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Proprietary Notice
This letter forwards proprietary information in accordance with 10CFR2.390. Upon the removal of Enclosures 2 and 4, the balance of this letter may be considered non-proprietary.

MFN 13-007

Docket number: 05200010

February 19, 2013

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555-0001

Subject: NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Draft Response to RAI 3.9-292

References:

1. MFN 12-037 Letter from USNRC to Jerald G. Head, GEH, Subject: Request for Additional Information Letter No. 414 related to ESBWR Design Certification Application (DCD) Revision 9, received May 1, 2012.
2. MFN 12-043, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response to **RAI 3.9-269**, February 7, 2013.
3. MFN 13-003, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response for **RAI 3.9-270**, January 21, 2013.
4. MFN 12-045, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-271**, February 8, 2013.
5. MFN 12-046, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling

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Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response to **RAI 3.9-272**, January 24, 2013.

6. MFN 12-038, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – **RAI 3.9-273**, June 1, 2012.
7. MFN 12-040, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response to **RAI 3.9-274**, January 24, 2013.
8. MFN 12-047, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-275**, February 13, 2013.
9. MFN 12-048, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response to **RAI 3.9-276**, January 23, 2013.
10. MFN 12-086, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-277**, February 11, 2013.
11. MFN 12-049, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-278**, January 31, 2013.
12. MFN 12-050, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Response to **RAI 3.9-279**, January 24, 2013.
13. MFN 12-051, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-280**, February 15, 2013.
14. MFN 12-052, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – **RAI 3.9-281**, June 12, 2012.

15. MFN 12-070, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – **RAI 3.9-282**, June 5, 2012.
16. MFN 12-054, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-283**, February 14, 2013.
17. MFN 12-055, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-284**, February 14, 2013.
18. MFN 12-077, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Responses to **RAI 3.9-285 and RAI 3.9-286**, February 15, 2013.
19. MFN 12-058, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-287**, February 14, 2013.
20. MFN 12-059, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Final Response to **RAI 3.9-288**, February 8, 2013.
21. MFN 12-066, Revision 2, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Responses to **RAI 3.9-289, 3.9-290, and 3.9-291**, January 30, 2013.
22. MFN 12-065, Revision 1, Letter from Jerald G. Head to USNRC, NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – Final Responses to **RAI 3.9-293**, February 8, 2013.

In regard to the Requests for Additional Information that you have transmitted in your May 1, 2012 Letter, Reference 1, to support the NRC ESBWR Steam Dryer Methodology Audit conducted March 21 – 23, 2012 Docket 05200010, please find attached the GEH draft response to RAI 3.9-292. This response is considered draft in order to discuss and finalize changes to the ESBWR licensing basis before a revision to the Design Control Document (DCD) is issued in the near future.

Enclosure 1 contains the complete response, and is acceptable for public release. Separate from the response, Enclosure 2, which contains proprietary information, is a roadmap for reviewing the RAI responses in total and is considered a tool for reviewers and not part of the RAI response. Enclosure 3 is a public version of the roadmap. Enclosure 4 is a proprietary version of an engineering report and Enclosure 5 is a public version of the report. Enclosure 6 provides marked-up pages to the DCD for the changes described in the response. Enclosure 7 is an affidavit for withholding the proprietary information in Enclosure 2 and Enclosure 4.

If you have any questions concerning this letter, please contact Peter Yandow at 910-819-6378.

I declare under penalty of perjury that the foregoing information is true and correct to the best of my knowledge, information, and belief.

Sincerely,

Jerald Head

Jerald G. Head
Senior Vice President, Regulatory Affairs

Commitments: No additional commitments are made in this response.

Enclosures:

1. GEH Draft Response to RAI 3.9-292
2. NRC RAIs and Licensing Basis Changes Roadmap - Proprietary Version
3. NRC RAIs and Licensing Basis Changes Roadmap - Public Version
4. GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDE-33313P, Class III (Proprietary), Revision 3, February 2013
5. GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDO-33313, Class I (Non-Proprietary), Revision 3, February 2013
6. ESBWR Design Control Document Marked-Up Pages
7. Affidavit

cc: Glen Watford, GEH
Peter Yandow, GEH
Patricia Campbell, GEH
Mark Colby, GEH
Daniel Pappone, GEH
DRF Section 0000-0147-3921

Enclosure 7

MFN 13-007

Affidavit

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, **Jerald G. Head**, state as follows:

(1) I am the Senior Vice President, Regulatory Affairs of GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosures 2 and 4 of GEH's letter MFN 13-007, Jerald G. Head (GEH) to USNRC, "NRC Requests for Additional Information Related to the Audit of the Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document – GEH Draft Response to RAI 3.9-292," February 19, 2013. The GEH proprietary information in Enclosure 2 of MFN 13-007 is identified by a [[dark red, dotted underline inside double square brackets{3}]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding and determination of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act (FOIA), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies under the narrower definition of trade secret, within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over GEH and/or other companies.

b. Information that, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information that reveals aspects of past, present, or future GEH customer-funded development plans and programs, that may include potential products of GEH.

d. Information that discloses trade secret and/or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to the NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary and/or confidentiality agreements that provide for maintaining the information in confidence. The initial designation of this information as proprietary information and the subsequent steps taken to prevent its unauthorized disclosure are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited to a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary and/or confidentiality agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it communicates sensitive business information regarding commercial communications, plans, and strategies associated with future actions related to GEH's extensive body of ESBWR technology, design, and regulatory information and it's protection is important to the design certification process.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate

evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH. The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial. GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 19th day of February 2013.

