SUPPLEMENTAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**324-8362**
SRP Section:	**06.02.01.04 – Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures**
Application Section:	**6.2.1.4**
Date of RAI Issue:	**12/02/2015**

Question No. 06.02.01.04-1

General Design Criteria (GDC) 50, "Containment design basis", and GDC 16, "Containment design", of Appendix A to 10 CFR Part 50 require, in part, that the reactor containment structure and associated heat removal system shall be designed with sufficient margin to accommodate the calculated pressure and temperature conditions resulting from any loss-of-coolant accident (LOCA). NUREG-0800, SRP Section 6.2.1.1A, Acceptance Criterion No. 1 specifies that the containment design pressure should provide at least a 10% margin above the accepted peak calculated containment pressure following a loss-of-coolant accident, a main steam line break (MSLB), or a main feedwater line break (MFLB), to satisfy the GDC 16 and 50 requirements for sufficient design margin. In addition, ANSI/ANS 56.4-1983, which has established detailed guidelines for containment response to design basis accidents (DBAs), specifies that initial conditions should be chosen to yield a conservatively high peak containment atmosphere pressure and temperature. These guidance documents ensure sufficient conservatism in the mass and energy release analysis for the postulated primary and secondary system pipe ruptures during the DBA such that the reactor containment structure and heat removal system design can accommodate the calculated peak pressure and temperature conditions.

In this backdrop, the staff seeks the following additional information to gain safety insights into the initial and boundary conditions the applicant used for the limiting MSLB analysis for the containment. The applicant is also requested to update the APR1400 DCD and/or the Technical Report (TeR), "LOCA Mass and Energy Release Methodology", APR1400-Z-A-NR-14007-P, Rev.0, to appropriately document the respective explanations.

Following the acceptance criteria, the limiting single failure MSLB analysis is based on two assumptions:

(1) maximizing the flow of saturated and superheated steam out of the break; and (2) minimizing the rate of heat removal from the containment atmosphere. Since the APR1400 containment response analysis does not credit any fan coolers, the latter assumption is accomplished by not crediting the containment spray system (CSS). The former assumption can be based on any one of the several possible single failures including the failure of condensate booster pump to trip, FRV (Feedwater Regulating Valve) to close, or MSIV (Main Steam Isolation Valve) to shut. The APR1400 MSLB analysis has considered the CSS and MSIV single failures to see which one is conservative. The applicant is requested to clarify whether the single failure of the feedwater regulating valve to close was also examined. The staff is concerned that during the time the feedwater bypass valve takes to shut the flow, considerable amount of feedwater may enter the steam generator, gain heat from the hot primary-side, and the resulting additional steam would enter the containment to further increase the containment peak pressure and, especially, the peak temperature. Please demonstrate that the current limiting MSLB analysis is bounding for all possible single failures.

Response

For added clarity regarding the initial conditions of the limiting main steam line break (MSLB), DCD Tier 2, Section 6.2.1.4.4 and Table 6.2.1-20 will be revised as Attachment 1 to state the maximum feedwater enthalpy is assumed in the analysis and provide the pressurizer pressure, respectively.

The FCV (Feedwater Control Valve) is conservatively assumed to be wide-open in order to deliver the maximum feedwater flow to the affected steam generator in the MSLB analysis.

There are two MFIVs in series in each main feedwater line. If one MFIV fails, the second MFIV provides isolation. The single failure of the MFIVs in main feedwater line does not need.

The feedwater bypass control valve is a non-safety related and normally closed valve. The FBCV is used for the steam generator initial filling condition by operator. The FBCV is not designed to receive any automatic actuation signal. Therefore, the single failure of the FBCV is not considered for the MSLB analysis.

In conclusion, the single failure of these components has not been considered for the MSLB analysis, and the current limiting MSLB analysis is bounding for all possible single failures.

Supplemental Question (July 7, 2016 Public Teleconference)

In the RAI response, the applicant concludes that the current limiting MSLB analysis is bounding for all possible single failures, even though neither the DCD nor the RAI response present any other single failure analysis. The staff would like to develop better appreciation of the applicant’s reasoning presented in the RAI response.

Supplemental Response (July 7, 2016 Public Teleconference)

Table 1 below summarizes the single failures that were considered in the APR1400 nuclear power plant from Table 15.0-4 in DCD Chapter 15. Single failures in the control system are typically actuated to mitigate the MSLB accident and, therefore, are excluded from Table 1. Single failures of the safety and electrical system applicable for the MSLB mass and energy release analysis are qualitatively evaluated in the table. This supplemental information will be included in KHNP Technical Report APR1400-Z-A-NR-14007-P/NP, as indicated in Attachment 2.

