

APR1400 DESIGN CONTROL DOCUMENT SECTIONS 3.7 AND 3.8 AUDIT

June 20 – 24, 2016

APR1400 DESIGN CERTIFICATION

**Korea Hydro and Nuclear Power Co., Ltd. and Korea Electric Power Corporation
Docket No. 52-046**

Locations: Westinghouse Electric Co.
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NRC Headquarters
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Rockville, MD 20852-2738

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Purpose:

The purpose of this audit is to review the seismic analysis and structural design of the Advanced Power Reactor 1400 (APR1400). The APR1400 Reactor Containment Building (RCB) which consists of the Prestressed Concrete Containment Vessel (PCCV), the Containment Internal Structures (CIS), and the Auxiliary Building (AB); the common basemat for the nuclear island (NI); the Emergency Diesel Generator Building (EDGB); and the Fuel Diesel Oil Tank (FDOT). The staff intends to audit the related documentation and supporting calculations for the seismic analysis and structural design of those structures used in the APR1400 design in order to:

- (1) Address outstanding technical issues associated with the analysis and design of these structures.
- (2) Obtain and review additional pertinent information that is not documented in the application.
- (3) Verify that the design methodology used for the design of the RCB Complex including the PCCV and the RCB Foundation are consistent with the methodology presented in the Design Control Document (DCD).
- (4) Verify that the key seismic analysis and structural design calculations have been conducted in accordance with applicable codes and regulations.

The audit will review and evaluate the design and analysis methods and the implementation for the RCB, PCCV, AB, CIS, EDGB, FDOT, and the common basemat for the NI for confirmation of its performance in accordance with the APR1400 DCD Tier 2, Sections 3.7 and 3.8.

This audit follows the guidelines in the Office of New Reactors (NRO) Office Instruction, NRO-REG-108 (Revision 0), "Regulatory Audits" (Reference 1).

Background:

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed Korea Hydro and Nuclear Power Co., Ltd. (KHNP's) information contained in the APR1400 DCD along with KHNP's responses to the NRC staff's Request for Additional Information (RAI) regarding the structural and seismic design of the KHNP application. To gain a better understanding of the design and analysis methods of those structures and to confirm the design approach used by KHNP, the NRC staff will audit the design and analysis reports for the basic design of those structures. This audit will also assist the NRC staff to complete its technical review of the RCB, PCCV, AB, CIS, EDGB, FDOT, and the Foundation design and to make a safety finding.

Regulatory Bases:

- DCD Tier 2, Sections 3.7 and 3.8 are being reviewed by the NRC staff in accordance with the relevant requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) 52.47(a)(9); and 10 CFR Appendix B.
- In addition, the acceptance criteria associated with the relevant requirements of the NRC regulations General Design Criteria (GDC) 1, 2, 4 and 5 of Appendix A to 10 CFR Part 50; Appendix S to 10 CFR Part 50, and Appendix A to 10 CFR Part 100.23.
- Implementing guidance such as the Standard Review Plan NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Regulatory Guides, and Interim Staff Guidance, along with cited codes and standards, informs the staff review and represents an acceptable technical approach for demonstrating compliance with the regulations.

Regulatory Audit Scope and Methodology:

Details regarding the seismic analysis and structural design of the APR1400 will be reviewed by the NRC staff and used to support the evaluation of DCD Sections 3.7.1, 3.7.2, 3.7.3, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design reports along with calculations supporting the applicant's RAI responses to the staff's RAIs will also be reviewed. In particular, the staff plans to audit calculations supporting the applicant's approach for:

Section 3.7:

1. The compatibility of the power spectrum density (PSD) functions with the certified seismic design response spectra (CSDRS) - RAI 182-8160, Question 3.7.1-1.
2. The methods used to estimate the PSD for the CSDRS and the hard rock high frequency (HRHF) time histories - RAI 182-8160, Question 3.7.1-3.
3. The adequacy of the methodology; and results for analyzing the effects of HRHF input ground motion on the standard plant - RAI 183-8197, Question 3.7.2-1.

