

September 11, 2013

**SEISMIC ANALYSIS AUDIT PLAN  
DESIGN CERTIFICATION DOCUMENT SECTION 3.7**

**September 23-27, 2013**

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

Location: URS Corporation  
510 Carnegie Center  
Princeton, NJ 08540

Purpose:

The purpose of this audit is to review the details regarding the seismic analysis and design of the nuclear island structures in support of the safety evaluation of the United States-Advanced Pressurized Water Reactor (US-APWR) Design Certification Document (DCD) Tier 2, Sections 3.7.1, 3.7.2, and 3.7.3. Calculations supporting the applicant's development of design time histories, soil profiles, structural models, and soil-structure interaction (SSI) models will be reviewed. The seismic analysis of the nuclear island structures is described in the US-APWR DCD Tier 2, Section 3.7 and in several referenced technical reports.

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

Background:

In 2007, Mitsubishi Heavy Industries, Ltd. (MHI) submitted an application for a Standard Design Certification for the US-APWR. The US-APWR Reactor Building complex, which includes the Reactor Building, Pre-stressed Concrete Containment Vessel (PCCV), Containment Internal Structures, Fuel Handling Area, Auxiliary Building, East and West Power Source Buildings, and the Essential Service Water Pipe Chase, is supported on a common reinforced concrete mat foundation embedded approximately 42 ft below grade. The seismic analysis of the Reactor Building complex, which considers SSI effects, is described in DCD Tier 2, Section 3.7 and in several referenced technical reports. DCD Tier 2, Section 3.7 also describes the seismic analysis of the Turbine Building, which is adjacent to the Reactor Building complex. Structure-soil-structure interaction (SSSI) effects are also evaluated. The staff is currently performing a detailed review of the application, including several technical reports relating to seismic analysis.

The focus of this audit will be on reviewing the calculations supporting the seismic analysis of the Reactor Building complex, including the SSSI effects on the Reactor Building Complex and the Turbine Building. The staff will review the implementation of DCD commitment in the detailed analysis models. Analysis code validation efforts, particularly as they relate to the SASSI Subtraction Method, will be reviewed.

Regulatory Audit Bases:

DCD Tier 2, Section 3.7 is being reviewed by the U.S. Nuclear Regulatory Commission (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 (GDC) 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.

Regulatory Audit Scope or Methodology:

Details regarding the seismic analysis and design of the nuclear island will be reviewed by staff and used to support the safety evaluation of DCD Tier 2, Sections 3.7.1, 3.7.2, and 3.7.3. Calculations supporting the applicant's development of design time histories, soil profiles, structural models, and SSI models will be reviewed. In particular, staff plans to audit the following items:

1. Calculations supporting the development of the six generic strain-compatible soil profiles used in the standard plant design-basis SSI analyses (Reference 1, Part 1).
2. Calculations supporting the adequacy of the SASSI SSI model, including:
  - a. Consideration of SASSI-Subtraction Methods.
  - b. Consideration of soil element mesh refinement and model passing frequency.
  - c. Consideration of shell-to-solid and beam-to-solid connections.
  - d. Use of rotational constraints in the SASSI structural model, to eliminate singularities.
  - e. Modeling adjustments for flexible floor slabs and walls in the dynamic model, to match the modal response of the detailed model.
  - f. Correlation of SASSI acceleration transfer functions with ANSYS dynamic model harmonic analysis results.
  - g. Consideration of backfill material modeling to ensure evaluations capture expected range of iterated shear wave velocities of backfill.
  - h. Consideration of basemat solid element discretization, to capture flexural response.
  - i. Consideration of saturated soil conditions and impact of high Poisson's ratio on stability of SASSI calculations. (Reference 1, Parts 2 and 3, and Reference 4).

