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Analysis of MSLB for APR1400 using SPACE Mass and Energy Release Methodology

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1. Introduction

Main Steam Line Break (MSLB) accident is most important Design Basis Accident for containment building functional design. Mass and Energy Release (MER) analysis methodology using Safety and Performance Analysis CodE (SPACE) has been developing. The SPACE which is best estimated code for safety analysis is used to analyze nuclear steam supply system with Containment Analysis Package (CAP). Mass and energy release is predicted for APR1400 during MSLB accident. Using the MER data, containment peak pressure and temperature analysis is performed by stand-alone CAP code with conservative containment initial condition. The peak pressure and temperature are compared with previous MER analysis methodology, KEPCO E&C improved mass and energy release analysis (KIMERA).

2. Analysis Methodology

To establish the SPACE MER analysis methodology, thermal hydraulic mechanism of NSSS is analyzed by SPACE and that of containment is analyzed by CAP. Thermal hydraulics analysis in NSSS and back pressure analysis and MER analysis are calculated with linked process between SPACE and CAP.

2.1 SPACE MER Model

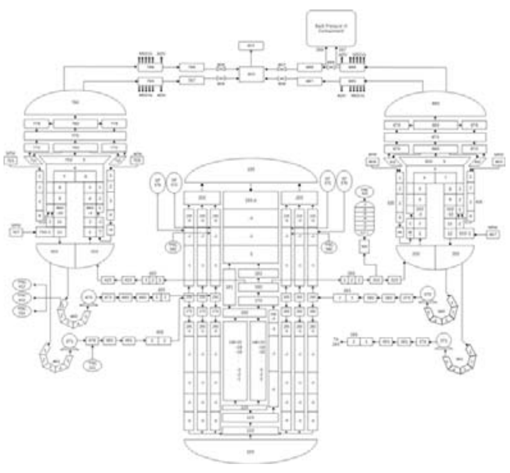

Figure 1. SPACE nodalization for APR 1400

Figure 1 shows nodalization of APR1400 for MER analysis during MSLB accident. Reactor coolant system and secondary system, emergency core cooling system are modeled with control volume, junction and heat structure.

2.2 Assumptions

Assumptions made to conservatively predict MER during an MSLB include the follows:

- The MSIVs are closed in 5.0 seconds and the MFIVs are closed in 10.0 seconds.
- Auxiliary feedwater flow to the affected steam generator is assumed.
- The turbine stop valve is closed at 0 second for conservatism.
- The limiting break size and reactor power are used.
- The operating conditions and parameters including containment parameters are assumed to provide the limiting results with respect to the containment peak pressure.
- The feedwater flow to the affected steam generator is conservatively modeled as 165% of total feedwater flow for the 102%, 75%, and 50% power and 110% of total feedwater flow for the 20%.

The sensitivity studies for the initial power and discharge coefficient of the break flow were performed. To determine the limiting break size, sensitivity for Cd is performed.

3. Analysis Results

3.1 Main Steam Isolation Valve Failure

Various power levels and break size spectrum analyses are performed for MSLB M/E release analysis for APR1400. Single failures are MSIV Failure (MSIVF) and Loss of Containment Cooling (LCC). At the beginning of MSLB accident, SG pressure is rapidly decreased with massive steam release through the break and the core power is increased by excessive heat removal through break area. Reactor trip is activated by High Containment Pressure (HCP) trip signal to stop increasing power at 5.7 seconds. Activating MSIV signal by HCP, MSIV is closed at 10.7 seconds and MFIVs are closed at 15.7 seconds. Water inventory in the broken SG is exhausted at 350 seconds. Because feedwater could not make up following the MFIV close, auxiliary feedwater is continued to supply after activation. Containment spray is started to cool containment down at 113 seconds by HCP signal. After

1,800 seconds, operator stops to supply auxiliary feedwater to broken SG.

