September 20, 2013

Mr. Ikuo Otake, Quality Assurance
Department Manager
Mitsubishi Heavy Industries, Ltd.
1-1. Wadasaki-Cho 1-Chome, Hyogo-Ku
Kobe, 652-8585, Japan

SUBJECT: NUCLEAR REGULATORY COMMISSION INSPECTION REPORT
NO. 99901030/2013-201, NOTICE OF NONCONFORMANCE

Dear Mr. Otake:

From August 5-9, 2013, the U.S. Nuclear Regulatory Commission (NRC) staff conducted an inspection of Mitsubishi Heavy Industries, Ltd (MHI) at the Mitsubishi Nuclear Energy Systems, Inc. offices in Arlington, Virginia. The purpose of this inspection was to assess MHI's compliance with the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 21, "Reporting of Defects and Noncompliance," and selected portions of Appendix B, "Quality Assurance Program Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

This inspection was performed to verify that the documented MHI Root Cause Analysis and supporting corrective actions were consistent with the requirements of 10 CFR Part 50, Appendix B Criterion XVI, Corrective Action. Specifically, that in the case of significant conditions adverse to quality, measures were taken by MHI to assure that the cause of the condition was determined and corrective action were taken to preclude repetition. The vendor inspection focused on the implementation of the areas of the MHI quality assurance (QA) program and Part 50 Appendix B specific to the documented MHI root cause analysis and corrective actions relative to the San Onofre Nuclear Generating Station Unit 2 and Unit 3 replacement steam generator tube issues.

Additionally, the inspection evaluated if sufficient corrective action was taken by MHI to preclude the design interface control issues that led to the San Onofre Nuclear Generating Station replacement steam generator tube failures from being introduced into future U.S. design and fabrication activities.

The enclosed report presents the results of this inspection. This NRC inspection report does not constitute NRC endorsement of MHI's overall QA or 10 CFR Part 21 programs. During this inspection, one potential notice of nonconformance was identified related to inadequate design interface control between different design sections within the MHI organization. Specifically, MHI failed to ensure adequate design interface control between the MHI Steam Generator Design Section and the MHI Takasago Research and Development Center, related to the thermal hydraulic and vibration analyses used for aspects of the San Onofre Nuclear Generating Station, Unit 2 and Unit 3 replacement steam generator design. Specifically, the output of the FIT-III thermal and hydraulic code and input to the FIVATS vibration analysis code were not verified to be in accordance with MHI design requirements. MHI failed to convert the

wide gap flow velocity output results from the FIT-III analysis to narrow gap flow velocities needed as input for the FIVATS vibration analysis code.

Please provide a written statement or explanation within 30 days from the date of this letter in accordance with the instructions specified in the enclosed Notice of Nonconformance. We will consider extending the response time if you show good cause for us to do so.

In accordance with 10 CFR 2.390, "Public Inspections, Exemptions, Requests for Withholding," of the NRC's "Rules of Practice," a copy of this letter, its enclosures, and your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's Agencywide Document Access and Management System, which is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html.

To the extent possible (and if applicable), your response should not include any personal privacy, proprietary, or Safeguards Information (SGI) so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, please provide a bracketed copy of your response that identifies the information that should be protected, as well as a redacted copy of your response that deletes such information. If you request that such material be withheld from public disclosure, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If SGI is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, "Protection of Safeguards Information: Performance Requirements."

Sincerely,

/RA/

Michael Cheok, Acting Director
Division of Construction Inspection
and Operational Programs
Office of New Reactors

Docket No. 99901030

Enclosures:
1. Notice of Nonconformance
2. Inspection Report No. 99901030/2013-201
and Attachment(s)

wide gap flow velocity output results from the FIT-III analysis to narrow gap flow velocities needed as input for the FIVATS vibration analysis code.

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Sincerely,

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NOTICE OF NONCONFORMANCE

Mitsubishi Heavy Industries, Ltd
1-1. Wadasaki-Cho 1-Chome, Hyogo-Ku
Kobe, 652-8585, Japan

Docket No. 99901030
Report No. 2013-201

Based on the results of a U.S. Nuclear Regulatory Commission (NRC) inspection of Mitsubishi Heavy Industries, Ltd (MHI) conducted at the Mitsubishi Nuclear Energy Systems offices in Arlington, Virginia, from August 5 through August 9, 2013, certain activities were not conducted in accordance with NRC requirements that were contractually imposed upon MHI by its customers or by NRC licensees.

Criterion III of Appendix B to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, states, in part, that, "measures shall be established to assure that applicable regulatory requirements and the design basis…are correctly translated into specifications, drawings, procedures, and instructions. It also states, in part, that, "measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces."

Contrary to the above, during the design of replacement steam generators for Southern California Edison, from approximately 2004 to 2008, MHI did not establish measures for control of design interfaces between the MHI Steam Generator Design Section and the MHI Takasago Research and Development Center, related to the thermal hydraulic and vibration analyses used for aspects of the San Onofre Nuclear Generating Station, Unit 2 and Unit 3 replacement steam generator design. Specifically, the output of the FIT-III thermal-hydraulic code and input to the flow induced vibration analysis software (FIVATS) vibration code were not verified to be in accordance with MHI design requirements. MHI failed to convert the wide gap flow velocity output results from the FIT-III analysis to narrow gap flow velocities needed as input for the FIVATS vibration analysis code.

