

KHNPDCRAIsPEm Resource

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Sent: Monday, August 31, 2015 12:25 PM
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Cc: Thomas, Vaughn; Roche, Robert; Betancourt, Luis; Lee, Samuel
Subject: APR1400 Design Certification Application RAI 183-8197 (03.07.02 - Seismic System Analysis)
Attachments: APR1400 DC RAI 183 SEB1 8197.pdf; image001.jpg

KHNP,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. However, KHNP requests, and we grant, 60 days to respond to this RAI. We may adjust the schedule accordingly.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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Issue Date: 08/31/2015
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 03.07.02 - Seismic System Analysis
Application Section: 3.7.2

QUESTIONS

03.07.02-1

10 CFR 50 Appendix S requires that safety-related structures, systems, and components (SSCs) remain functional and within applicable stress, strain, and deformation limits for safe shutdown earthquake (SSE) ground motions. The seismic analysis and design of the APR1400 standard plant are based on the certified seismic design response spectra (CSDRS) described in DCD Subsection 3.7.1.1.1 which, per DCD Section 3.7.1 is the SSE for the APR 1400 standard plant. Additionally, the APR1400 standard plant is evaluated for the potential effects of hard rock high frequency (HRHF) spectra. DCD Appendix 3.7B and technical report APR1400-E-S-NR-14004-P, Rev 1, summarize the methodology and results of the evaluation of the effects of hard rock high frequency (HRHF) input ground motion on SSCs of the APR1400 standard plant. To assist the staff in assessing whether the acceptance criteria in SRP Section 3.7.2 II.4 have been adequately addressed, the applicant is requested to provide additional information related to the following aspects of the HRHF evaluation.

a) In-structure Response Spectra (ISRS) Reduction Limits

In Figures 5-5 through 5-23 in APR1400-E-S-NR-14004-P, Rev 1, the applicant provided comparisons of HRHF-based ISRS with and without consideration of spatial incoherence of seismic ground motion (i.e., incoherent ISRS and coherent ISRS, respectively). Staff review of these ISRS comparisons finds that while the HRHF-based incoherent ISRS generally show the expected outcome of reduced spectral accelerations in high frequencies, the magnitude of the reductions exceed the reduction limits set forth in SRP Section 3.7.2.II.4. Per the guidance in SRP Section 3.7.2.II.4, larger ISRS reductions may be acceptable subject to the applicant providing sufficient technical information supporting the larger reductions. As such the staff requests the applicant to provide justification for implementing ISRS reduction levels in excess of those provided in SRP Section 3.7.2.II.4.

b) SSI Analysis Results using 7 and 12 Modes

DCD Section 3.7B.4 and Section 5.4 in APR1400-E-S-NR-14004-P, Rev 1, describe the use of 7 modes for capturing the incoherent-motion SSI response based on a comparison with the response obtained by using 12 modes. Staff review of such comparisons as provided in Appendix B of APR1400-E-S-NR-14004-P finds that the use of 7 modes generally results in greater reductions in the ISRS, above 10 Hz, than the reductions presented in SRP Section 3.7.2.II.4 as indicated in item (a) above. Further, the staff notes that a 15 mode solution was also calculated; however, the 15 mode results were not presented in the aforementioned comparison. Based on staff experience, the staff finds that the use of 7, 12, or 15 modes may not be sufficient to adequately capture the incoherent-motion and structural responses. Therefore, the staff requests the applicant to provide the technical justification for the selection of the appropriate number of modes to be used to capture the incoherent-motion and structural responses.

