REVISED 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:	**3.8.1**
Date of RAI Issue:	**08/05/2015**

Question No. 03.08.01-2

10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 16 and 50 provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II.4.D discusses the approach for obtaining the concrete creep and concrete shrinkage values for the containment. DCD Tier 2, Section 3.8.1.4.6, “Creep and Shrinkage Analysis,” states that the effects of concrete creep, concrete shrinkage, concrete elastic shortening, and tendon steel relaxation are included in the computations for prestress losses in the tendons. The applicant also provided values for these items. DCD Section 3.8.1.4.8 also indicates that the values are based on engineering experience. Based on the above information, it is not clear to the staff as to how the values provided were obtained. SRP 3.8.1, Section II.4.D states that creep and shrinkage values should be established by tests performed on the concrete to be used or from data obtained from completed containments with the same kind of concrete. In accordance with SRP 3.8.1, and Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, the applicant is requested to address the following:

a. Describe in Section 3.8.1.4.6 of the DCD how the values provided were obtained.

b. DCD Section 3.8.1.4.6 describes the various parameters for prestress tendon losses but does not discuss (1) frictional loses due to curvature of the tendons and (2) slip at the anchorage. These are additional items that are identified in the ASME Code and should also be addressed in Section 3.8.1.4.6 of the DCD.

c. To understand how all of the parameters affect the prestress losses over the life of the plant and to ensure sufficient prestressing in the tendons, the applicant is requested to provide a table for each type of tendon (hoop and vertical), at the start of prestressing and at the end of life (60 years), the following: initial prestress; the actual losses in prestress (in terms of stress or percent) from all of the individual sources; total value of losses; and final prestress.

d. The staff reviewed DCD Section 3.8.1 and noted that the applicant did not provide a description of how concrete cracking is considered in the analysis and design of the concrete containment (containment shell and basemat). The applicant is requested to provide a description of the effects of concrete cracking in Section 3.8.1 of the DCD or provide a technical basis for not considering the effects of concrete cracking.

Response – (Rev. 3)

a. Concrete creep, shrinkage, and tendon relaxation coefficients for prestress losses were established based on engineering experience gained through the construction of Shin-Kori units 3&4. DCD Tier 2, Subsection 3.8.1.4.8 refers to this experience as “experience with similar construction and materials”. These values are to be evaluated and confirmed by certified material test reports (CMTRs) and concrete long-term material testing. A COL item (3.8[14]) will be added to reflect this. Elastic shortening coefficients of concrete are to be computed using the static modulus of elasticity when calculating the losses of prestress. The static modulus of elasticity is also to be evaluated by concrete long-term material testing. DCD Tier 2, Subsection 3.8.1.4.8, 3.8.6 and Table 1.8-2 will be revised as shown in the attachment associated with this response.

b. There are two types of friction losses, wobble friction loss from unintended curvature and curvature friction loss from intended curvature. The two kinds of curvature in tendons induce friction loss of tensile stress. Friction losses are calculated in accordance with CC-3542 of the ASME Code and taken into account in the design of prestressing tendons. The wobble and curvature friction coefficients are determined experimentally and verified by testing while stressing tendons. Description of friction losses in tendons is presented in DCD Tier 2, Subsection 3.8.1.5.1.2. DCD Tier 2, Subsection 3.8.1.4.6 will be revised as shown in the attachment associated with this response.

   Slip at anchorage is also considered in the design of the containment post-tensioning system as described in DCD Tier 2, Subsection 3.8.1.5.2.2. Due to slipping at the anchorage, 5 percent of the maximum stress is lost at the anchor point. Thus, 95 percent of the maximum stress at the anchor point is applied to calculate the tendon stress. The value of 5 percent is provided by the supplier.

c. Tendon stresses at each design point are calculated in accordance with CC-3433 of the ASME Code to consider stress limits and CC-3542 to consider friction loss. Also, stress losses in tendons, such as creep, shrinkage of concrete, and relaxation of prestressing steel, are computed in conformance with tolerance bands in NRC Regulatory Guide 1.35.1. Calculation results are shown in Table 1 for vertical tendons and Table 2 for horizontal (hoop) tendons. Tables 1 and 2 (below) will be included in the DCD to present stress profiles of typical tendons with losses of prestress.

Table 1 Stress Profiles of Typical Prestressing Tendons - Vertical

Stress Point	Stress in Tendon [MPa(ksi)]		Losses of Stress [MPa(ksi)]
	Initial	Final	
Anchor Point	1291.0(187.24)	1007.0(146.06)	Elastic Shortening: 23.9(3.46) Creep: 142.7 (20.70) Shrinkage: 27.8(4.03) Relaxation: 89.6(12.99) Total Loss: 284.0 (41.18)
Spring Line	1372.1(199.00)	1088.1(157.81)	
Dome Apex	1089.9(158.08)	806.0(116.90)	

Table 2 Stress Profiles of Typical Prestressing Tendons - Horizontal

Stress Point	Stress in Tendon [MPa(ksi)]		Losses of Stress [MPa(ksi)]
	Initial	Final	
Anchor Point	1291.0(187.24)	914.2(132.60)	Elastic Shortening: 37.5(5.44) Creep: 224.4(32.55) Shrinkage: 27.8(4.03) Relaxation: 87.1(12.63) Total Loss: 376.8(54.65)
Tangent Point	1300.1(188.57)	923.4(133.93)	
Midpoint of Tendon	1080.1(156.66)	703.3(102.01)	

d. Concrete cracking is considered in seismic analysis according to ASCE 43-05 as described in DCD Tier 2, Subsection 3.7.2.8.