This issue has been identified as Nonconformance 99901030/2013-201-01

Please provide a written statement or explanation to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, DC 20555-0001, with a copy to the Chief, Construction Mechanical Vendor Branch, Division of Construction Inspection and Operational Programs, Office of New Reactors, within 30 days of the date of the letter transmitting this Notice of Nonconformance. This reply should be clearly marked as a "Reply to a Notice of Nonconformance" and should include for each noncompliance: (1) the reason for the noncompliance or, if contested, the basis for disputing the noncompliance; (2) the corrective steps that have been taken and the results achieved; (3) the corrective steps that will be taken to avoid further noncompliance; and (4) the date when the corrective action will be completed. Where good cause is shown, consideration will be given to extending the response time. Because your response will be made available electronically for public inspection in the NRC Public Document Room or from the NRC's Agencywide Documents Access and Management System, which is accessible from the NRC web site at http://www.nrc.gov/reading-rm/adams.html, to the extent possible it should not include any personal privacy, proprietary, or Safeguards Information (SGI) so that it can be made available to the public without redaction. If personal privacy or proprietary information is necessary to provide an acceptable response, then please provide a bracketed copy of your response that identifies the information that

should be protected and a redacted copy of your response that deletes such information. If you request that such material be withheld, you must specifically identify the portions of your response that you seek to have withheld and provide in detail the bases for your claim of withholding (e.g., explain why the disclosure of information will create an unwarranted invasion of personal privacy or provide the information required by 10 CFR 2.390(b) to support a request for withholding confidential commercial or financial information). If SGI is necessary to provide an acceptable response, please provide the level of protection described in 10 CFR 73.21, "Requirements for the Protection of Safeguards Information."

Dated this 20th day of September 2013.

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NEW REACTORS
DIVISION OF CONSTRUCTION INSPECTION AND OPERATIONAL PROGRAMS
VENDOR INSPECTION REPORT

Docket No.:	99901030	
Report No.:	99901030/2013-201	
Vendor:	Mitsubishi Heavy Industries, Ltd. 1-1. Wadasaki-Cho 1-Chome, Hyogo-Ku Kobe, 652-8585, Japan	
Vendor Contact:	Mr. Ikuo Otake, Quality Assurance Department Manager Mitsubishi Heavy Industries Telephone: 81-78-672-3782 E-mail: ikuo_otake@mhi.co.jp	
Nuclear Industry Activity:	Mitsubishi Heavy Industries (MHI) manufactures safety-related and American Society of Mechanical Engineers Boiler and Pressure Vessel Code items and components. MHI supplies reactor vessels, steam generators, reactor internals, and balance of plant components for the nuclear industry and has provided some of these components to the current U.S. fleet of nuclear reactors as replacement components.	
Inspection Dates:	August 5 - 9, 2013, (Arlington, VA))	
Inspection Team Leader:	Richard McIntyre	NRO/DCIP/MVIB
Inspection Team Members:	Laura Dudes	NRO/Director/DCIP/Sr Mgmt Rep
	Edward Roach	NRO/DCIP/MVIB/Team Manager
	Jonathan Ortega	NRO/DCIP/MVIB
	Greg Werner	R IV/SPB/Inspection and Assessment Lead
	Emmett Murphy	NRR/DE/ESGB
	Andrew Johnson	NRR/DE/ESGB
Approved by:	Edward H. Roach, Chief Mechanical Vendor Inspection Branch Division of Construction Inspection and Operational Programs Office of New Reactors	

EXECUTIVE SUMMARY

Mitsubishi Heavy Industries, Ltd.
99901030/2013-201

The U.S. Nuclear Regulatory Commission (NRC) conducted this inspection to verify that the Mitsubishi Heavy Industries, Ltd. (MHI) implemented a quality assurance (QA) program that complies with the requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." The NRC inspection team conducted the inspection of MHI at the Mitsubishi Nuclear Energy Systems offices in Arlington, Virginia, from August 5 through 9, 2013.

The purpose of this vendor inspection was to verify that the documented MHI root cause analysis and supporting corrective actions were consistent with the requirements of 10 CFR Part 50, Appendix B Criterion XVI, Corrective Action, and that in the case of significant conditions adverse to quality, measures were taken to assure that the cause of the condition was determined and corrective actions were taken to preclude repetition.

This vendor inspection focused on the implementation of the areas of the MHI QA program and Part 50 Appendix B specific to the documented MHI root cause analysis and specific corrective actions relative to the Southern California Edison San Onofre Nuclear Generating Station (SONGS), Unit 2 and Unit 3 replacement steam generator (RSG) tube issues.

Finally, the inspection evaluated if sufficient corrective action was taken by MHI to preclude the issues that led to the SONGS RSG tube failures from being introduced into future U.S. design and fabrication activities.