Jerald Head

Jerald G. Head
GE-Hitachi Nuclear Energy Americas LLC

Enclosure 1

MFN 13-007

GEH Draft Response to RAI 3.9-292

NRC RAI 3.9-292

The staff's question is in regard to describing the changes that will be made to the [ESBWR licensing basis documents]. GEH is requested to describe the changes to the topical reports for ESBWR steam dryer analysis that will be made to rely on the SSES steam dryer data to benchmark the steam dryer analysis in support of the ESBWR design certification application.

GEH Response

This response addresses changes made to the ESBWR design certification licensing basis that are described in responses to other steam dryer Requests for Additional Information (RAIs). Changes to the ESBWR licensing basis documents are compiled in this response. Editorial changes to the licensing basis changes identified in the RAI responses may be reflected in the licensing basis changes in this response, but no technical content changes are intended to be addressed in this response. Also note that the Susquehanna Steam Electric Station (SSES) benchmark has been replaced with the Grand Gulf Nuclear Station (GGNS) benchmark in response to RAI 3.9-269.

Roadmap: A tool for cross-referencing the licensing basis changes to the associated RAIs is provided as Enclosure 2 (proprietary version) and Enclosure 3 (public version). This "roadmap" is not part of the response to RAI 3.9-292, but is considered a tool for purposes of identifying where specific RAIs and NRC feedback are addressed and what licensing basis changes are associated with the change.

Licensing Basis Changes: The table below identifies whether or not the GEH response to each of the NRC RAIs impacts the ESBWR licensing basis documents, and includes a brief summary of the nature of the changes. The table mentions whether the change impacts the ESBWR Design Control Document (DCD) or supporting engineering reports.

Design Control Document (DCD) Changes: A detailed change list describing changes to the ESBWR DCD is included below and reflects changes shown in the marked-up pages attached. These changes will be incorporated into the ESBWR DCD. The table of changes includes notes that describe changes to the content that may be different from the content described specifically in RAI responses. However, the information regarding the changes to the DCD will be finalized in the final response to RAI 3.9-292.

Engineering Report Changes: In addition to changes to the ESBWR DCD, supporting engineering reports are revised, and one report has been deleted. A revision for Engineering Report NED-33313, which is a final report, is included in this response because of changes related to multiple RAI responses for RAIs 3.9-269, 3.9-270, 3.9-277, 3.9-284, 3.9-285, and 3.9-293. Engineering Report NED-33408 is included in the response to RAI 3.9-269. Engineering Report NED-33312 is included in the response to RAI 3.9-293. These engineering reports replace Licensing Topical Reports that were previously approved versions, which are now superseded by the three reports listed below; and NED-33408, Supplement 1, is deleted.

These engineering reports are applicable only to the ESBWR steam dryer methodologies. This change from referring to these previously as topical reports is consistent with NRC guidance in LIC-500, Rev. 4 (12/2009), "Topical Report Process." This guidance was issued during the NRC review of the ESBWR design certification and GEH did not previously change the designated "type" of report, whether the NRC issued a separate Safety Evaluation Report or not (the ESBWR licensing basis was essentially complete by 12/2009 except for changes to address NRC Requests for Additional Information). It is expected that the NRC Supplemental Safety Evaluation Report will explain that these reports superseded the previous approved versions, as explained herein and as discussed in LIC-500, Rev. 4.

NRC LIC-500, Rev. 4, added the following note for design certification applications in Section 4.1.1 (page 2 of 23):

> NOTE: Technical reports submitted to support an application for design certification or plant-specific licensing actions are not defined as TRs under this program. A technical report is typically submitted by a vendor. The information in the technical report is subsequently captured in an application (perhaps by reference); however, the NRC's evaluation of that technical report is included in the SE for the design certification or plant-specific licensing application (a separate SE is not provided for each technical report).

The three engineering reports that support the ESBWR design certification steam dryer methodologies (proprietary and non-proprietary versions) are as follows:

- GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Acoustic Load Definition," NEDE-33312P, Class III (Proprietary), Revision 3, February 2013, and NEDO-33312, Class I (Non-Proprietary), Revision 3, February 2013.

- GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDE-33313P, Class III (Proprietary), Revision 3, February 2013, and NEDO-33313, Class I (Non-Proprietary), Revision 3, February 2013.

- GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDC-33408P, Revision 2, Class III (Proprietary), February 2013, and NEDO-33408, Revision 2, Class I (Nonproprietary), February 2013.

