Experimental study on size effect of siphon-breaking hole in the real-scaled reactor pool

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1. Introduction

A rupture in the primary piping of a cooling system with a heat source or in a research reactor could lead to a loss-of-coolant accident (LOCA). However, if the water level of the reactor pool could be sustained and a reactor scram follows, the heat source could be cooled by natural convection, and significant accidents could be avoided. When a piping-system rupture accident occurs, the coolant starts to siphon out of the reactor pool until the pressure head between the inlet and outlet is removed or the siphon flow is interrupted. Therefore, a siphon-breaker mechanism can be adopted as a passive safety device to maintain the reactor water level. The gas entrainment is used to block the continuous loss of coolant by interrupting the siphon flow.

Siphon breaking is complicated due to the transient, turbulent, two-phase flow mode, so suitable models or correlations that describe this phenomenon do not exist, and no general analysis been developed. Previous researchers have conducted experiments and numerical simulations to design a siphon breaker to meet their needs. [1, 2, 3] Previous research on siphon breaking has not been conducted systemically, and no literature exists, even though the topic is greatly concerned with hydraulic safety.

In this study, siphon-breaking holes were used as siphon breakers, and their performance was evaluated by the residual water quantity. Flow visualization was conducted to interpret the siphon-breaking phenomenon.

2. Experiment

The experimental facility is described and the experimental results are also discussed in this section. All of the experimental tests were conducted at atmospheric pressure and temperature.

2.1 Experimental apparatus

The siphon-breaker experimental facility consisted mainly of an upper tank, a lower tank, a piping system, and a return pump. Fig. 1 shows a schematic diagram of the experimental facility, respectively. The upper tank had a capacity of 60 m^3, with a 4-m depth and 16-inch steel pipe was used as main pipe. A ruler was

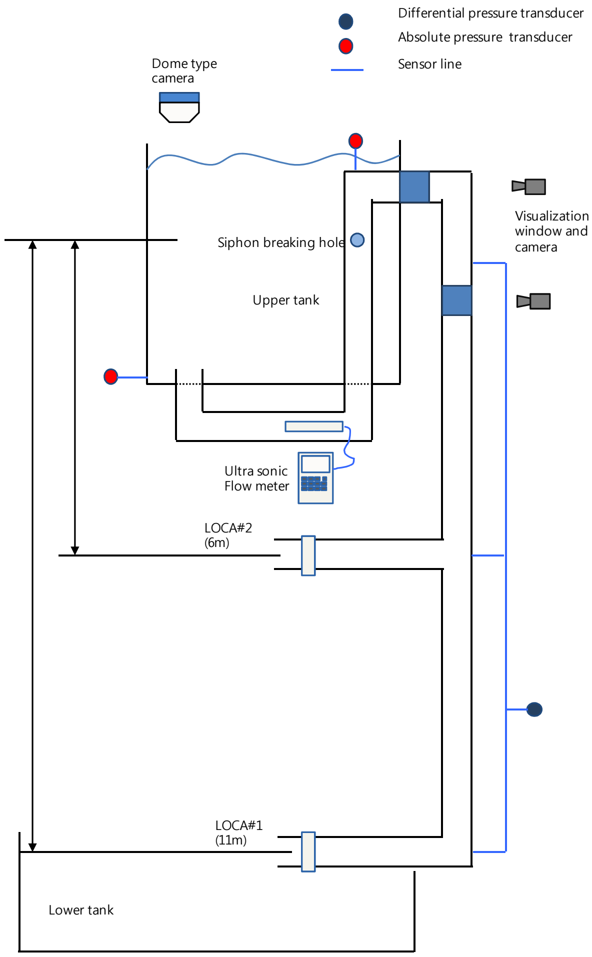

Fig. 1. The schematic diagram of experimental facility

installed on the wall of the upper tank to measure the water level of the pool. The lower tank had a capacity of 70 m^3. The LOCA positions mimicked the rupture position of a pipe in a real reactor and each LOCA position had a butterfly valve that was controlled by an air compressor and an electric controller. The siphon-breaking holes were made of acrylic plate for ease of visualization, changing, and manufacturing. They were located 2.7 m from the pool bottom, measured to the center of the hole. Two differential-pressure transducers, an absolute-pressure transducer, and an ultrasonic flow meter were installed in the experimental facility to investigate the actual change of pressure behavior and phenomena.