Table1 Single Failure Evaluation for MSLB analysis

Single Failure	Application	Evaluation
Main feedwater system		
1. One main feedwater isolation valve fails to close	Not Applied	Two valves exist in series. If one MFIV fails, the second MFIV provides isolation. A single failure of the MFIVs in the main feedwater line has no impact.
2. One main feedwater isolation valve back-flow check valve fails to close	Not Applied	Single failure of the MFIV back-flow check valve has no conservative effect on the view of SG water inventory for MSLB M/E analysis.
Main steam system		
3. One main steam isolation valve fails to close	Applied	Single failure of one MSIV results in more steam release to containment.
4. One main steam isolation valve bypass valve fails to close	Not Applied	MSIV bypass valve is used for balance of plant warmup and pressure equalization across the MSIVs prior to opening. The size of the MSIV bypass valve is much smaller than that of MSIV and, therefore, is bounded by an MSIV failure.
5. One atmospheric dump valve (ADV) fails to open	Not Applied	If the ADV is open, the mass and energy will be released to the outside of containment. It does not contribute to increase the containment pressure and temperature. Therefore, the single failure of ADV is not applied in the MSLB M/E release analysis.
6. One atmospheric dump valve (ADV) fails to reclose	Not Applied	
Auxiliary feedwater system		
7. Failure of any one auxiliary feedwater pump to start or auxiliary feedwater valve to function	Not Applied	The auxiliary feedwater system is conservatively assumed to be injecting at a run-out flow rate to maximize the mass and energy release through the break.
Safety injection system		
8. Failure of one SI pump	Not Applied	SI injection containing the relatively low enthalpy will decrease the high enthalpy of primary coolant. It will decrease the heat transfer from primary-side system to the affected SG. Since this failure is not conservative to the MSLB M/E release analysis, the single failure of SI pump is not applied in the MSLB M/E release analysis.

Single Failure	Application	Evaluation
Electrical power sources		
9. Failure of one emergency diesel generator to start, run, or load (each SI pump is powered from each emergency diesel generator)	Not Applied	For the MSLB M/E, the analysis conservatively assumes that offsite power is available to keep the RCPs operating.

Impact on DCD

DCD Section 6.2.1.4.4 and Table 6.2.1-20 will be revised, as indicated in Attachment 1, which is associated with the first response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

KHNP Technical Report (TeR) will be revised to provide the updated information, as indicated in Attachment 2 associated with this supplemental response.

Steam line capacity is modeled by performing mass, energy, and volume balances on a steam line node. Figure 6.2.1-37 shows the flow paths into and out of the steam line node. The mass, energy, and volume balances for the steam line node are as follows:

$$\dot{M} = \sum \dot{m}$$

$$\dot{E} = \sum \dot{m} h$$

$$\dot{V} = 0$$

Where:

$\sum \dot{m} = \dot{m}_1 + \dot{m}_2 + \dot{m}_4 - \dot{m}_B - \dot{m}_T$ for slot breaks

$\sum \dot{m} = \dot{m}_1 + \dot{m}_2 - \dot{m}_T - \dot{m}_{B2}$ for guillotine breaks (see Figure 6.2.1-37 for subscript definition)

The break flow rate is obtained from the Moody critical flow model for zero flow resistance according to NUREG-0800, Section 6.2.1.4.

The contribution to the containment pressure of the feedwater flow is handled by a feedwater flow addition to the affected steam generator and the boiling off of the feedwater by a primary-to-secondary heat transfer. The feedwater flow is the sum of the pumped feedwater flow before isolation plus the expansion of the fluid in the feedwater line between the affected steam generator and its MFIV. The feedwater flow pumped to the affected steam generator is conservatively modeled as 165 percent of the full-power feedwater flow for the 102 percent and 75 percent power cases, 110 percent of the full-power feedwater for the 50 percent power case, and 55 percent of the full-power feedwater for the 20 percent and 0 percent power cases to account for spiking. No degradation of the feedwater flow occurs until the closure of the MFIVs. For consistency, no feedwater is added to the unaffected steam generator.

The maximum feedwater enthalpy is assumed.

Following closure of the MFIVs, there is an inventory of feedwater between the MFIVs and the affected steam generator. As the affected steam generator depressurizes, this inventory starts to boil. As steam in the line expands, this feedwater inventory is pushed into the steam generator and is boiled off by primary-to-secondary heat transfer. The expansion of the feedwater inventory into the affected steam generator is considered in the analysis. The expansion is assumed to be isentropic.

Table 6.2.1-20 (1 of 2)

Initial Conditions for Containment Peak Pressure and Temperature Analysis

Part A. Reactor Coolant Systems (Based on a nominal core power of 3,983 MWt)

Parameter	Value
Reactor Coolant System	
Reactor power level (1), MWt	4,091.86
Pressurizer pressure, 10^6 Pa (psia)	16.030 (2325)
Average coolant temperature, °C (°F)	312.45 (594.4)
Mass of reactor coolant system liquid, kg (lbm)	304,767.84 (671,898.0)
Mass of reactor coolant system steam, kg (lbm)	3,025.05 (6,669.1)
Energy in Reactor coolant system liquid plus steam (2), 10^6 kcal (10^6 Btu)	103.04 (408.91)
Energy from feedwater nozzle to MSIV per Steam Generator (2), 10^6 kcal (10^6 Btu)	33.047 (131.14)

This mark-up page will be newly inserted in the full revision of TeR "APR1400-Z-A-NR-14007-NP, Rev.01"

There are two MFIVs in series in each main feedwater line. If one MFIV fails, the second MFIV provides isolation. The total volume of fluid between the upstream MFIV and each steam generator is assumed to be the maximum. These assumed volumes conservatively exceed the actual design values of the APR1400 volumes. All cases analyzed consider the flashing of the fluid in the lines from the upstream MFIVs to the affected steam generator. Therefore, a separate analysis assuming MFIV failure is not needed.