Table of RAI Responses and Licensing Basis Changes

RAI Number	RAI Summary	Licensing Basis Changes
3.9-269	The staff's question is in regard to submitting an end-to-end frequency-dependent steam dryer strain simulation validation using steam dryer loads computed using the GEH Plant-Based Load Evaluation (PBLE) method 1, along with described adjustments to the methodology and/or bias and uncertainty to ensure the strain gage spectra for an instrumented steam dryer are bounded.	MFN 12-043, Rev. 1 (02/07/2013). Changes to the ESBWR licensing basis are addressed in the response and are in the following sections: Changes to DCD Tier 2: -Table 1.6-1, Section 3L.4.4, and Section 3L.6 are revised to address changes to references. Reports NEDC-33408P and NEDO-33408 are revised to include a new PBLE Method 1 end-to-end benchmark. NOTE: NEDC-33408P, Supplement 1, and NEDO-33408, Supplement 1, are no longer used as ESBWR design certification licensing basis documents. References to these reports are deleted in DCD Revision 10. The additional deletions are included in the change table herein.
3.9-270	The staff's question is in regard to submitting an updated PBLE method 2 benchmark that resolves the errors and concerns raised by the NRC regarding the QC2 benchmark.	MFN 13-003 (01/21/2013). The response results in several changes to the ESBWR DCD Tier 2 and to the supporting reports to remove information related to PBLE Method 2. The DCD Tier 2 changes are in Sections 3.9.2.3, 3L.1, 3L.2.2, 3L.4.4, and 3L.4.6 and in Table 3L-5, Footnote (2).
3.9-271	The staff's question is in regard to confirming that the PBLE method 1 and 2 benchmarks are performed using the same version of PBLE that will be used for the ESBWR certified design.	MFN 12-045, Rev. 1 (02/08/2013). No change is proposed in regard to this response for the DCD or other licensing basis documents.

RAI Number	RAI Summary	Licensing Basis Changes
3.9-272	The staff's question is in regard to submitting the performance and results of the ongoing strain gage calibration studies.	MFN 12-046, Rev. 2 (01/24/2013). ESBWR DCD Tier 2 Section 3L.4.6 is revised to explain calibration of strain gauges.
3.9-273	The staff's question is in regard to describing the performance and results of the hammer tests on the SSES steam dryer.	MFN 12-038, Rev. 1 (06/01/2012) No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-274	The staff's question is in regard to resolving the main steam line (MSL) strain gage calibration errors.	MFN 12-040, Rev. 2 (01/24/2013). Revisions to ESBWR Report NEDC-33408P address the licensing basis changes for this response.
3.9-275	The staff's question is in regard to evaluating the strain measured on the SSES steam dryer during EPU operation in comparison to the strain calculated from the SSES steam dryer analysis.	MFN 12-047, Rev. 1 (02/13/2013) No change is proposed in regard to this response for the DCD or other licensing basis documents.
3.9-276	The staff's question is in regard to providing a specific analysis of the MSL nozzle location and size for the QC2 acoustic model and the SSES acoustic model.	MFN 12-048, Rev. 1 (01/23/2013). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-277	The staff's question is in regard to the use of specific types of welds in the ESBWR steam dryer and the justification for fatigue and quality factors for each weld type.	MFN 12-086. Rev.2 (02/11/2013) Changes to ESBWR Report NED-33313 are made as a result of this response.
3.9-278	The staff's question is in regard to describing the potential for loose parts resulting from the failure of welds.	MFN 12-049, Rev. 1 (01/31/2013). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-279	The staff's question is in regard to describing the welds in the SSES structural model used as the validation benchmark.	MFN 12-050, Rev. 1 (01/24/2013). No changes are made to the ESBWR licensing basis as a result of this RAI response.

RAI Number	RAI Summary	Licensing Basis Changes
3.9-280	The staff's question is in regard to providing a description of the transition interface modeling.	MFN 12-051, Rev. 2 (02/15/2013) No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-281	The staff's question is in regard to describing SSES dryer components requiring further post evaluation to determine the stress reduction factors.	MFN 12-052, Rev. 1 (06/12/2012). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-282	The staff's question is in regard to providing justification for applying dynamic analysis to unconnected nodes in CAR# 57911.	MFN 12-070 (06/05/2012). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-283	The staff's question is in regard to providing additional justification for the submodel analysis used in GGNS if a similar approach was applied to SSES steam dryer or validate the conclusion based on additional submodels.	MFN 12-054, Rev. 1 (02/14/2013) No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-284	The staff's question is in regard to clarifying information included in Table 1 (on sheet 4 of DRF 0000-0087-2787, "SSES Dryer FEM with Superelement Vane Bundle Representations and Other Modifications").	MFN 12-055, Rev. 2 (02/14/2013) No changes are made to the ESBWR licensing basis as a result of this RAI response. However, NED-33313, Section 5.1, is revised to address shell-to-solid element interface modeling (see the response to RAI 3.9-292).
3.9-285	The staff's question is in regard to clarifying the "peak" stress from the shell model.	MFN 12-077, Rev. 2 (02/15/2013) Changes to the ESBWR licensing basis result from this response. • DCD Tier 2, Sections 3.9.2.3 and 3L. • NED-33313

RAI Number	RAI Summary	Licensing Basis Changes
3.9-286	The staff's question is in regard to developing alternating peak stress intensity predictions using the solid element submodel approach for a representative set of cases, and to compare the results with the corresponding method (1) and method (2) results.	MFN 12-077, Rev. 2 (02/15/2013) No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-287	The staff's question is in regard to describing the structural finite element model for the additional benchmark.	MFN 12-058, Rev. 1 (02/14/2013) No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-288	The staff's question is in regard to submitting GEH's proposed technical approach to ensure that the ESBWR steam dryer shell model has a sufficiently refined mesh to accurately respond at the highest loading frequency of interest.	MFN 12-059, Rev. 1 (02/08/2013). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-289	The staff's question is in regard to describing the process for the combined license (COL) licensee to satisfy ESBWR DCD Tier 1, Table 2.1.1-3, "ITAAC for the Reactor Pressure Vessel and Internals," in ITAAC 8.b.	MFN 12-066, Rev. 2 (01/30/2013). No changes are made to the ESBWR licensing basis as a result of this RAI response.
3.9-290	The staff's question is in regard to describing the process for the COL licensee to satisfy ESBWR DCD Tier 1, Table 2.1.2-3, "ITAAC for the Nuclear Boiler System," in ITAAC 36 and the process for the COL licensee to identify and resolve low frequency.	MFN 12-066, Rev. 2 (01/30/2013). ESBWR DCD Tier 2 Section 3.9.5.3 is revised as a result of this RAI response.

