`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.:	**267-8301**
SRP Section:	**03.07.03 – Seismic Subsystem Analysis**
Application Section:	**3.7.3**
Date of RAI Issue:	**10/22/2015**

Question No. 03.07.03-1

10CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviewed the adequacy of methods for seismic analysis of above-ground tanks, as described in DCD Section 3.7.3.9. This section provides a brief and generic description of the methods for seismic analysis of tanks, but the actual analysis will be performed by the COL applicant (COL 3.7(7)). The DCD indicates that the above-ground tanks can either be anchored to reinforced concrete pads or directly on a building structure.

Section 3.7.3.9 states that "because of the symmetry of these vertical tanks, the larger of the two horizontal earthquake components, if they are not equal in magnitude, is combined by the SRSS method with the vertical earthquake component." Neglecting the input component in the other horizontal direction, which is smaller than but generally at the same level as the larger direction, can be unconservative due to the vector (combination) effect of two horizontal components of the input motion. The vector effect may not be an issue for a cylindrical tank mounted on the ground surface if the input motion is truly statistically independent in the two horizontal directions, but can be significant for tanks that are not cylindrical or tanks mounted in a structure that can yield highly correlated input motions to the base of the tanks. Therefore, the applicant is requested to provide a technical basis for considering only the larger of the two horizontal input motions in seismic analysis of tanks.

Response

Since DCD Tier 2, Subsection 3.7.1.1.2 states that the two horizontal earthquake components are statistically independent by the result of the correlation coefficient, and above-ground seismic Category I tanks in DCD Tier 2, Subsection 3.7.3.9 are all cylindrical tanks anchored to reinforced concrete pads, the larger one of the two horizontal earthquake components is considered.

To avoid confusion regarding the location of tanks, DCD Tier 2, Subsection 3.7.3.9 will be revised to eliminate the statement that tanks can be anchored directly to a building structure, as indicated in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Subsection 3.7.3.9 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.

induced upper-bound strains and corresponding stresses in the buried piping and concrete electrical ducts are calculated using expressions given by ASCE 4-98 (Reference 12).

Seismic design for buried seismic Category I structures takes the effect of wave propagation into consideration, based on the assumption that there is no movement of the buried structure remote from anchor points relative to the surrounding soil referred to in ASCE 4-98, Subsection 3.5.2. That is, the strain of the structure is the same as that of the surrounding soil medium, and the stress of the structure is calculated from the strain. Consideration of relative deformation between anchor points and the adjacent soil is applied to the design using the SRSS method for the three orthogonal stresses calculated from the relative displacements of the seismic analysis results.

The resistance effect of the surrounding soil for deformation or displacement of the buried structures, differential movement of the anchors, and shape or curvature changes of the bent parts is taken into account in the analysis. The structures can be modeled by beam elements supported by an elastic foundation representing the stiffness of the adjacent soil.

Lateral dynamic soil pressure on buried seismic Category I structures is calculated in accordance with elastic theory by Wood referred to in ASCE 4-98, Subsection 3.5.3. The effect of underground water is considered by applying the equation proposed by Matuo and O'Hara based on the theory from Westergaard that is referred to in ASCE 4-98, Subsection 3.5.3.1.

The COL applicant is to perform a seismic analysis of buried seismic Category I piping, conduits, and tunnels (COL 3.7(6)).

3.7.3.8 Methods for Seismic Analysis of Category I Concrete Dams

The COL applicant is to perform seismic analysis for any site-specific seismic Category I dams, if required (COL 3.7(5)).

3.7.3.9 Methods for Seismic Analysis of Above-ground Tanks

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Above-ground seismic Category I tanks are ~~generally~~ large, flat-bottomed, single-shell, free-standing cylindrical tanks anchored to reinforced concrete pads ~~or directly on a~~

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~~building structure~~. Seismic analysis procedures address the issues described in NUREG/CR-1161RD (Reference 24), pages 28-30, based primarily on the methods of Haroun and Housner (Reference 25). The hydrodynamic mass effects following the procedures described in ASCE 4-98, Subsection 3.1.6, are considered in the seismic analysis model.

Because of the symmetry of these vertical tanks, the larger of the two horizontal earthquake components, if they are not equal in magnitude, is combined by the SRSS method with the vertical earthquake component.

The assessment of dynamic loading on storage tanks verifies stability of the tank wall against buckling behavior, accounting for hydrodynamic loads (impulsive and convective) and shell flexibility.

In the generation of dynamic loads, tanks are evaluated as filled, with consideration of convective (sloshing), impulsive (fluid-shell interaction), and rigid modes of behavior. For the convective mode, fluid damping is taken as 0.5 percent of critical damping in accordance with NRC RG 1.61. For the impulsive mode, structural (tank wall) damping is taken for the SSE, in accordance with SRP 3.7.3 (Reference 26). The effective mass, its location, and natural frequency for each mode of behavior are obtained from the equations and graphs in Haroun and Housner.

