Experimental Study of Negative Pressure Pipe Breakage Accidents according to the Breakage Size

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1. Introduction

This research team has conducted an experimental study on negative pressure pipe breakage accidents in research reactors [1]. Through the experiment, the system behavior and air inflow rate due to the rupture of the negative pressure pipe were checked, and the role of the decay tank as an accident response facility and whether the air leaked to the outlet was confirmed.

Through the experiment, it was confirmed that the pipe pressure at the break point and breakage size were the major factors affecting the system behavior and air flow rate in the breakage accident of the negative pressure pipe. The pipe pressure at the break point is determined by the coolant flow rate, and the coolant flow rate has a certain range based on the minimum core cooling flow rate TDF (Thermal Design Flow). As the coolant flow rate increases, the core pressure drop increases, and accordingly, the pipe pressure decreases. In research reactors, the breakage size is determined by the power, shape, and purpose of the reactor, and in many research reactors, Dt/4 is applied as the breakage size.

In this study, the effect of breakage size change on negative pressure pipe failure accidents was experimentally evaluated. The change in the amount of air inflow according to the change of the breakage size was evaluated, and the stratification phenomenon of the decay tank was observed when different amounts of air were introduced.

2. Test facility and test condition

The test facility was configured as shown in Figure 1, and an orifice located in the pipe break part was used to change the breakage size [2-3]. The test conditions are system flow rate 40 kg/s and the absolute pressure in the pipe is 70 kPa. For the breakage size, total three (3) cases of 3/4 inch based on Dt/4 and other 1/5 inch and two (2) inch cases were applied. The rupture test was performed after the pressure located at the rupture part was sufficiently converged to the test conditions, and the rupture was performed using an AOV (Air Operated Valve) located on the pipe break part.

3. Test results

System characteristics according to breakage size were compared. In Fig. 2, the pipe break occurred at 10 seconds, and the pump stop signal occurred at 70 seconds after the breakage proceeded for 60 seconds. However, in the case of 2 inch break, the pump was stopped after simulating the pipe break for 45 seconds in consideration of the higher air inflow. After the pump stop signal, the flow by the pump flywheel continued for 20-30 seconds, and then the experiment was ended.

Figure 2 shows the change in coolant flow rate and pressure in front and rear of the pump according to the breakage size. After the breakage, the pressure near the break part increases as the coolant is exposed to the atmosphere.

In the case of a small breakage size of 1/5 inch, the system pressure change is not large, so the pressure and system flow rate change at the front and rear ends of the pump hardly appear. In 3/4 inch and two (2) inch, the pressure in front of the pump is lowered according to the inflow of air, and accordingly, the system flow rate is reduced. At two (2) inch break, the system flow rate greatly vibrates as the pressure fluctuation in front of the pump is large.

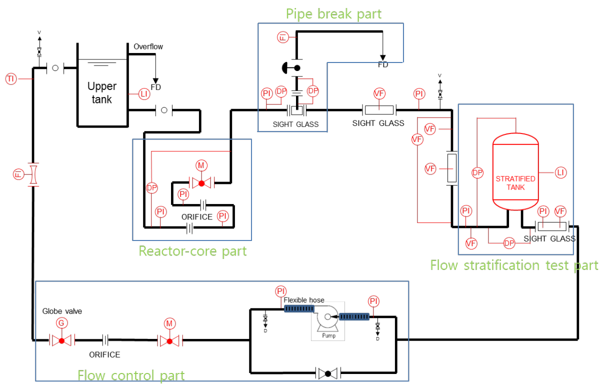
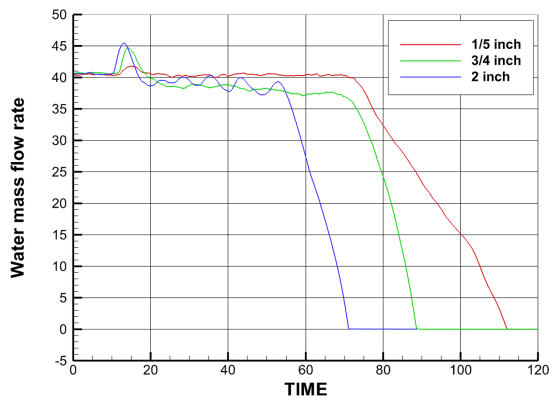


Fig. 1. Schematic diagram of negative pressure pipe breakage test facility



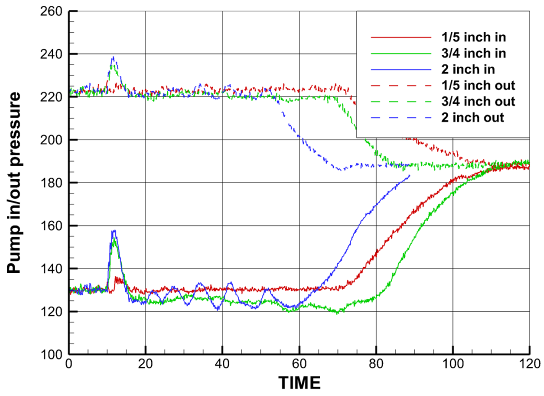


Fig. 2. Water mass flow rate and Pump in/out pressure according to the breakage size

The comparison of air inflow according to the breakage size was shown in Fig. 3. As the breakage size increases, the air inflow increases, but the ascent rate decreases slightly. The average air inflow is estimated to be 0.00046 kg/s at 1/5 inch, 0.00256 kg/s at 3/4 inch, and 0.00288 kg/s at 2 inch. At the break size of two (2) inches, the fluctuation of the air inflows is very large. This can be seen as a result of the fact that the coolant flows out simultaneously with the air inflow because the breakage size is very large.