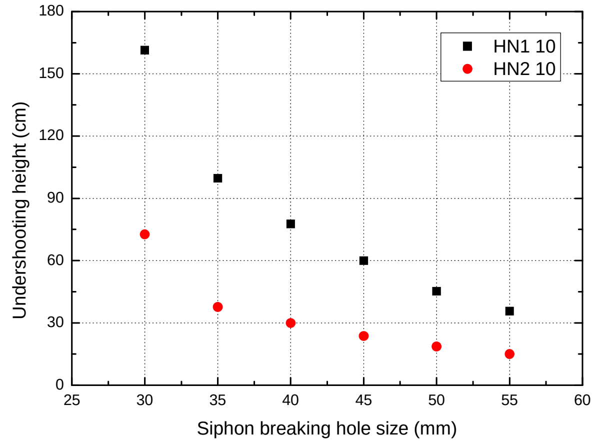

Fig. 2. Undershooting height for various siphon-breaking hole sizes and LOCA positions

2.2 Experimental result

The undershooting height was chosen to evaluate the performance of the siphon breaker, and indicated how much the water level decreased during the siphon breaking, i.e., how much coolant was lost before the penetrated air blocked the coolant flow stream.

Siphon-breaking hole tests were conducted with various hole sizes and LOCA positions. The diameter of the siphon-breaking hole varied from 30 to 55 mm. Fig. 2 shows the undershooting height results of the siphon-breaking hole tests. Fig. 3 and 4 shows the transient pressure behavior with various siphon-breaking hole sizes. In the designed range of the siphon-breaking hole size, the siphon breaker operated well at all of the cases. As decreasing the siphon-breaking hole size, the undershooting height was increased and the undershooting height with LOCA#1 was more than with LOCA#2. The difference of the siphon-breaking hole size is concerned with the flow rate of entrained air which can break the siphon effect. The larger siphon-breaking hole has the higher air flow rate with shorter breaking time. The differential pressure results show the gradual increasing trends after the mixing of air in downward pipe and the void fraction of air in the downward main pipe can be predicted instead by assuming that the change in differential pressure is caused by a change in density and void fraction, even though the flow rate of the blocking air is different. The differential pressure results show the change of mode on siphon-breaking by different trends of differential pressure, whether the air flowed out or not. The change of slope at each case could be the evidence of the existence of separate air-sweep-out modes.

The additional research on the parameters, such as the different siphon-breaker type, water flow rate, and etc, could give the more obvious understanding on the siphon-breaking phenomenon.

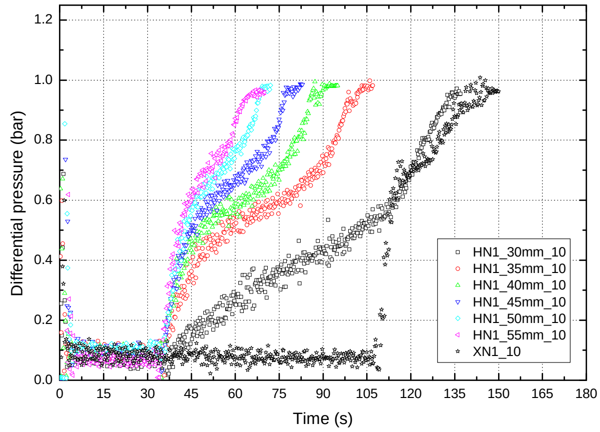

Fig. 3 Differential pressure data for various siphon-breaking hole sizes at LOCA#1

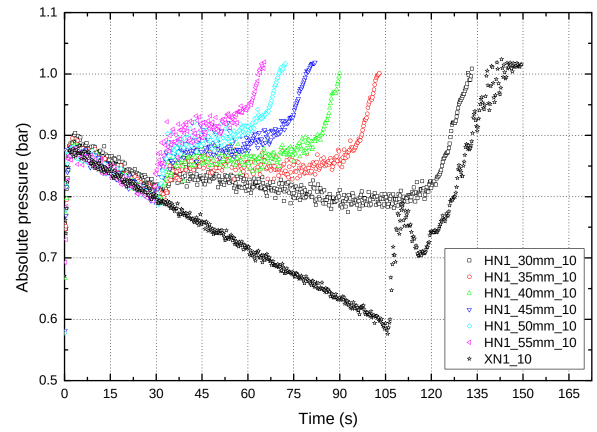

Fig. 4 Absolute pressure data for various siphon-breaking hole sizes at LOCA#1

3. Conclusions

Siphon breakers were investigated using a full-scale experiment. The undershooting height was used as a means of evaluating size effect of siphon-breaking holes, and transient data were used to analyze the siphon-breaking phenomenon. With the designed range of siphon-breaking hole, the siphon breaker operated well and shows the similar trends at all cases.

ACKNOWLEDGEMENT

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