# Preliminary Analysis of Negative Pressure Pipe Break Test using MARS-KS

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## 1. Introduction

Research reactors were utilized to apply the various fields such as neutron beam applications, nuclear fuel & material test, RI production, medical application, and so on. In Korea, it is considered that Research reactor with a downward flow of reactor core is one of the design candidates due to convenience for installing the neutron utilization tools. However, in case of the downward flow, there are safety issue of air-entrainment phenomenon during negative pressure pipe break accident. Recently, to solve critical safety issues, design enhancement of a primary cooling system was conducted and numerically validated [1-4].

In this study, an experiment was conducted using the test facility established by applying a scaling method to verify that air capture is possible using a decay tank when a negative pressure pipe is broken [5]. Preliminary analysis was performed using the MARS-KS code to analyze the air-water flow behavior that occur in the test facility. It was also confirmed whether air entrained through the broken pipe was collected due to air-water stratification in the decay tank.

## 2. Test facility

Scaling analysis was conducted to design the test facility for negative pressure pipe break accident. The flow distortion effect was mitigated using the three-level scaling method [6,7]. Fig. 1 shows the design of the test facility.

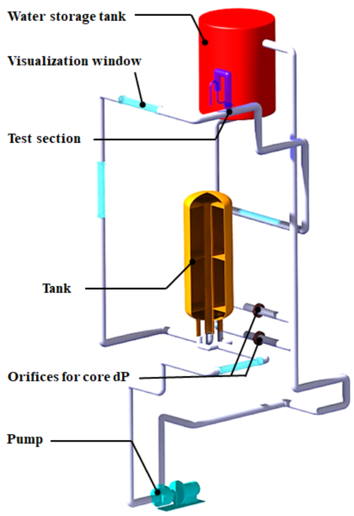


Fig. 1. Design of the test facility [5]

The experiment was performed under the test conditions, shown in Table I. The pressure and mass flow rates of the negative pressure pipe were 70.0 kPa and 40.0 kg/s, respectively. The cross-sectional area of break pipe was determined through installed orifice. The test scenario is to open the air-operated valve (AOV) and stop the pump after 1 minute. The experiment was terminated when the mass flow rate of the pump reached 0.0 kg/s.

Table I: Test conditions of the experiments

| Test parameters | Values | Unit |
|---|---|---|
| Break pipe pressure | 70.0 | kPa |
| Break size (Circular) | 0.75 | inch |
| Mass flow rate | 40.0 | kg/s |

## 3. Analysis

### *3.1 Steady-state*

Nodalization is constructed as shown in Fig. 2 to perform a calculation on the negative pressure pipe break accident. The calculation is performed using MARS-KS 1.5 code. For calculation, the size of the piping, the water storage tank, and the decay tank were constructed in the same way as the geometry of the test facility. The AOV was simulated using the trip valve. The experimental data and calculation results of steady-state are as shown in Table II.

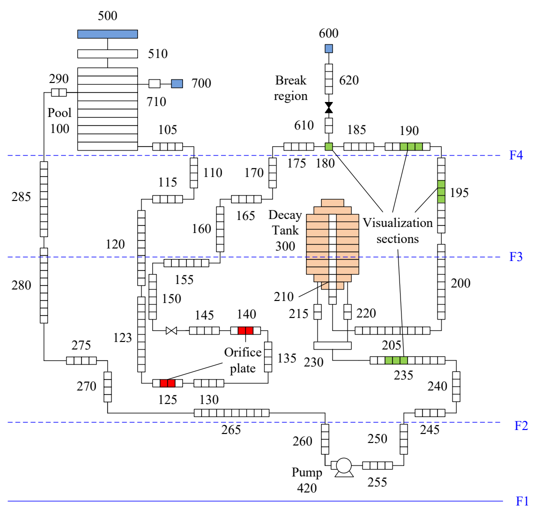


Fig. 2. Nodalization for MARS-KS calculation

Table II: Steady state results

| Parameters | Experimental data | Calculation results |
|---|---|---|
| Pressure : node 125 [kPa] | 159.9±1.2 | 157.6 |
| Pressure : node 180 [kPa] | 68.7±1.3 | 70.6 |
| Pressure : node 190 [kPa] | 65.6±1.4 | 69.8 |
| Pressure : node 205 [kPa] | 114.5±1.9 | 119.9 |
| Pressure : node 215 [kPa] | 109.7±1.9 | 115.6 |
| Pressure : node 255 [kPa] | 130.1±1.2 | 133.3 |
| Differential pressure of decay tank (inlet to outlet) [kPa] | 4.7±0.9 | 4.4 |
| Differential pressure of decay tank (top to outlet) [kPa] | 8.0±0.7 | 5.8 |
| Mass flow rate [kg/s] | 40.5±0.2 | 40.1 |

### *3.2 Transient state*

In the calculation, the AOV trip signal occurs and the valve is opened at a time of 50.0 sec. The pump was stopped after one minute after opening the AOV as in the test procedure. The calculation result was ended to the point where the mass flow rate of the pump reached 0.0 kg/s.

## 4. Results

When the AOV is opened at 50 seconds, air entrains the broken pipe because the pressure of the pipe is lower than the atmospheric pressure. Comparing the calculation results with the data measured by the air flow meter, it can be seen that similar flow rates are present. The experimental results show that the delay time occurs when the airflow rate increases to a measurable flow rate after the AOV is opened. Therefore, the initial flow rate occurs slower than the calculation result, shown in Fig. 3. The entrained airflow into the decay tank, which collects the air at the top of the decay tank and reduces the water level. The experimental data and calculation results show that the differential pressure between the top and the outlet of the decay tank changes due to the reduced water level, and this phenomenon shows that stratification occurs, quantitatively, shown in Fig. 4. The differential pressure between the top and the outlet of the decay tank tends to increase gradually as the water level decreases. Furthermore, the calculation results were predicted to be lower than the experimental data, which appears to be the effect of small differential pressure on the structure in the tank.