c) Seismic Response Demands of the HRHF Spectra

In DCD Section 3.7B.7.1 and Section 6.1 of APR1400-E-S-NR-14004-P, Rev 1, the applicant states that the NI structures are considered qualified for high frequency input if the seismic loads and equivalent acceleration from the CSDRS envelope those from the high frequency input. The staff's review of the results provided in Tables 6-1 through 6-3, and Table 6-6 of APR1400-E-S-NR-14004-P, Rev. 1, for the containment internal structures (CIS) and the emergency diesel generator building (EDGB)/diesel fuel oil tank (DFOT) room, respectively, finds that generally the HRHF-based results exceed the CSDRS-based results. Furthermore, the staff notes that while the applicant documented these exceedances in Section 6.1 of APR1400-E-S-NR-14004-P, Rev 1, the applicant did not provide the basis for their acceptance. Based on the current results and lack of justification, the staff does not have sufficient basis to conclude that the APR1400 standard plant structures are qualified for the applicant's HRHF input motions. Therefore, the staff requests the applicant to provide additional information including analysis results that demonstrate that the APR1400 standard plant is qualified for the HRHF input motions. After addressing items (a) and (b) above, the staff requests the applicant to provide revised results for ISRS comparisons and seismic loads, between the CSDRS and the HRHF, and to provide a detailed justification for the acceptability of all HRHF exceedances. Additionally, in accordance with the guidance in SRP Section 3.7.2.II.4, the staff requests the applicant to confirm that (1) all reductions in structural loads based on consideration of incoherency will be limited to 10%; and (2) all increases in structural loads based on consideration of incoherency will be used in the structural evaluation.

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03.07.02-2

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. Per the guidance in SRP Section 3.7.2.II.12, if both the time history analysis (THA) method and the response spectrum analysis (RSA) method are used to analyze an SSC, the peak responses obtained from these two methods should be compared, to demonstrate approximately equivalency between the two methods. The comparison of the RSA and the THA methods is also important since the RSA method only utilizes the translational response spectra at the basemat of the NI as input to the containment and containment internal structures without consideration of the rotational input at the basemat. Staff review finds that while DCD Sections 3.7.2.1.1 and 3.7.2.1.2 identify the RSA and THA methods, respectively, as methods used in the analysis/design of APR1400 standard plant structures, a comparison between the peak responses obtained from these methods is not provided. Further, the staff finds that DCD Section 3.7.2.11, Comparison of Responses, is inconsistent with DCD Section 3.7.2.1.1. Specifically, DCD Section 3.7.2.1.1 states that RSA is used to compute the seismic design forces of the containment structure and internal structure in the reactor containment building using the in-structure response spectra (ISRS) at the top of basemat generated from seismic soil-structure interaction (SSI) analysis. However, DCD Section 3.7.2.11 states that only the THA method based on complex frequency response method is used for seismic Category I structures, and comparison with the RSA method is not applicable. Further, DCD Table 3.7-9, Summary of Models and Analysis Methods, state that maximum member forces and moments for the Nuclear Island (NI) are obtained from SASSI. Additionally this table does not identify the RSA as an analysis method used for the APR1400 standard plant.

Staff review also finds inconsistent information regarding the description of the analysis methods used for the auxiliary building (AB) and emergency diesel generator building (EDGB)/diesel fuel oil tank (DFOT). Specifically, while DCD Table 3.7-9 states that maximum member forces and moments for the NI (which includes the AB) and EDGB/DFOT are obtained from the SASSI analysis, DCD Sections 3.8A.2.3.1 and 3.8A.3.3.1, for the AB and EDGB respectively, indicate that an equivalent static method of analysis is performed to obtain the member forces for these structures. Further, DCD Table 3.7-9, does not identify the equivalent static method as an analysis method used for the APR1400 standard plant.

In addition, DCD Section 3.7.2.1 also describes the time history modal superposition method of analysis. However, DCD Table 3.7-9 does not identify such analysis. Based on the above, in order to assist the staff in assessing whether the acceptance criteria in SRP Section 3.7.2 II.12 have been adequately addressed, and to assist the staff in reviewing the adequacy of the analysis methods used for seismic Category I structures and the use of the respective analysis results, the applicant is requested to provide the following additional information.

- (a) Per SRP Section 3.7.2 II.12, provide comparisons between time history and response spectrum analysis results for the containment structure and containment internal structure and correct the inconsistencies between DCD Sections 3.7.2.1 and 3.7.2.11 regarding the use of the RSA method.
- (b) Update DCD Table 3.7-9 to show all the seismic analysis methods used for seismic Category I structures (including seismic analysis methods used for seismic design) and clearly identify the analysis model (including damping values used and consideration of uncracked and cracked stiffnesses), analysis method, computer program, purpose of the analysis, type of building response(s) (e.g., ISRS, member forces, displacements), and section in the DCD and/or technical reports where these are explained and figures are given for each respective model. This table should include the use of multiple models for structures such as the containment, which utilizes the global model, partial model, and containment basemat model. Further, correct inconsistencies between the information in Table 3.7-9 and respective DCD sections related to the NI and EDGB/DFOT structures, such as those mentioned above.
- (c) As applicable, delete DCD descriptions of analysis methods that are not currently used in the analysis of seismic Category I SSCs. As an example, while DCD Section 3.7.2.1.2 describes the time history modal superposition method of analysis, the staff has not been able to identify in the DCD and/or technical reports where this method of analysis is used. If it is used or is a candidate for use in the analysis of seismic Category I systems and components, identify the applications.