Using the site-specific foundation input response spectra developed at the base of the tank, spectral accelerations obtained for each mode at the appropriate damping and frequency are applied to the computation of appropriate effective mass.

Structural adequacy of the anchorage provisions for the tank (e.g., anchor bolts, embedments) is developed assuming that the overturning moment on the tank is resisted only by compression in the shell and tension in the anchor bolts. The overturning moment at the base of the tank is computed as the sum of the flexible and rigid mode responses, each of which is the product of the applicable mass, height, and spectral acceleration.

The COL applicant is to perform seismic analysis for the seismic Category I above-ground tanks (COL 3.7(7)).

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Question No. 03.07.03-3

In accordance with 10 CFR 50 Appendix S, the staff reviewed the seismic subsystem analysis for the APR1400 standard design. The applicant is requested to provide the following additional information to assist the staff review:

(a) DCD Section 3.7.3.6, Use of Constant Vertical Factors, states: "In general, seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Subsection 3.7.3.1. No constant vertical static factors are used for subsystems." The phrase "in general" suggests that methods other than those in Subsection 3.7.3.1 may be used. As such, the applicant is requested to explain whether methods other than those in Subsection 3.7.3.1 are used for the APR1400 standard design, and if so, to describe these methods in the DCD.

(b) DCD Section 3.7.3.10 references DCD Section 3.9.2.2.4, Basis for Selection of Frequencies, which states: "The stiffness of the restraints and supports system is designed to be greater than the zero period acceleration (ZPA)." The staff has interpreted that the intent of this sentence is "The fundamental frequency of the restraints and supports system is designed to be greater than the ZPA frequency of the applicable ISRS, to ensure no additional amplification of the seismic loads on the restrained/supported equipment and components." The applicant is requested to confirm the staff's interpretation and if confirmed, to revise the DCD accordingly. If there is a different intent, provide a detailed explanation of the meaning of the quoted sentence from DCD Section 3.9.2.2.4.

Response

(a) Based on the SRP sections applicable to each of the items mentioned above, each item will be revised as follows;

3.7.3.6 Use of Constant Vertical Static Factors

The seismic analysis of seismic category I subsystems can be performed using the response spectrum analysis method, the time history analysis method, or the equivalent static load method, as specified in Subsection 3.7.3.1. When the equivalent static load method is employed, the constant vertical static factor is used to calculate the vertical response loads for the seismic design of seismic Category I SSCs.

(b) For the restraints and supports system mentioned in DCD Section 3.9.2.2.4, the fundamental frequencies of equipment supports, which consist of the concrete foundation with anchor bolts, are to be greater than the ZPA frequency of the applicable ISRS. The other types of supports for cable trays, conduits, HVAC ducts, and piping are adequately designed for the applicable loads because their fundamental frequencies are within the ranges where resonance can occur.

For general seismic subsystems identified in SRP 3.7.3, DCD Section 3.7.3.10 will be revised according to the response to Question 03.07.03-2 of RAI 267-8301 regarding Section 3.7.3.10.

Impact on DCD

DCD Tier 2, Subsection 3.7.3.6 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.

3.7.3.3 Analysis Procedures for Damping

The analysis procedure used to account for the damping in subsystems conforms with Subsections 3.7.1.2 and 3.7.2.15.

3.7.3.4 Three Components of Earthquake Motion

Seismic responses resulting from analysis of subsystems due to three components of earthquake motions are combined in the same manner as the seismic response resulting from the analysis of building structures as specified in Subsection 3.7.2.6.

3.7.3.5 Combination of Modal Responses

When a response spectrum method of analysis is used to analyze a subsystem, the maximum responses such as accelerations, shears, and moments in each mode are calculated regardless of time. If the frequencies of the modes are well separated, the SRSS method of mode combination gives acceptable results; however, where the structural frequencies are not well separated, the modes are combined in accordance with NRC RG 1.92.

3.7.3.6 Use of Constant Vertical Static Factors

~~In general, seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Subsection 3.7.3.1. No constant vertical static factors are used for subsystems.~~

See page 2.

3.7.3.7 Buried Seismic Category I Piping, Conduits, and Tunnels

During an earthquake, buried structures such as piping, conduits, and tunnels respond to various seismic waves propagating through the surrounding soil as well as to the dynamic differential movements of the buildings to which the structures are connected. The various waves associated with earthquake motion are P (compression) waves, S (shear) waves, and Rayleigh waves. The stresses in the buried structure are governed by the velocity and angle of incidence of these traveling waves. However, the wave types and their directions during an earthquake are very complex. For design purposes, the seismic-

The seismic analysis of seismic Category I subsystems can be performed using the response spectrum analysis method, the time history analysis method, or the equivalent static load method, as specified in Subsection 3.7.3.1. When the equivalent static load method is employed, the constant vertical static factor is used to calculate the vertical response loads for the seismic design of seismic Category I SSCs.