Review of Root Cause

The inspection reviewed the programmatic MHI "Root Cause Analysis Report for tube wear identified in the Unit 2 and Unit 3 Steam Generators of San Onofre Nuclear Generating Station," Revision 0, in order to determine if the two root and three contributing causes were determined using a systematic methodology to appropriately address the significant condition adverse to quality. As part of this review, the inspection team made an assessment as to the adequacy of the extent of condition review, extent of cause review, and corrective actions taken and/or planned to be taken to preclude repetition. The review included looking at the following items:

- Correspondence between senior managers at Southern California Edison and MHI
- Design consultation purchase orders
- Design review meeting minutes and presentations
- Third party design review documents
- Operating experience – both internal and external to MHI
- Draft root cause evaluation reports and presentations
- Design specifications
- MHI procedures
- Numerous e-mails

The inspection team also interviewed a number of individuals that participated in the root cause evaluation to understand what was reviewed and how the cause evaluation dispositioned the results.
The inspection team concluded that the MHI root and contributing causes were programmatically and technically reasonable. The corrective actions identified and implemented to the address the root and contributing causes were reasonable and should prevent the same types of errors from being introduced during future design and fabrication activities. No findings were identified.

Review of Corrective Action

The inspection evaluated if sufficient corrective action was taken by MHI to preclude the issues that led to the SONGS RSG tube failures from being introduced into future U.S. design and fabrication activities. The inspection team reviewed Corrective Action Reports (CAR) written to support MHI's root cause analysis results for SONGS RSG tube wear vibration issues. This included the review of the specific cause that led to the corrective actions, the extent of condition, and the preventive actions to preclude repetition.

The team verified that MHI took corrective actions related to the identified FIT-III computer code issues and commercial grade dedication for other non safety-related computer programs. Also, as part of the corrective actions and extent of condition, MHI revised all the software procedures to include measures to ensure that the software was used within their limitations as applicable. As part of the extent of condition, MHI took action to evaluate all the software uses across the different design centers, to dedicate that software, and to revise their respective procedures as applicable. MHI dedicated all the software that could be used in future safety-related design activities.

Also, the team verified that MHI conducted a program review for design of all pressure boundary components such as steam generators, reactor vessels, core internals, pressurizer, reactor coolant piping, and control rod drive mechanisms. This review was performed to identify other design features and assumptions that needed to be programmatically captured to prevent repetition of similar design issues that led to the SONGS RSG tube failures. This program review included an evaluation of the Steam Generator Design Section, Reactor Internal Design Section, and the Component Design Section. The team verified that the identified changes were incorporated accordingly and are adequate to resolve the significant conditions adverse to quality documented in several MHI CARs.

During the review of the CARs, Nonconformance 99901030/2013-201-01 was identified for MHI's failure to ensure adequate design interface control between the MHI Steam Generator Design Section and the MHI Takasago Research and Development Center, related to the thermal hydraulic and vibration analyses used for aspects of the SONGS Unit 2 and Unit 3 RSG design. Specifically, the output of the FIT-III thermal-hydraulic code and input to the flow induced vibration analysis software (FIVATS) vibration code were not verified to be in accordance with MHI design requirements. MHI failed to convert the wide gap flow velocity output results from the FIT-III analysis to narrow gap flow velocities needed as input for the FIVATS vibration analysis code.

REPORT DETAILS

1. Root Cause Analysis

a. Inspection Scope

The inspection team reviewed the Mitsubishi Heavy Industries (MHI) programmatic "Root Cause Analysis Report for tube wear identified in the Unit 2 and Unit 3 Steam Generators of San Onofre Nuclear Generating Station (SONGS)," Revision 0, in order to determine if the two root and three contributing causes were determined using a systematic methodology to appropriately address the significant condition adverse to quality. As part of this review, the inspection team made an assessment as to the adequacy of the extent of condition review, extent of cause review, and corrective actions taken and/or planned to be taken to preclude repetition. The review included looking at the following items:

- Correspondence between senior managers at Southern California Edison and MHI
- Design consultation purchase orders
- Design review meeting minutes and presentations
- Third party design review documents
- Operating experience – both internal and external to MHI
- Draft root cause evaluation reports and presentations
- Design specifications
- MHI procedures
- Numerous e-mails

The inspection team also interviewed a number of individuals that participated in the root cause evaluation to understand what was reviewed and how the cause evaluation dispositioned the results of the various methods. This NRC inspection was focused specifically on MHI's root cause analysis (RCA) and corrective actions.

b. Observations and Findings

b.1 Background

The MHI Three-Dimensional Thermal and Hydraulic Analysis computer code (FIT-III) was initially developed in 1978 for use in modifying Westinghouse designed square pitch tube steam generators. In 1992, the MHI Takasago Research and Development Center (Takasago) modified FIT-III for use on triangular pitch tube steam generators. At the time of the conversion to triangular pitch, the output of FIT-III was the wide gap velocity versus the narrow gap velocity required to be input into the flow induced vibration analysis software (FIVATS) vibration analysis code. The MHI Steam Generator Design Section (SGDS) thought the output of FIT-III was the narrow gap velocity. All MHI designed triangular pitch steam generators up through SONGS (total of five nuclear power plants) used the incorrect gap velocities. However, no other operating steam generator has developed fluid elastic instability as found at SONGS.