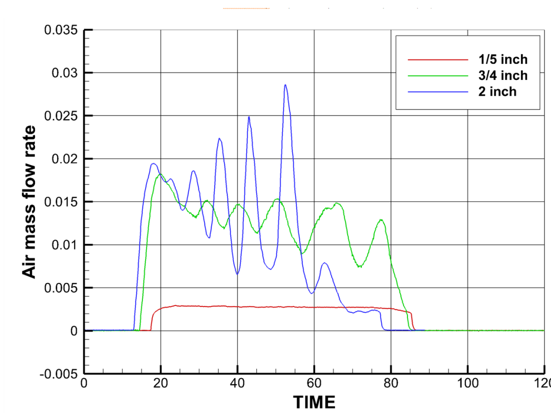


Fig. 3. Air inflow rate according to the breakage size

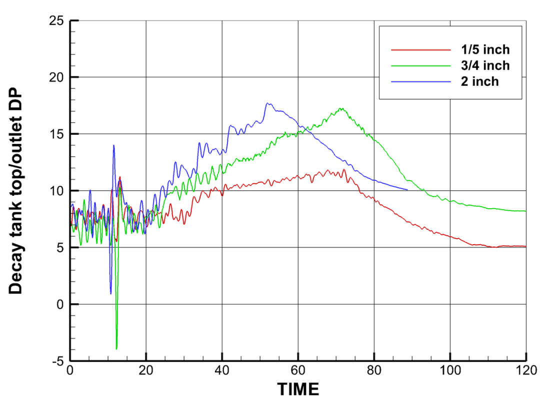


Fig. 4. Decay tank top/outlet pressure difference according to the breakage size

Fig. 4 compares the differential pressure at the top/outlet of the decay tank according to the breakage size. The larger the breakage size, the larger the gradient of the differential pressure rise. After a pipe breakage accident occurs, the pressure at the break point rises first, then the pressure rise is transmitted to the decay tank and pump. A time difference occurs in the process of transferring the pressure rise, and as s result, it can be seen that the pressure difference of the decay tank fluctuates greatly immediately after the breakage. At a small breakage size of 1/5 inch, the interface in the decay tank is not created for a considerable period of time, maintaining a constant differential pressure, and then the differential pressure tends to rise after the interface is created. At the largest 2-inch break, the differential pressure rise appears in the form of a step, which can be seen as a result of the flow of air as shown in Figure 3.

Figure 5 shows the air fraction in front and rear of the decay tank to check whether the decay tank outlet air leaks or not. The larger the breakage size, the larger the air fraction at the decay tank inlet is confirmed.

In a 1/5 inch breakage accident, the air fraction in front of decay tank appears very late despite the same coolant flow rate. This can be seen as the effect that a small amount of air inflow is transferred to the decay tank after it is accumulated in the pipe. The result of no air leakage can be seen through the no significant change of air fraction at the rear end of the decay tank, and this was also confirmed through the visualization window.

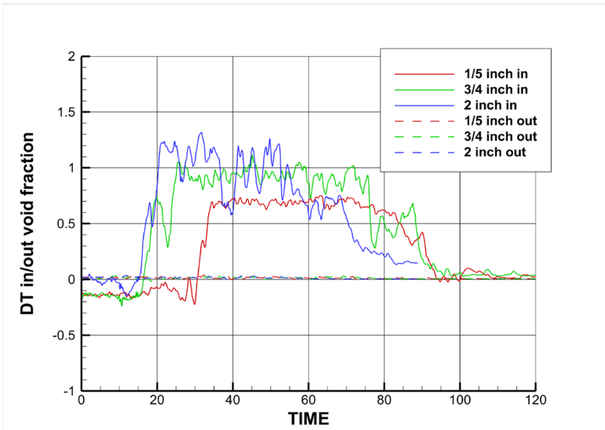


Fig. 5. Void fraction change at decay tank inlet/outlet according to the breakage size

4. Conclusions

In this study, the breakage accident of negative pressure pipe according to the breakage size was experimentally studied. With a large breakage size, the pressure recovery at the breakage portion is large, and the pump shear pressure rises, and accordingly, the coolant flow rate decreases. It was confirmed that as the breakage size increased, the pressure recovery of the breakage size was large, and the air inflow rate also increased. However, as the breakage size increases, the increase rate of air inflow decreases, and in breakage larger than a certain size, air inflow and coolant outflow were confirmed. This trend was also confirmed in the differential pressure trend of the decay tank. In addition, no significant level of air leakage to the decay tank outlet was confirmed at various breakage sizes.

ACKNOWLEDGEMENTS

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