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.:	**385-8465**
SRP Section:	**06.02.01.04 - Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures**
Application Section:	**6.2.1.4 - Mass and Energy Release Analysis for Postulated Secondary System Pipe Rupture Inside Containment**
Date of RAI Issue:	**02/01/2016**

Question No. 06.02.01.04-4

General Design Criterion (GDC) 50 requires analyses of the most severe consequences for the spectrum of postulated secondary pipe breaks sizes, locations, and single failures. Standard Review Plan (SRP) Section 6.2.1.4, "Mass and Energy Release Analysis for Postulated Secondary System Pipe Ruptures," lays out several acceptance criteria to ensure that the containment mass and energy (M&E) release calculations are performed for the worst design basis accident (DBA). The staff seeks information on the conservative treatment of M&E release calculations for the limiting main steamline break (MSLB) and main feedwater line break (MFLB) analyses from the containment response standpoint, such that the post-accident containment pressure and temperature are maximized. The applicant is also requested to update the APR1400 DCD or the KHNP Technical Report (TeR) APR1400-Z-A-NR-14007-P/NP (LOCA Mass and Energy Release Methodology) to document the explanations. (The regulatory basis identified in the above is applicable to all subsequent questions in this RAI.)

SRP Section 6.2.1.4 specifies that single-failure analyses should be performed for both MSLBs and MFLBs. DCD Tier 2, Table 6.2.1-1, "Spectrum of Postulated Accidents," describes five loss of coolant accident (LOCA) and ten MSLB cases analyzed to identify the most severe DBA to meet the requirements of GDC 50, 16, and 38. However, no information is provided in either DCD Tier 2, Chapter 6 or in KHNP Technical Report (TeR) APR1400-Z-A-NR-14007-P/NP, "LOCA Mass and Energy Release Methodology," (Reference 3) about the MFLB analysis or results. DCD Tier 2, Table 6.2.1-37, "Stored Energy Sources," reports data only for LOCAs and MSLBs, but does not include any MFLB data. The applicant is requested to describe their MFLB analyses in the DCD or TeR, or justify why they were not considered in the break spectrum analysis and that it did not affect the conservatism in the limiting secondary pipe rupture DBA.

Response

The conservative M&E release calculations for containment pressure and temperature in the DCD are the LOCA and MSLB analyses.

Following a postulated MSLB or a MFLB inside the containment, the contents of the affected steam generator are released to the containment. Containment pressurization following a secondary side rupture depends almost entirely on how much of the break fluid enters the containment atmosphere as steam. MSLB flows can be either pure steam or a two phase mixture. With a pure steam blowdown, all of the break flow enters the containment atmosphere. With a two-phase blowdown, part of the liquid in the break flow flashes in the containment and the steam is added to the atmosphere while the remaining liquid falls to the sump without contributing significantly to primary containment pressurization. For the MSLB, the saturated steam containing the high enthalpy is released from the steam line. However, for the MFLB, the subcooled liquid containing the relatively low enthalpy is released from the feedwater line. As a result, more steam is released from the MSLB than the MFLB, and the MSLB shows more severe containment pressure and temperature results than the MFLB.

The MFLB analysis is described in the DCD Tier 2, Section 6.2.1.4 as follows:

"The feedwater distribution box is below the steam generator water level; therefore, MFLB cases result in a two-phase blowdown and do not produce peak containment pressure as severe as MSLBs."

Therefore, the MFLB analysis is not considered in M/E release analysis.

Impact on DCD

There is no impact on the DCD.

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

There is no impact on any Technical, Topical, or Environment Report.

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Question No. 06.02.01.04-5

SRP Section 6.2.1.4 Acceptance Criterion No. 2A specifies that mass release rates for the secondary-system pipe rupture should be calculated using the Moody model for saturated conditions or a model that is demonstrated to be equally conservative. DCD Tier 2, Section 6.2.1.4.4 briefly mentions that the break flow rate for secondary pipe ruptures is calculated using the Moody critical flow model for zero flow resistance. No further information is provided in either the DCD or in the TeR (Reference 3) about the application of the Moody's model. The applicant is asked to justify how Moody's critical flow model was used conservatively for secondary system pipe break analysis and provide more details on the assumptions, e.g., about the fluid phase; and about the empiricism used in the model, e.g., Moody flowrate multiplier.

