Sensitivity analysis on the MSLB scenario for LCO condition of APR1400 using CAP code

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1. Introduction

Containment pressure and temperature are most important factor to maintain the containment integrity and these factors are defined as the Limiting Conditions for Operation (LCO) in Technical Specification (TS). According to the background document [1], the containment pressure and average air temperature are limited during normal operation to preserve the initial conditions assumed in the accident analyses for a Loss of Coolant Accident (LOCA) or Main Steam Line Break (MSLB). According to the TS document, the containment pressure should be maintained below the 1.0 psig and containment temperature below the 48.9 °C (≈ 120 °F) during normal operation.

Korean nuclear industry launched the project for development of domestic safety analysis codes as a part of Nu-Tech project in 2006 and the CAP (Containment Analysis Package) code was developed for the analysis of containment thermal hydraulic behaviors [2]. In this paper, a sensitivity analysis was performed using CAP code to confirm the results on the overall pressure and temperature conditions in case the dome is relatively high temperature condition.

2. Methods and Results

2.1 Initial conditions and scenario assumptions

In this section, initial conditions and scenario assumptions for sensitivity analysis using CAP code are described. For the analysis, Shin-Kori units 3 and 4 are selected for reference plant. Initial conditions for analysis is described in table I. These conditions applied the conditions specified in the reference document [3].

Table I: Initial conditions

		1 node	**2 nodes (Cylinder, Dome)**
Containment	**Volume**	88,575 m^3	C: 63,555 m^3 D: 25,020 m^3
	Pressure	111 kPa	
	Temp.	322.05 K (≈48.9 °C)	
	Humidity	5 %	
Environment	**Temp.**	322.04 K (≈48.89 °C)	

According to the U.S. NRC report, the worst case MSLB generates larger mass and energy releases than the worst case LOCA [1]. Thus, the MSLB event bounds the LOCA event from the containment peak pressure and temperature point of view. In this reason, the released mass and energy data for the MSLB (102 % power condition) – Containment spray 1 train fail scenario was applied [3].

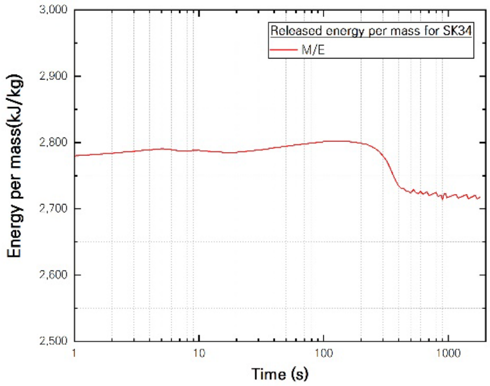

Fig. 1. Released energy per mass of MSLB scenario for analysis.

As mentioned in introduction, containment pressure and average air temperature are limited during normal operation to preserve the initial conditions used in the safety analysis. According to the background document, the limit for containment average air temperature ensures that operation is maintained within the assumptions used in the safety analysis for containment. During actual normal operation, the containment air temperature may be locally high due to the air cooling equipment failure or hypothetical abnormal conditions. So, it is assumed that the dome temperature is locally high at 335.75 K which exceeds the LCO condition of average air temperature. Calculation cases are one node case and two nodes cases. One node case is conventional method that containment is modelled only one node. Two nodes case is modelled by cylinder part and dome part, and the elevation criteria was determined by elevation of the polar crane installation. Additionally, the sensitivity analysis for spray injection time is also performed. The spray initiation time are selected to 126.0 s, 93.0 s, respectively. 126.0 s is based on scenario and 93.0 s is based on the delay time of the containment spray [3].