Moreover, Feedwater Control Valve (FCV) is conservatively assumed to be wide-open in order to deliver the maximum feedwater flow to the affected steam generator. The feedwater bypass control valve is a non-safety related and normally closed valve. The FBCV is used for the steam generator initial filling condition by operator. The FBCV is not designed to receive any automatic actuation signal.

Table 3-3 shows the single failures that were considered in the APR1400 nuclear power plant. Table 3-3 is taken from Table 15.0-4 in DCD Chapter 15. Single failures in the control system are typically actuated to mitigate the MSLB accident and, therefore, these single failures are excluded from Table 3-3. Single failures of safety and electrical system applicable for the MSLB mass and energy release analysis are qualitatively evaluated in the Table 3-3.

In conclusion, the current limiting MSLB analysis is bounding for all possible single failures.

This part is the description associated with RAI response 324-8362-Q.6.2.1.4-1.

3.2.6 Initial Conditions

RCS parameters for a nominal core power of 3,983 MWt are given in Table 4-3. The steam generator pressure varies from 71.71 kg/cm^{2}A (1,020 psia) (nominal full load) to 77.33 kg/cm^{2}A (1,100 psia) (zero core power). The initial steam generator inventory is calculated assuming manufacturing tolerances, which maximize the initial inventory. The increase in the initial inventory resulting from thermal expansion of the steam generator is included.

3.2.7 Heat Transfer Model

According to the SRP Section 6.2.1.4 Acceptance Criteria No.2B, the nucleate boiling heat transfer coefficient should be considered for the water in the affected SG. In DCD Tier 2, the mass and energy release in the MSLB analysis is calculated by considering the nucleate boiling heat transfer coefficient, as in the LOCA analysis. In the SGNIII code, the secondary heat transfer coefficient for heat transfer to two-phase is a boiling heat transfer coefficient based on the design conditions, and the heat transfer coefficient used in the two SG tubes is the overall heat transfer coefficient considering the film, wall, fouling and boiling resistances in the design data. The overall heat transfer coefficient for the two SGs is calculated as follows:

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This mark-up page will be newly inserted in the full revision of TeR "APR1400-Z-A-NR-14007-NP, Rev.01"

Table 3-3 Single Failure Evaluation for MSLB analysis

Single Failure	Application	Evaluation
Main feedwater system		
1. One main feedwater isolation valve fails to close	Not Applied	Two valves exist in series. If one MFIV fails, the second MFIV provides isolation. A single failure of the MFIVs in the main feedwater line has no impact.
2. One main feedwater isolation valve back-flow check valve fails to close	Not Applied	Single failure of the MFIV back-flow check valve has no conservative effect on the view of SG water inventory for MSLB M/E analysis.
Main steam system		
3. One main steam isolation valve fails to close	Applied	Single failure of one MSIV results in more steam release to containment.
4. One main steam isolation valve bypass valve fails to close	Not Applied	MSIV bypass valve is used for balance of plant warmup and pressure equalization across the MSIVs prior to opening. The size of the MSIV bypass valve is much smaller than that of MSIV and, therefore, is bounded by an MSIV failure.
5. One atmospheric dump valve (ADV) fails to open	Not Applied	If the ADV is open, the mass and energy will be released to the outside of containment. And, it does not contribute to increase the containment pressure and temperature. Therefore, the single failure of ADV is not applied in the MSLB M/E release analysis.
6. One atmospheric dump valve (ADV) fails to reclose	Not Applied	
Auxiliary feedwater system		
7. Failure of any one auxiliary feedwater pump to start or auxiliary feedwater valve to function	Not Applied	The auxiliary feedwater system is conservatively assumed to be injecting at run-out flow rate to maximize the mass and energy release through the break.
Safety injection system		
8. Failure of one SI pump	Not Applied	SI injection containing the relatively low enthalpy will decrease the high enthalpy of primary coolant. And, it will decrease the heat transfer from primary-side system to the affected SG. It`s not conservative to the MSLB M/E release analysis. Therefore, the single failure of SI pump does not credit in the MSLB M/E release analysis.
Electrical power sources		
9. Failure of one emergency diesel generator to start, run, or load (each SI pump is powered from each emergency diesel generator)	Not Applied	For the MSLB M/E, the analysis conservatively assumes that offsite power is available to keep the RCPs operating.

This part is the description associated with RAI response 324-8362-Q.6.2.1.4-1.