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.:	**129-8085**
SRP Section:	**03.08.01 –Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**08/05/2015**

Question No. 03.08.01-5

10CFR Part 50, Appendix A, GDC 16, “Containment Design,” requires concrete containment to act as a leak-tight membrane to prevent the uncontrolled release of radioactive effluents to the environment. DCD Section 3.8.1.4.11, “Ultimate Pressure Capacity,” states that the ultimate pressure capacity (UPC) of the containment is evaluated based on the design results of the structure. The applicant further states that the analysis for the UPC is performed considering material nonlinear behaviors for the reinforced concrete containment.

In reviewing DCD Section 3.8.1.4.11 of the application, the staff noted that additional information is needed to better understand the applicant’s approach for determining the UPC of the containment. Standard Review Plan (SRP) 3.8.1, Section II.4.K discusses the regulatory criteria for determining the internal pressure capacity of the containment. SRP 3.8.1 states that the design and analysis procedure for the UPC of the containment is acceptable if performed in accordance with Regulatory Guide (RG) 1.216, “Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure.”

In accordance with SRP 3.8.1, and GDC 16, the applicant is requested to provide a detailed description of the approach used to calculate the UPC of the containment identified in Section 3.8.1.4.11 of the DCD and explain how this approach compares to that described in Regulatory Position 1 of the RG 1.216.

Response

The ultimate pressure capacity (UPC) of the prestressed concrete containment, which is for assessment of the safety margin above the design-basis accident pressure, is evaluated based on the design results (rebar arrangements) of the structure. A full three-dimensional finite element model is developed for the analysis of the concrete containment. Material nonlinear models for steel and concrete are constructed on the basis of the design code and a few references. For simulating the crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration. The steel is assumed to be a linear elasto-plastic material. The stress-strain curves for the reinforcing steel and tendons are based on the ASME code-specified minimum yield strengths. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendons. In the initial state of the nonlinear analysis, the containment structure is subject to dead and prestressing loads. During the UPC analysis, the internal pressure is monotonically increased until a specified failure criterion is reached. The pressure corresponding to failure criterion of the liner, rebar, and tendons is recorded. The pressure at which the first failure criterion is reached is determined to be the ultimate pressure capacity of the prestressed concrete containment.

Origionally, SRP 3.8.1 (Rev.3), which was issued in May 2010, was used to establish the criteria used to determine the UPC. The UPC was determined based on attaining a maximum global membrane strain away from discontinuities of 0.8 percent. This strain limit was applicable to all materials which contribute to resisting the internal pressure (i.e., tendons, rebars, and liner). When the UPC was evaluated based on SRP 3.8.1 (Rev.3), the UPC of the containment was a pressure of 1.269 MPa (184 psi), as currently described in Section 3.8.1.4.11 of the DCD.

Since the original analysis was performed, SRP 3.8.1 (Rev.3) was revised to Rev.4, which was issued in September 2013. In the revised SRP, it states that the design and analysis procedures for UPC are acceptable if performed in accordance with RG 1.216, which was issued in August 2010. RG 1.216 states that the UPC can be estimated based on satisfying both of the following strain limits: (1) a total tensile average strain in tendons away from discontinuities of 0.8 percent, which includes the strains in the tendons before pressurization (typically about 0.4 percent) and the additional straining from pressurization; and (2) a global free-field strain for the other materials that contribute to resist the internal pressure (i.e., liner, if considered, and rebars) of 0.4 percent.

In accordance with RG 1.216, the ultimate pressure capacity of the containment is a pressure of 1.089 MPa (158 psi), at which the maximum strain of the liner plate is approximately 0.4 percent. It is noted that this UPC pressure is the lowest pressure from the acceptance criteria in RG 1.216, and is determined to occur near the upper portion of the equipment hatch.

The COL applicant is to provide a detailed evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetrations, and fuel transfer tube sleeve, based on supplier design information or detailed design results (COL 3.8(11)).

Impact on DCD

DCD Tier 2, Table 1.8-2 and Sections 3.8.1.4.11 and 3.8.6 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 Environmental Report.

The liner anchorage system is analyzed, which includes calculating the force and deflection at anchorage points. The design of the liner anchorage conforms with the force and displacement allowables in Subarticle CC-3730 of Section III of the ASME Code.

For the structural design of containment liner plates, the stresses at formworks are calculated for basemat liner, shell liner, and dome liner, respectively. The lowest ratio of allowable stress to induced stress for each part is shown in Table 3.8-12 as margins of safety for the design.

3.8.1.4.11 Ultimate Pressure Capacity

~~The ultimate pressure capacity (UPC) of the containment is evaluated based on the design results of the structure. The UPC is estimated based on attaining a maximum global membrane strain away from discontinuities of 0.8 percent. This strain limit is applied to the tendons, rebars, and liner. When the pressure capacity contribution is calculated from the tendons, the above-specified strain limit is applied to the full range of strain. The UPC analysis is performed considering material nonlinear behaviors for the reinforced concrete.~~

~~The stress-strain curves for the reinforcing steel and tendon are based on the code-specified minimum yield strength. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendon, respectively. The stress-strain curves are developed for the design basis accident temperature.~~

~~The ultimate pressure capacity of the containment is a pressure of 1.269 MPa (184 psi) at which the maximum strain of the liner plate and horizontal tendon is approximately 0.8 percent.~~

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3.8.1.4.12 Severe Accident Capability

The safety of the containment under severe accident conditions is assessed and demonstrated to conform with the allowable values in Subarticle CC-3720 of the ASME Code.

