Experimental Study on the Break Accident for the Negative Pressure Pipe in the Primary Cooling System of a Research Reactor

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1. Introduction

Research reactors are designed to include open-pools and have core-upward or downward flow paths depending on the purpose of their use and design characteristics. In a reactor with a core-downward flow path, a very large core pressure drop and the piping height of the PCS (Primary Cooling System) result in a subpressure lower than atmospheric pressure at the highest-positioned pipe of PCS. The external air inflow is caused by the breakage of the negative pressure pipe, which can lead to the degradation of the performance of the major fluidic devices, such as decay tank, pump, and so on, in the PCS.

The researchers conducted an experiment to simulate a breakage accident for negative pressure pipes. In addition, it was also evaluated whether the air trapping performance of the decay tank is suitable for incident response. The contents to be checked in this study are listed below.

1. Check the air inflow rate due to the negative pressure pipe breakage and the air-water mixture behavior in the pipe
2. Observation of air-water stratification in the decay tank
3. Check whether air is leaking through the decay tank outlet

2. Test facility and test condition

The target reference of the test facility is the PCS of the medium-powered research reactor designed by this team. To implement cooling system experimentally, a three-level scaling method presented by Ishii and Kataoka has been utilized [2]. The test facility consisted of four parts: reactor core, pipe break, flow stratification test, and flow control as shown in Fig. 1. Reactor core part consisted of two orifices and a flow control valve to impose the core pressure drop. And, pipe break part is composed of an orifice indicating the size of the pipe break, an air operating valve for break operation, and an air flow meter. The stratification test part consisted of a decay tank and related measuring instruments to check the behavior of the air-water mixture introduced into the tank and whether air is leaked for a certain period of time. The flow control part was constructed to form a system flow rate with a pump and a flow control valve.

Test conditions are system flow rate 40 kg/s, the absolute pressure in the pipe is 70 kPa, and the breaking size is 3/4 inch based on Dt/4. The pipe break was performed while the system behavior was sufficiently maintained in a steady state.

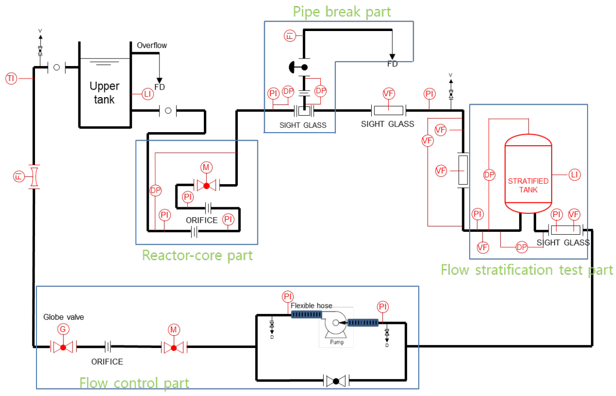

Fig. 1. Schematic diagram of negative pressure pipe breakage test facility

3. Test results

The objectives of present study is to understand the system behavior of PCS, check air inflow at the breakage region, observe the behavior of the air-water mixture in the decay tank, and determine whether air is leaked to tank outlet due to the negative pressure pipe breakage accident. In order to understand the system behavior according to the pipe breakage, the pressure change at the break region and the front and rear of the pump are shown in Fig. 2. It can be seen that the pressure at the fracture position rapidly rises from negative pressure to about 95 kPa immediately after pipe breakage and then gradually converged to atmospheric pressure. On the other hand, the pressure at the front and rear of the pump tends to decrease again after the initial pressure increase. In particular, as the pressure change at the front of the pump is larger, it can be seen that the differential pressure at the front and rear of the pump decreases after pipe rupture and then gradually increases again.

Figure 3 shows the changes in the system flow rate passing through the pump and the change in the air flow rate from broken area according to the pipe breakage. The flow rate, which was maintained at about 40 kg/s before rupture, increased to a maximum of 45 kg/s as the differential pressure at the front and rear of the pump decreased after rupture. After that, it is reduced to about 36 kg/s before the pump stop signal, which can be seen as an effect of the pressure decrease at the front of the pump. After the pipe breaks, the pressure rises at the break and air inflow starts at the same time. The air flow rate increased to 0.018 kg/s and then decreased to 0.015 kg/s, and then the flow rate decreased with fluctuations before the pump stop signal. The fluctuation of the air flow rate can be seen as a result of the pressure change due to the fluctuation of the water level in the upper water tank and the air-water interaction at the break position. In addition, the decrease in air flow rate can be inferred as the cause of the decrease in the differential pressure with outside due to the rise in the water level in the upper water tank.