b.2 MHI Root Case Analysis

The inspection team determined that MHI used a number of accepted techniques to complete their programmatic root cause. The methods used by MHI were the cause-effect analysis, barrier analysis, and change analysis which resulted in the identification of two root causes and

three contributing causes. As part of the review, the inspection team examined the corrective actions taken for each root and contributing cause as follows:

- Root Cause 1: Insufficient programmatic requirement to ensure effective anti-vibration bar contact force to prevent in-plane fluid elastic instability and random vibration (and subsequent wear) under localized thermal-hydraulic conditions that included high void fraction, high flow velocity, and high hydro-dynamic pressure.

  MHI revised Procedure 5BBB60-N01 "Procedure for Controlling of the Design Activities." The revised procedure requires all new steam generator designs to address the need for effective tube-to-anti-vibration bar contact force under localized thermal-hydraulic conditions that included high void fraction, high flow velocity, and high hydro-dynamic pressure. MHI also added a requirement to compare the steam generator design parameters to the design parameters of previous successful MHI steam generator designs, and provided training to all steam generator engineers on the SONGS steam generator event and the revised procedure.

- Root Cause 2: The design control process did not provide sufficient direction to ensure that an evaluation of the need for an analysis of flow induced vibration of the retainer bar was performed and verified.

  MHI revised Procedure 5BBB60-N01 "Procedure for Controlling of the Design Activities." The revised procedure requires evaluation of retainer bars, and other steam generator parts subject to flow induced vibration, to determine the different analyses (and the level of analysis) that need to be performed to support the steam generator design. MHI revised the engineer training program (for both new and existing employees) to include the necessary training for engineers to be able to determine the required analyses of each steam generator part subject to flow induced vibration.

- Contributing Cause 1: The FIT-III user manual and design procedure did not specify the need to convert the output for the triangular configuration that is used as an input to the vibration analysis.

  MHI developed Procedure MS5BBB1-N0002, "Procedure for Tube Vibration Analysis," and revised procedure KAS-20120303, "FIT-III Code Description Note (Code User's Manual)" that supports the use of both square and triangular pitch tube configurations. The inspector determined that the new procedure on tube vibration analysis provides a high-level overview of the tube vibration analysis process and lists the basic inputs and outputs that are calculated in each step of the tube vibration analysis. The appendices of the vibration analysis procedure address the details of how the damping ratio and critical factors for in-plane flow elastic instability are calculated. The review of the Code User's Manual showed that equations, detailed color figures, and text have been added to the manual to show the difference between the wide and narrow gaps and to clearly state the need to convert wide gap velocity to narrow gap velocity for triangle pitch steam generators. The training records documented attendance at the training and each participant's acknowledgement of understanding of the training.

- Contributing Cause 2: Insufficient programmatic requirement for code validation procedure (only one of five validation methods was performed).

MHI determined that future computer software validations should require additional comparison to other validation methods in steam generator design analysis, if necessary, depending on the complexity and/or importance of the analysis. MHI added validation requirements to Procedure 5BB60-N08, "Procedure for Development and Control of Computer Software." The inspection team determined that this procedure showed that the scope of the additional validation requirements was based on whether the analysis being performed by the computer software was defined as complex or important. Complex analyses were defined as those analyses that analyze physical phenomena, such as fluid dynamic simulations or structural analyses. Important analyses were defined as safety related analyses.

- Contributing Cause 3: The design process did not require the systematic identification of operationally significant changes from the current design to the new design and require the comprehensive evaluation of the effects of individual changes and the cumulative effect of all changes to assure risks associated with the changes were understood and addressed.

  MHI added new requirements to Procedure 5BBB60-N01, "Procedure for Controlling of Design Activities," to systematically identify operationally significant changes from the current design to the new design, and require comprehensive evaluation of both individual and cumulative changes. The inspector identified that the procedure was modified by adding requirements for: 1) a tube vibration report, 2) a checklist for the structural integrity analysis of parts in the tube bundle, 3) the design analysis to be documented in a detailed checklist, 4) adding a requirement for an evaluation of the cumulative effects of all design changes, and 5) the design features review to be documented in a detailed checklist. The detailed checklists referenced above were added to the procedure as two new appendices.

The inspection team reviewed the two root causes and the three contributing causes identified in the MHI root cause analysis, to assess whether the causes were programmatically and technically reasonable, whether corrective actions were taken to address the root and contributing causes, and whether the corrective actions taken will prevent the issues that led to the SONGS RSG tube failures from being introduced into future U.S. design and fabrication activities. Based on the documents reviewed, the inspection team concluded that the root and contributing causes were both programmatically and technically reasonable and should prevent the same type of design errors from being introduced in the future.

