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.:	**378-8442**
SRP Section:	**06.02.01.01.A – PWR Dry Containments, Including Subatmospheric Containments**
Application Section:	**6.2.1.1 Containment Structure**
Date of RAI Issued:	**01/28/2016**

Question No. 06.02.01.01.A-9

Containment Peak Pressure/Temperature Analyses for APR1400

General Design Criteria (GDC) 50, “Containment design basis”, and GDC 16, “Containment design”, of Appendix A to 10 CFR Part 50, “ECCS Evaluation Models” 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). GDC 38, “Containment heat removal,” of Appendix A to 10 CFR Part 50 requires, in part, that the containment heat removal system shall rapidly reduce the containment pressure following any LOCA, lessening the challenge to the containment integrity. In this context, the staff seeks the following additional information to gain safety insights into the applicant’s limiting peak pressure/temperature analyses for the containment. The applicant is also requested to update the APR1400 DCD accordingly.

NUREG-0800, SRP Section 6.2.1.1A, “PWR Dry Containments, including Subatmospheric Containments,” 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 LOCA, or a steam line or feedwater line break, to satisfy the GDC 16 and 50 requirements for sufficient design margin. The calculations referenced in DCD Tier 2, Section 6.2.1.1 show a greater than 10% margin to the containment design pressure (60 psig) for all LOCA and main steam line break (MSLB) cases analyzed. However, preliminary confirmatory calculations performed by the staff for the limiting double-ended discharge leg slot break (DEDLSB) LOCA case using a multi-node MELCOR model yield a peak pressure higher than the value (51.09 psig) calculated by the applicant’s single-node GOTHIC model for the containment atmosphere region, such that the resulting margin to the design pressure is significantly less than 10%. The staff’s multi-node confirmatory calculations also resulted in a much higher (380.9 °F) peak containment temperature for the limiting MSLB case, as compared to 333.41 °F from the applicant’s single-node model, as documented in DCD Tier 2 Table 6.2.1-2. DCD Tier 2 Section 6.2.1.1.3.3 acknowledges that the MSLB containment temperature exceeds the containment design temperature (290.0 °F) for a period prior to containment spray (CS) actuation. Figures 6.2.1-6 through 6.2.1-15 show that the containment temperature exceeds the containment design temperature for a couple of minutes for all MSLB cases analyzed.

In order for the staff to understand the discrepancies in the calculated pressure and temperature and reconcile the differences between the two models, please provide a full accounting of the input data, sensitivity coefficients (inertial lengths, loss coefficients, etc.), assumptions used to capture the heat transfer correlations used in containment or mass and energy release, in addition to any other assumptions or uncertainties not listed in Section 6.2.1.1 that could adversely impact the design margins in the containment peak pressure or temperature. Also address any potential impact of excessive heating on the containment integrity and equipment qualifications for other safety-related systems.

Response

Technical report (TeR) APR1400-Z-A-NR-14007-P, Rev. 0, "LOCA Mass and Energy Release Methodology," which was submitted to NRC, describes the GOTHIC containment model used to predict the containment pressure and temperature response to a design-basis accident (DBA) in the containment building.

In this response, some primary variables and considerations that impact the containment peak pressure and temperature, such as containment volume, passive and active heat sinks, boundary conditions, initial conditions and assumptions, are described for the NRC staff to identify discrepancies between the NRC staff's MELCOR model and the GOTHIC model used by the applicant. Please refer to appendices A through G of the TeR, which provide the details of the GOTHIC containment model.

1. Containment Model

Containment Volume

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Passive Heat Sinks

A total of 18 passive heat structures are considered in the containment atmosphere volume. The material types, thicknesses, surface areas, and surface conditions of each of the structures are provided in detail in Table A-3A of the TeR. Assumptions used in modeling passive heat structures are described in Section A.2.3.3 of the TeR.

Active Heat Sinks

The containment spray system (CSS) is modeled using the pump, heat exchanger, and spray nozzle components of the GOTHIC code to transfer water from the IRWST to the containment atmosphere as liquid droplets. The containment spray (CS) actuates automatically from a high-high containment pressure setpoint of 22 psig with a time delay of 110 seconds for a loss of coolant accident (LOCA), or 90 seconds for a main steam line break (MSLB) accident. The water which is supplied to the CS nozzle is specified as a fixed flow of 10.026 ft3/sec and the droplet size through the CS nozzle is assumed to be a fixed value of 1,000 microns. Section A.2.3.4 of the TeR describes the components used in CSS modeling in detail.

2. Boundary Conditions

M/E releases

GOTHIC flow boundary conditions are used to model break flow to the containment from the RCS. The time history flow and enthalpy data are included in the GOTHIC flow boundary input. Table 4-2 of the TeR presents M/E releases on each phase (Blowdown, reflood, post-reflood and decay heat period) of the limiting LOCA (Double-Ended Discharge Leg Slot Break with maximum SIS flow).

Containment Structures

The outer surfaces of the containment shell (wall and dome) and inner surface of the containment floor are modeled adiabatically to prevent heat release to the atmosphere through the containment structure. Appendix A Section A.2.3.3 of the TeR provides a detailed description of each passive heat sink type.

CS Heat Exchangers

A CS heat exchanger is modeled using a GOTHIC heat exchanger component with specified inlet flow and temperature on the shell (cooling) side. Section A.2.3.4 and Table A-5 of the TeR details the design specification of the CS heat exchanger and the secondary side inlet conditions.