Response

Based on SRP Section 6.2.1.4 Acceptance Criterion No. 2A, the SGNIII code calculates the break flow rate by using the Moody critical flow model.

The steam line flows are determined from the Moody data which is tabulated in SGNIII as a function of flow, pressure, and quality for different flow resistance factors. For the MSLB analysis, the postulated rupture is assumed to occur at the nozzle of the steam generators, and the flow friction coefficient from the affected steam generator to the break is zero. Therefore, the Moody critical flow model for zero flow resistance is conservatively applied to calculate the M/E release in the MSLB analysis.

Moody critical flow correlation:

$$M_b = A_b \, G_{k=0} (P_b, X_b)$$

M_b : Break mass flow

A_b : Break area

$G_{k=0}$: Moody critical flow for fL/D=0, lbm/ft^2/sec

P_b : Break pressure

X_b : Break quality

And, the Moody critical flow rate for zero flow resistance is tabulated by the SGNIII code, as shown below.

TS

Impact on DCD

There is no impact on the DCD.

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

There is no impact on any Technical, Topical, or Environment Report.

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Question No. 06.02.01.04-6

SRP Section 6.2.1.4 Acceptance Criterion No. 2B specifies that the calculations of heat transfer to the water in the affected steam generator (SG) should be based on nucleate boiling heat transfer. DCD Tier 2, Section 6.2.1.3 (Mass and Energy Release Analyses for Postulated Loss of Coolant Accidents) does mention that a nucleate boiling heat transfer coefficient is used to model the heat transfer from the SG tubes to the primary coolant, for the M&E release analysis for postulated LOCAs. However, no such information is provided in DCD Tier 2, Section 6.2.1.4 for secondary system pipe rupture or in the TeR, so it is not clear whether the statement made in DCD Tier 2, Section 6.2.1.3 applied to LOCA only or would also apply to MSLB. The applicant is request to provide information about the heat transfer correlation used and justify it to be conservative.

Response

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:

TS

Impact on DCD

DCD Section 6.2.1.4.4 will be revised, as indicated in the attachment associated with this 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

There is no impact on any Technical, Topical, or Environment Report.

valve is tested periodically. A single failure in the actuation signal does not prevent valve closure because both trains of MSIS actuation are provided to each MSIV. Any failure would result in the valve going to the closed position so that no additional steam could be added to the containment. Therefore, the failure of an MSIV is not considered a credible event. However, MSIV failure events for MSLB mass and energy analysis are considered.

There are two MFIVs in series in each main feedwater line. If one MFIV fails, the second MFIV provides isolation. 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.

The MSLB data in Tables 6.2.1-9, 6.2.1-11, 6.2.1-13, 6.2.1-15, and 6.2.1-17 are based on a loss of one CSS train. The data in Tables 6.2.1-10, 6.2.1-12, 6.2.1-14, 6.2.1-16, and 6.2.1-18 are based on an MSIV failure.

6.2.1.4.3 Initial Conditions

RCS parameters for a nominal core power of 3,983 MWt are given in Table 6.2.1-20. The steam generator pressure varies from 71.71 kg/cm^2A (1,020 psia) (nominal full load) to 77.33 kg/cm^2A (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.

6.2.1.4.4 Description of Blowdown Model

The SGN-III digital computer code described in Appendix 6B of Reference 15 is used for the secondary system pipe break analysis. All significant equations, including those for the calculation of primary-to-secondary, core-to-coolant, and metal-to-coolant heat transfer and for the calculation of steam separation and moisture carryover are discussed in Appendix 6B of Reference 15. Experimental justification for all heat transfer coefficients, steam separation velocities, and two-phase flow correlations is provided in Appendix 6B of Reference 15.

A nucleate boiling heat transfer coefficient is used to model the heat transfer from the steam generator tubes to the secondary coolant.