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The Best Estimate Calculation of LBLOCA Considering the Uncertainty of the SIT with FD

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1. Introduction

The performance and uncertainty of Safety Injection Tank (SIT) with Fluidic Device (FD) can affect the overall performance of Emergency Core Cooling System during Large Break Loss-of-Coolant Accident (LBLOCA) in the APR1400 plant. In the course of design and licensing reviews of APR1400 plants (Shin Kori Unit 3 & 4, Shin Hanul Unit 1 & 2), extensive studies to resolve the several concerns related to the SIT hydrodynamics have been conducted [1, 2, 3]. Among concerns, 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 modified MARS-KS model for the SIT with FD was suggested to control discharge flow rate and nitrogen release, which composed of only K-factors instead of valve component in comparison to the previous model [4]. The comprehensive effect of SIT with FD on LBLOCA was evaluated by the best estimate calculation taking into account eighteen uncertainty parameters including the uncertainty of the SIT with FD [5].

2. MARS-KS Model

In the previous study, a pipe component model for the SIT with FD has been developed to simulate high flow injection phase, the subsequent transition and low flow phase of the SIT using a valve component at standpipe discharge [4]. During the validation of the model, a possibility that the valve actuation in the model may affect the pressure of the primary system during the reflood phase has been raised. Therefore, the previous model has been modified to use the only K-factor instead of the valve component. Fig. 1 shows the configuration of the SIT with FD and the modified

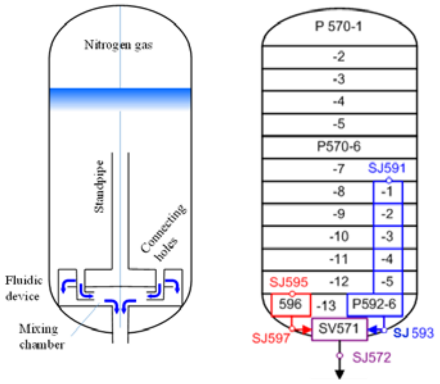

Fig. 1. Configuration of SIT with FD and Modeling

MARS-KS model. The flow path from standpipe to mixing chamber used to be modeled as the valve component (Valve 593) but changed to use the K-factor (SJ 593). The K-factor model was designed to cover the change of the hydraulic resistance from high to low flow phase based on that changes at high flow phase. It was assumed that the circumferential velocities of the standpipe and the FD at the mixing chamber can be cancelled out each other as the SIT was designed with such a design principle. The K-factor at transition phase assumed to be changed exponentially. Fig. 2 shows the K-factors at single junction 597 and 593. It could be confirmed that the change of the K-factor was appropriately implemented according to the model so that the K-factor exponentially changed when the standpipe level reached a certain level.

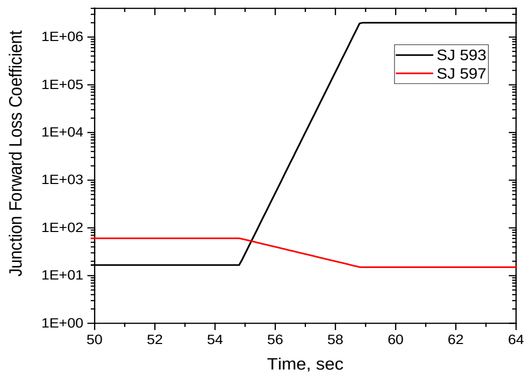

Fig. 2. K-fators at SJ 593 and SJ 597

3. LBLOCA Best Estimate Calculation

In order to identify the comprehensive effect of the SIT with FD on LBLOCA, the best estimate (BE) calculation of LBLOCA has been carried out. The calculation was performed as assuming 100% double-ended cold-leg break. It was assumed that only 2 safety injection pumps were available after break as considering the failure of one emergency diesel generator, which was the limiting single failure criteria. Table I shows the range and distribution of uncertainty parameters used in this calculation. The SIT K-factor was added as an uncertainty parameter (No.17) and totally 18 uncertainty parameters were considered in this calculation. Fig. 3 shows nitrogen mass at the reactor core for 124 cases. The nitrogen intruded into the core might influence the heat transfer rate because MARS-KS has been coded to decrease the heat transfer coefficient if a non-condensable gas of 1.0e-09 or more based on quality exists at the core.

