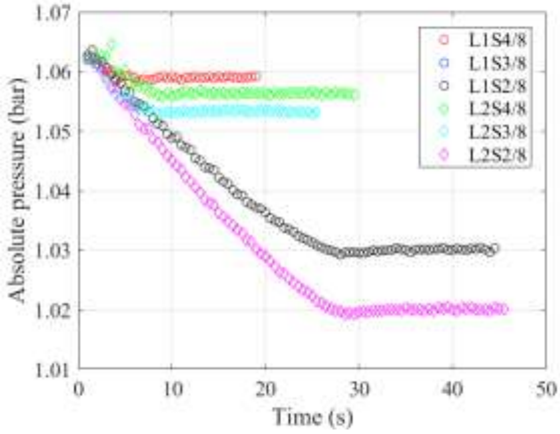



*FIG 2. Schematic diagram of experimental facility*

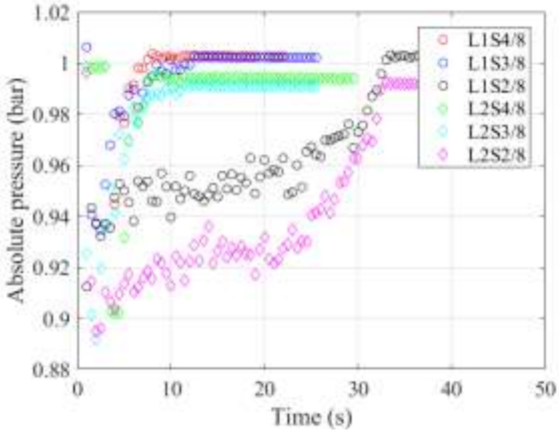
*FIG 3. The small-scale experimental facility*



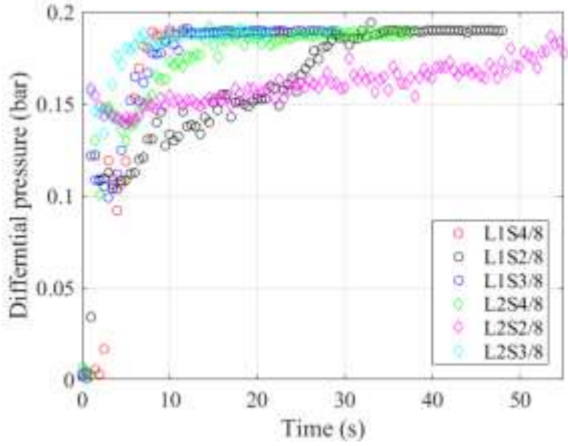

*(a) Flow rate*




*(b) Absolute pressure in the upper tank*




*(c) Absolute pressure in the apex of the main pipe*




*(d) Differential pressure in downcomer*

*FIG 4. The results of experiments*

## 3. Experimental Results

In this study, measurement was performed in units of 0.2 seconds when measuring data. Figure 4(a) shows transient flow rate differentiated by measuring the amount of water in units of 0.2 seconds using a weighting machine. It was observed that the siphon phenomenon of SBL 2/8-inch occurred for a long time compared to SBL 3/8-inch and 4/8-inch. Figure 4(b) shows that the water level inside the upper tank is measured by water pressure, and the undershooting height is measured by the difference from the tip of the SBL to the water level. It can be derived by converting undershooting height as the absolute pressure value in Figure 4(b). Figure 4(c) shows measuring value of the pressure at the point 2 in the schematic diagram. Through this result, it is possible to measure the pressure loss coefficient of the experimental facility. Contrary to the sudden occurrence of the siphon braking phenomenon on SBL 3/8-inch and SBL 4/8-inch, it was observed that siphon braking occurred over 20 seconds in SBL 2/8-inch experiment. Figure 4(d) shows measuring the differential pressure between point 2 and point 3 of the schematic diagram. Moreover, if a visible pipe is installed between point 2 and point 3, Figure 4(d) can interpret the sweep-out modes with Figure 4(c). As sudden siphon braking occurred at SBL 3/8-inch and SBL 4/8-inch, it was observed that its sweep-out mode is zero sweep-out mode. In SBL 2/8-inch, after the full sweep-out mode has lasted long, it was observed that the water flow rate has decreased and it suddenly changed in zero-sweep out mode

## 4. Discussion

### 4.1 Undershooting height

Figure 5 shows the results of undershooting height while changing LOCA sizes and SBL sizes. The results show 3.6-cm, 4.1-cm for SBL 4/8-inch, 6.5-cm, 7.1-cm for SBL 3/8-inch, and 32.4cm, 41.2-cm for SBL 2/8-inch from LOCA 1 to LOCA 2. In SBL 2/8-inch, the undershooting height got higher than the other SBL size because the sweep-out mode is different. SBL 2/8-inch did not have zero sweep-out mode at first and siphon braking was delayed as the results, the undershooting height appeared high. When applying the siphon breaker to the design, we have to design considering the effect of sweep-out modes.

