Attachment 3

Question 3.8.1-2

The staff reviewed and evaluated the applicant response to Question 3.8.1-2 and considered the following:

Part A: Acceptable - Confirmatory Item (CI)

Part B: Acceptable – CI

Part C: Unresolved - The staff reviewed the applicant response and noted the following:

a. What does “Initial” correspond to (e.g., at time of tendon lockoff or plant startup) in Table 1, "Typical Stresses of Vertical Tendons?"

KHNP INPUT

“Initial” corresponds to “at time of tendon lockoff”.

b. What does “Final” correspond to (e.g., 60 years after tendon lockoff or 60 years after plant startup, in which case explain whether the values consider the additional period of time between tendon lockoff and plant startup) in Table 1?

KHNP INPUT

“Final” corresponds to “60 years after plant startup”. The additional period of time between tendon lockoff and plant startup is considered by adding a margin to each time-dependent loss of prestress at 60 years after tendon lockoff. In this process, the losses of prestress due to concrete creep, shrinkage, and tendon steel relaxation are increased by 25%, 20%, and 15%, respectively.

c. Following the provisions of ASME Section III, Article CC-3542, explain why the effects of loss of prestress due to friction and slip at anchorage are not presented.

KHNP INPUT

“Losses of Stress” in Table 1 includes the time-dependent losses of prestress to show the difference between the initial and final stress in the tendon. The loss of prestress due to friction and slip at the anchorage is not presented in Table 1 since these losses are not a time-dependent loss.

However, the effects of loss of prestress due to friction and slip at the anchorage are considered in the calculation of the Initial Stress in Table 1. Friction loss induces the differences between stresses of the tendon at each stress point in Table 1. The stress of the tendon at the anchor point loss is 5% of the maximum stress at the anchorage due to anchor slip. Thus, the stress of the tendon at the anchor point is reduced to 95% of the maximum stress at the anchor point.

d. In view of the safety significance of the tendon design values, the above discussion and Table 1 should be included in the DCD.

KHNP INPUT
The above discussion and Table 1 will be included in the DCD after Part C is resolved.

Part D: Unresolved - The response does not explain how ASCE 43-05 is used for the seismic analysis and design of the concrete containment. Also, the response refers to DCD Tier 2, Subsection 3.7.2.8, which appears to address the effects of concrete cracking on floor response spectra. For seismic analysis, KHNP report APR1400-E-S-NR-14003-P, Rev. 0, indicates that seismic SSI analyses are performed for both cracked and uncracked cases. However, for developing member forces to be used in design, it appears from the report that only the cracked cases were used. Also, for the separate design analysis of the NI, it is not clear whether cracked or uncracked, or both cases were evaluated in the FEM analyses. Therefore, the applicant is requested to describe how concrete cracking is considered in seismic analyses, for purpose of developing member forces, and in design analyses. It is noted that for some of the structures, instead of member forces from SASSI, response spectra analysis and equivalent static analyses were used. So the updated response should address how cracking, if applicable, was considered for seismic analysis and design, for containment and the other seismic Category I structures. If only the cracked case or only uncracked case was considered, also provide the basis for this approach.

KHNP INPUT
DCD Tier 2, Subsection 3.7.2.8 and technical report APR1400-E-S-NR-14003-P, Rev. 0, seismic SSI analyses are performed for both a cracked concrete model with the SSE damping value and an uncracked concrete model with OBE damping value. All the seismic analysis results, except the maximum member forces, are enveloped by the seismic SSI analysis cases. For generating the maximum member forces, only the results from the cracked concrete model with SSE damping value are used, in accordance with the following guidance in RG 1.61, Rev.1.

RG 1.61, Rev. 1, Subsection 1.2

However, there may be cases where the predicted structural response to load combinations that include SSE is significantly below the applicable code stress limits. Because equivalent viscous damping ratios have been shown to be dependent on the structural response level, it is necessary to consider that the SSE damping values specified in Table 1 may be inconsistent with the predicted structural response level.

For structural evaluation, this is not a concern, because the stresses resulting from the use of damping-compatible structural response will still be less than the applicable code stress limits.