3. Calculations supporting the assessment of foundation uplift impact on seismic demands (Reference 1, Part 3).
4. Calculations supporting the assessment of foundation basemat sliding (Reference 2).
5. Calculations supporting the assessment of relative building displacements, with emphasis on the interaction of the PCCV and Reactor Building (Reference 1, Part 3).
6. Calculations supporting the assessment of SSSI on the Turbine Building response (Reference 3).
7. Calculations supporting the assessment of hydrodynamic effects in water-filled pools and tanks (Reference 1, Part 2).

Proposed Audit Tasks:

Audit Task 1 (Day 1, PM):

- Applicant to provide overall summary of seismic analysis approach and identify key design/modeling assumptions. The nexus to structural design and how seismic demands are used as input to various structural models should also be discussed.

Audit Task 2 (Days 1, 2):

- NRC staff to review calculations supporting the development of the six generic strain-compatible soil profiles used in the standard plant design-basis SSI analyses.

Audit Task 3 (Days 1, 2, 3, 4):

- NRC staff to review SASSI modeling assumptions, sensitivity studies, and method of addressing SASSI Subtraction Method. This review will include an assessment of soil mesh refinement, soil backfill assumptions, SSI model passing frequency, and water table effects on SSI response.

Audit Task 4 (Days 2, 3, 4):

- NRC staff to review ANSYS structural model, including idealization of tanks, representation of flexible floors/walls, and validation of ANSYS to SASSI conversion. Modeling assumptions relating to element connections (e.g., beam-to-solid and shell-to-solid) and applied rotational constraints will be reviewed.

Audit Task 5 (Days 3, 4):

- NRC staff to review calculations supporting the assessment of building differential displacement and basemat uplift.

Audit Task 6 (Days 1, 2):

- NRC staff to review calculations supporting the analysis of basemat sliding.

Audit Task 7 (Days 3, 4):

- NRC staff to review calculations supporting the seismic analysis of the Turbine Building; i.e., SSSI effects.

Audit Task 8 (Day 5, AM):

- NRC staff and MHI discuss and compile the audit commitments and action items; conduct Exit meeting.

Additional Information and Material Necessary for the Regulatory Audit:

The NRC staff requests MHI to make available the documents discussed in the audit scope. MHI is also requested to identify other documents, which it deems as necessary to support the NRC staff's audit, outlined under the audit tasks and any documents or calculations referenced by them. MHI is also requested to prepare a list of the documents made available, 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 request for additional information.

The NRC staff requests access (guided by MHI/URS) to ANSYS and detailed and dynamic models (including SASSI) and numerical results, as needed during the audit to address the staff's questions.

Logistics:

The audit will be conducted at the URS offices in Princeton, NJ and will begin on September 23, 2013. An escort is requested to meet the audit team in the lobby of the building at 12:45 p.m. on the first day. The entrance briefing is scheduled for 1:00 p.m. An exit briefing will be tentatively scheduled for Friday morning (note that this may change according to the requirements of the audit and availability of principals).

The NRC staff request space for the team members to meet privately and discuss the progress of the audit. Audit team members will bring computers for note taking and preparation of a report on the audit. In addition to workspace with power for the team's computers, the NRC staff requests access to a printer. Finally, please arrange a teleconference line to permit the project manager, and NRC headquarters management to participate as needed.

Audit Team:

Mohamed Shams, NRC, Structural Engineering Branch Chief  
Bret Tegeler, NRC, Structural Engineer  
Robert Roche-Rivera, NRC, Structural Engineer  
Rich Morante, NRC Consultant (Seismic)  
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Joseph Braverman, NRC Consultant (Seismic)  
Dennis Galvin, NRC, Project Manager, or  
Stephen Monarque NRC, Project Manager

Deliverables:

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

References:

1. MUAP-10006-SRI-P, Revision 3, Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant, November, 2012.
2. MUAP-12002-P, Revision 1, Sliding Evaluation and Results, January, 2013.
3. Letter Response to RAI 1018-7083, dated July 19, 2013.
4. MUAP-11007-P, Revision 2, Ground Water Effect on SSI, November, 2012.

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cc: See next page

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**NRC-001**

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(Revised 07/25/2013)

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