RAI Number	RAI Summary	Licensing Basis Changes
3.9-291	The staff's question is in regard to specifying the provision that will require the COL applicant to demonstrate that the FEA and post-processing of peak stress has been performed to confirm that the ESBWR steam dryer is structurally acceptable as part of a COL Information Item.	MFN 12-066, Rev. 2 (01/30/2013). ESBWR DCD Tier 1 Section 2.1.1 and Table 2.1.1-3 are revised as a result of this RAI response. ESBWR Tier 2 Table 1.9-21 and Sections 3.9.2.4, 3L.4.6, 3L.5.5.1.3, and 3L.6.
3.9-292	The staff's question is in regard to describing the changes that will be made to the topical reports (or DCD).	MFN 13-007 (02/18/2013) See detailed change list. Also included in this response is revised NEDC-33313P and NEDO-33313.
3.9-293	The staff's question is in regard to describing the conservatisms in the steam dryer assessment.	MFN 12-065, Rev. 1 (02/08/2013). ESBWR NEDE-33312 to address 2.0 MASR.
End		

ESBWR Licensing Basis Impact

The changes to the ESBWR DCD are described in the Tables below. Changes to the above-referenced engineering reports are listed on a change list that is part of each individual report.

ESBWR Design Control Document Changes – Tier 1

<table>
<tr><th>Item</th><th>Tier 1 Location</th><th>Description of Change (red/strike through text is deleted and blue text is added)</th></tr>
<tr><td>1.</td><td>S2.1.1</td><td>RAI 3.9-291:
Add:
(16) The as-built steam dryer predicted peak stress is below the fatigue limit.</td></tr>
<tr><td>2.</td><td>T2.1.1-3</td><td>RAI 3.9-291:
Add the following ITAAC to the table:
<table>
<tr><th>Design Commitment</th><th>Inspections, Tests, Analyses</th><th>Acceptance Criteria</th></tr>
<tr><td>16. The as-built steam dryer predicted peak stress is below the fatigue limit.</td><td>Analyses using NRC-approved methodologies are performed.</td><td>Fatigue analyses of the as-built steam dryer verify that the maximum calculated alternating stress intensity provides at least a Minimum Alternating Stress Ratio of 2.0 to the allowable alternating stress intensity of 93.7 MPa (13,600 psi).</td></tr>
</table>
NOTE: The Acceptance Criteria is modified from the response to RAI 3.9-291.

In response to RAI 3.9-291:
calculated alternating stress intensity meets or exceeds a Minimum Alternating Stress Ratio of 2.0
To:
calculated alternating stress intensity provides at least a Minimum Alternating Stress Ratio of 2.0</td></tr>
</table>

ESBWR Design Control Document Changes – Tier 2
[NOTE: Text in Italics is Tier 2* Content in the DCD.]

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
3.	T 1.6-1	**RAI 3.9-293** Change the reference to NEDE-33312P-A/NEDO-33312-A, as follows: Report No.: NEDE-33312P~~-A~~/NEDO-33312~~-A~~ Title: GE Hitachi Nuclear Energy, “ESBWR Steam Dryer Acoustic Load Definition,” NEDE-33312P~~-A~~, Class III (Proprietary), Revision 3~~2~~, February 2013~~October 2010~~, and NEDO-33312~~-A~~, Class I (Non-Proprietary), Revision 3~~2~~, February 2013~~October 2010~~.
4.	T 1.6-1	**RAI 3.9-292** Change the reference to NEDE-33313P-A/NEDO-33313-A, as follows: Report No.: NEDE-33313P~~-A~~/NEDO-33313~~-A~~ Title: GE Hitachi Nuclear Energy, “ESBWR Steam Dryer Structural Evaluation,” NEDE-33313P~~-A~~, Class III (Proprietary), Revision 3~~2~~, February 2013~~October 2010~~, and NEDO-33313~~-A~~, Class I (Non-Proprietary), Revision 3~~2~~, February 2013~~October 2010~~.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
5.	T 1.6-1	**RAI 3.9-269** Change the reference to NEDC-33408P-A/NEDO-33408-A, as follows: Report No.: NEDC-33408P~~-A~~/NEDO-33408~~-A~~ Title: GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDC-33408P~~-A~~, Revision ~~1~~2, Class III (Proprietary), February 2013~~October 2010~~, and NEDO-33408, Revision ~~1~~2, Class I (Nonproprietary), February 2013~~October 2010~~.
6.	T 1.6-1	**RAI 3.9-269 and RAI 3.9-292** Delete the reference to NEDC-33408 Supplement 1P-A/NEDO-33408 Supplement 1-A.
7.	T 1.9-21	**RAI 3.9-291 and CR 3857:** In the row for Regulatory Guide 1.20, for the column "Appl. Rev.", add "3", and for the column "Issued Date", add "03/2007".

