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

In Guk Kim*, Min Kyu Jung, Ki-Jung Park, Kyoung Woo Seo
Korea Atomic Energy Research Institute (KAERI)
989-111, Deadeok-daero, Yuseong-gu, Daejeon, 34057, Korea
*Corresponding author: kimig@kaeri.re.kr

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

Introduction

❑ 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.

❑ Preliminary analysis was performed using the MARS-KS code to analyze the air-water flow behaviors.

❑ It was also confirmed whether air entrained through the broken pipe was collected due to air-water stratification in the decay tank.

Test Facility

❑ Based on the three-level scaling method, the test facility is currently being designed.

❑The pressure and mass flow rates of the negative pressure pipe were 70.0 kPa and 40.0 kg/s, respectively.

❑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

Table II : Dimensionless numbers for test facility

Dimensionless number	Equation	Ratio
Air source number	$N_{AS} = \frac{G_{as0}}{\rho_{g0}} \frac{l_0}{u_{g0}}$	1.00
Drift number	$N_{dri} = \frac{\rho_{f0}}{\rho_{m0}} \frac{V_{gj0}}{u_{g0}}$	1.01
Froude number	$N_{froude} = \sqrt{\frac{u_{m0}^2}{g_z l_0}}$	0.96
Density ratio	$R_d = \frac{\rho}{\rho_g}$	1.00
Friction number	$N_{fr} = \frac{f_m}{2D^*}$	1.00

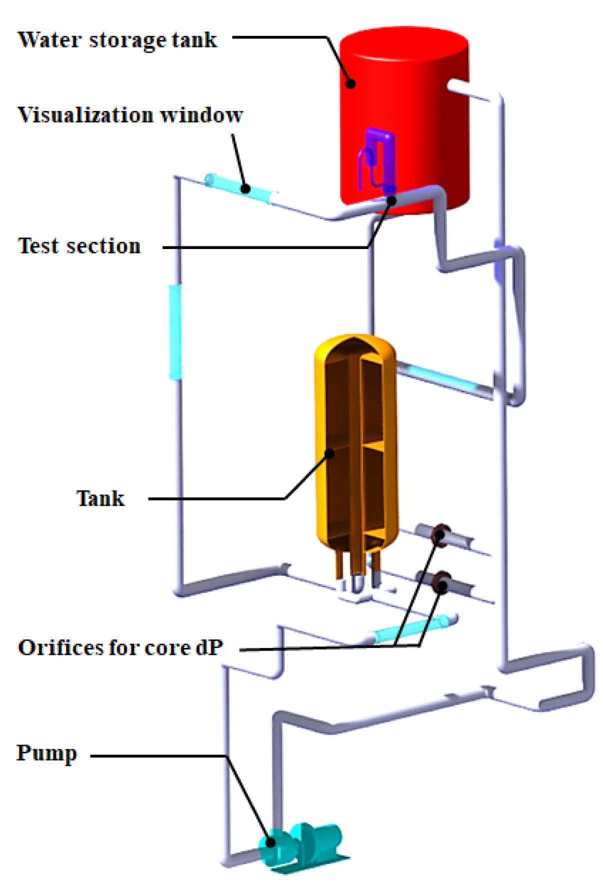


Fig. 1 Design of the test facility [5]

Modeling

❑The calculation is performed using MARS-KS 1.5 code (shown in Fig. 2).

❑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.