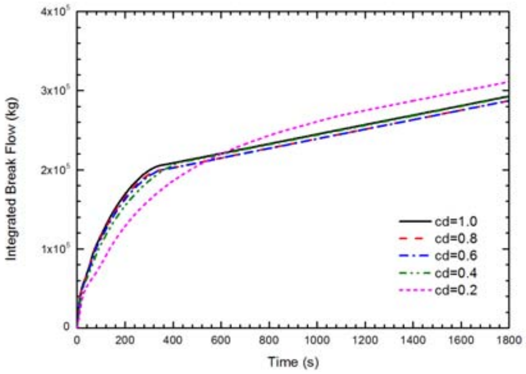

Figure 2. Integrated Break Flow of 102% power (MSIVF)

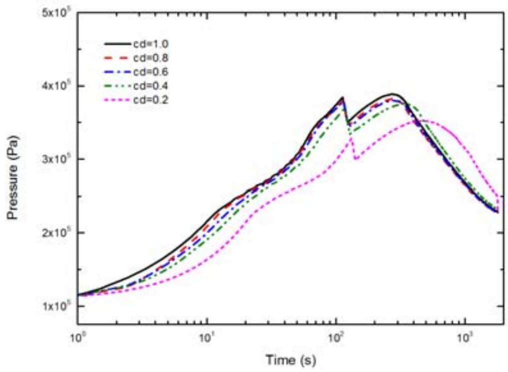

Figure 3. Containment Pressure of 102% power (MSIVF)

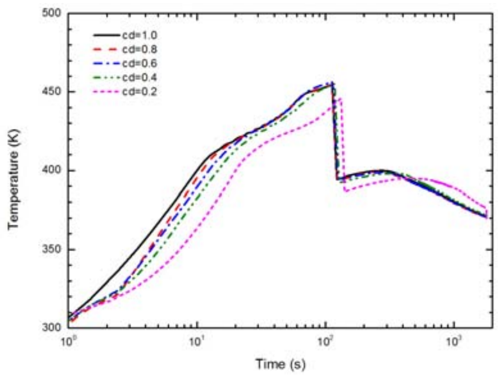

Figure 4. Containment Temperature of 102% power (MSIVF)

Integrated break flow with various values of Cd (discharge coefficients) for the case of MSIV failure with 102% power is shown in Figure 2. Figure 3 and 4 presents predicted containment pressure and temperature behaviors, respectively. The maximum peak pressure occurred for 1.0 of Cd whereas the peak temperature is for 0.6 of Cd for 102% power case.

Table 1. Peak Pressure and Temperature for MSIV failure

Power (%FP)	Discharge Coefficient (Cd)	Pressure (Pa)	Temperature (K)
102	**1.0**	**388,740**	**454.28**
	0.8	382,090	454.81
	0.6	380,240	456.5
	0.4	375,430	455.3
	0.2	351,850	445.86
75	1.0	382,930	453.26
	0.8	380,540	454.58
	0.6	378,180	455.83
	0.4	369,610	455.21
	0.2	345,740	449.16
50	1.0	379,670	452.59
	0.8	379,840	454.66
	0.6	375,800	455.67
	0.4	367,390	455.16
	0.2	338,420	449.31
20	1.0	376,360	450.93
	0.8	374,000	452.48
	0.6	370,230	453.96
	0.4	360,720	453.58
	0.2	332,030	447.79

Table 1 is shows peak pressure and temperature with various kinds of Cd for the case of MSIV failure with different initial power. As shown in the table, the maximum peak pressure is calculated with 1.0 of Cd for the case of 102% power. Decreasing Cd the peak pressure is decreased. At 276 seconds, the maximum peak pressure is 388,740 Pa (56.4 psia). The maximum peak temperature of containment is calculated with 0.6 of Cd. At 114 seconds, the maximum peak temperature is 456.5 K (362 ˚F)

3.2 Loss of Containment Cooling

During MSLB accident with LCC, the mass and energy release rate is decreased rapidly compared with the rate of the case by MSIV failure.

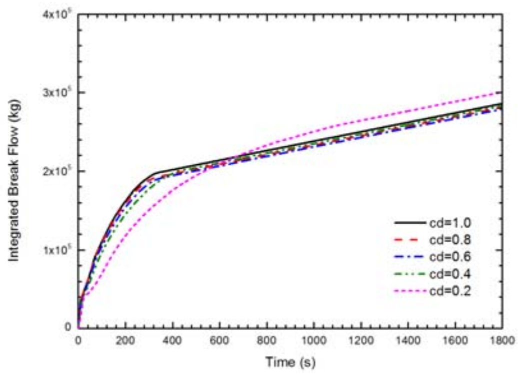

Figure 5. Integrated Break Flow of 102% power (LCC)