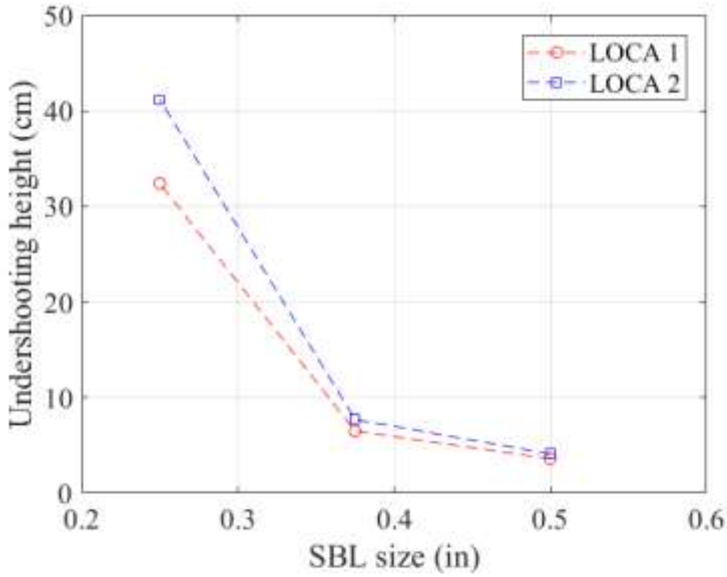



*FIG 5. Result of undershooting height*

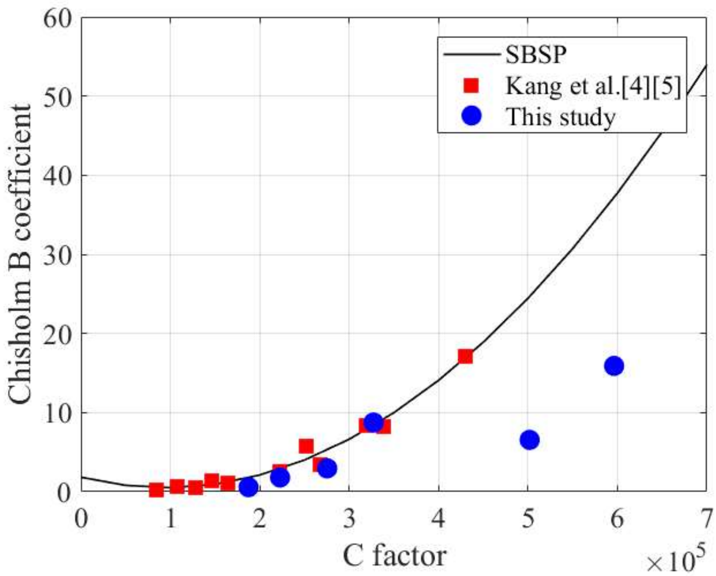



*FIG 6. Tendency of C factor & Chisholm coefficient B*

### 4.2 Chisholm coefficient B & C factor

Figure 6 shows a graph comparing the relational expression of Chisholm coefficient B used in SBSP, and the experimental results. It was confirmed that SBL 4/8-inch and 3/8-inch trace the trend of SBSP model, but SBL 2/8-inch, the extrapolation, was not. Since full sweep-out mode is displayed on SBL 2/8-inch, it was confirmed that it does not follow the expected results of SBSP.

## 5. Conclusion

In this study, we designed and manufactured small siphon breaking experiment facility using SBSP which was developed by Lee et al.[7]. Experiments were conducted while changing two kinds of LOCA size and three kinds of SBL size. The results checked pressure, differential pressure, and flow rate. In the SBL 4/8-inch and 3/8-inch, the results showed siphon braking at the beginning of the experiment, but the full sweep-out mode was displayed at SBL 2/8-inch. In addition, it was confirmed that the siphon braking was delayed. SBL 2/8-inch, also, did not follow the trend of relational expressions in comparison with SBSP. In conclusion, this study confirmed that SBSP predicts the results except for the extrapolation.

## 6. References

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