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.:	**226-8235**
SRP Section:	**03.07.02 – Seismic System Analysis**
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Question No. 03.07.02-5

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 reviews the adequacy of the seismic analysis methods used to demonstrate that SSCs can withstand seismic loads and remain functional. In Sections 3.2.5, 3.2.7, and 4.2.9 in APR1400-E-S-NR-14002-P, the applicant discusses that the weight of the RCS, the hydrodynamic masses of IRWST (i.e. both impulsive and convective masses), and hydrodynamic masses for the AFW and FHA tanks that are included in the finite element models (FEMs) for use in SSI analysis. However, in contrast with the information in APR1400-E-S-NR-14002-P, in Section 6.1 of APR1400-E-S-NR-14003-P the applicant states that the RCS masses and the convective (sloshing) hydrodynamic masses for the first and second horizontal sloshing modes of IRWST were not included in the maximum building seismic response forces and moments obtained from the SSI analysis. This section also states that, for the structural design, the maximum seismic response RCS support reaction forces and moments and the maximum hydrodynamic pressures generated from the maximum seismic response of the horizontal sloshing modes of IRWST, AFW and FHA tanks are added to the maximum building seismic response forces and moments that are computed.

To assist the staff in evaluating whether the aforementioned masses and their effect have been adequately considered in the seismic analysis and design, the staff requests the applicant to clarify if these masses are included in or excluded from the FEMs used in the SSI analyses. If the hydrodynamic masses were included in the FEMs used in the SSI analyses, describe the process used to estimate the slosh height. If the masses described in the paragraph above are excluded from the FEMs used in the SSI analyses, describe the process (including a numerical example) for developing design loads that correspond to these masses and how these loads are combined with the seismic design loads. Additionally and as necessary, correct any inconsistencies between the aforementioned technical reports.

Response

The RCS masses are automatically incorporated in the finite element models for use in SSI analysis through modeling the major RCS components.

The hydrodynamic effect of significant mass interacting with the structure for IRWST, AFW and FHA tanks are included in the FEMs used in the SSI analysis. Both convective (sloshing) and impulsive horizontal masses and frequencies are calculated for modeling of hydrodynamic effect on tank walls.

The analytical approach used to model the horizontal hydrodynamic effect on the annular cylindrical tank, IRWST, is based on the formulations given by Tang, et.al. (Reference 1). From the formulation given by Tang et al., the hydrodynamic effects on the rigid tank are simplified to equivalent mechanical models consisting of impulsive and convective parts similar to those previously formulated by Housner (Reference 2) for cylindrical and rectangular tanks.

Using the formulation given by Tang et al., the hydrodynamic properties of equivalent mechanical models for IRWST, such as impulsive mass for the impulsive part, and sloshing frequencies and masses for the convective part, are calculated. The characteristic values, ξ_n, for sloshing mode, n, are calculated first, and the sloshing frequencies from ξ_n and corresponding Eigen functions are obtained. From these values and related coefficients, impulsive mass and its height from the tank base, as well as convective mass and the height, are calculated.

To implement the horizontal hydrodynamic model developed for IRWST, as described above, the horizontal impulsive mass computed is distributed into lumped masses in a circular ring. The ring is located at the height of the impulsive mass, and the distributed lumped water masses in the circular ring are linked circumferentially by rigid beams. Each distributed lumped water mass in the circular ring is then connected by a radial beam element to a corresponding node on the IRWST inner wall. For the horizontal convective hydrodynamic masses associated with the first two sloshing modes, the lumped total sloshing mass for each mode is placed at the center of the IRWST at the height for each mode. The lumped sloshing water mass for each mode is then connected to every node on the inner wall of the IRWST by radial beam elements.

For the vertical vibration, all of the water in the tank is assumed to move vertically as a rigid body with the vertical motion of the tank base. Thus, all of the vertical water mass in the tank is uniformly distributed as lumped masses attached to structural nodes at the bottom of the tank.

The Hounser's formulas, and the similar approach described above, are also applied separately for two orthogonal horizontal directions to model the horizontal responses of water in the AFW and FHA tanks inside the auxiliary building (AB). Hydrodynamic effects from these water tanks are included with horizontal hydrodynamic mass and support stiffness to simulate the horizontal sloshing (convective) mass of water. The mass is attached with flexible springs to the upper portion of the tank wall. Horizontal impulsive hydrodynamic mass is calculated as lumped masses attached rigidly to the lower portion of tank wall. In the vertical direction, the total water mass is lumped at the bottom slab of the tank.

Calculations of hydrodynamic sloshing heights for the annular cylindrical IRWST tank are based on formulas for annular tanks given also by Tang et al. The sloshing heights which come from the vertical surface displacements at outer and inner tank walls are based on tank dimensions, water height, and sloshing frequencies. From the sloshing height calculation, it is checked that sloshing water does not reach the tank roof.

Calculations of hydrodynamic sloshing heights for rectangular AFW and FHA tanks are based on Housner's formulas for rectangular tanks, and are also based on tank dimensions and sloshing frequencies of water contained in the tanks. From the vertical sloshing displacements, it is identified whether water will reach the tank roof or spill over the top of an open tank.

The in-house post-processor calculates the mass matrix and multiplies it with the nodal accelerations from the SSI analysis to obtain the building story shear forces and overturning moments. Therefore, only mass that contributes to the building shear and overturning moment for the component under consideration is included. For this reason, the RCS masses and the convective (sloshing) hydrodynamic masses of the IRWST, AFW and FHA tanks are not included in the calculation of seismic response forces and moments. For the structural design, the effects from the RCS masses and hydrodynamic masses are considered separately. However, the ISRS developed from the SSI analysis already includes the RCS masses and hydrodynamic mass effects on tank walls.

References

1. Tang, Yu, Grandy, C., and Seidensticker, R., "Seismic Response of Annular Cylindrical Tanks," Nuclear Engineering and Design, 240(2010), 2614 - 2625.

2. TID-7024, “Nuclear Reactor and Earthquakes,” Chapter 6 and Appendix F.

Impact on DCD

There is no impact on the DCD.

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.