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
8.	S 3.9.2.3	**RAI 3.9-270, RAI 3.9-293** Change as follows (Tier 2* content in Italics): *Extensive predictive evaluations have been performed for the steam dryer loading and structural evaluation. These evaluations are described in Appendix 3L.4. In the dryer design and in the development of the initial strain and accelerations acceptance limits used during startup, the fatigue analysis performed for the ESBWR steam dryer uses a fatigue limit stress amplitude of 93.7 MPa (13,600 psi). For additional conservatism in the predictive analysis, the analysis stress results will also meet a minimum alternating stress ratio of 2.0 between the analysis results and the fatigue acceptance limit. ~~For the outer hood component, which is subjected to higher pressure loading in the region of the main steamlines, the fatigue limit stress amplitude is 74.4 MPa (10,800 psi).~~ Following the startup testing of the first unit or if an acceptance limit is reached during power ascension, the ~~load~~ FIV load definition is defined from the recorded dryer pressure ~~or dryer pressure and steam line~~ data. ~~The load definition bias and uncertainty is benchmarked against the dryer pressure sensor data.~~ A structural assessment is performed to benchmark the FE model strain and acceleration predictions against the measured data. The dryer peak stress based on test data, adjusted for ~~load, FE model, and instrument~~end-to-end benchmark bias and uncertainties, is then calculated and maintained less than 93.7 MPa (13,600 psi). The subsequent ESBWR steam dryers ~~includes dryer~~will follow the same FIV monitoring ~~via main steam line~~process using on-dryer instruments. The acceptance limits for subsequent plants is based on assuring that the stresses remain less than 93.7 MPa (13,600 psi) allowable stress. The limit is justified because first steam dryer is heavily instrumented, subsequent plants is also monitored for FIV loads, and the load and response is explicitly evaluated based on test data with consideration of bias and uncertainty. The steam dryer is a nonsafety-related component, performs no safety-related functions, and is only required to maintain its structural integrity (no loose parts generated) for normal, transient and accident conditions.*
9.	S 3.9.2.3	**RAI 3.9-285:** Change "peak component stress" to "highest components stress" (one place) as follows: *The dynamic modal analysis forms the basis for interpretation of the initial startup test results (Subsection 3.9.2.4). Modal stresses are calculated and relationships are obtained between sensor response amplitudes and ~~peak~~ highest component stresses for each of the lower normal modes.*

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
10.	S 3.9.2.3	**RAI 3.9-285:** Change "peak stress" to "highest stress" (three places) as follows: *The allowable vibratory amplitude in each mode is that which produces a ~~peak~~ highest stress amplitude of ±68.95 MPa (±10,000 psi). For the steam dryer and its components, a higher allowable ~~peak~~ highest stress limit is used as explained in the following paragraphs.* ... *The dryer ~~peak~~ highest stress based on test data, adjusted for load, FE model, and instrument bias and uncertainties, is then calculated and maintained less than 93.7 MPa (13,600 psi).*
11.	S 3.9.2.4	**RAI 3.9-292:** Add a comma between "steam dryer" and "chimney." The visual inspections conducted prior to and remote inspections conducted following startup testing are for damage, excessive wear, or loose parts. At the completion of initial startup testing, remote inspections of major components are performed on a selected basis. The remote inspections cover the steam dryer, chimney, chimney head, core support structures, the peripheral CRD and incore housings. Access is provided to the reactor lower plenum for these inspections.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
12.	S 3.9.2.4	**RAI 3.9-291:** Add to the end of the following sentences: GEH continues these test programs for subsequent plants to verify structural integrity and to establish the margin of safety. The FIV evaluation program pertaining to reactor internal components is addressed in Appendix 3L. **As part of the initial implementation of the vibration assessment program, RG 1.20 guidance in Section 2.4 states that** if inspection of the reactor internals reveals defects, evidence of unacceptable motion, or excessive or undue wear; if results from the measurement program fail to satisfy the specified test acceptance criteria; or if results from the analysis, measurement, and inspection programs are inconsistent, then further evaluations, modifications, or other actions are taken to justify the structural adequacy of the reactor internals. Such results and actions are reported to the NRC as part of the **final report** documentation of results of the comprehensive vibration assessment program **following testing**. **NOTE:** This added content is modified from the response to RAI 3.9-291. The following wording is added (as shown in bold above): **"As part of the initial implementation of the vibration assessment program, RG 1.20 guidance in Section 2.4 states that"** **"final report"** **"following testing"**

