Performance Assessment of Safety Injection Tank with Fluidic Device during LBLOCA

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1. Introduction

Safety Injection Tank (SIT) with Fluidic Device (FD) has been developed for APR1400 nuclear power plants to improve a safety performance during Large Break Loss-of-Coolant Accident (LBLOCA) [1]. The emergency core cooling water provided by the SIT was controlled by the standpipe and the FD in the SIT. The mixing chamber inside the FD was designed to control the flow resistance and combine the flow through the supply port of the stand pipe and the control port of the FD. It enabled to achieve a longer passive safety injection than the existing accumulator by its characteristic flow phases, such as the high flow injection phase, the subsequent low flow injection phase and the transition flow one between them [2].

During the review process of APR1400 plants, the performance and uncertainty of the SIT safety injection, the possibility of nitrogen intrusion of the SIT into the reactor core and the comprehensive impact of the aforementioned factors on the LBLOCA have been highlighted. In this study, a pipe component model for the SIT with FD was developed for MARS-KS 1.4 calculation and the flow resistance ranges of the model to cover the measurement data from the Shin Kori Unit 3 test was derived. And the comprehensive influences on the LBLOCA were evaluated.

2. MARS-KS 1.4 Calculation

2.1 Shin Kori Unit 3 Test

The safety injection blowdown test of the SIT with FD was carried out at the Shin Kori Unit 3. The test pressure was 44 bar, which is similar to actual operational pressure of the SIT. Fig. 1 shows the overall loss factor, K_U which was estimated from the pressure and water level measured from the blowdown test of the Shin Kori Unit 3 [3]. The Fig. 1 shows the trend of K-factor from high flow phase to low flow phase. From this figure, lower and upper bound of K-factor were obtained.

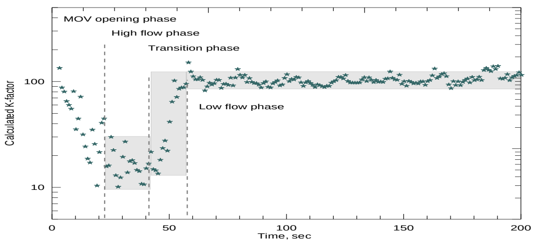

Fig. 1. Estimated Overall K-factor

2.2 SIT with FD Model

A pipe component model with two flow paths was developed [4]. Fig 2 shows the configuration and nodalization of the SIT. In order to simulate the variable hydraulic resistance at the standpipe and the FD, two flow paths were modeled. The pipe 592 and single volume 596 stands for the standpipe and the control port (connecting holes) of the FD.

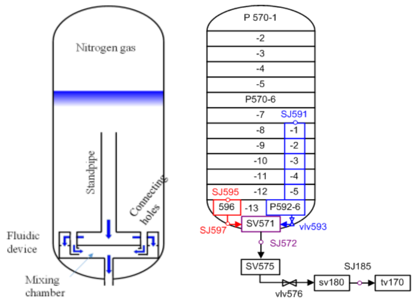

Fig. 2. Configuration and Nodalization of SIT

Table 1 shows the overall K-factor estimated from the Fig. 1 and the local K-factor estimated from the overall K-factor for the SIT with FD model. The subscript 1 and 2 mean the standpipe and connecting holes. The values of K_1 and K_2 were applied to the valve 593 and single junction 597.

Table 1. K-factor of SIT

Overall K-factor				
Case	High flow			Low flow
	K_{UH}			K_{UL}
Lower bound	9			80
Mean	20			100
Upper bound	30			120
Local K-factor				
Case	High Flow		Transition	Low flow
	K_{1H}	K_{2H}	K_{2T}	K_{2L}
Lower bound	9	16	$2.67*Y_{23}+10.67$	12
Mean	18	49	$22.67*Y_{23}+3.67$	15
Upper bound	27	70	$34.67*Y_{23}+0.67$	18

Note: Transition phase ranges $0.5<Y_{23}<2$, Y_{23} is an accumulated water level from the bottom of the standpipe. Transition of K_{1T} is interpolated and low flow of K_{1L} is infinite.