Table I: Uncertainty Parameter, Distribution and Range

No	Model/Parameters	Dis.	Mean	Range
1	Gap conductance	Uniform	0.95	0.4~1.5
2	Fuel conductivity	Uniform	1	0.847~1.153
3	Core power	Normal	1	0.98~1.02
4	Decay heat	Normal	1	0.934~1.066
5	Groeneveld-CHF	Normal	0.985	0.17~1.8
6	Chen nucleate boiling	Normal	0.995	0.53~1.46
7	Chen transition boiling	Normal	1	0.54~1.46
8	Dittus-Boelter liquid	Normal	0.998	0.606~1.39
9	Dittus-Boelter vapor	Normal	0.998	0.606~1.39
10	Bromley film boiling	Normal	1.004	0.428~1.58
11	Break CD	Normal	0.947	0.729~1.165
12	Pump 2p head multiplier	Uniform	0.5	0.0~1.0
13	Pump 2p torque multiplier	Uniform	0.5	0.0~1.0
14	SIT pressure(MPa)	Uniform	4.307	4.03~4.46
15	SIT water inventory(m^3)	Uniform	52.63	45.31~54.57
16	SIT water temp.(K)	Uniform	302.5	283~321.9
17	SIT K-factor	Normal	20	10~30
18	IRWST water temp.(K)	Uniform	302.5	283~321.9

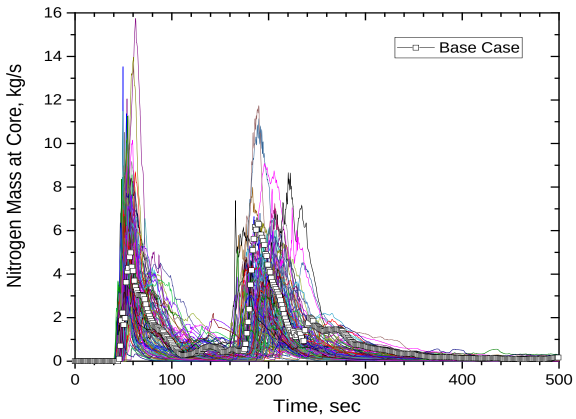

Fig. 3. Nitrogen Mass at Reactor Core

Fig. 4 shows the peak cladding temperatures for 124 runs [5]. The 95 percentile peak cladding temperature with 95 percent confidence level($PCT_{95/95}$) for LBLOCA calculation could be determined by 124 simple random sampling for each uncertainty parameter and 124 code runs based on Wilks' formula of the non-parametric statistics [6]. The $PCT_{95/95}$ was estimated to be 1315.6 K at 10 seconds in blowdown phase [5]. The $PCT_{95/95}$ of the previous calculation of LBLOCA for APR1400 was estimated to be 1284.7 K [7], which had the simple "Accum model" for the SIT with FD that could not simulate the nitrogen release during the transition phase. The model modification has induced the increase of the reflood PCT. The uncertainty of the SIT with FD has resulted in the 3rd PCT rise of 31 K in comparison to the previous calculation.

The PCT calculated in this study met the acceptance criteria of 1477.6 K and had the margin of 162 K. It was confirmed that the ECCS satisfies the acceptance criteria although the performance and uncertainty of the

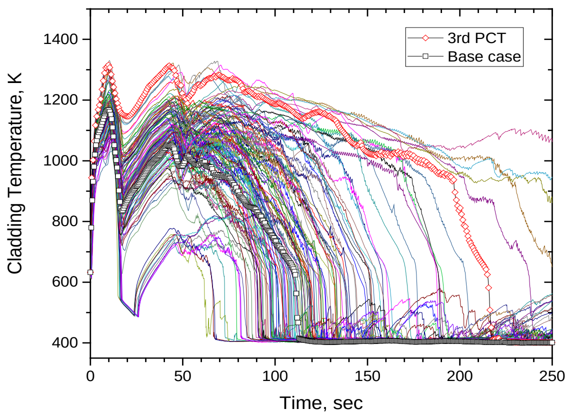

Fig. 4. PCTs for 124 runs

SIT with FD such as the variation of discharge flow rate according to the change of K-factors and the nitrogen intrusion at transition phase were taken into account.

4. Conclusions

The best estimate calculation of LBLOCA with eighteen uncertainty parameters has performed to resolve the issues raised during the design and licensing review process of APR1400 plants. The MARS-KS model for the SIT with FD has been modified to use the only K-factor to minimize the effect of the valve operation on the primary system pressure. The 95 percentile peak cladding temperature with 95 percent confidence level was estimated to be 1315.6 K in blowdown phase. This is an increase of 31 K compared to the previous calculation. The PCT met the acceptance criteria of 1477.6 K. Therefore, it was confirmed that the ECCS of APR1400 has capability to appropriately mitigate LBLOCA.

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