Based on the results of the analyses, all of the tendons and rebars are still in the elastic stage. At the maximum pressure loading level of the critical severe accident scenario, the

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The ultimate pressure capacity (UPC) of the prestressed concrete containment, which is for assessment of the safety margin above the design-basis accident pressure, is evaluated based on the design results (rebar arrangements) of the structure. A full three-dimensional finite element model is developed for the analysis of the concrete containment. Material nonlinear models for steel and concrete are constructed on the basis of the design code and a few references. For simulating the cracking behavior of concrete, smeared crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration. The steel is assumed to be a linear elasto-plastic model. The stress-strain curves for the reinforcing steel and tendons are based on the ASME code-specified minimum yield strengths. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendons. In the initial state of the nonlinear analysis, the containment structure is subject to dead and prestressing loads. During the UPC analysis, the internal pressure is monotonically increased until a specified failure criterion is reached. The pressure corresponding to failure criterion of the liner, rebar, and tendons is recorded. The pressure at which the first failure criterion is reached is determined to be the ultimate pressure capacity of the prestressed concrete containment.

The design and analysis procedures for determining the UPC are performed in accordance with RG 1.216, and is estimated based on satisfying both of the following strain limits: (1) a total tensile average strain in tendons away from discontinuities of 0.8 percent, which includes the strains in the tendons before pressurization (typically about 0.4 percent) and the additional straining from pressurization; and (2) a global free-field strain for the other materials that contribute to resist the internal pressure (i.e., liner, if considered, and rebars) of 0.4 percent.

The ultimate pressure capacity of the containment is a pressure of 1.089 MPa (158 psi), at which the maximum strain of the liner plate is approximately 0.4 percent. It is noted that this UPC pressure is the lowest pressure from the acceptance criteria in RG 1.216, and is determined to occur near the upper portion of the equipment hatch.

The COL applicant is to provide a detailed evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and pipe penetrations, and fuel transfer tube sleeve, based on supplier design information or detailed design results (COL 3.8(11)).

COL 3.8(7) The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.

COL 3.8(8) The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.

COL 3.8(9) The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.

COL 3.8.(10) The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.

COL 3.8(11) The COL applicant is to provide a detailed evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetrations, and fuel transfer tube sleeve, based on supplier design information or detailed design results.

3.8.7 References

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission.

2. ASME Section III, Subsection NE, "Class MC Components," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

3. ASME Section III, Division 2, "Code for Concrete Containments," Subsection CC, American Society of Mechanical Engineers, 2001 Edition with 2003 Addenda.

4. Regulatory Guide 1.35, "Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment," Rev. 3, U.S. Nuclear Regulatory Commission, July 1990.

5. Regulatory Guide 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," U.S. Nuclear Regulatory Commission, July 1990.

Table 1.8-2 (5 of 29)

Item No.	Description
COL 3.8(7)	The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.
COL 3.8(8)	The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.
COL 3.8(9)	The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.
COL 3.8(10)	The COL application is to provide the following soil information for APR1400 site: 1) Elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) Consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) Moisture content, Atterberg limits, grain size analyses, and soil classification, 4) Construction sequence and loading history, and 5) Excavation and dewatering programs.
COL 3.9(1)	The COL applicant is to provide the inspection results for the APR1400 reactor internals classified as non-prototype Category I in accordance with RG 1.20.
COL 3.9(2)	The COL applicant is to provide a summary of the maximum total stress, deformation, and cumulative usage factor values for each of the component operating conditions for ASME Code Class 1 components except for ASME Code Class 1 nine major components. For those values that differ from the allowable limits by less than 10 percent, the contribution of each loading category (e.g., seismic, deadweight, pressure, and thermal) to the total stress is provided for each maximum stress value identified in this range. The COL applicant is to also provide a summary of the maximum total stress and deformation values for each of the component operating conditions for Class 2 and 3 components required to shut down the reactor or mitigate consequences of a postulated piping failure without offsite power (with identification of those values that differ from the allowable limits by less than 10 percent).
COL 3.9(3)	The COL applicant is to identify the site-specific active pumps.
COL 3.9(4)	The COL applicant is to confirm the type of testing and frequency of site-specific pumps subject to IST in accordance with the ASME Code.
COL 3.9(5)	The COL applicant is to confirm the type of testing and frequency of site-specific valves subject to IST in accordance with the ASME Code.
COL 3.9(6)	The COL applicant is to provide a table listing all safety-related components that use snubbers in their support systems.

COL 3.8(11) The COL applicant is to provide a detailed evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetrations, and fuel transfer tube sleeve, based on supplier design information or detailed design results.