Preliminary Assessment of Depressurization Performance of Reactor Building Spray dedicated to Severe Accident

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1. Introduction

In these days, the global demand for the nuclear power plant is gradually increasing and then it is encouraging to see the mood in which the possibility of exportation of Korean has been realized. According to this situation, the need for development of the country-tailored NPP is emerging because that there are some differences among the safety requirements of each country. Especially, European countries require relatively conservative safety criteria for the severe accident [1]. Thus, development of a tactical NPP with the enhanced safety features dedicated to the severe accident is on the way. One of these safety features is the containment spray system dedicated to the severe accident. In this study, the depressurization capacity of the SA spray is assessed and the minimum capacity ensuring applicable performance is estimated with MAAP4 [2] code. The reference plant for this analysis is chosen as APR1400 [3].

2. Analysis and Results

2.1 Accident scenario

The representative accident accompanying RCS discharge, such as LOCA (loss of coolant accident), MSLB (main steam line break) analyzed with various conditions.

Table 1. Accident scenarios for analysis

Case ID	Sequence
LLOCA1	Cold-leg DEG break + No ESF
LLOCA2	Cold-leg DEG break+ SIT
MLOCA1	6 inch break + No ESF
MLOCA2	6 inch cold-leg break + SIT
SLOCA1	1 inch cold-leg break + No ESF
SLOCA2	1 inch cold-leg break + SDS actuation
SLOCA3	1 inch break + F&B (6 hr)
MSLB1	Steam line break + No ESF
MSLB2	Steam line break + SDS actuation
MSLB3	1 inch break + F&B (6 hr)
TLOFW1	Loss of MFW + No ESF
TLOFW2	Loss of MFW + SDS actuation
TLOFW3	Loss of MFW + F&B (6 hr)

In addition, LOFW (loss of feed water) is selected for considering the general transients. The accident scenarios are enlisted in Table 1.

2.2 The Analysis Conditions

In Table 2, the analysis conditions are described. The SA spray is assumed to be actuated when the reactor building pressure exceeds 200% of Design Pressure after at least 12 hours elapse since SA entry condition, from which the core exit temperature exceeds 1,200 ˚F.

Table 2. Analysis Conditions

Contents	Description
■ DBA containment spray	Available until SA entry
■ Rated flow of SA spray pump	RF1 (50% of DBA spray), RF2 (60% of DBA spray), RF3 (80% of DBA spray),
■ Water source of SA spray	IRWST
■ Initiation of SA spray injection	When reactor building pressure reaches to 200% of design pressure (at least 12 hours after SA entry)
■ Hydrogen control systems	Not available
■ Hydrogen burning	Excluded
■ Corium pool area	110 m^2 (reflecting core catcher design)
■ Availability of cavity water at reactor vessel failure	Nearly dry condition
■ SDS operation	Actuation : 1 hr after SA entry
■ Initiation time of cavity flooding	Right after reactor vessel failure
■ Mode of cavity flooding	Passive injection depending on the static head difference between IRWST and Cavity

2.3 Performance Criteria for SA spray

With respect to the design basis accident, the containment spray should be able to reduce the containment pressure to the half of design pressure within 12 hours as prescribed in KURD [4]. However, for the severe accident situation, there are no criteria established in domestic requirements. Thus, for the evaluation of the SA spray, the provisional performance criterion was defined as that the SA spray should have depressurization capacity with which reactor building pressure can be decreased to 50% of design pressure from 200% of design pressure within the specified mission time. In this study, the mission time is considered as 6 hours or 12 hours.

2.4 The analysis results

The analysis results are presented in Table 3, which show that with the flow rate of RF3, the SA spray can depressurize the containment to the half of design pressure level within 6 hours.