03.07.02-3

10 CFR 50 Appendix S requires that safety-related structures, systems, and components (SSCs) remain functional and within applicable stress, strain, and deformation limits for safe shutdown earthquake (SSE) ground motions. Staff review of Section 3 in APR1400-E-S-NR-14003-P finds that additional information is needed to confirm that safety-related SSCs will remain functional and within applicable stress, strain, and deformation limits. Specifically, Section 3 of APR1400-E-S-NR-14003-P states that the reactor containment building (RCB) and the auxiliary building (AB) are separate from each other above the basemat and have a minimum 2 inch seismic gap between them. Additionally, Section 3.1 in the same report states that the containment structure (CS) and internal structure (IS) are also separated by a 2 inch gap. However the staff review of the relative displacement results in DCD Tables 3.7-15 and 3.7-21 and Appendix E in APR1400-E-S-NR-14003-P finds instances of combined RCB and AB relative displacements exceeding 2 inches which would result in interaction between these structures. Therefore, in light of the aforementioned relative displacement results, the staff requests the applicant to describe the approach used for determining the

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adequacy of the seismic gaps between the aforementioned structures and to justify the appropriateness and sufficiency of the minimum 2 inch gap to preclude adverse interaction between these structures during an SSE event. This justification should address the maximum relative displacements between the AB and the RCB and between the CS and IS throughout coincident elevations and explain whether these relative displacements pertain to a worst case condition such as out-of-phase displacements or justify an alternate condition as necessary. Also, address how construction tolerances have been considered in determining the minimum required gap between these structures.

The staff also request the applicant to clarify the relative displacement discussion in Section 6.3 of APR1400-E-S-NR-14003-P. Specifically, in Section 6.3 of APR1400-E-S-NR-14003-P, the applicant states that displacements relative to the basemat for the RCB are obtained by removing the rigid basemat rotations computed for the region of the basemat under the RCB footprint. In Appendix E of APR1400-E-S-NR-14003-P, for the RCB, the applicant provided relative displacements to the basemat with and without basemat rotations included. The staff review identified that the relative displacements provided in the DCD are those corresponding to those reported in Appendix E of APR1400-E-S-NR-14003-P that include the basemat rotation. The staff requests the applicant to clarify the intent and use of removing basemat rotations as stated in Section 6.3 of APR1400-E-S-NR-14003-P.

03.07.02-4

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. Per the guidance in SRP Section 3.7.2.II.4, the staff reviews the calculation of the ground contact ratio to ensure that linear SSI analysis remains valid. The ground contact ratio is defined as the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation, computed in each time step throughout the SSI analysis. The acceptance criterion is that linear SSI analysis methods are appropriate provided the ground contact ratio is equal to or greater than 80 percent. The ground contact ratio can be calculated from the linear SSI analysis using the minimum basemat area that remains in compression with the soil. If the ratio is less than 80 percent, then the effect of the nonlinearity due to the foundation uplift should be evaluated.

In Sections 4.1.1 and A.4.1.1 in APR1400-E-S-NR-14006-P, Rev. 1 the applicant described its ground contact ratio calculation for the nuclear island (NI) common basemat and EDGB/DFOT basemat respectively. Further, Tables 4-1 and A-2 of the report provide the calculated ground contact ratios for the NI common basemat and EDGB/DFOT basemat, respectively. Per the guidance in SRP Section 3.7.2.II.4, in order to assist the staff in its review of the adequacy of the calculated ground contact ratios, the applicant is requested to clarify whether the specified ground contact ratios represent the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation, computed in each time step throughout the SSI analysis time history. If not, provide the technical basis for the adequacy of the alternate method used to calculate the ground contact ratio as applicable.