Conclusions

The inspection team concluded that the MHI root and contributing causes were programmatically and technically reasonable. The corrective actions identified and implemented to address the root and contributing causes were reasonable and should prevent the same types of design errors from being introduced during future design and fabrication activities. No findings were identified.

2. Corrective Action

a. Inspection Scope

The inspection team reviewed the implementation of MHI's quality assurance program to determine if significant conditions adverse to quality have been identified and corrected relative

to SONGS Unit 2 and Unit 3 RSG tube failures. Also, the Inspection team looked into whether the corrective actions taken to address the significant conditions adverse to quality identified in MHI's RCA were appropriate to resolve the significant conditions adverse to quality to preclude the types of design errors that led to the SONGS RSG tube failures from being introduced into future U.S. design and fabrication activities.

The NRC inspection team reviewed CAR written to support MHI's RCA results for SONGS RSG tube wear vibration issues. This included the review of the specific cause that led to the corrective actions, the extent of condition, and the preventive actions to preclude repetition.

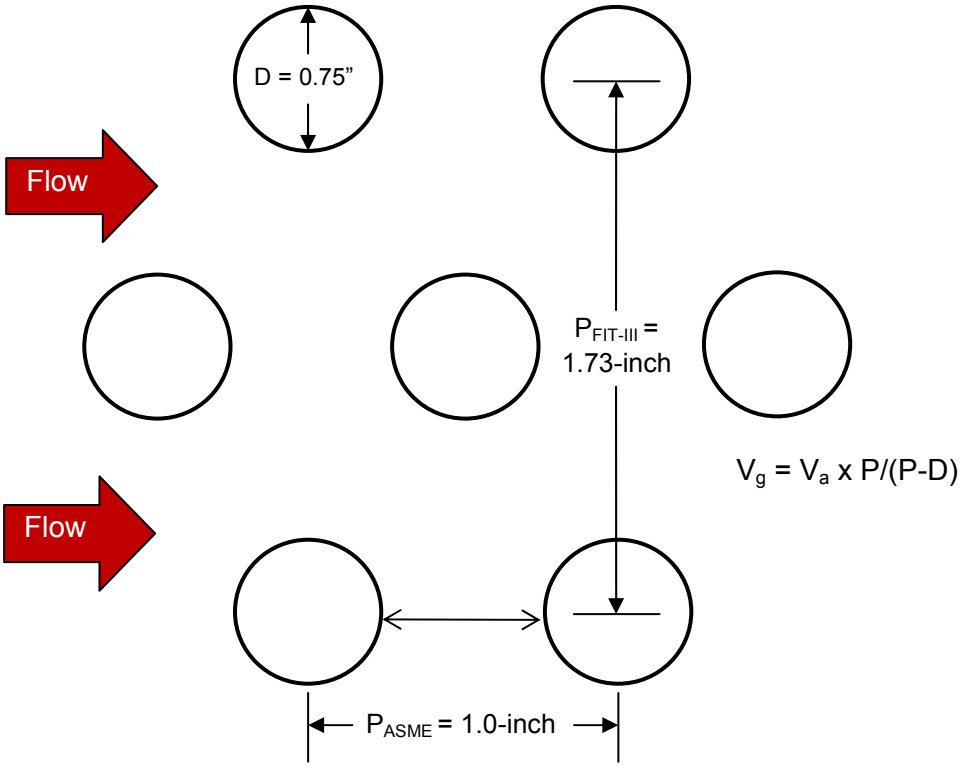
b. Observations and Findings

MHI identified that they had issued 19 CARs related to corrective actions for the SONGS RSG tube wear. All CARs had been previously closed by MHI prior to this inspection. During the review of the MHI CARs, the Inspection team noted that CARs-12-028, 12-037, 12-045, and 12-055 described deficiencies that were directly related to the lack of appropriate interface and coordination of design information among the participating design groups/sections within the MHI organization.

During the review of the MHI corrective actions, the team determined that the design interface control issue was addressed as part of these MHI CARS and specifically relates to the design interface control between the MHI Steam Generator Design Section and the MHI Takasago Research and Development Center.

CAR-12-028

CAR-12-028 was issued May 10, 2012, for using the incorrect fluid elastic velocity as input into the evaluation of FIVATS. Specifically, the SGDS had planned and documented that they had applied the analysis method of American Society of Mechanical Engineers (ASME) Code Section III Division 1, Non-Mandatory Appendix N-1300, "Flow Induced Vibration of Tubes and Tube Banks," in to the evaluation of flow induced vibration of the tubes. Flow velocity "V" used in the analysis is defined as gap velocity between the tubes as shown in the figure below, and the gap of tube arrangement in SONGS RSG should be defined as "P-D." (narrow gap - 1.0 inches). The MHI SGDS applied the different flow velocity which is defined by another gap (wide gap – 1.73 inches).



