Study on LOCA Frequency and Contribution to Risk of Nuclear Power Plant

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1. Introduction

LOCA occurs as the result of break in RCS pressure boundary, and ECCS is required to mitigate such LOCAs in PWR. Currently US NRC is working with revision of the ECCS technical requirements based on the study of LOCA frequency and contribution to plant risk. In this study we reviewed the latest trends associated with the revision and analyzed the technical feasibility for the revision of ECCS technical requirements in Korea by the assessment of LOCA frequency applied in Korea and foreign countries and its contribution to risk of nuclear power plants.

2. Analysis and Results

2.1 LOCA frequency

Most PSA uses RCS pipe break frequency as LOCA frequency and it is based on WASH-1400 [1] which is the first PSA conducted by USA in 1970s. NUREG-1150[2] to be published later evaluated two sets of RCS pipe frequency; one for BWR and the other for PWR. In NUREG/CR-5750 [3] reflecting the results of latest study, the frequency of large and medium RCS pipe break was estimated by calculating the frequency of axial through-wall cracks to be observed and estimating the rupture probability of those axial through-wall cracks. The values provided in NUREG/CR-5750 represent the best estimates of LOCA frequency that are currently available in public, but it did not consider recent events involving primary stress corrosion cracking (PWSCC).

In Korea, while PSA for KSNP used LOCA frequency of EPRI URD [4], PSA for reactors of other types used LOCA frequency of NUREG/CR-5750. But in PSA for ULCHIN 1,2, the medium LOCA frequency (=4.0E-5/year) was modified to 7.6E-5/year due to considering the possibility of stuck-open of pressurizer safety valve. LOCA frequency used in Korean PWRs is shown in Fig. 1.

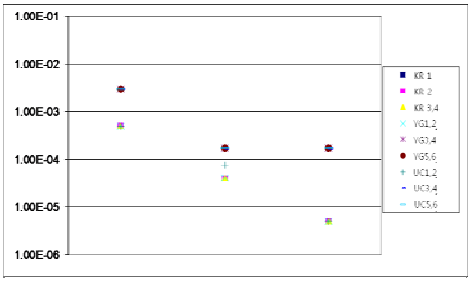

Fig. 1. LOCA frequency used in Korean PWRs

2.2 Risk Contribution by LOCA

The core damage frequency (CDF) by LOCA in Korean PWRs is shown in Fig. 2.

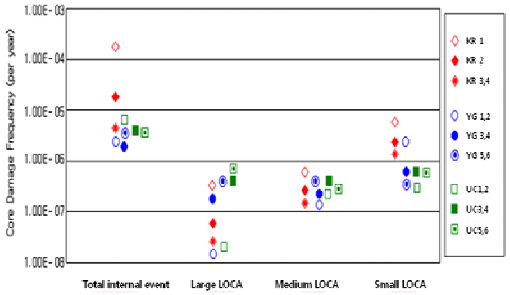

Fig. 2. CDF by LOCA in Korean PWRs

As indicated in Fig. 2, the contribution of large LOCA to CDF is generally small. On average, CDF by LOCA is approximately 5% of CDF by the total internal event in USA, whereas it is approximately 24% in Korea. The reason that the contribution of LOCA to CDF in Korea is higher than in USA is considered to be due to actions for safety improvement against transient events such as loss of instrumentation air or station blackout and not to LOCA.

The large early release frequency (LERF) by LOCA is presented in Table I. As indicated in Table I, LERF values by large LOCA are significantly lower than the quantitative limit, 10^{-5}/year. Also the average value of conditional LERF is below the quantitative limit, 0.1.