4. The adequacy of the method used to calculate the ground contact ratio - RAI 183-8197, Question 3.7.2-4.
5. Consideration of hydrodynamic masses (e.g. IRWST, AFW, and the FHA tank masses) in the seismic analysis - RAI 226-8235, Question 3.7.2-5.
6. Consideration of embedment effects in the SSSI analyses - RAI 226-8235, Question 3.7.2-6.
7. The adequacy of the finite element models used in the seismic analysis - RAI 252-8299, Question 3.7.2-7.
8. The consideration of accidental torsion in the seismic analysis - RAI 252-8299, Question 3.7.2-8.
9. The adequacy of the analysis methods used for seismic Category I structures with the inclusion of all the soil cases that contribute to the determination of the in-structure response spectra (ISRS) - RAI 252-8299, Question 3.7.2-9.
10. Modeling of flexible floors and walls in the RCB and AB - RAI 252-8299, Question 3.7.2-10.
11. Consideration of soil/sidewalls separation effects and implementation of SSI methodologies - RAI 252-8299, Question 3.7.2-11.
12. The adequacy of the method used for the seismic analysis of tanks - RAI 267-8301, Question 3.7.3-1.
13. The separation of modal frequencies - RAI 267-8301, Question 3.7.3-5.

Section 3.8:

1. The method used for combining dynamic loads that include SSE, LOCA, and safety/relief valve actuation; the consideration of full or portion of live load for evaluating the seismic response forces - RAI 129-8085, Question 3.8.1-1.
2. The consideration of concrete cracking in the seismic analysis and design of the NI structures; the parameters affecting the prestress losses over the life of the plant - RAI 129-8085, Question 3.8.1-2.
3. The methodology for computing the ultimate pressure capacity of the containment - RAI 129-8085, Question 3.8.1-5.
4. The description of the approach for analyzing the hydrogen pressure load due to fuel-clad and water interaction – RAI 199-8223, Question 3.8.1-8.
5. The evaluation of the severe accident performance goal for the containment - RAI 199-8223, Question 3.8.1-10.

6. The design approach of various critical sections; and the V&V of the computer code - RAI 199-8223, Question 3.8.1-15.
7. The criteria for the analysis and design of the penetrations - RAI 200-8225, Question 3.8.2-2.
8. The methodology for analyzing the hydrodynamic pressure loads in the design and analysis IRWST structure - RAI 208-8245, Question 3.8.3-1.
9. Loads and load combinations for the CIS - RAI 208-8245, Question 3.8.3-3.
10. The consideration of accidental thermal loads in the analysis and design of the CIS - RAI 208-8245, Question 3.8.3-4.
11. Slabs in CIS (decoupling, mass distribution, support/connection of slabs) - RAI 208-8245, Question 3.8.3-5.
12. The adequacy of the concrete fill on top of the basemat liner - RAI 208-8245, Question 3.8.3-7.
13. The design and analysis approach of the leak chase channels in the containment liner plate, the IRWST, and the HVT liner plates - RAI 332-8382, Question 3.8.3-8.
14. The inclusion of hydrodynamic load and dynamic soil pressure in loads generated by SSE - RAI 227-8274, Question 3.8.4-7.
15. Waterproofing membranes and their effect on the shear resistance of the NI common basemat - RAI 255-8285, Question 3.8.5-4.
16. Construction sequence and differential settlement of foundation - RAI 255-8285, Question 3.8.5-7.
17. Short and long term settlements - RAI 255-8285, Question 3.8.5-9.
18. Checking of differential settlements by the COL applicant - RAI 255-8285, Question 3.8.5-18.

