

October 25, 2013

**SECTIONS 3.8.1, 3.8.4, AND 3.8.5 STRUCTURAL ANALYSIS AND DESIGN
AUDIT PLAN**

November 4 - 8, 2013

**US-APWR DESIGN CERTIFICATION
Mitsubishi Heavy Industries, Ltd.
Docket No. 52-021**

Location: Mitsubishi Nuclear Energy Systems, Inc.
1001 19th Street North, Suite 710
Arlington, VA 22209

Purpose:

The purpose of this audit is to review the design reports for the Reactor Building (R/B) Complex which consists of the Prestressed Concrete Containment Vessel (PCCV), R/B, the East Power Source Building (PS/B), the West PS/B, the Auxiliary Building (A/B), and the Essential Service Water Pipe Chase (ESWPC); the common basemat for the nuclear island; and the related documentation and supporting calculations for the structural design of those structures used in the United States - Advanced Pressurized Water Reactor (US-APWR) design in order to:

- (1) Address outstanding technical issues associated with the analysis and design of these structures.
- (2) Verify that the design methodology used for the design of the R/B Complex including the PCCV and the R/B Foundation are consistent with the methodology presented in the Design Certification Document (DCD).
- (3) Verify that the key structural design calculations have been conducted in accordance with applicable codes and regulations.

The audit will review and evaluate the design methods and their implementation for the PCCV, R/B complex, and the common basemat for the nuclear island for confirmation of their performance in accordance with the US-APWR Design Certification Document (DCD) Tier 2, Sections 3.8.1, "Concrete Containment," 3.8.4, "Other Seismic Category I Structures," 3.8.5, "Foundations," and Appendix 3L, "Critical Sections for Reactor Building Complex," as well as the related Technical Report MUAP-10018-P, Revision 1, "US-APWR Containment Performance for Pressure Loads."

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

Background:

The U.S. Nuclear Regulatory Commission (NRC) staff reviewed information contained in the US-APWR DCD and Mitsubishi Heavy Industries, Ltd. (MHI's) responses to the NRC staff's Requests for Additional Information (RAIs) regarding the design of the PCCV, the R/B Complex, and the R/B foundation for the US-APWR design. To gain a better understanding of the structure's design method and to confirm the design approach used by MHI, the NRC staff will audit the design reports for the basic design of those structures. This audit will also assist the NRC staff in completing its technical review of the PCCV, the R/B Complex and the R/B Foundation design and to make safety findings.

Regulatory Audit Bases:

DCD Tier 2, Sections 3.8.1, 3.8.4, and 3.8.5 are being reviewed by the NRC staff in accordance with the relevant requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Part 52, and Part 100. In addition, the acceptance criteria associated with the relevant requirements of the NRC regulations General Design Criteria 2 of Appendix A to 10 CFR Part 50; Appendix S to 10 CFR Part 50, and Appendix A to 10 CFR Part 100. Implementing guidance such as the Standard Review Plan (NUREG-0800), 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.

Scope:

1. MHI to provide an overview of the design and analysis of the R/B Complex.
2. The use of linear and nonlinear analyses results for the design of the nuclear island structures (R/B complex, and their common basemat).
 - a. description of mathematical models and their boundary conditions including the response spectrum analysis for the superstructure,
 - b. input loadings to the models,
 - c. analysis procedures for the models (RAI 1040-7139, Questions 03.08.01-17),
 - d. the adequacy and application of linear and nonlinear analysis results to the design of the nuclear island structures seismic analyses results from the linear and nonlinear analyses and their applications to the design of the nuclear island structure,
 - e. application of analysis results of applicable loads other than seismic, such as thermal and pressure, to the design of the nuclear island structure,
 - f. the use of load combinations, such as dead load, live load, safe-shutdown earthquake (SSE) load, vertical and lateral soil pressures on the nuclear island structure, and their combined effect (bending moment, shear, torsion, and axial) on the design of concrete sections of the nuclear island structures,
 - g. stress caused by tensioning the tendons at PCCV,
 - h. steel girders in the fuel handling area.

