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Safety Depressurization System Capability for High Pressure Core Melting Accidents in APR1400

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1. Introduction

In the case of a high-pressure core melt-down accident, the released molten material from a reactor vessel can lead to increase the containment pressure and temperature by heat transfer via direct contact between the containment atmosphere and the dispersed molten material. This phenomenon is known as direct containment heating (DCH) [1].

High-pressure melt ejection (HPME) and DCH became severe accident (SA) safety issues in the 1980s. Many studies were performed in the USA to understand these events during the 1980s and 1990s. Currently, a reliable safety depressurization system (SDS) is required to prevent HPME/DCH events.

A number of ALWRs such as EPR, APWR and AP1000 have been adopted SDS in their design. Especially, a dedicated SDS for severe accident mitigation is required in Europe.

The APR1400 is designed with dedicated SDS for severe accidents in order to meet European requirements. In this paper, an evaluation of the SDS capacity is performed for high-pressure accidents of the APR1400 using MAAP4 [2]; The result can be expected to be technical basis for a serve accident management guidelines (SAMGs).

2. Analysis and Results

2.1 Accident scenario

Hypothetical high pressure scenarios leading to RV failure are selected for the analysis of the SDS capacity; these scenarios were initiated by TLOFW (total loss of feed water), SBO (station blackout) and SLOCA (small loss of coolant accident). All of the ESFs (Engineered Safety Features) and operator measures, except SDS valve opening, are assumed to be unavailable.

2.2 Time span from SA entry to RV failure

The SDS operation should be done in the period from severe accident (SA) entry to Reactor vessel (RV) failure. Generally, the severe accident entry condition is recognized as the point of time at which the core exit temperature exceeds 1200°F (922K). Figure 1 shows the analysis result of TLOFW with no ESFs.

It takes about two hours from SA entry to RV failure.

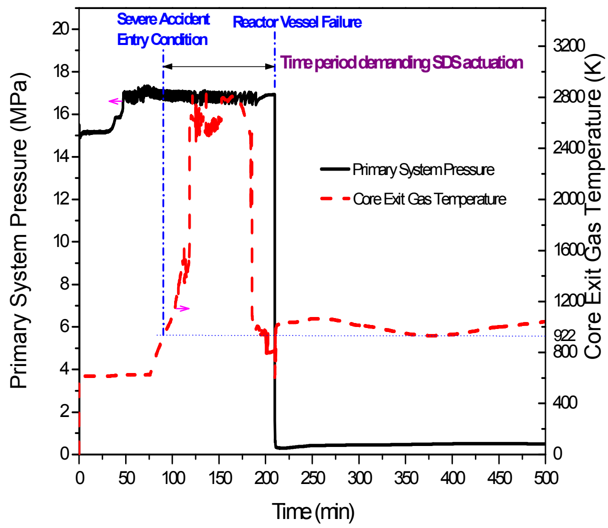

Figure 1. Analysis result of TLOFW with no ESFs

2.3 Analysis conditions for estimation of the SDS capacity

The depressurization performance of SDS is mainly dominated by the discharge capacity of the SDS valve. The current APR1400 design is equipped with four POSRVs [3].

The optimal valve capacity of the SDS is estimated to be in a range from the capacity of one POSRV to that of four POSRVs. In addition to the discharge capacity, a delay of SDS operation is assumed for estimation of the marginal time of SDS operation. In Table 1, the analysis conditions are listed.

The time delay means the time elapsed from the severe accident entry condition. For conservative evaluation, the condition in which the POSRVs get stuck-closed from the SA entry condition is also considered.

Table 1. Analysis conditions and IDs

Delay of SDS opening	SDS discharge capacity (expressed as number of current POSRVs)			
	C1 (x 1)	C2 (x 2)	C3 (x 3)	C4 (x 4)
30 min	**C11**	**C21**	**C31**	**C41**
45 min	**C12**	**C22**	**C32**	**C42**
60 min	**C13**	**C23**	**C33**	**C43**

2.4 Analysis result

The SDS must be operated before the RV failure so that the RCS pressure can be reduced to the target pressure. The target pressure of the depressurization is presented as 250 psi in the EPRI-URD and 20 bars in the EUR. Figure 2 shows the analysis results for each case listed in Table 1.

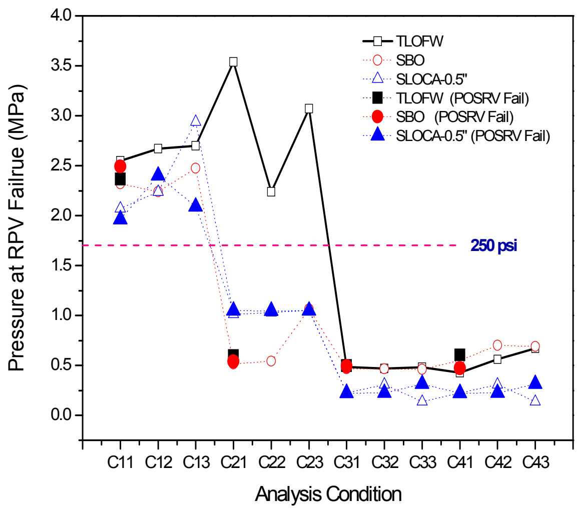

Figure 2. Depressurization performance according to SDS capacity and operation time

As the results show, the TLOFW gives the bounding conditions for the RCS pressure.

It can be seen that the RCS pressure at RV failure doesn't exceed 250 psi with SDS of discharge capacity over C3, even with a 60 minute delay.

Thus, it can be inferred that the optimal capacity of the SDS lies between C2 and C3. For this range, a detailed analysis is performed for TLOFW; the results are presented in Figure 3.

In this analysis, a 60 minute delay of SDS actuation is assumed for the case in which the POSRVs are available as the safety valves for the whole accident period.

For the condition in which POSRVs are stuck-closed after SA entry condition, a 30 minute delay is applied.

The results show that if the SDS capacity is slightly larger than C2, the SDS performance requirement can be satisfied even with some actuation delay.

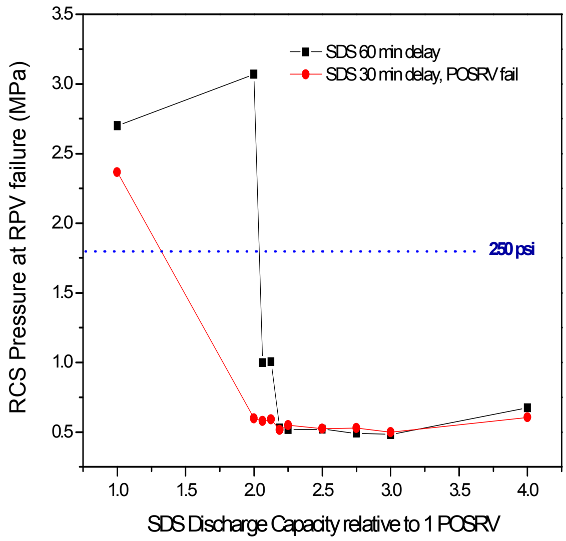

Figure 3. Depressurization performance according to SDS capacity in TLOFW

3. Conclusion

The feasibility study shows that SDS capacity satisfies the European requirements even with an actuation delay of 60 minute. The results of this study can provide a technical basis for planning severe accident management strategies with SDS operations to prevent HPME/DCH events.

References

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[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, 2001