Technical issues have been raised in the prior review and some of the details are expected to be provided in the calculations available for this audit. The following RAI questions are included in this category:

RAIs	Question	Comments
183-8197	03.07.02-2	
352-8299	03.07.02-12	
208-8245	03.08.03-6	
255-8285	03.08.05-8	

255-8285	03.08.05-11	
255-8285	03.08.05-12	
255-8285	03.08.05-13	
255-8285	03.08.05-14	
255-8285	03.08.05-16	
255-8285	03.08.05-17	

*Review of the design reports including:

- a) drawings (plan and section views) and descriptions that reflect the design results, including reinforcing steel bars, of the structure;
- b) assumptions of the analysis and design methods used to reach the design results, as shown in the drawings;
- c) modeling techniques of the analysis methods;
- d) calculated natural frequencies, mode shape plots, and stress or force results (i.e., tabulated values/contour plots) of the seismic Category I structures.

Information and Documents Necessary for the Audit:

The NRC staff requests KHNP to provide the design technical reports, calculations and related documents discussed in the audit scope. KHNP is also requested to identify other documents, which the applicant deems as necessary to support the NRC staff's audit (e.g., drawings, QA requirements) and any other documents or calculations referenced by the various reports and related documents. KHNP is also requested to prepare a list of the documents that will be made available during the audit, including the document titles, identifying numbers, and revisions/dates.

All material subject to the site visit (hard copy or electronic) will be left at the site. If any documentation is required to support the staff's regulatory findings, the staff will identify it in a request for additional information.

KHNP is requested to make available, personnel who are knowledgeable in the seismic analysis and structural design of the APR1400 along with the associated technical reports. KHNP should also have the ability to make available modeling/analysis information as necessary to support the audit.

Audit Team:

John Ma, NRC, Structural Design
Ata Istar, NRC, Structural Design
Robert Roche, NRC, Seismic Analysis
Jinsuo Nie, NRC, Seismic Analysis
Vaughn Thomas, NRC, Structural Design
Joseph Braverman, NRC Consultant, Structural Design

Richard Morante, NRC Consultant, Seismic Analysis
Carl Costantino, NRC Consultant, Seismic Analysis
Thomas Houston, NRC Consultant, Seismic Analysis
John Vera, NRC, Project Manager

Applicant Contact:

Steven Mannon, KHNP

Logistics:

The NRC staff and the applicant have agreed that the audit will be conducted from June 20, 2016, through June 24, 2016, at the Westinghouse Electric Co. (WEC) facilities in Rockville, Maryland, at the U.S. Nuclear Regulatory Commission (NRC) Headquarters via KHNP's electronic reading room, or at KHNP's facilities in Vienna, Virginia. In support of this audit, the applicant has agreed to make knowledgeable staff available, along with relevant documentation, to support staff review and discussion of the material. The NRC staff will have internal meetings throughout the audit to discuss preliminary findings. The team will audit documents and discuss with the applicant as appropriate throughout the audit. An exit meeting will be conducted to summarize the staff findings at the end of the audit.

Audit Activities and Deliverables:

The NRC audit team review will cover the technical areas identified previously in this audit plan. Depending upon how much effort is needed in a given area, the NRC team members may be reassigned to ensure adequate coverage of important technical elements. The NRC Project Manager will coordinate with KHNP in advance of audit activities to verify specific documents and identify any changes to the audit schedule and requested documents.

The NRC staff acknowledges the proprietary nature of the information requested and will be handled appropriately throughout the audit. While the NRC staff will take notes, the NRC staff will not remove hard copies or electronic files from the audit site(s).

At the completion of the audit, the audit team will issue an audit summary within 90 days that will be declared and entered as an official agency record in the NRC's Agency wide Documents Access and Management System (ADAMS) records management system. The audit outcome may be used to identify any additional information to be submitted for making regulatory decisions, and it will assist the NRC staff in the issuance of RAIs (if necessary) for the licensing review of APR1400 DCD Chapter 3 and any related information provided in other chapters, in preparation of the NRC staff's SER.

If necessary, any circumstances related to the conductance of the audit will be communicated to John Vera, NRC Project Manager at 301-415-5790 or via email at john.vera@nrc.gov.

A summary report of the audit will be prepared and issued in accordance with NRO-REG-108.

References:

1. NRO Office Instruction NRO-REG-108 (Revision 0), "Regulatory Audits."