Figure 4 shows the differential pressure at the top/outlet of the tank to observe the differential pressure change of the decay tank due to air inflow. The differential pressure of the decay tank maintains about 8 kPa in a steady state, and then vibrates greatly after breakage. Since then, as air accumulates in the decay tank, the differential pressure of the tank increases.

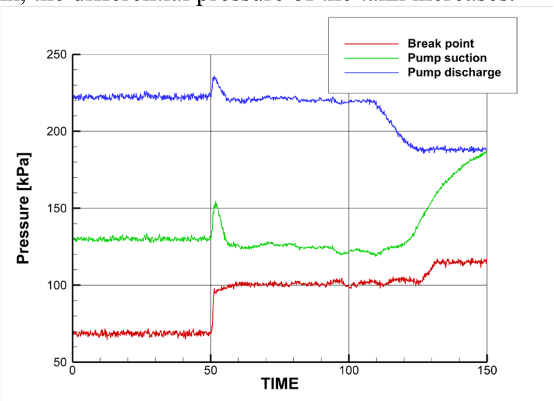

Fig. 2. Pressure change at the break point, the front and rear of the pump

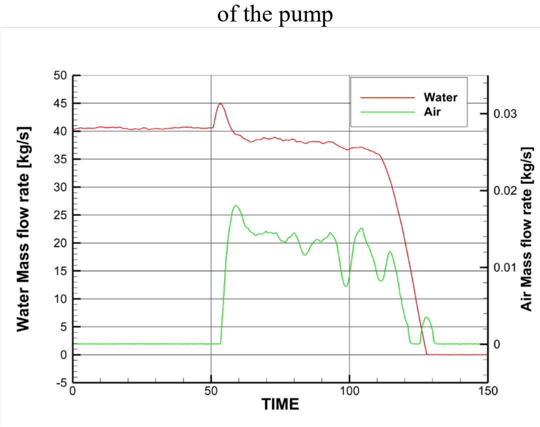

Fig. 3. Mass flow rate for water and air inflow

In order to check whether air is leaking through the decay tank outlet, observation through the visualization window and air fraction measurement using the pipe head were performed. Figure 5 shows the air fraction of the decay tank inlet and outlet. In the case of the tank front, a large differential pressure increases with the air inflow, whereas a significant differential pressure change does not appear at the rear. This was observed in the same way in visualization, and through this, it can be determined that there is no significant level of air leakage.

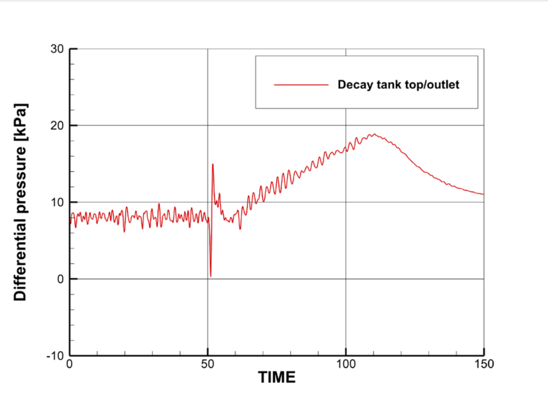

Fig. 4. Differential pressure for decay tank top/outlet

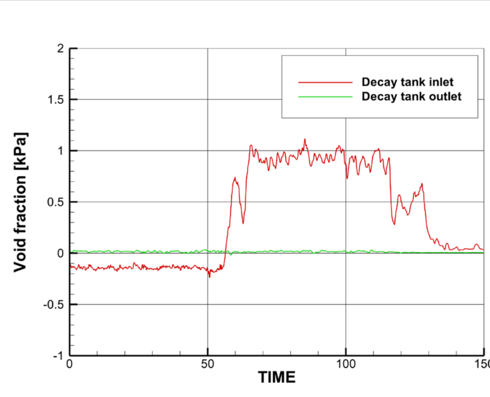

Fig. 5. Void fraction change at decay tank inlet/outlet

4. Conclusions

In this study, the negative pressure pipe breakage accident was experimentally implemented, and the system behavior according to the accident, the air-water stratification phenomenon in the decay tank, and air leakage to the decay tank outlet was evaluated. Air inflow from the break point accumulates due to the air-water stratification in the decay tank, and no significant air leakage was observed. Based on the present results, experiments on various experimental variables, such as negative pressure magnitude and fracture area size, will be conducted.

ACKNOWLEDGEMENTS

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