The differential pressure data in Fig.4 and Fig.5 show different trends during the transient state. The inlet pipe has a shape penetrating upward from the lower plenum of the decay tank, shown in Fig. 2 (node 210). Therefore, when air is introduced into the inlet pipe, the water head in the inlet pipe becomes smaller, and the differential pressure between the inlet and outlet of the decay tank is rapidly reduced. When the water level falls lower than the inlet pipe, the pressure of the outlet pipe gradually decreases as the water level decreases. As a result, the differential pressure between the inlet and outlet of the decay tank tends to increase. The calculation results confirmed that the experimental results were well predicted, shown in Fig. 5. Experimental data showed that entrained air was collected in the decay tank. It was also confirmed that the MARS-KS code predicted the amount of entrained air and the water-air stratification phenomenon occurring within the test facility.

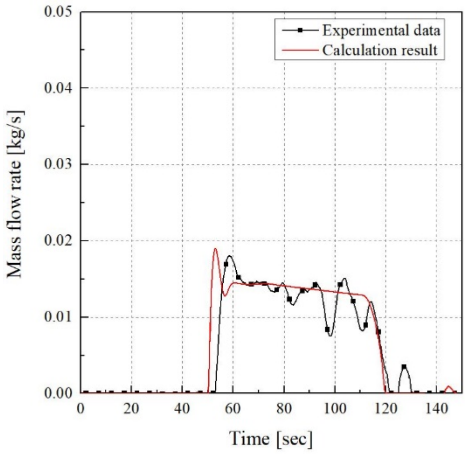


Fig. 3. Air mass flow rate

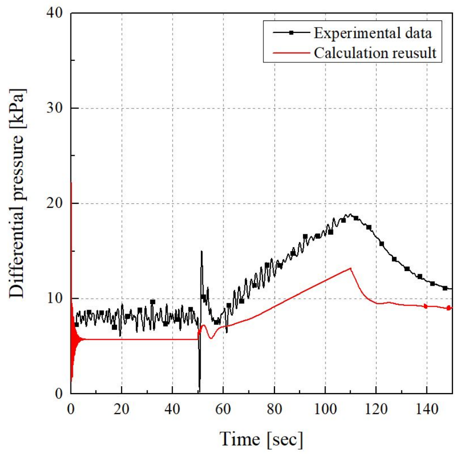


Fig. 4. Differential pressure (top to outlet)

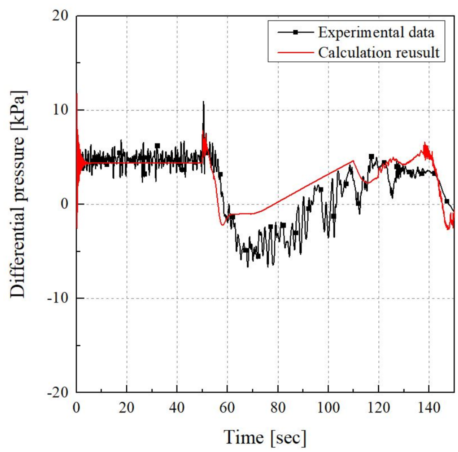


Fig. 5. Differential pressure (inlet to outlet)

## 3. Conclusions and Plans

The results demonstrate that air can be collected using the decay tank if air flows into the system during negative pressure pipe break, such as research reactors. Furthermore, it was confirmed that the MARS-KS could be utilized to predict and analyze air-water stratification phenomena within the test facility. The results of the calculation similarly predicted the flow behavior and tendency compared to the experimental data.

The next plans are to analyze the effects of air-water flow and stratification due to changes in cross-sectional area of break region and mass flow rate. In addition, it is intended to identify phenomena that affect safety when the negative pressure pipe breaks in research reactors and propose methods to improve system design.

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## REFERENCES

[1] K.Y. Lee, W.S. Kim, Theoretical study on loss of coolant accident of a research reactor, Nuclear engineering and design, Vol.309, p.151-160, 2016

[2] D.Y. Ji, S.H. Kim, K.Y. Lee, D.K. Park, Experimental study of small scale siphon breaker to verify siphon breaker simulation program (SBSP), Annals of nuclear energy, Vol.121, p.406-413, 2018

[3] I. K. Park, H.Y. Yoon, H.B. Park, Numerical approach to siphon break phenomena in a research reactor pool using the CUPID code, Nuclear Engineering and Design, Vol.326, p.133-142, 2018

[4] K.W. Seo, H.B. Park, M.K. Jung, K.J. Park, S.H. Kim, Numerical analysis for the siphon break phenomena of a research reactor according to pipe breaks, KSME17-We05D001, p.632-635, 2017

[5] I.G. Kim, K-J Park, M K. Jung, H.J. Kim, K.W. Seo, S-H. Kim, Study on a Scaling Method and Design of an Air-Water Flow Test Facility, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 23-24, 2019

[6] A.N. Nahavandi, F.S. Castellana, E.N. Moradikhanian, Scaling laws for modeling nuclear reactor systems, Nuclear science and engineering: the journal of the American nuclear society, Vol.72, 1979

[7] M. Ishii, I. Kataoka, Similarity analysis and scaling criteria for LWRs under single-phase and two-phase natural circulation, NUREG/CR-3267, ANL-83-32, 1983