It is important to note that Takasago performs the thermal hydraulic analysis (FIT-III) for the steam generators and provides the output to MHI SGDS in the form of a spreadsheet containing various technical information, including gap velocities. The spreadsheet information is used for input into the vibration model which is performed by the SGDS group. The velocity output from FIT-III is based on the wide gap, which is different from the gap velocity defined in the ASME code for a triangular array. In order to calculate the gap velocity based on the narrow gap as defined in the ASME code, a post process conversion for the gap velocity was necessary. The SGDS thought that the gap velocities provided by Takasago were the narrow gap, whereas Takasago knew the velocities were the wide gap. The situation which resulted in the use of the wide gap flow velocity in the fluid elastic vibration analysis, which is different from the narrow gap velocity defined in ASME code, was due to inadequate design interface control. The design engineers in SGDS recognized the fluid elastic vibration analysis needed to be performed using the gap velocity based on the narrow gap as defined by the ASME code.

At the time of the design of the SONGS RSGs, the FIT-III code program manual did not provide an explanation or definition of which velocity was provided as an output (based on the wide or narrow gap). Furthermore, the SGDS procurement specification for FIT-III analysis that was provided to Takasago failed to include a clear description of the requirements to output the narrow gap velocity defined in the ASME code.

The Inspection team identified these issues as Nonconformance 99901030/2013-201-01 for MHI’s failure to ensure adequate design interface control between the MHI SGDS and the Takasago Research & Development Center related to the thermal hydraulic and vibration analyses used for aspects of the SONGS RSG design. Specifically, the output of the FIT-III thermal and hydraulic code and input to the FIVATS vibration analysis code were not verified to be in accordance with MHI design requirements. MHI failed to convert the wide gap flow

velocity output results from the FIT-III analysis to narrow gap flow velocities needed as input for the FIVATS vibration analysis code.

As a result of certain deficiencies identified in CAR-12-028, MHI issued CARs-12-045, and 12-055 to address some of the contributing causes addressed in CAR-12-028.

CAR-12-045

CAR-12-045 was generated on October 15, 2012, to identify that proper user documentation for the FIT-III computer code, used to calculate gap velocity was not provided to the user. Specifically, the user documentation for FIT-III did not provide a definition of gap velocity and acceptable ranges for calculation parameters. As part of the extent of condition, MHI reviewed all the software used during the design of SONGS RSG to identified additional software that was developed by Takasago. For the software identified along with FIT-III, MHI revised the user manual for each of the software programs. The FIT-III manual was revised to include the gap definition for the velocity and applicable parameter ranges. As part of the corrective action taken, MHI confirmed and documented objective evidence that the user documents of both vibration analysis software (IVHET and FIVATS) that use FIT-III output as input, shall include input/output specification to ensure that the correct gap velocity is being used.

CAR-12-055

CAR-12-055 was issued on September 3, 2012, as a result of an audit finding performed during a 2012 periodic joint U.S. utility audit. MHI did not provide a description of system limitations for the use of FIT-III (both the user manual and verification report) and did not provide clear guidance to distinguish between applications when using Department Procedure 5BB60-N08, "Procedure for Development and Control of Computer Software." The FIT-III software documentation did not include any limitations specific to the output range. During the development of the FIT-III documentation by SGDS, the engineers failed to recognize the necessity to provide a clear description of the importance of validated output range and that the software should be used only within the validated output ranges. As a result, the description of the system limitations included in the documentation used during the design of the SONGS RSG, did not explicitly state that the software should only be used within the validated output ranges.

During the process of evaluating CAR 12-055, the MHI SGDS engineers recognized that the MHI Quality Assurance Manual, section 1.3.7.1.1, includes requirements for use of computer software as required by ASME NQA-1a-2009 (Quality Assurance Requirements for Nuclear Facility Applications). MHI SGDS engineers did not provide adequate description to implement controls for the following requirements in 5BB60-N08: (a) the computer program shall be verified to show that its produces correct solutions for the encoded mathematical model within defined limits for each of the parameters employed and (b) the encoded mathematical model shall be shown to produce valid solutions to the physical problem associated with the particular application.

MHI corrected the failure of the SGDS engineers to recognize the requirements for use of computer software as described in NQA-1 by revising the FIT-III software documents to include system limitations. Also, Procedure 5BB60-N08 was revised to include specific controls to implement the requirements of NQA-1. At the time of the inspection, MHI presented objective evidence of the updated documents and the completion of the indoctrination to all the affected personnel as a result of the revision to the documents. Finally, as part of the extent of condition

review, MHI took action to evaluate all the software uses across the different design centers and revised their respective procedures as applicable.