3. Initial Conditions

The upper-bound pressure and temperature and lower-bound relative humidity are chosen as the initial conditions of the containment atmosphere to yield a high peak containment pressure and temperature. The initial values are shown below. Appendix C.1 of the TeR provides the bounding analysis to determine the conservative initial conditions, and Table C-1A presents the values shown below.

Parameter	Unit	Initial value
Pressure	psia	16.12
Temperature	°F	120.0
Relative Humidity	%	100.0

4. Assumptions

The LOCA containment pressure and temperature response analysis is based on the loss-of offsite power (LOOP) with a single failure of the CSS. The principal assumptions used in the analysis are listed below;

Break flow Model

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Wall Heat transfer Model

The GOTHIC direct heat transfer option with Diffusion Layer Model (DLM) is used to calculate condensation on surface of each heat structure. Natural convection is chosen as the heat transfer correlation for sensible heat transfer on structure surfaces. Forced convection is not allowed and the radiation heat transfer to the containment structures from the atmosphere is conservatively neglected.

Interphase Heat transfer Model (Liquid / Vapor / Droplet)

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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 Report

There is no impact on any Technical, Topical and Environmental Report.

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Question No. 06.02.01.01.A-10

NUREG-0800, SRP Section 6.2.1.1.A Acceptance Criterion No. 2 specifies that the containment pressure should be reduced to less than 50% of the peak calculated pressure for the design basis LOCA within 24 hours after the postulated accident, to satisfy the GDC 38 requirements for the containment as the final barrier against the release of radioactivity to the environment. DCD Tier 2 Table 1.9-2, "APR1400 Conformance with the Standard Review Plan," states that the APR-1400 conforms to SRP Section 6.2.1.1.A Acceptance Criterion No. 2. DCD Tier 2 Section 6.2.1.1.3.2 states that "The calculated containment pressure at 24 hours, 1.795 kg/cm^2G (25.54 psig), is 42.35 percent of the peak calculated pressure for the limiting LOCA and thus meets the requirements of GDC 38." Using the values provided in the DCD, the staff calculates the pressure of 40.24 psia at 24 hours to be equal to 61.2% of the peak calculated pressure of 65.79 psia. Therefore, the applicant is requested to justify how the calculated containment pressure at 24 hours, 40.24 psia (25.54 psig), is reduced to less than 50% of the peak calculated pressure, 65.79 psia (51.09 psig).

Response

The containment pressure at 24 hours, 1.795 kg/cm^2G (25.54 psig), is an incorrect value. It should instead be 1.521 kg/cm^2G (21.64 psig). DCD Tier 2, Section 6.2.1.1.3.2 is shown in the attachment associated with this response.

In determining the pressure margins at 24 hours after the accident, as well as at the containment peak pressure time, the British pressure gauge unit, pounds per square inch gauge (psig), is used since the basic pressure unit system describing the containment pressure in the DCD is the gauge pressure unit, in accordance with the requirement described in the RG 1.206 Table 6-1. The pressure at 24 hours is estimated to be 42.35 percent of the peak calculated pressure, as shown below.

$$\frac{Pressure\ at\ 24\ hours\ (psig)}{Peak\ Pressure\ at\ the\ limiting\ LOCA\ (psig)} = \frac{21.64}{51.09} = 42.35\ \%$$

Additionally, Table B-6 of Appendix B of technical report APR1400-Z-A-NR-14007-P/NP, Rev.0, “LOCA Mass and Energy release Methodology” provides a summary of the containment analyses results.

Impact on DCD

DCD Tier 2, Section 6.2.1.1.3.2 is to be revised, as shown 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 Report

There is no impact on any Technical, Topical and Environmental Report.

response analyses. Thus, DEDLSB with maximum SI system capabilities with no EDG single failure is determined as the containment design basis LOCA.

As listed in Table 6.2.1-2, the DBA LOCA calculated peak pressure is 3.59 kg/cm^{2}G (51.09 psig). This limiting peak pressure bounds all the secondary system piping breaks addressed and listed in Part B of Table 6.2.1-19. The calculated LOCA peak temperature is 134.59 °C (274.27 °F).

A containment response analysis following a DBA LOCA is also performed to consider the impact from thermal conductivity degradation (TCD) of the fuel pellets. The containment peak pressure of the TCD analysis is 0.3 psi higher than the case without TCD consideration. The TCD case peak pressure remains below the containment design limit, thus ensuring containment integrity at these conditions. A detailed description of the TCD effects on the containment integrity analysis is provided in Reference 5.

Consistent with the requirements of GDC 15 and 50, it has been demonstrated that the APR1400 containment design pressure provides more than a 10 percent margin (14.8 percent) above the maximum calculated peak pressure. The calculated containment pressure at 24 hours, 1.795 kg/cm^{2}G (25.54 psig), is 42.35 percent of the peak calculated pressure for the limiting LOCA and thus meets the requirements of GDC 38.

1.521 Kg/cm^{2}G (21.64 psig)

Throughout the LOCA, the containment temperature remains at saturated conditions. Per Reference 3, the DBA LOCA peak saturation temperature of 134.59 °C (274.25 °F), which is higher than the maximum calculated surface temperature of all the containment internal structures including liner plate, is less than the containment design temperature of 143.3 °C (290.0 °F).

6.2.1.1.3.3 Analysis of Containment Response to Secondary System Piping Ruptures

This subsection describes the containment response analysis following a postulated main steam line break (MSLB) event. Containment response analyses to various combinations of power level, break size, and break location were performed to determine the limiting MSLB from a containment peak temperature and pressure standpoint. The bases for the selection of break size, power level, and single failure are discussed in Subsection 6.2.1.4 and listed in Table 6.2.1-1.