Table 3. Depressurization Performance of SA spray

Case		Reactor Building Pressure (x10^5 Pa)		
ID	SACSS Flow rate	at SACSS actuation	at 6 hr after SACSS actuation	at 12 hr after SACSS actuation
LLOCA1	RF1	9.2	4.21 (Fail)	2.91 (OK)
	RF2	9.2	3.62 (Fail)	2.40 (OK)
	RF3	9.2	2.80 (OK)	1.84 (OK)
LLOCA2	RF1	9.2	3.80 (Fail)	2.71 (OK)
	RF2	9.2	3.26 (Fail)	2.28 (OK)
	RF3	9.2	2.56 (OK)	1.81 (OK)
MLOCA1	RF1	9.2	4.40 (Fail)	2.95 (OK)
	RF2	9.2	3.77 (Fail)	2.44 (OK)
	RF3	9.2	2.92 (OK)	1.87 (OK)
MLOCA2	RF1	9.2	3.76 (Fail)	2.69 (OK)
	RF2	9.2	3.22 (Fail)	2.27 (OK)
	RF3	9.2	2.54 (OK)	1.81 (OK)
SLOCA1	NA (calculation fail) but covered by SLOCA3			
SLOCA2	NA (calculation fail) but covered by SLOCA3			
SLOCA3	RF1	9.2	4.40 (Fail)	3.00 (OK)
	RF2	9.2	3.80 (Fail)	2.49 (OK)
	RF3	9.2	2.98 (OK)	1.93 (OK)
MSLB1	RF1	9.2	3.84 (Fail)	2.84 (OK)
	RF2	9.2	3.30 (Fail)	2.40 (OK)
	RF3	9.2	2.61(OK)	1.92 (OK)
MSLB2	RF1	9.2	3.84 (Fail)	2.84 (OK)
	RF2	9.2	3.30 (Fail)	2.40 (OK)
	RF3	9.2	2.62 (OK)	1.92 (OK)
MSLB3	RF1	9.2	4.29 (Fail)	2.95 (OK)
	RF2	9.2	3.71 (Fail)	2.47 (OK)
	RF3	9.2	2.92 (OK)	1.92 (OK)
TLOFW1	NA (calculation fail) but covered by TLOFW3			
TLOFW2	NA (calculation fail) but covered by TLOFW3			
TLOFW3	RF1	9.2	4.33 (Fail)	2.91 (OK)
	RF2	9.2	3.73 (Fail)	2.43 (OK)
	RF3	9.2	2.91 (OK)	1.89 (OK)

If the specified mission time is prescribed as 12 hours, the SA spray with flow rate of RF1 can satisfy the performance criteria described section 2.3. As the results, the SDS actuation is found to have no significant effect to the long-term depressurization. And it is shown that the depressurization performance is degraded due to the long-term feed and bleed operation.

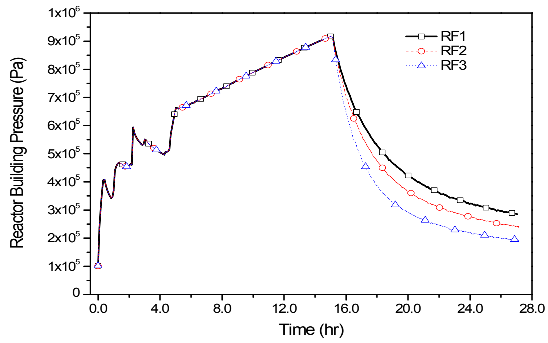

Figure 1. Containment Depressurization for MSLB1 case

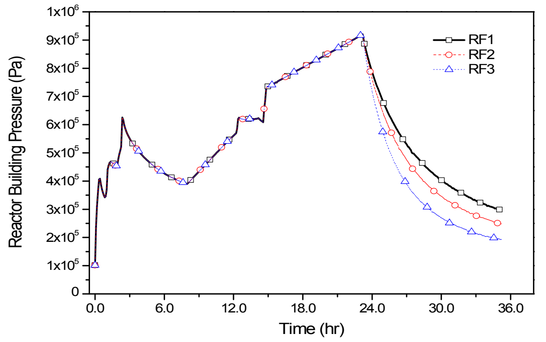

Figure 2. Containment Depressurization for MSLB3 case

3. Conclusion

The analysis was performed to evaluate the depressurization capacity of the SA spray. The applicable pump flow rate was estimated for the specified performance criteria. As the results, the flow rate of 80% of current DBA spray pump is found to be applicable for depressurization to the target level within 6 hours. With the flow rate of 60% of DBA pump, it was shown to be possible to do within 12 hours.

References

[1] “European Utility Requirements (EUR) for LWR Nuclear Power Plants", Volume 2, Revision C, April 2001.
[2] "MAAP 4.0 User's Manual", RP3131-02, EPRI, May, 1994.
[3] “Advanced Power Reactor 1400 Standard Safety Analysis Report,” Rev. 0, Korea Hydro & Nuclear Power Co., Ltd.
[4] Korean Utility Requirements Document, Rev. 0, June 1998