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
13.	S 3.9.5.3	**RAI 3.9-290:** Add to the end of this section: Steam Dryer Acoustic Loading Effects from Safety-Relief Valve Standpipes and Main Steam Piping The safety relief valves (SRV) and safety valves (SV) standpipes and main steam branch lines in the ESBWR are specifically designed to preclude first and second shear layer wave acoustic resonance conditions from occurring and to avoid pressure loads on the steam dryer at plant normal operating conditions. Appropriate selection of SRV standpipes vertical height between main steam piping and the valves, along with selection of valve entrance effects, minimizes vortex generation. Design of piping is based on Strouhal numbers outside the range for which adverse impacts due to acoustic resonance would occur (based on resonance frequency determined using velocity at the speed of sound). Calculations performed as described below show that design features and selections can acceptably eliminate first and second shear wave resonances in SRV/SV standpipes and main steam piping. For standpipe configuration, main steam and SRV/SV configuration (dimensions and arrangement) and attachment of standpipes to the main steam piping are considered. System geometry and flow rates are used to calculate critical Strouhal ranges. Then the Strouhal values for flow at 100% and 102% power levels are calculated to ensure that the values at normal operating flow rates are not within the critical range and that additional margin is provided. As shown on Figure 5.2-2, the ESBWR main steam system has two longer main steam lines with 5 SRV/SVs, and two shorter main steam lines with 4 SRV/SVs, mounted perpendicular to the main steam pipe centerline. For eliminating main steam flow acoustic frequency at branchline connections, boundary conditions at the connections are evaluated to ensure flow disturbances are not on the same order as acoustic waves that may pass through the system. Design features such as dimensions, diameter ratios, lengths of piping from reactor vessel nozzles, entrance effects, and flow rate effects are considered in the evaluation. Acceptance criteria are to demonstrate through the evaluation that the final as-built design of the main steam line and SRV/SV branch piping geometry precludes first and second shear layer wave acoustic resonance conditions from occurring and results in no significant pressure loads on the steam dryer at plant normal operating conditions. This is demonstrated by analysis showing that the final design maximum velocity, Strouhal range, and power level are outside the critical range of values where first and second shear resonances would occur. See Subsection 3.9.2.1 for piping vibration and dynamics effects testing during preoperational and startup testing. NOTE: Added "testing" at the end of the last sentence (not in RAI 3.9-290 response).

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
14.	S 3.9.10	**RAI 3.9-292:** Change Reference 3.9-7 for latest revision of NEDE-33313P-A and NEDO-33313-A.
15.	S 3L.1	**RAI 3.9-270:** Change as follows: "References 3L-5, 3L-6, 3L-7, and 3L-8 ~~and 3L-9~~;"
16.	S 3L.2.2	**RAI 3.9-270:** Change as follows: "references 3L-5, 3L-6, 3L-7, and 3L-8 ~~and 3L-9~~;"
17.	S 3L.3.3	**RAI 3.9-285** Change "peak stress" to "highest stress" (one place) as follows: This stress value is bounded by the allowable vibration ~~peak~~ highest stress amplitude of 68.9 MPa (10,000 psi) specified in Subsection 3.9.2.3.
18.	S 3L.4.4	**RAI 3.9-269 and RAI 3.9-270:** Change as follows: "Reference~~s~~ 3L-8 ~~and 3L-9~~ provides the theoretical basis of the methodology, describes the analytical model, and provides benchmark … "

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
19.	S 3L.4.4	**RAI 3.9-270:** Delete the last paragraph: ~~Reference 3L-9 provides the results of benchmarking and sensitivity studies of the pressure load definition methodology against measured pressure data taken during power ascension testing of a replacement steam dryer installed at an operating nuclear plant. Reference 3L-9 concludes that, based on comparisons of model predictions to actual measurements, the methodology predicts good frequency content and spatial distribution, and the safety relief valve resonances are well captured. The methodology provides accurate predictions of main steamline phenomena occurring downstream of the main steamline sensors, valve whistling (safety relief valve branch line) and broadband excitations (venturi, main steam isolation valve turbulence). The methodology also accurately predicts the dryer pressure loads resulting from vessel hydrodynamic phenomena.~~
20.	S 3L.4.6	**RAI 3.9-291:** Add sentence to the end of the first paragraph: The ESBWR steam dryer is instrumented with temporary vibration sensors to obtain flow induced vibration data during power operation. The primary function of this vibration measurement program is to confirm FIV load definition used in the structural evaluation is conservative with respect to the actual loading measured on the steam dryer during power operation, and to verify that the steam dryer can adequately withstand stresses from flow induced vibration forces for the design life of the steam dryer. The instrumentation and startup testing program for the ESBWR steam dryer follows NRC regulatory guidance in Reference 3L-10, as described below.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
21.	S 3L.4.6	**RAI 3.9-270:** Change as follows: ~~The distribution of steamline instruments is determined using the Plant Based Load Evaluation model (Reference 3L-8) to provide an adequate measure of the acoustic loading through the frequency range of interest. The instrument layout permits steam dryer load development with steam dryer data alone, steamline data alone, or a combination using both sets of data.~~ The approach used to determine the number and locations of pressure instruments is described in Subsections 2.3.2 and 4.4.2 of Reference 3L-8 ~~and Subsections 4.4.3.1 and 4.4.4 of Reference 3L-9~~.
22.	S 3L.4.6	**RAI 3.9-292 Editorial Change:** Change “are” to “is”: Each of the sensors ~~are~~is pressure tested in an autoclave prior to assembly and installation on the steam dryer.
23.	S 3L.4.6	**RAI 3.9-292 Editorial Change:** Change “are” to “is”: The dome cover plate with the pressure transducer ~~are~~is welded to an annular pad that is welded permanently to the steam dryer surface.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
24.	S 3L.4.6	**RAI 3.9-272:** Modify as follows: The strain gages, accelerometer and pressure transducers are field calibrated prior to data collection and analysis. This calibration includes the addition of natural strain gauge factors based on the specific vendor supplied calibration sheets and their effects on the final stress tables. The locations of the gauges are more distributed than BWR EPU gauge locations. The locations are selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. The final pressure transmitter locations are evaluated using the PBLE model with multiple combinations of Frequency Response Function (FRF) sets corresponding to different transmitter locations. The resulting data are used to find locations that provide redundancy and minimize singularities over the frequency ranges of interest, with special consideration at frequencies critical to high stress locations in the dryer. The sensitivity of locations to dimensional tolerances is also considered. Strain gauge manufacturer installation procedures are followed to duplicate previous installations. Care is taken to assure surface preparation (attachment surface area polish), spot weld welding energy, and weld strength recommendations are followed for each gauge. Applicable lessons learned from manufacturer's recommendation were also incorporated into the GEH welding procedure specification. Furthermore, knowledge is passed to the welders by holding pre-job briefs and discussing the proper technique for applying the gauges, emphasizing the uniform placement of spot welds at approximately 0.7 – 0.8 mm intervals. Afterwards, the welders will practice on shims until peel tests are successfully completed. Quality Control personnel are present to accept the weld process. The temporary vibration sensors are removed after the first outage. **NOTE:** Minor editorial changes are made to this insert from the content described in response to RAI 3.9-272: • "data is" changed to "data are" • "manufacture" changed to "manufacturer" • "manufacture's" changed to "manufacturer's" • "welders practiced" to "welders will practice"