3. The design of the nuclear island basemat and supporting calculations*
 - a. the factor of safety of the basemat for the static gravity load, including design live load (vertical load vs. soil bearing capacity),
 - b. the factor of safety of the basemat for the SSE event (toe pressure versus soil bearing capacity (RAI 304-2004, Question 03.08.05-18; RAI 1045-7141, Question 03.08.05-67),
 - c. the assumed basemat flexural stiffness, EI, such as the use of the gross moment of inertia or the effective (cracked) moment of inertia, and the assumed soil stiffness or modulus of subgrade reaction, K, for the analysis,
 - d. whether a constant K value or variable K values under the basemat are used,
 - e. the deflected shape (differential settlement) of the basemat due to the static gravity load,
 - f. bending moment and shear generated in the basemat due to soil settlement caused by construction sequence and long-term differential settlement (RAI 304-2004, Questions 03.08.05-11 and 13; RAI 1045-7141, Question 03.08.05-66),
 - g. the design bending moment, shear, and torsion diagrams for the basemat,
 - h. the magnitude of short-term and long term settlements of the basemat,
 - i. ANSYS 3D model,
 - j. rebar layout,
 - k. underground wall design.
4. The design of the PCCV, critical sections, and supporting calculations*
 - a. consideration of concrete cracking for the design of the PCCV due to thermal loading, including the liner plate spike load (RAI 223-1996, Question 03.08.01-1, Subquestion 9; RAI 490-3732, Questions 03.08.01-9; RAI 1040-7139, Question 03.08.01-21),
 - b. the calculated strains and stresses for the liner per Table CC-3720-1 of the American Society of Mechanical Engineers Section III, Division 2 (RAI 223-1996, Question 03.08.01-1, Subquestion 1),
 - c. the design to achieve the ultimate capacity of the PCCV, including the load associated with the release of hydrogen generated from 100 percent metal-water reaction of the fuel cladding and accompanied by uncontrolled hydrogen burning (RAI 223-1996, Question 03.08.01-1, Subquestion 3; RAI 490-3732, Questions 03.08.01-2 and 4),
 - d. the stresses at the boundary of the PCCV Equipment Hatch (E/H) submodel and the structural details around the E/H.
5. The design of the R/B complex (R/B, East and West PS/B, A/B, ESWPC), critical sections, and supporting calculations*
6. The design of the polar crane support
7. Key technical issues that have been raised in the prior review and for which 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	Questions	Comments
223-1996	03.08.01-1, Subquestion 11	
1040-7139	03.08.01-15	
1040-7139	03.08.01-22	
497-3734	03.08.04-39	
1044-7140	03.08.04-56	
340-2004	03.08.05-9	
855-6090	03.08.05-42, 43, 44	
1045-7141	03.08.05 (12 Questions)	

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

Audit Team:

- Mohamed Shams, NRC (Branch Chief SEB1)
- John Ma, NRC (Sr. Structural Engineer, SEB1)
- Bret Tegeler, NRC (Sr. Structural Engineer, SEB1)
- Anthony Ponko, NRC (Structural Engineer, SEB1)
- Vaughn Thomas, NRC (Structural Engineer, SEB1)
- Dennis Galvin, NRC (Project Manager, DNRL)
- Yu Tang, Argonne National Laboratory -Technical Reviewer
- David Ma, Argonne National Laboratory -Technical Reviewer

Information and Other Materials Needed for the Audit:

The NRC staff requests MHI to provide the design reports and related documents discussed in the audit scope. MHI is also requested to identify other documents, which the licensee deems as necessary to support the NRC staff's audit (e.g., drawings, quality assurance requirements) and any other documents or calculations referenced by them. MHI 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 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 RAI.

MHI is requested to make available applicant personnel who are knowledgeable in the analysis and design US-APWR of the PCCV, the R/B Complex, and the R/B foundation as discussed in

the DCD and MHI technical reports. MHI should also have the ability to make available, modeling/analysis information as necessary to support the audit.

Logistics:

The audit will be conducted at Mitsubishi Nuclear Energy Systems, Inc., located in Arlington, Virginia. The audit is scheduled to start on November 4, 2013, and run through November 8, 2013, as necessary (i.e., until finished). The audit is scheduled to begin at 9:00 a.m. each day but, may start earlier on any day, if there is a need to discuss issues with MHI's staff in Japan. Participating individuals will meet at the audit location. An exit briefing will be conducted with MHI on the last day.

The NRC staff request space for the team members to meet privately and discuss the progress of the audit.

Schedule and Deliverables:

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."
2. MHI's Letter, "Updated Closure Plan for US-APWR Seismic and Structural Analyses – Schedule Improvement," issued February 15, 2013.
3. MHI's Letter, "US-APWR Update to the Seismic Closure Plan and Submittals related to DCD Chapter 3," issued August 2, 2013.
4. US-APWR DCD, Revision 4.
5. MUAP-100018-P, Revision 1, "US-APWR Containment Performance for Pressure Loads."

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