Table II: Initial temperature conditions for sensitivity analysis

CASE	**Initial temperature**		**Spray initiation time**
	Cylinder	**Dome**	
1 node	322.05 K		126.0 s
2 nodes - BASE			
2 nodes - 62.6C	322.05 K	335.75 K	
2 nodes - 93.0s	322.05 K		93.0 s

2.2 Sensitivity analysis results

First of all, the results of node sensitivity are compared. Figure 2 shows containment pressure behavior in case of 1 node and 2 nodes-BASE, respectively. In case of 1 node case, maximum pressure is higher than 2 nodes-BASE case. The maximum pressure in case of 1 node case is 410.1 kPa and that of 2 node-BASE case is 394.4 kPa. From a pressure perspective, it can be confirmed that the calculation result of 1 node case is more conservative. Figure 3 shows containment temperature calculation results in case of 1 node and 2 nodes-BASE cases. The maximum temperature of 1 node case is about 403.3 K and the cylinder part and dome part of 2 nodes-BASE case are 408.8 K and 401.5 K, respectively. Unlike the pressure calculation result, the temperature calculation result in case of 2 nodes-BASE case is predicted to be higher than 1 node case. Both pressure and temperature calculation results of 1node and 2nodes-BASE cases are within design criteria.

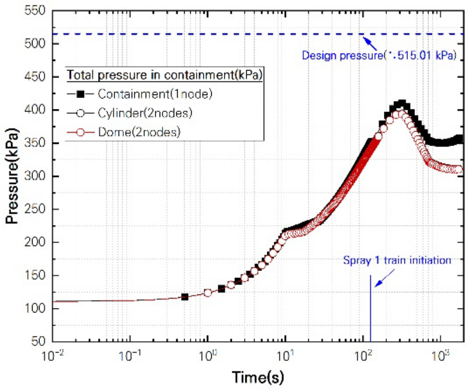

Fig. 2. Pressure calculation result of 1node and 2nodes-BASE cases.

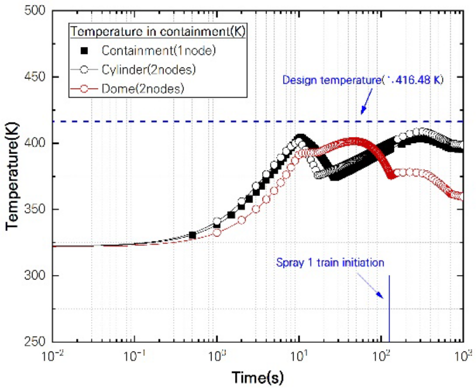

Fig. 3. Gas temperature calculation result of 1node and 2nodes-BASE cases.

The pressure calculation result in case of 2 node cases is shown in figure 4. Both 2 nodes-BASE case and 2 nodes-62.6C case are same pressure behavior. This result shows that the local high temperature condition of dome part do not affect the overall pressure condition. Figure 5 shows temperature calculation result in case of 2 node cases. Due to the initial high temperature condition, the dome temperature of 2 nodes-62.6C case is higher than that of 2 nodes-BASE case. The maximum temperature are 408.7 K and 401.5 K, respectively. And, the dome temperature decreases after initiating the spray injection. Unlike the dome temperature, the temperature of cylinder part in case of both cases are same. These results shows the local high temperature condition do not affect overall pressure and temperature conditions.

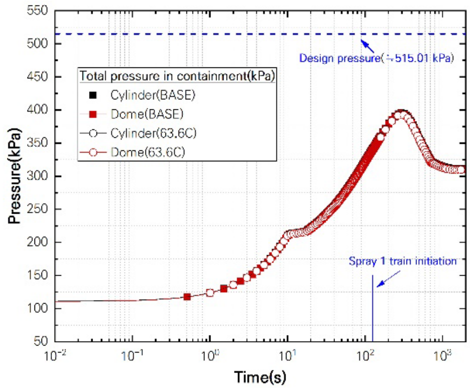

Fig. 4. Pressure calculation result of 2nodes-BASE and 62.6C cases.