Impact on DCD

DCD Tier 2, Subsection 3.8.1.4.6, 3.8.1.4.8, 3.8.6 and Table 1.8-2 will be revised, and DCD Tier 2, Table 3.8A-40 will be added, 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 Reports

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

d. Elastic modulus

1) Containment external concrete wall = 30,441.74 MPa (4.415×10^6 psi)

2) Containment internal concrete structure = 30,441.74 MPa (4.415×10^6 psi)

3) Containment concrete basemat = 27,789.38 MPa (4.031×10^6 psi)

4) Prestressing steel material = 193,053.20 MPa (2.8×10^7 psi)

e. Elastic shortening of concrete

1) Vertical direction = 124×10^{-6} mm/mm (in/in)

2) Horizontal direction = 194×10^{-6} mm/mm (in/in)

insert A(Next page)

f. Tendon relaxation = 6 %

3.8.1.4.7 Tangential Shear

The design and analysis procedures for tangential shear are in accordance with ASME Section III, Division 2 and NRC RG 1.136.

Tangential shear is resisted by the vertical reinforcement and the horizontal hoop reinforcement in the containment wall.

3.8.1.4.8 Variations in Physical Properties

In the design and analysis of the containment, consideration is given to the effects of possible variations in the physical properties of materials on the analytical results. The properties used for analysis purposes were established based on engineering experience [gained through the construction of Shin-Kori units 3&4 in Korea] with similar construction and materials. The values that were used are delineated in Subsection 3.8.1.4.6. [insert B(Next page)] Additional reviews of materials and their effects on the analysis and design of the containment will be included in design specification development and materials selection.

insert A

g. Friction coefficients

There are two types of friction losses, wobble friction loss from unintended curvature and curvature friction loss from intended curvature. The two kinds of curvature in tendons induce friction loss of tensile stress. Friction losses are calculated in accordance with CC-3542 of the ASME Code and taken into account in the design of the post-tensioning system. The friction coefficients are determined experimentally and verified by testing while stressing tendons.

insert B

The values are to be evaluated and confirmed by certified material test reports (CMTRs) and concrete long-term material testing. The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the ~~characters~~ characteristics of long term deformation of concrete (COL 3.8(14)). The test results are to be reviewed by designers.

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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(14) The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the ~~characters~~ characteristics of long term deformation of concrete.

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.

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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 3.8(14)	The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the ~~characters~~ characteristics of long term deformation of concrete.
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.

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Internal Pressure

The design basis accident (DBA) pressure of 413.7 kPa (60 psig) is applied to the inside surface of the containment wall and dome. The structural integrity test pressure is 1.15 times the design pressure. External or internal events such as containment spray actuation can induce a negative pressure on the containment. Therefore, the containment is designed for a negative pressure of 27.6 kPa (4 psig). To consider the pressure, which acts on the equipment hatch cover and attached doors in personnel airlocks, additional point loads are applied through reference nodes, which are located at the center of the penetration holes and inside surface of concrete wall. These reference nodes control and transfer the pressure loads to the surface of the corresponding cylindrical sleeve using the RBE3 command in the ANSYS program.

Prestress

The prestress is divided into two cases. The initial prestress is used for service categories to maximize the concrete compressive stress. For factored categories, the final (effective) prestress is considered to maximize the tensile stress of the reinforcing steels. The prestress losses are estimated in accordance with the guidelines specified in NRC RG 1.35.1. The stress profiles of vertical and horizontal tendons including losses of prestress are shown in Table 3.8A-40.

It is assumed that the stresses of the vertical tendon are constant from the anchor point to the springline and from the springline to the apex of the dome. Horizontal tendons that anchor to different buttresses 240 degrees apart are spaced closely enough to offset the stress variations. Hence, the stress, which is averaged throughout the length of the horizontal tendon, is used as a representative value.

Temperature Load

The thermal effect considers temperature variations during normal operating and accident conditions combined with the worst temperature condition (summer/winter) on the outside of the containment wall and dome. During normal operation, the containment is subject to a steady-state temperature condition. The linear gradient from the steady-state heat transfer analysis is applied to the stress analysis model. The containment is subject to a rapid temperature transient in the event of a loss-of-coolant accident (LOCA). The temperature transients result in a nonlinear temperature distribution within the concrete, which comes from the results of the transient heat transfer analysis.

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Table 3.8A-40

Stress Profiles of Typical Prestressing Tendons

Vertical Tendon

Stress Point	Stress in Tendon [Mpa(Ksi)]		Losses of Stress [MPa(ksi)]
	Initial(1)	Final(2)	
Anchor Point	1291.0 (187.24)	1007.0 (146.06)	Elastic Shortening: 23.9(3.46) Creep: 142.7 (20.70) Shrinkage: 27.8(4.03) Relaxation: 89.6(12.99) Total Loss: 284.0 (41.18)
Spring Line	1372.1 (199.00)	1088.1 (157.81)	
Dome Apex	1089.9 (158.08)	806.0 (116.90)	

Horizontal Tendon

Stress Point	Stress in Tendon [Mpa(Ksi)]		Losses of Stress [MPa(ksi)]
	Initial(1)	Final(2)	
Anchor Point	1291.0 (187.24)	914.2 (132.60)	Elastic Shortening: 37.5(5.44) Creep: 224.4(32.55) Shrinkage: 27.8(4.03) Relaxation: 87.1(12.63) Total Loss: 376.8(54.65)
Tangent Point	1300.1 (188.57)	923.4 (133.93)	
Midpoint of Tendon	1080.1 (156.66)	703.3 (102.01)	

(1) At time of tendon lock off
(2) 60 years after plant startup