CAR-12-037

CAR 12-037 was issued on June 28, 2012, as a result of SGDS engineers omitting five commercial software analysis programs that required commercial grade dedication as part of CAR-11-012 implementation. Specifically, the SGDS engineers failed to properly evaluate if existing software that was acquired before the implementation of the software control procedure required commercial grade dedication to be performed. MHI did not recognize that the FIT-III, FIVATS and IVHET being used for the safety-related flow induced vibration analysis for the SONGS RSG design activity. At the time of the CAR-11-012 evaluation of the software analysis programs requiring dedication, SGDS did not categorize the software computer programs (FIT-III, FIVATS, and IVHET) as safety-related because the analysis was categorized as non-mandatory in accordance with the ASME code Non-Mandatory Appendix N-1300. Using that judgment SGDS did not to perform a commercial grade dedication of the software (FIT-III, FIVATS, and IVHET) used to calculate the flow induced vibration. As a result of this error, as part of CAR-12-037 corrective actions, MHI dedicated all the software and performed an extent of condition to verify there were not any other commercial software programs that were omitted and needed to be dedicated. Also, the SGDS design engineers were trained as to the proper classification that flow induced vibration analysis is considered a safety related activity.

c. Conclusion

The inspection team found that the corrective actions taken to the address the root and contributing causes were reasonable and should prevent the same type of design errors from occurring during future design and fabrication activities. However, the Inspection team identified Nonconformance 99901030/2013-201-01 for MHI's failure to ensure adequate design interface control between the MHI Steam Generator Design Section and the Takasago Research and Development Center related to the thermal hydraulic and vibration analyses used for aspects of the SONGS RSG design

3. Entrance and Exit Meetings

On August 5, 2013, the Inspection team discussed the scope of the inspection with Mr. Ikuo Otake, MHI Quality Assurance Department Manager, other MHI staff members and MNES staff at MNES offices in Arlington, Virginia. On August 9, 2013, the Inspection team presented the inspection results and observations during an exit meeting with MHI and MNES staff. The attachment to this report lists the entrance and exit meeting attendees, as well as those individuals interviewed by the Inspection team.

ATTACHMENT

1. **ENTRANCE / EXIT MEETING ATTENDEES AND PERSONS CONTACTED**

Name	Organization	Email	Entrance	Exit
Richard McIntyre	NRC/NRO	Richard.McIntyre@nrc.gov	X	X
Laura Dudes	NRC/NRO	Laura.Dudes@nrc.gov	X	X
Emmett Murphy	NRC/NRR	Emmett.Murphy@nrc.gov	X	X
Andrew Johnson	NRC/NRR	Andrew.Johnson@nrc.gov	X	X
Jonathan Ortega	NRC/NRO	Jonathan.Ortega-Luciano@nrc.gov	X	X
Edward H. Roach	NRC/NRO	Edward.Roach@nrc.gov	X	X
Greg Werner	NRC/R-IV	Greg.Werner@nrc.gov		X
Ikuo Otake	MHI	Ikuo_Otake@mhi.co.jp	X	X
Hitoshi Kaguchi	MNES	Hitoshi_Kaguchi@mnes-us.com	X	X
M. Vann Mitchell	MNES	Vann_Mitchell@mnes-us.com	X	X
Frank Gillespie	MNES	FrankGillespie@mnes-us.com	X	
Kathleen L. Horvat	MNES	Kathy_Horvat@mnes-us.com		X
Bruce Hinkley	Consultant	BHink20@aol.com	X	X
John O'Neill	Pillsbury	John.ONeill@pillburylaw.com		X

2. **INSPECTION PROCEDURES USED**

Inspection Procedure 43003, "Reactive Inspection of Nuclear Vendors," dated April 25, 2011

3. **LIST OF ITEMS OPENED, CLOSED, AND DISCUSSED**

Item Number	Status	Type	Description
99901030/2013-201-01	Open	NON	Criterion III

4. DOCUMENTS REVIEWED

Document Number	Title	Revision/Date
	Design Review Meeting	December 14, 2005
	Design Review Meeting #2 and Technical Discussion Report	February 14 – 17, 2005
	Technical Discussion Action Items	May 23, 2005
	Design Review Meeting, May 24 – 25, 2005 in Kobe, Japan	May 24 – 25, 2005
	Record of Technical Discussion and Design Review Meetings The week of July 11, 2005 in Kobe, Japan	Week of July 11, 2005
	Design Review and Technical Meetings August 17 – 20, 2005, Attachment 8, "Technical Discussion on RSG Performance Topics on Aug. 2005"	August 17 – 20, 2005
	DRM #6, Record of Design Review and Technical Meetings, October 17-21, 2005 in Kobe, Japan, Attachment 6, "Design Review of Anti-Vibration Bar"	October 17 – 21, 2005
	Record of Technical Discussion Meeting December 5-9, 2005 in Kobe Japan, Attachment 18, "Technical Discussion of Anti-Vibration Bar Fabrication," Slide 37, "Comparison between average gap flow velocity in U-bend region of SONGS and that of domestic plant"	December 5 – 9, 2005
	Record of the #8 Design Review and Technical Meeting March 13-17, 2006 in Kobe, Japan	March 13-17, 2006
	MHI Programmatic Root Cause – Draft	July 6, 2012
	MHI Programmatic Root Cause – Draft	August 10, 2012
	MHI Programmatic Root Cause – Draft	August 30, 2012
	MHI Programmatic Root Cause – Draft	August 26, 2012
	[Programmatic] Root Cause Analysis Report for tube wear identified in the Unit 2 and Unit 3 Steam Generators of San Onofre Nuclear Generating Station	Revision 0 October 12, 2012
	Letter from Dwight E. Nunn, Vice President SCE to Akira Sawa, General Manager, MHI, LTD Subject: Replacement Steam Generators San Onofre Nuclear Generating Stations, Units 2 & 3	November 30, 2004
	Letter from Akira Sawa, General Manager, MHI, LTD., to Dwight E. Nunn, Vice President SCE Subject: Replacement Steam Generators San Onofre Nuclear Generating Stations, Units 2 & 3	March 18, 2005
	RCA PowerPoint Presentation, "Summary of 'Root Cause Analysis for tube wear identified in the Unit 2 and Unit 3 Steam Generators of San Onofre Nuclear Generating Station (UES-20120254 R0'"	October 19, 2012