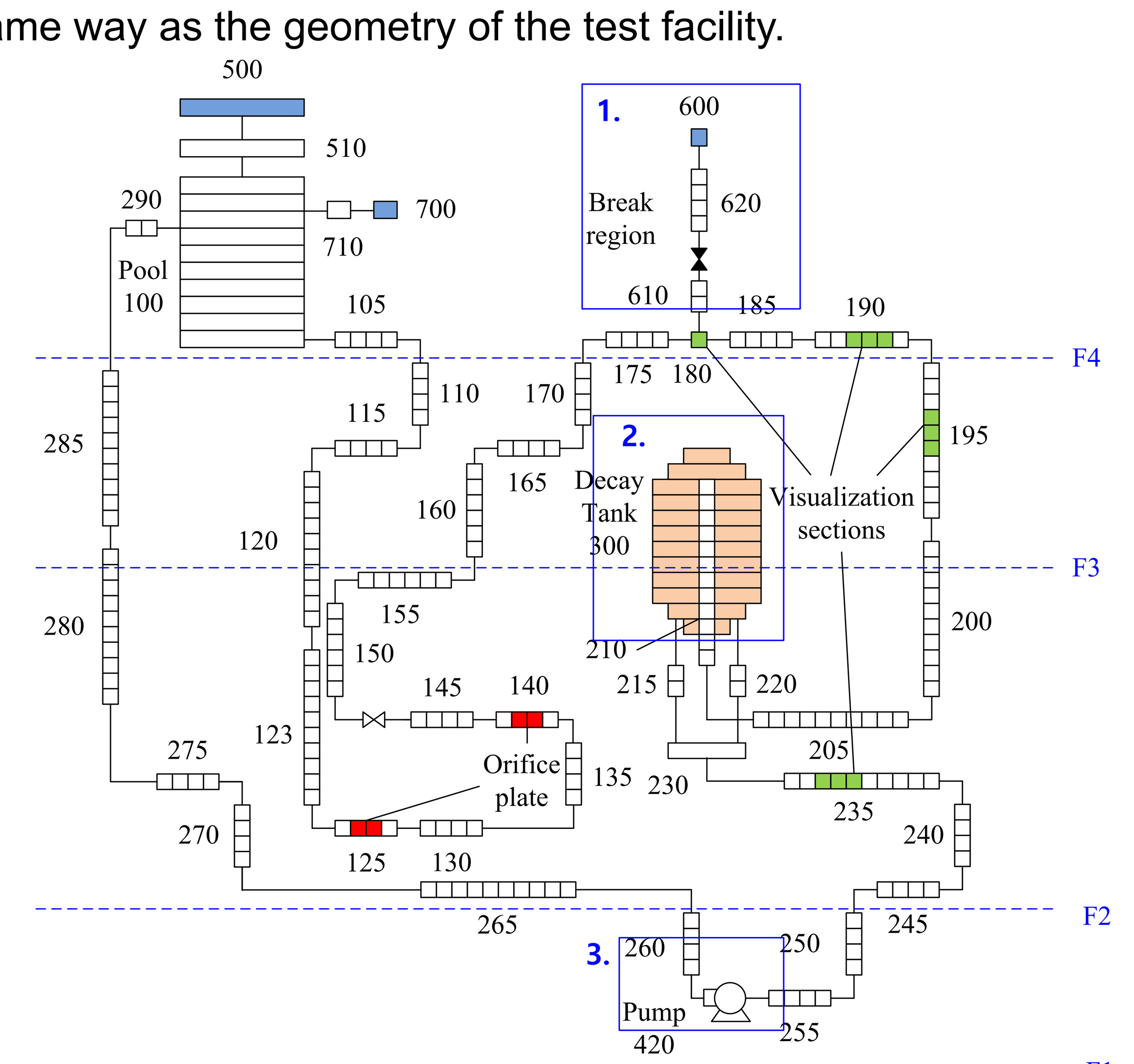
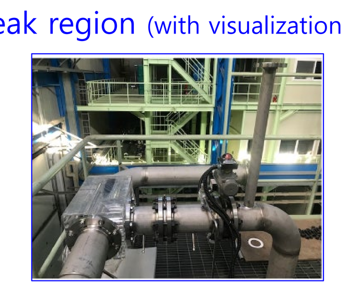


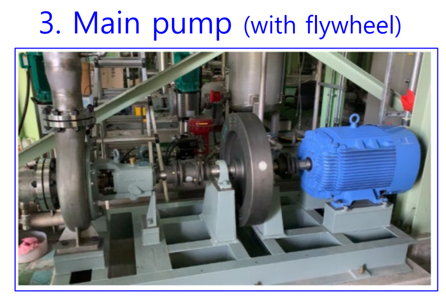
Fig. 2 Nodalization for MARS-KS calculation

1. Break region (with visualization section)



2. Decay tank

3. Main pump (with flywheel)



Results

Steady-state results

❑ The preliminary calculation results showed similar results to the experimental data (shown in Table III).

❑ The differential pressure of the decay tank was predicted to be low due to the complicated structure in the decay tank.

Table III: Steady state results of the experimental data and calculation 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
ΔP of decay tank (inlet to outlet) [kPa]	4.7±0.9	4.4
ΔP of decay tank (top to outlet) [kPa]	8.0±0.7	5.8
Mass flow rate [kg/s]	40.5±0.2	40.1

Transient state results

❑ At 50 sec, air entrains the broken pipe because of the low pressure condition.

