Performance Evaluation of a Passive Flow Controlling Safety Injection Tank Considering Nitrogen Gas Solubility

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1. Introduction

As one of the advanced safety features of APR+ (Advanced Power Reactor Plus), SIT (Safety Injection Tank) has a fluidic device inside to control ECC (Emergency Core Cooling) water passively. The fluidic device controls the discharge flow rate during LB-LOCA (Large Break-Loss of Cooling Accident). For the assessment of the device performance, a prototypical full scale test facility, called VAPER (Valve Performance Evaluation test Rig), had been constructed[1], and the performance of the fluidic device had been validated without considering nitrogen solubility[2]. Present paper shows the recent VAPER results including the solubility effect.

2. Fluidic Device

VAPER facility has a fluidic device, SIT, a 97 m^3 water reservoir, an air compression system, a data acquisition system. Among them, Fig. 1 shows the schematic diagram of a fluidic device in SIT. SIT has an inner diameter of 2.74 m, a height of 11.95 m, and a volume of 68.13 m^3.

The fluidic device in SIT is used for the refill and reflood phase during LB-LOCA. In refilling phase, ECC water through a stand pipe is dominant, while in reflooding phase, ECC water through control ports on the bottom plate is dominant. Fig. 1 shows the refill phase.

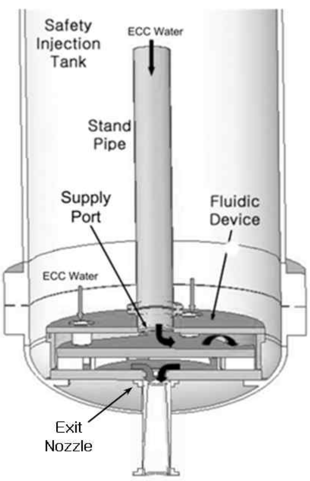
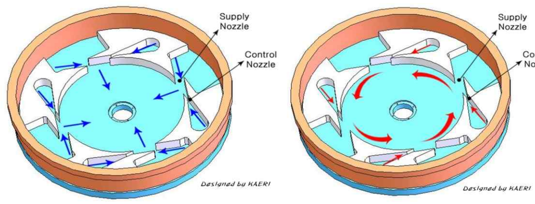


Fig. 1. Schematic diagram of a fluidic device in SIT[2].

Fig. 2 shows illustrations of typical flow structures in a vortex chamber of the fluidic device. Fig. 2(a) is the refill phase, and Fig. 2(b) is the reflood phase. The refill phase requires a large amount of ECC water in a short period. For the reflood phase, to eliminate excessive ECC water of conventional safety injection systems, the controlled low flow rate is achieved by increasing the flow resistance as shown in the vortex chamber of Fig. 2(b). If dissolved N_2 gas in ECC water is considered, the K factor in the low flow rate will be increased due to cavitation effects. Validating the effect would be an important issue especially in the controlled low flow rate case, which has a large K factor and longer injection time than the conventional safety injection systems.



(a) refill phase (b) reflood phase
Fig. 2 Principles of a fluidic device[2].

3. Test Conditions

Table 1 shows the test conditions and solubility variations. All values are normalized by test No. 1 case. The test matrix is consisted of the combinations of pressure, temperature and the solubility.

Table 1 Test Conditions including solubility variations

No.	SIT press. (ratio)	SIT temp. (ratio)	Solubility (%)
1	1.0	1.0	2%
2	1.0	1.1	2%
3	1.0	4.4	2%
4	2.8	1.4	2%
5	3.0	0.8	2%
6	3.1	1.7	88%
7	3.0	4.4	100%
8	3.0	4.4	2%
9	0.9	4.3	100%
10	3.0	4.4	2%
11	3.0	4.4	2%

4. Experimental Results

Table 2 shows the K factors for the high and low flow rate case. The K factors are normalized by the K factor of No. 1.

Temperature Variation

Test No. 1-3 are the low pressure experiments. Although high temperature is applied to test No. 3, K factors of the high and low flow rate case were 4.0% and 0.5%, respectively as presented in Table 2. If it is considered that the K factor of the low flow rate case is generally 10 times greater than the high flow rate case, 4.0% is negligible. Also 0.5% is small enough to be negligible as well.

Test No. 6-7 are the high pressure, high solubility experiments. For the increase of temperature, K factors of the high and low flow rate are obtained as 12.0% and 0.6%, respectively. The result shows the negligible increase of 0.6% in the low flow rate case.

Solubility Variation

Test No. 8, 10, and 11 are the same experiments for the high pressure, high temperature condition. If test No. 7 is compared to No. 8, 10, and 11, the K factor of the low flow rate case shows 2.4% increase by almost 100% increase of solubility. For high pressure and low temperature condition (test No. 5 and 6), the K factor of the low flow rate case shows 1.9% by almost 80% increase of solubility. For low pressure and high temperature condition (test No. 3 and 9), the K factor of the low flow rate case shows 0.9% by almost 100% increase of solubility. Hence, by the solubility, the K factors of the low flow rate cases are affected to max 2.4%. However, it is still a tiny change, even though the solubility change is almost 100%.

Table 2 K factors for the high and low flow rate

No.	K factor (high flow rate)	K factor (low flow rate)
1	1.000	1.000
2	1.008	0.979
3	1.045	0.995
4	1.107	0.972
5	1.046	0.989
6	1.004	1.008
7	1.129	1.014
8	1.108	0.989
9	0.962	1.004
10	1.095	0.990
11	1.106	0.994

5. Conclusions

Full scale experiments for the assessment of a fluidic device in SIT were performed. The influences of the N_2 gas solubility in ECC water on the K factor are analyzed. Finally, tests were done for various pressure, temperature and solubility conditions. As a result, a significant change in solubility did affect a little portion of the K factor in the low flow rate case.

ACKNOWLEDGEMENT

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