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
25.	S 3L.4.6	**RAI 3.9-270:** Delete information shown: ~~In addition to the instrumentation on the steam dryer, the main steamlines are instrumented in order to measure the acoustic pressures in the main steamlines.~~ The ~~main steamline pressure measurements with the~~ steam dryer pressure measurements are used as input to an acoustic model for determining the pressures acting on the steam dryer in order to provide a pressure load definition for use in performing confirmatory structural evaluations.
26.	S 3L.4.6	**RAI 3.9-291:** Add information as shown: In addition to the elements described above, NRC regulatory guidance (Reference 3L-10) describes elements of the comprehensive vibration assessment program that is implemented prior to and through startup testing. The following regulatory positions for prototype steam dryers address the program elements applicable to the ESBWR steam dryers: • Position 2.1 provides a description of the vibration and stress analysis program, including specific items that should be included in the vibration and stress analysis submittal prior to implementation of the vibration measurement program. • Position 2.2 provides a description of the vibration and stress measurement program, which is to verify the structural integrity of reactor internals, determine the margin of safety, and confirm results of the vibration analysis. • Position 2.3 describes the inspection program for inspection both prior to and following plant operation. • Position 2.4 describes documentation of results of the program. • Position 2.5 describes the schedule for conducting the vibration assessment program. COL Information Item 3.9.9-1-A implements the vibration assessment program. For each of the regulatory positions above, the NRC guidance (Reference 3L-10) explains how the program is to be conducted, how the processes assure structural integrity of the steam dryer, and identifies information and reports that are to be prepared and when the information and reports should be submitted. Steps in the process for the regulatory positions include the following key elements: Position 2.1: The steam dryer analysis and modeling methodologies for performing a vibration and stress analysis are described in References 3L-5, 3L-6, and 3L-8. NRC guidance specifies that a summary of the vibration

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
		analysis program should be submitted to the NRC at least 60 days prior to submission of the description of the vibration measurement and inspection programs (or 120 days if submitted with a description of the vibration measurement and inspection phases description). Thus, a summary of the as-built steam dryer structural analysis with the applied acoustic loads would be developed and submitted to the NRC. In addition, the supporting information will be available for NRC review for assuring acceptance criteria are met in accordance with ESBWR DCD Subsections 3.9 and 14.3. This analysis is used to correlate results obtained through vibration measurements during power ascension. Position 2.2: Details of the steam dryer monitoring program are described above and in References 3L-5, 3L-6, and 3L-8. According to NRC guidance, a description of the vibration measurement and inspection phases of the comprehensive vibration assessment program should be submitted to the NRC in sufficient time to permit utilization of the staff's related recommendations (allowing 90 days for staff's review and comment period). This submittal would be focused on the as-built steam dryer monitoring and instrumentation to be used for obtaining vibration measurements, with details of the data acquisition and reduction system (e.g., transducer types, transducer position, measures to maximize quality of data, online data evaluation system, procedures, and bias errors associated with the instruments). During power ascension, the steam dryer instrumentation (strain gages, accelerometers and dynamic pressure transducers) is monitored against established limits to assure the structural integrity of the steam dryer is maintained. If resonant frequencies are identified and the vibrations increase above the pre-determined criteria, power ascension is stopped. The acceptability of the steam dryer for continued operation is evaluated by revising the load definition based on the measured loading, repeating the structural analysis using the revised load definition, and determining revised operating limits based on the results of the structural analysis.
27.	S 3L.4.6	**RAI 3.9-270:** Delete the following: ~~It is expected that subsequent ESBWR units will be monitored using the main steam lines pressure data. Additional information on power ascension testing, acceptance criteria, benchmarking loads, and benchmarking of the FE model for the first and subsequent ESBWR units is included in references 3L-5 and 3L-6~~