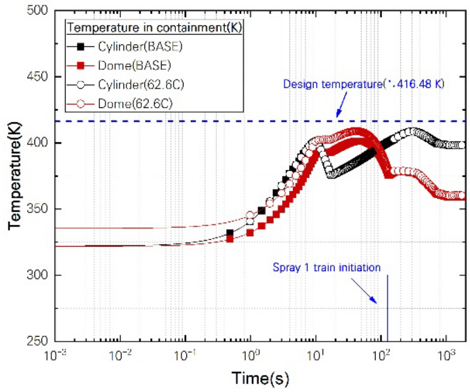

Fig. 5. Gas temperature calculation result of 2nodes-BASE and 62.6C cases.

Lastly, the pressure and temperature results according to the spray initiation time are confirmed. The maximum pressure in case of the 126.0 s and 93.0 s cases are 394.4 kPa and 386.6 kPa, respectively.

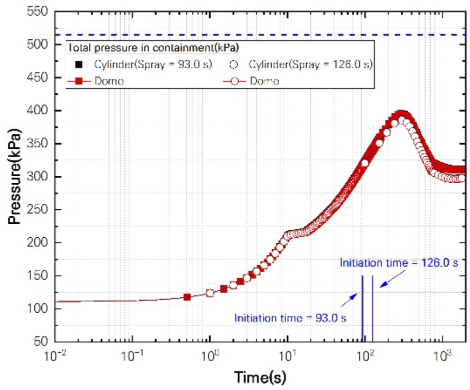

Fig. 6. Pressure calculation result when the containment spray

initiation occurs at 93.0 s, 126.0 s, respectively.

The maximum pressure was predicted to be lower when the spray initiation time was fast. On the other hand, the maximum temperature in both cylinder part and dome part shows 93.0 s and 126.0 s of spray initiation time cases are same. These results shows the spray initiation time can affect the maximum pressure and do not affect the maximum temperature.

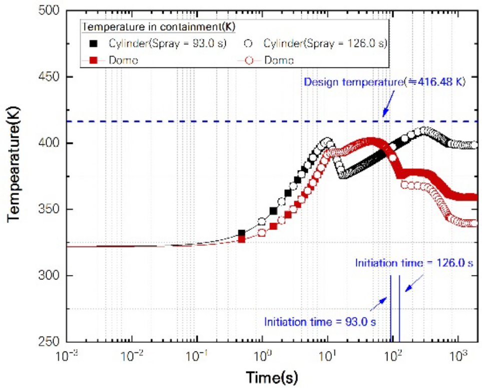

Fig. 7. Gas temperature calculation result when the containment spray initiation occurs at 93.0 s, 126.0 s, respectively.

3. Conclusions

In this paper, a sensitivity analysis was performed to study how the local high temperature condition of dome part affect the overall pressure and temperature conditions. Additionally, the sensitivity analysis for spray initiation time was also performed. The calculation results of node sensitivity shown the pressure of one node case was higher than that of two nodes cases. However, in terms of the maximum temperature, two nodes case was more conservative. The pressure and temperature both one node and two nodes cases not exceed the design criteria when the initial condition was maximum value which is mentioned in TS document. When the dome temperature is locally high, the dome temperature is only higher than that of 2 nodes-BASE case. These results shows the local high temperature condition do not affect overall pressure and temperature conditions. Based on the calculation results, it was concluded that the local high temperature condition do not have a significant effect on the containment integrity. Lastly, sensitivity results of spray initiation time shows the spray initiation time have an effect on the maximum pressure.

REFERENCES

[1] U.S. NRC, Standard Technical Specifications Combustion Engineering Plant, NUREG-1432, Volume 2, Rev.4, 2012.
[2] S. J. Hong, Y. J. Choo, S. H. Hwang, B. C. Lee, and S. J. Ha, Development of CAP code for nuclear power plant containment: Lumped model, Nuclear Engineering and Design, Vol.291, p. 47-63, 2015.
[3] KHNP, Final Safety Analysis Report for Shin-kori units 3 and 4, Chap. 6.2. rev.1, 2015.