Document Number	Title	Revision/Date
	Email to Paul Langford from MHI on the December 2005 Technical Discussion Meeting – Attachment 18, Technical Discussion of Anti-Vibration Bar Fabrication	November 28, 2005
	Email from Paul Langford to MHI, "Review Request: Meeting Material for AVB Fabrication [Attachment 18]"	November 30, 2005
5BB60-N07	ASME Code Job Procedure for Design Verification	Revision 1 March 27, 2012
5BB60-N08	Procedure for Development and Control of Computer Software	Revision 4 October 11, 2012
5BBB60-N01	Procedure for Controlling of Design Activities	Revision 0 May 31, 2011
5BBB60-N01	Procedure for Controlling of Design Activities	Revision 9 May 31, 2012
5ZD91-53 (1)	RCA (Root Cause Analysis) Procedure	Revision 1 February 17, 2012
KAE-20050029	Design Consultation	Revision 3 May 19, 2005
KAE-20050098	Design Consultation	Revision 0 October 21, 2005
KAE-20050098	Design Consultation	Revision 1 October 21, 2005
KAE-20060041	Design Consultation	Revision 0 April 5, 2006
KAE-20060060	Design Consultation	Revision 4 April 28, 2006
KAE-20060125	Design Consultation	Revision 0 August 7, 2006
KAE-2007004	Design Consultation	Revision 0 February 9, 2007
KAS-20050201	FIT-III Code Validation Report	Revision 2 August 25, 2005
KAS-20050202	FIT-III Code Description Note (Code User's Manual)	Revision 1 September 1, 2005
KAS-20120302	FIT-III Code Validation and Qualification Report	Revision 1 October 4, 2012
KAS-20120303	FIT-III Code Description Note (Code User's Manual)	Revision 2 October 4, 2012
L5-04FZ802	Certification of Design Report	Revision 1 June 5, 2007
L5-04GA428	Design of Anti-Vibration Bar	Revision 5 September 30, 2005
L5-04GA504	Evaluation of Tube Vibration	Revision 5 February 25, 2005
L5-04GA588	Supplemental Technical Evaluation Report	Revision 0 October 22, 2012

Document Number	Title	Revision/Date
L5-04GA591	Validity of Use of the FIT-III Results during Design	Revision 3 January 19, 2012
MS5BBB1-N0002	Procedure for Tube Vibration Analysis	Revision 1 October 18, 2012
UES-20120254	"Root Cause Analysis Report for tube wear identified in the Unit 2 and Unit 3 Steam generators of San Onofre Nuclear Generating Station"	Revision 0 October 12, 2012
M. K. Yang	MEMO- Flow-Induced Vibration of Power and Process Plant Components	July 2001
CAR-11-012(1)	"The computer software which existed from before software control procedure establishment were not CGD"	Revision 1 June 14, 2011
CAR-12-028(3)	"SGDS applied velocity which is different from the analysis procedure decided by SGDS"	Revision 3 May 10, 2012
CAR-12-037(2)	"The CGD of existing software acquired before software control procedure establishment were performed in CAR-11-12. But the analysis software (FIT-III, FIVATS, IVHET) were omitted from the objects dedicated and CGD had not been performed "	Revision2 June 28, 2012
CAR-12-045(1)	"Proper user documentation for computer code used to calculate Gap Velocity was not provided to the user"	Revision 1 October 8, 2012
CAR-12-046	"No guidance for use FIT-III was describe on the procedure"	August 8, 2012
CAR-12-048(0)	"Gap velocity and validation range"	August 3, 2012
Car-15-055(1)	"Findings were identified for SGDS during 2012 Periodic Joint U.S. Utility Audit."	Revision 1 September 3, 2012
CAR-12-067(0)	"Procedure for tube vibration analysis did not specify to ensure that the program used to calculate GAP Velocity has a user manual to support the use of MHI tube configuration"	Revision 1 October 2, 2012
CAR-12-068(0)	Procedure for development and control of computer software did not require the additional comparison to other validation methods in SG design analysis if necessary depending on complexity and/or importance of analysis"	Revision 0 October 2, 2012
CAR-12-069	Program design review for other SG designs procedures and primary pressure boundary components using senior engineer is needed to determine if other design features are assumptions that are not programmatically captured"	Revision 0 October 2, 2012
CAR-UGG-085(6)	"Steam Generator Tube to Tube Wear"	September 7, 2012