2.3 LBLOCA Calculation

The existing MARS-KS input for LBLOCA calculation has been improved by updating Reactor Coolant Pump curves such as homologous curves and multiplier tables. LBLOCA calculation was conducted as implementing the new SIT modelling scheme and variable hydraulic resistances at the standpipe and connecting holes. Fig. 3 shows a comparison of the nitrogen mass within the reactor vessel and the one accumulated at the break for the three cases of K-factors.

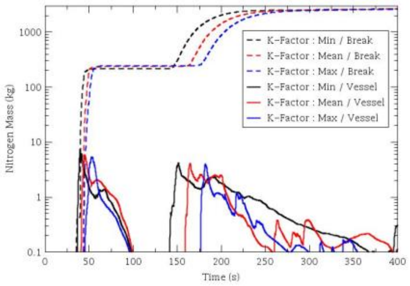

Fig. 3 Comparison of Nitrogen Mass

As shown in the figure, nitrogen gas was started to intrude the reactor vessel at approximately 40 sec, which is the starting point of the transition phase. The total released nitrogen during the transition phase was more than 200 kg, while only a few kilograms of nitrogen was introduced to the vessel. The timing of nitrogen release for the minimum K-factor was the earliest because the least flow resistance was applied for the component of the SIT. As the K-factor increased, the timing of nitrogen release has been delayed. Fig. 4 shows a comparison of total mass flow rate injected from the SIT for three cases. As the K-factor increased, the discharged mass flow rate from the SIT decreased at the high flow phase and the discharge period had been delayed at the low flow phase.

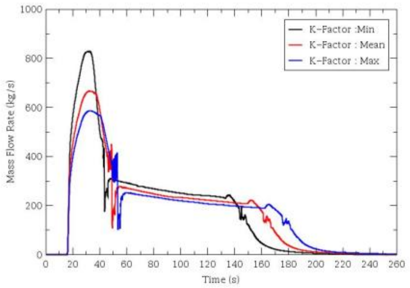

Fig. 4 Comparison of Discharged Mass Flow Rate

Fig. 5 shows a comparison of fuel cladding temperature following LBLOCA for three cases.

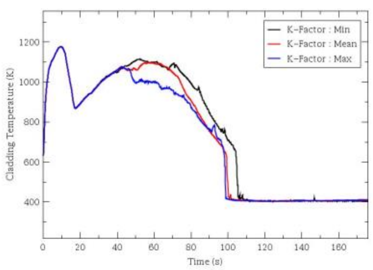

Fig. 5 Comparison of Peak Cladding Temperature

Three curves shows almost the same trend before 40 sec, while trends after that time were deviated significantly. The difference in peak cladding temperature (PCT) between the maximum-K case and minimum–K case was higher than 40 K, which was related to the amount of water injection from the SIT at the high flow phase, the timing of nitrogen intrusion to the reactor vessel and its influences on the heat transfer during reflood phase.

3. Conclusions

The performance and uncertainty issues of the SIT with FD raised during the review process of APR1400 plants has been assessed in the present study. A pipe component model was developed to simulate variable hydraulic resistance changes of the SIT with FD. The local K-factor for the stand pipe and the connecting holes were determined based on the SIT discharge test performed at Shin Kori Unit 3. The nitrogen gas intrusion into the reactor vessel was quantified during the transition phase. The comprehensive influences of the SIT performance and uncertainty on LBLOCA has been evaluated. The LBLOCA calculation of MARS-KS 1.4 indicated that the K-factor uncertainty may cause a variation of PCT in 40 K.

REFERENCES

[1] KHNP, Final Safety Analysis Report, Shinkori Units 3 and 4, KHNP, Seoul, Korea, 2008.
[2] Chu, I.C., et al, Development of Passive Flow Controlling Safety Injection Tank for APR1400, Nuclear Engineering and Design 238, p.200–206, 2008
[3] KHNP, SKN 3&4 Test Procedure (SIT Test), Rev. 1, 9P-C-441-02, Korea, 2012.
[4] Y.S. Bang, et al. Modeling Scheme of the Safety Injection Tank with Fluidic Device for Best Estimate Calculation of LBLOCA, Annals of Nuclear Energy, Vo.75, p.605-610, 2015.

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