Table I. Large early release frequency by LOCA

	Plant	LERF		CLERP
		Total initial event	Large LOCA	Large LOCA
USA	PWR	5E-6/yr	3E-8/yr	1.E-02
	BWR	2E-6/yr	4E-9/yr	3.E-02
Korea	KR 1	9.5E-7/yr	3.2E-11/yr	7.4E-06
	KR 2	2.2E-6/yr	4.1E-10/yr	8.4E-05
	KR 3,4	1.1E-6/yr	-	1.1E-06
	YG 1,2	9.3E-7/yr	-	9.3E-07
	YG 3,4	5.0E-7/yr	5.2E-10/yr	3.5E-06
	YG 5,6	8.9E-7/yr	1.8E-07/yr	1.0E-03
	UC 1,2	1.5E-6/yr	2.4E-09/yr	4.9E-04
	UC 3,4	8.9E-7/yr	1.8E-07/yr	1.0E-03
	UC 5,6	9.0E-7/yr	1.9E-07/yr	1.1E-03

2.3 Reevaluation of LOCA Frequency

The reevaluation of LOCA frequency was carried out

in USA for the purpose of reestablishing reasonably the break size which is to be design basis by considering the potential of occurrence and improving reasonably several operation requirements including the technical specification in accordance with the change of design basis.

LOCA frequency was estimated by using an expert elicitation process which took into account the knowledge of plant design, operation and material performance as well as the considerations from operating experiences and study of probabilistic fracture mechanics. The important qualitative considerations derived from the expert elicitation process are as follows : (1) The best method of estimating small LOCA frequency is the use of operating experience, (2) Adjustment of the experts' estimates with basic estimates based on operating experience, (3) Number of occurrence of precursor events such as cracking and leak is useful criteria for the possibility of LOCA occurrence caused by degradation mechanism, (4) Welding part is the susceptible position to the most likely LOCA occurrence, (5) Due to the smaller the size of piping or non-piping components, the more serious the effect of cracking occurring during manufacturing or in service, there is more likelihood to be broken completely.

The comparison result of LOCA frequency between the results of reevaluation (NUREG-1829) and NUREG/CR-5750 is summarized in Table II.

Table II. Comparison result of LOCA frequency between the result of reevaluation (NUREG-1829) and NUREG/CR-1750.

LOCA category	NUREG-1829 (/Calendar-Yr)	NUREG/CR-5750 (/Calendar-Yr)
Small LOCA	2.9E-03	4.0E-04
Medium LOCA	6.6E-04	3.0E-05
Large LOCA	1.6E-06	3.6E-06

The reason of the large increase of medium LOCA frequency of NUREG-1829 in Table II is that the effect of PWSCC of piping and non-piping component (ex, Control Rod Drive Mechanism) and the aging degradation phenomenon in the piping of this size region are reflected in evaluation of LOCA frequency.

2.4 The seismic effect to LOCA

USA also evaluated frequency of seismic-induced DEGB. Two potential causes for DEGB were considered in this study; direct DEGB induced by the combined effects of thermal, pressure, seismic, and other cyclic loads and indirect DEGB induced by the failure of supports of component such as reactor vessel, steam generator and RCP, etc or the failure of an overhead crane[6].

As showed in table III, the results of study indicate that frequency of direct DEGB is much lower than indirect DEGB. Because seismic frequency and intensity in Korea is generally lower than in USA, it is considered to be possible to apply the results of this study in domestic NPPs

Table III. Occurrence frequency of seismic-induced DEGB in PWR

Plant	Frequency of seismic-induced DEGB (/yr ; median value)	
	Direct	Indirect
CE PWR	1.0E-13	1.0E-8(newer plant) 1.0E-6(older plant)
W/H PWR	1.0E-10	1.0E-7(East in US) 1.0E-06(West in US)
B&W PWR	1.0E-10	1.0E-10, 1.0E-7

3. Conclusions

In this study we reviewed the latest study trends regarding the evaluation of LOCA frequency (including seismic-induced LOCA) and evaluated LOCA frequency and risk contribution applied to domestic and foreign NPPs. The results of study showed that due to the more new reliability data applied to PSA of Korean NPPs, LOCA frequency and risk contribution in Korea was lower than that in USA

Also in this study we analyzed technical feasibility of the revision of ECCS technical requirements through comparing the reevaluation results of LOCA frequency from expert elicitation process with the frequency of NUREG/CR-5750 used in PSA of domestic NPPs and analyzing the results of study on frequency of seismic-induced DEGB.

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