❑ The calculated mass flow shows well predicted results in comparison with experimental data.

❑ The experimental data show that the delay time occurs when the airflow increases to a measurable flow rate after the AOV is opened.

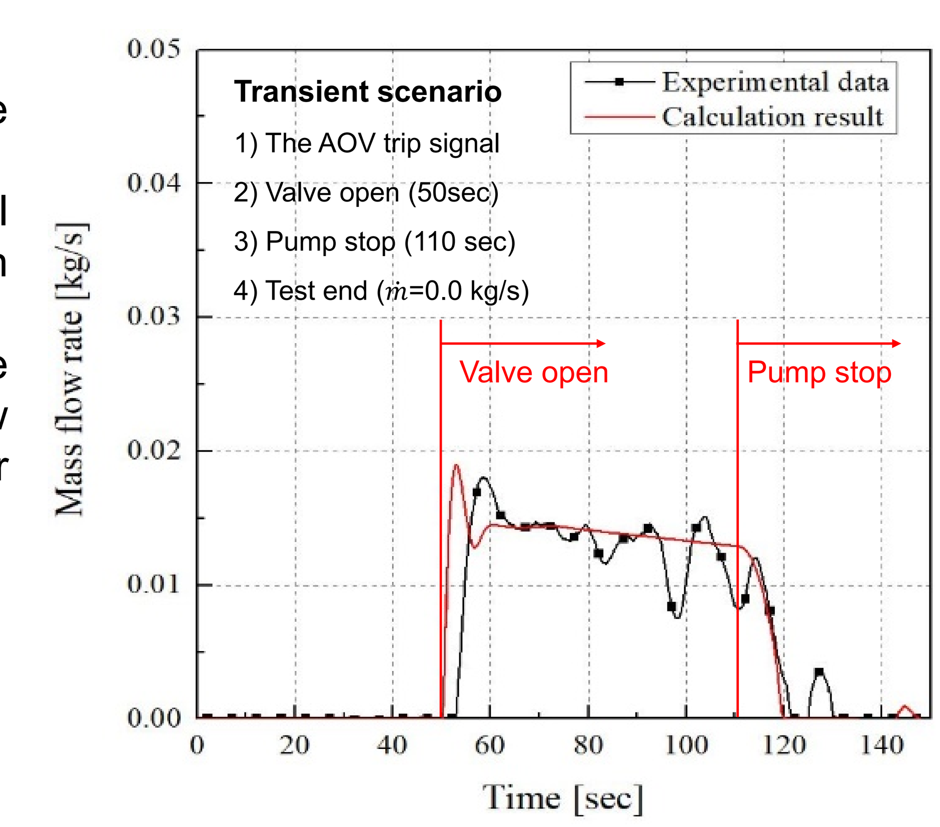


Fig. 3 Air mass flow rate

❑ The entrained airflow into the decay tank, which collects the air at the top of the decay tank and reduces the water level.

❑ ΔP in Fig. 4 and Fig. 5 show different trends during the transient state.

❑ In Fig. 4, the increase in ΔP is due to the inflow of air and a decrease in decay tank water level.

❑ In Fig. 5, ΔP is simultaneously affected by the pressure drop at the inlet and outlet and the change in the water level in the decay tank.

