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Preliminary Analysis of Interfacing Systems LOCA from a Fire Event PSA Perspective

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1. Introduction

An interfacing system loss of coolant accident (ISLOCA) is a class of nuclear power plant (NPP) loss of coolant accidents (LOCA) when a breach occurs in a system that interfaces with the RCS, where isolation between the breached system and the RCS fails[1,2]. An ISLOCA is usually characterized by the over-pressurization of a low-pressure system when subjected to RCS pressure and can result in containment bypass. It has been identified as the most hazardous accident scenario in the typical pressurized water reactors (PWRs) [3]. The previous studies [4, 5] have been mainly performed from an internal event PSA perspective. The ISLOCA scenarios are to be also addressed in the fire event PSA. This paper presents the preliminary analysis results of an ISLOCA from a fire event PSA perspective. Hanul Unit 3 & 4 was selected as a reference NPP of this study.

2. Methods and Results

2.1 Estimation of initiating event frequency

Initiating event (IE) frequency of an ISLOCA can be generally estimated using the following equation:

$$I \times BF \qquad (1)$$

Where,
I: Initiators (frequency)
BF: barrier failures (Probability)

In the internal event PSA, both causes of initiators and barrier failures come from only internal events. However, in the fire event PSA, the causes of initiators come from only fire events and those of barrier failures come from internal events or fire events. In the case where it is not easy to apply simple arithmetic Eq.(1) to the estimation of IE frequency of an ISLOCA, IE fault tree (FT) for it can be constructed.

2.2 Previous analysis results

In the previous study[5], fifteen scenarios were selected for potential ISLOCA pathways. Among them, three scenarios were selected for the estimation of ISLOCA frequency: Shutdown Cooling Suction Line Loop, Letdown Line from RC Loop 1B, CCW Supply & Return to RCP HP Cooler Line. Table I shows the potential ISLOCA scenarios and the list of detailed analysis for them. The other ISLOCA scenarios were screened out using the following screening criteria[5]:

1) The line neither connects to the RCS nor penetrate the containment.
2) The line has a diameter smaller than 3/8 inch. Its break does not result in core damage because normal charging can replace the lost inventory.
3) Design pressure of the line is not lower than that of RCS operation. Though it is high, the possibility of the line break was considered.
4) The line is isolated from the RCS pressure by four or more normally closed valves or periodically leak-tested check valves in series.

2.2 Preliminary analysis from a fire event PSA Perspective

All previous analysis results including screening criteria were revisited from a fire event PSA perspective. According to the ASME PRA Standard (QNS-C1)[2], the sum of the large early release frequency (LERF) contributions for all screened-out fire compartments is < 10% of the estimated total LERF for fire events. Based on this ASME requirement, in this study, 1.0E-9, the conditional probability of barrier failures was established for the quantitative screening criterion for the estimation of ISLOCA frequency. This is a conservative approach because the fire frequency of the fire compartment or fire scenario is generally estimated less than 1.0E-2/yr and general LERF frequency is higher than 1.0E-7/yr. As screening criteria, the simultaneous breaks of the lines having a diameter smaller than 3/8 inch were considered due to a fire. In Table I, the qualitative analysis results for the potential ISLOCA scenarios were presented. The qualitative analysis results different from the internal event PSA are presented as follows:

- Shutdown Cooling Suction Line Loop: This line has two normally closed motor-operated valves (MOVs) in series. During normal power operation, circuit breaker for one of two MOVs is racked-out. The fire-induced spurious operation for AC power circuit was not considered due to its incredible possibility[6]. Thus, this scenario was eliminated.
- SIT Fill & Drain Line(RCS Loop boundary): There are two kinds of RCS lines for this scenario. One is two check valves in series. The other is one check valve and one air-operated valve. Because the probability of fire-induced spurious open for the air-operated valve is high, the second RCS line was considered for the detailed analysis.
- Letdown Line from RC Loop 1B: This scenario may occur due to pipe rupture during power operation. During 24 hr mission time of PSA, the probability of pipe rupture is very low. Thus, this scenario was screened out.

- Primary Sampling Lines: Each diameter of this lines is less than 3/8 inch. However, there is a possibility of the simultaneous breaks of these lines due to a fire.

If the quantitative screening criterion on the conditional probability of barrier failures was changed from 1.0E-9 to 1.0E-8, only one scenario, primary sampling line, was selected for the detailed analysis.

3. Conclusions

In this study, we performed the qualitative analysis of an ISLOCA for Hanul Unit 3 & 4 from a fire event PSA perspective. All previous analysis results conducted from the aspects of internal event PSA were revisited from the fire event PSA perspective. Among fifteen potential ISLOCA scenarios resulting from the internal event PSA, three scenarios were selected for the detailed analysis of a fire event PSA. Two scenarios were eliminated from the list of ISLOCA for the internal event PSA. Additional two scenarios were selected from the list of the scenarios screened out in the internal event PSA. As a future study, the quantification of the selected scenarios in this study is to be performed for the estimation of core damage frequency.

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Table I: ISLOCA scenarios of Reference NPP

No.	ISLOCA scenarios	Internal event PSA	Fire event PSA
1	**Shutdown Cooling Suction Line Loop**	**Detailed analysis**	**Screened out**
2	LPSI Cold Leg Injection Loop	Screened out	Screened out
3	HPSI Cold Leg Injection Loop	Screened out	Screened out
4	Hot Leg Injection Loop	Screened out	Screened out
5	**SIT Fill & Drain Line(RCS Loop boundary)**	**Screened out**	**Partial Detailed analysis**
6	SIT(1A/1B/1C/1D) Outlet Lines	Screened out	Screened out
7	**Letdown Line from RC Loop 1B**	**Detailed analysis**	**Screened out**
8	Charging Line to RC Loop 1A	Screened out	Screened out
9	CVCS Reactor Drain Tank (RDT) Outlet Line	Screened out	Screened out
10	Resin supply header to RDT	Screened out	Screened out
11	Pressurizer Auxiliary Spray Line	Screened out	Screened out
12	CVCS Seal Injection Line to RCP	Screened out	Screened out
13	RCP Controlled Bleedoff Line from RCP	Screened out	Screened out
14	**CCW Supply & Return to RCP HP Cooler Line**	**Detailed analysis**	**Detailed analysis**
15	**Primary Sampling Lines - RCS hot leg loop, PZ surgeline, PZ steam space line**	**Screened out**	**Detailed analysis**