KHNP believes this statement indicates that the use of damping values less than the SSE damping values is not a concern for the structural evaluation, and it is sufficient to consider only the SSE damping values for the structural design. Therefore, only the results of the cracked concrete model, which is coupled with SSE damping values, are used in generating the maximum member forces.

Question 3.8.1-5

The staff reviewed and evaluated the applicant response to Question 3.8.1-5 and considered the overall description of the UPC evaluation to be acceptable. However, there are several important items that were not identified and therefore, the applicant is requested to address the following:

a. Confirm that the material properties in the model correspond to the design-basis accident temperature.

KHNP INPUT

For the UPC evaluation, the material degradation corresponding to the temperature is based on NUREC/CR-6906. The design-basis accident temperature is 290°F. In NUREC/CR-6906, the strength ratio of concrete and steel strength is as follows:

For concrete strength ratio, $S_{Rc} = \exp -(T/632)^{1.8}$ where T is in degrees C.

For steel yield strength ratio, $S_{Rs} = \exp -((T-300)/300)^{1.9}$ where T is in degrees C. If T is less than 340°C, $S_{Rs} = 1.0$

Based on the results obtained by applying the equations in NUREC/CR-6906, the compressive strength of concrete is 5,600 psi and 4,660 psi at 290°F for the containment external wall and basemat, respectively. The design compressive strength of concrete is 6,000 psi and 5,000 psi for the containment external wall and basemat, respectively. In addition, for the reinforcing steel and prestressing tendon, the yield strength ratio is 1.0 because the design-basis accident temperature is less than 340°C. The material degradation of liner steel (SA-516 Gr. 60) is based on the ASME Section II – D, the yield strength and tensile strength of the liner steel are 28.5 ksi and 60 ksi at 290°F, respectively. The design yield strength and tensile strength of liner steel are 32 ksi and 60 ksi, respectively.

b. If a static pressure analysis was performed to obtain the UPC, explain whether the dynamic nature of the design-basis accident may affect the response of the containment. If the dynamic effects do not affect the UPC, explain why not, and if it does, then explain how the dynamic effects were considered in the analysis.

KHNP INPUT

"Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure" is related to Position 1 of RG 1.216. In Position 1 of RG 1.216, it is described that the internal pressure is incrementally increased until a specified failure criterion is reached. Therefore, RG 1.216 did not require the dynamic effects for UPC evaluation.

c. Explain whether a report exists which contains the details of the analysis and results including the information listed in RG 1.216, Rev. 0, for review by the staff in an upcoming audit.

KHNP INPUT

There is no report for UPC. However, there is the calculation of UPC which contains the detailed analysis and results.

d. Confirm whether the evaluation of the ultimate pressure capacity of penetrations for COL 3.8(11) is to be performed in accordance with RG 1.216, Revision 0.

KHNP INPUT

The evaluation of the ultimate pressure capacity of penetrations for COL 3.8(11) is to be performed in accordance with RG 1.216, Rev.0.

e. Insert A in the markup should be revised to – (1) Correct the phrase in the first paragraph which states "The tensile strength of concrete does not considered in the concrete model;" and (2) In the second paragraph, last sentence, which states "In addition, the additional failure modes, such as concrete shear and concrete crushing, which may occur near discontinuities should be considered." should be revised to explain what was done rather than what should be done. The information to be included here should describe that these additional failure modes such as concrete shear and concrete crushing, which may occur near discontinuities were considered, assuming these were checked.

KHNP INPUT

(1) The tension strength of concrete should be neglected, however, for the finite element predictions, it make convergence of a unique solution difficult. For this reason, the behavior of reinforced concrete allows the tension stiffening considering the effects of the reinforcement interaction with concrete. The tension stiffening is required in the concrete damaged plasticity model and most finite element model should include the tension softening behavior of concrete after cracking. To avoid confusion, the sentence "The tensile strength of concrete does not considered in the concrete model" is deleted in the markup.

(2) To provide clarity, that paragraph is modified as follows:

“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. In addition, the additional failure modes, such as concrete shear and concrete crushing which may occur near discontinuities should be considered.

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. “