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.:	**267-8301**
SRP Section:	**03.07.03 – Seismic Subsystem Analysis**
Application Section:	**3.7.3**
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Question No. 03.07.03-1

10 CFR 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 – (Rev. 1)

DCD Tier 2, Subsection 3.7.1.1.2 states that the two horizontal earthquake components are statistically independent based on the results of the correlation coefficients. The above-ground seismic Category I tanks stated in the DCD Tier 2, Subsection 3.7.3.9 are all cylindrical tanks which are anchored to reinforced concrete pads. Therefore, the seismic analysis of the above-ground SC-I cylindrical tanks that consider only the larger of the two horizontal components in the SRSS combination is justified based on symmetry and statistically independent seismic input motion.

The seismic Category I tanks which are constructed as part of buildings are included in the seismic analysis finite element model. As such, their seismic analyses are performed considering the effect of the three (two horizontal and one vertical) input motions.

For other seismic Category I tanks, (such as firewater tanks, fuel tanks for the emergency diesel generator, and other mechanical tanks which are installed in buildings), the seismic analyses are performed using a separate (decoupled) finite element model to determine its natural frequencies and mode shape. Seismic loads are calculated, depending on the natural frequency results from the finite element analysis, either by using the equivalent static method or dynamic method if the tanks are considered flexible (i.e., frequency less than 33 Hz). The impulsive and convective forces are also considered in the tank analyses. The stress evaluation of the mechanical tanks, bolts, tank plates, and tank supports are performed to ensure that the calculated stresses at all investigated locations are less than the corresponding allowable values. This method of seismic analyses will be provided in DCD Tier 2, Subsection 3.9.2.2.14, as indicated in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Subsections 3.7.3.9 and 3.9.2.2.14 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.

See page 3.

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

For the seismic Category I tanks constructed as a part of buildings, the seismic analyses are performed considering input motions in three directions, two horizontal and one vertical, as the building is analyzed according to Subsection 3.7.2.3.
For seismic Category I tanks installed in buildings, the seismic analyses are performed in accordance with Subsection 3.9.2.2.14.

3.9.2.2.13 Analysis Procedure for Damping

The damping values used for seismic analysis are consistent with NRC RG 1.61 (Reference 40) as described in Table 3.7-7.

3.9.2.2.15

See page 5.

~~3.9.2.2.14~~ Test and Analysis Results

The test and analysis results are documented and available for review. The implementation program that includes milestones and completion dates is further described in Section 3.10.

3.9.2.3 Dynamic Response Analysis for Reactor Internals under Operational Flow Transients and Steady-State Conditions

The flow-induced vibration of the reactor internals components during normal operation can be characterized as a forced response to both deterministic and random pressure fluctuations in the coolant. Methods have been developed to predict the various components of the hydraulic forcing function and the response of the reactor internals to such excitation.

This analytical methodology is summarized in Figure 3.9-2. The method separates the response calculations into two groups in accordance with the physical nature of the loading. Methods for developing the deterministic component of the hydraulic forcing function are described in Subsection 3.9.2.3.1.1, while those relating to the random component are described in Subsection 3.9.2.3.1.2.

The responses of the reactor vessel core support and internal structures, including core support barrel assembly, upper guide structure assembly, and lower support structure assembly, to the normal operating hydraulic loads are calculated by finite element techniques. The mathematical models used in these response analyses are described in Subsection 3.9.2.3.2. The methods used in calculating the structural responses are described in Subsection 3.9.2.3.3.

3.9.2.2.14 Seismic Analysis for Mechanical Tanks

The structural integrity of tanks such as fire water tank, fuel tanks for the emergency diesel generator, and other mechanical tanks that are classified as seismic Category I is demonstrated by analysis. Structural analysis without testing is used if the structural integrity of such tanks can verify the intended design function.

The seismic analyses of the mechanical tanks are performed using a separate (decoupled) finite element model to determine their natural frequencies and mode shape. Seismic loads are calculated, depending on the natural frequency results from the finite element analysis, either by using the equivalent static method or dynamic method if the tanks are considered flexible (i.e., frequency less than 33 Hz). The impulsive and convective forces are also considered in the tank analyses. The stress evaluation of the mechanical tanks, bolts, tank plates, and tank supports are performed to ensure that the calculated stresses at all investigated locations are less than their corresponding allowable values.