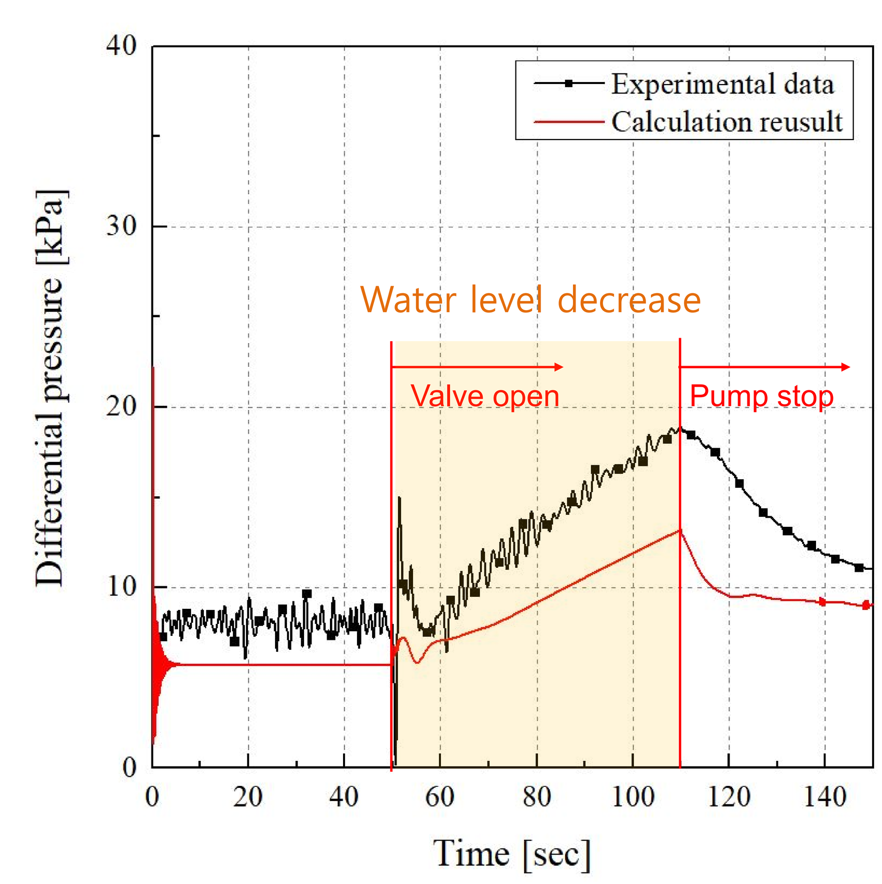


Fig. 4 ΔP (decay tank top to outlet)

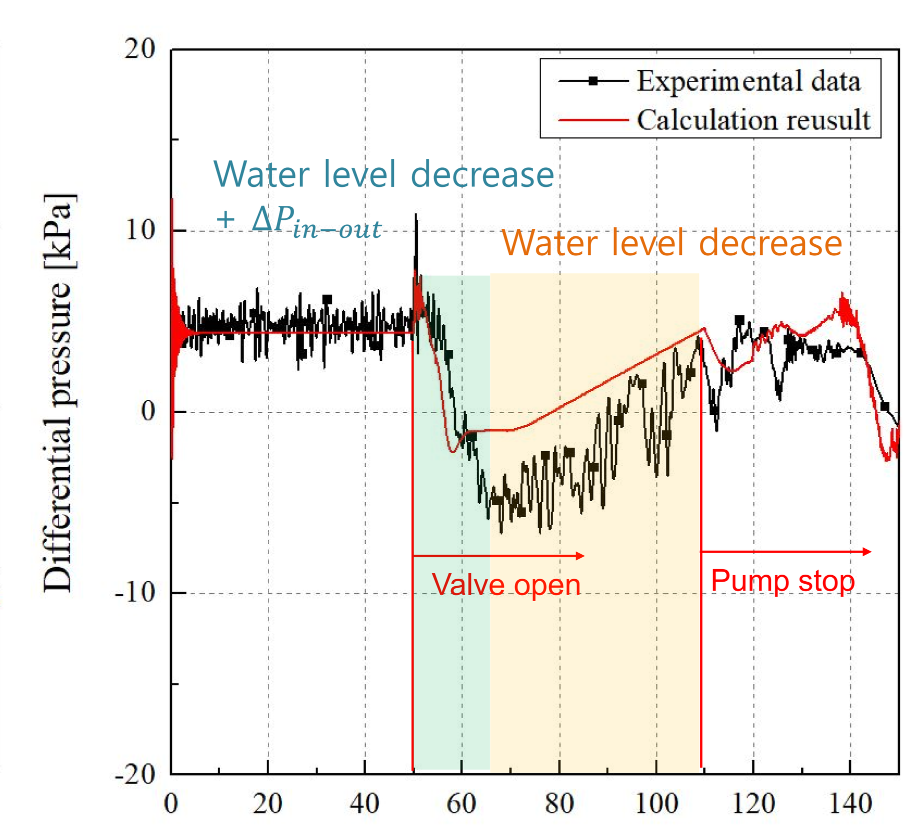


Fig. 4 ΔP (decay tank inlet to outlet)

Conclusions

❑ 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.

❑ 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.

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