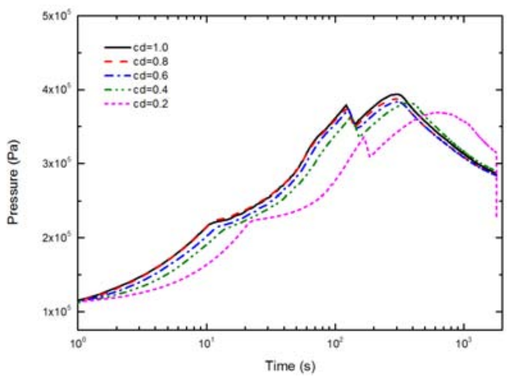

Figure 6. Containment Pressure of 102% power (LCC)

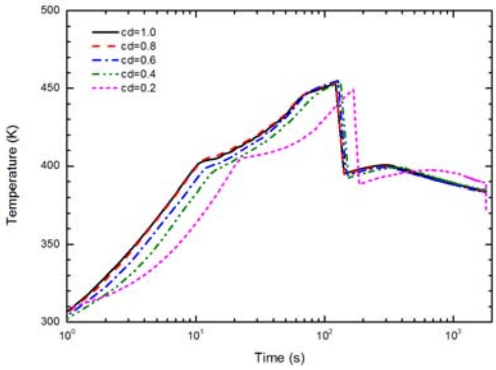

Figure 7. Containment Temperature of 102% power (LCC)

Integrated break flow with various values of Cd for the case of LCC with 102% power is shown in Figure 5. Figure 6 and 7 presents predicted containment pressure and temperature behaviors, respectively. Comparison with case of MSIV failure, the time for peak value is delayed. The maximum peak pressure occurred for 1.0 of Cd whereas the peak temperature is for 0.6 of Cd for 102% power case.

Table 2. Peak Pressure and Temperature for LCC

Power (%FP)	Discharge Coefficient (Cd)	Pressure (Pa)	Temperature (K)
102	**1.0**	**393,740**	453.08
	0.8	387,800	454.11
	0.6	383,530	**455.27**
	0.4	382,090	454.56
	0.2	368,630	449.15
75	1.0	389,790	452.35
	0.8	387,160	453.63
	0.6	385,580	454.99
	0.4	378,910	454.43
	0.2	359,610	451.06
50	1.0	378,450	451.43
	0.8	375,550	453.39
	0.6	373,530	454.62
	0.4	366,000	454.66
	0.2	343,930	449.27
20	1.0	372,070	450.05
	0.8	369,170	451.51
	0.6	365,050	453.04
	0.4	354,440	452.96
	0.2	329,090	446.46

Table 2 is shown as peak pressure and temperature with various kinds of Cd for the case of LCC by sensitivity analysis of power. As shown in the table, the maximum peak pressure is calculated with 1.0 of Cd for 102% power. Decreasing Cd the peak pressure is decreased. At 299 seconds, the maximum peak pressure is 393,740 Pa (57.1 psia). The maximum peak temperature of containment is calculated with 0.6 of Cd for 102% power. At 127 seconds, the maximum peak temperature is 455.3 K (359.8 ˚F).

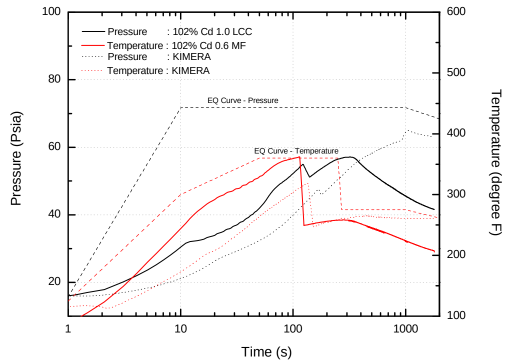

Figure 8. Comparison of MER analysis and EQ curve

Figure 8 compares the results with the limiting case of previous MER analysis methodology. The limiting case of pressure is predicted the case of MSIVF with 1.0 of Cd for 102% power case. The maximum peak pressure is lower than the result of previous methodology. The limiting case of temperature is predicted the case of LCC with 0.6 of Cd for 102% power case. The maximum peak temperature is higher than the result of previous methodology and Equipment Qualification (EQ) curve of containment building functional design.

4. Conclusions

Various kinds of MSLB for APR1400 are analyzed with MSIV failure and LCC for 102%, 75%, 50%, 20% power. MSLB analysis is performed using linked calculation between SPACE and CAP. As a conclusion, the maximum peak pressure is less conservative than peak pressure by previous methodology. The maximum peak temperature is more conservative than peak temperature by previous methodology. Further work to compare with mass and energy release by previous methodology is needed to establish SPACE MER analysis methodology.

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