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
28.	S 3L.4.6	**RAI 3.9-291:** Modify with additions as shown: Position 2.3: Specific steam dryer inspection recommendations for the ESBWR steam dryer design are developed based on the final as-built design and structural analysis results. The steam dryer inspection recommendations are consistent with Reference 3L-2, and consistent with Boiling Water Reactor Vessel Internals Program guidance issued by the BWR owners group specific to reactor internals vibration. According to NRC guidance, a description of the inspection phase would be included in the submittal with a description of the vibration measurement program. This description would identify any inspections that are to be performed prior to and following operation during power ascension, and describe procedures and method of inspections, if any, of the steam dryer. Position 2.4: According to NRC guidance, results of the comprehensive vibration assessment program should be reviewed and correlated to determine the extent to which test acceptance criteria are satisfied. The preliminary report following startup testing should compare preliminary comparison of data to test acceptance criteria and identify anomalous data that could bear on the steam dryer structural integrity. If results are acceptable, the final report should include a description of any deviations, comparison between measured and analytically determined modes of structural response and hydraulic response for verifying analytical technique, determination of margins of safety, and evaluation of unanticipated observations or measurements that exceeded acceptable limits not specified as test acceptance criteria (as well as disposition of such deviations). If testing or inspections reveal defects or unacceptable results, the final report should also include an evaluation and description of the modifications or actions planned to justify the structural adequacy of the steam dryer. Position 2.5: A schedule for conducting the elements of the comprehensive vibration assessment program is inherent in COL Information Item 3.9.9-1-A. NRC guidance specifies that the steam dryer be classified as prototype or non-prototype; that a commitment be made in the DCD or COL application regarding the scope of the comprehensive vibration assessment program; and that certain submittals be made describing the program and results with suggested schedules for the submittals. With the detailed description above and implementation of COL Information Item 3.9.9-1-A, the instrumentation and startup testing program elements are consistent with NRC regulatory guidance and adequately ensure steam dryer structural integrity.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
29.	S 3L.5.2	**RAI 3.9-285** Change "peak stress" to "highest stress" (two places) as follows: Based on knowledge of the natural mode shapes of the structure or calculated stress distribution, ~~peak~~ highest stresses at other locations on the structure are determined from these data. Accelerometers (with double integration of the output signal) provide measurements of local structural displacement. This information, together with knowledge of the natural mode shapes of the structure or calculated stress distribution, allows the ~~peak~~ highest stresses to be calculated at other locations.
30.	S 3L.5.5.1.3	**RAI 3.9-291:** Add to the end of this section: Prior analytical models have predicted that the vibration modes are closely spaced. The final as-built structural predictive vibration analysis is performed prior to startup testing for correlation to final measurement results of acoustic loads measured on the steam dryer during startup testing, as elements of a comprehensive vibration assessment program described in Subsection 3L.4.6.
31.	S 3L.5.5.2	**RAI 3.9-285** Change "peak stress" to "highest stress" (one place) as follows: ~~peak~~ highest Where $\sigma_{i,sensor,allowed}$ = Maximum allowed zero to ~~peak~~ highest stress amplitude at sensor location for vibration mode i (stress amplitude at sensor when maximum stress amplitude in structure is 68.9 MPa)

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
32.	S 3L.5.5.2.1	**RAI 3.9-285** Change "peak stress" to "highest stress" (two places) as follows: Where $\varepsilon_{II,allowed}$ = Allowable strain value between ω_I and ω_{II}, which includes the SCF It should be noted that this step conservatively assumes that the ~~peak~~ highest stress of each mode occurs at the same physical location on the structure. ... It should be noted that this step conservatively assumes that the ~~peak~~ highest stress of each mode occurs at the same time.
33.	S 3L.5.5.2.2	**RAI 3.9-285** Change "peak stress" to "highest stress" (one place) as follows: It should be noted that this step conservatively assumes that the ~~peak~~ highest stress of each mode occurs at the same physical location on the structure and at the same time.
34.	S 3L.6	**RAI 3.9-293** Change reference 3L-5 to latest revision of NEDE-33312P-A and NEDO-33312-A. 3L-5 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Acoustic Load Definition," NEDE-33312P~~-A~~, Class III (Proprietary), Revision 3~~2~~, February 2013~~October 2010~~, and NEDO-33312~~-A~~, Class I (Non-Proprietary), Revision 3~~2~~, February 2013~~October 2010~~.

Item	Tier 2 Location	Description of Change (red/strike through text is deleted and blue text is added)
35.	S 3L.6	**RAI 3.9-292** Change reference 3L-6 to latest revision of NEDE-33313P-A and NEDO-33313-A. 3L-6 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDE-33313P~~-A~~, Class III (Proprietary), Revision 3~~2~~, February 2013~~October 2010~~, and NEDO-33313~~-A~~, Class I (Non-Proprietary), Revision 3~~2~~, February 2013~~October 2010~~.
36.	S 3L.6	**RAI 3.9-269** Change reference 3L-8 to latest revision of NEDC-33408P-A and NEDO-33408-A. 3L-8 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDC-33408P~~-A~~, Revision 12, Class III (Proprietary), February 2013~~October 2010~~, and NEDO-33408, Revision ~~1~~2, Class I (Nonproprietary), February 2013~~October 2010~~.
37.	S 3L.6	**RAI 3.9-269 and RAI 3.9-270** Change reference 3L-9 to "(Deleted)" based on deleting NEDC-33408 Supplement 1P-A and NEDO-33408 Supplement 1-A. 3L-9 (Deleted)
38.	S 3L.6	**RAI 3.9-291:** Add the following: 3L-10 Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program For Reactor Internals During Preoperational And Initial Startup Testing," Revision 3, March 2007.
39.	T 3L-5, Footnote (2)	**RAI 3.9-270:** Delete "and the main steamlines": The pressure data from these components ~~and the main steamlines~~ are discussed in Subsection 3L.4.6.

Enclosure 3

MFN 13-007

NRC RAIs and Licensing Basis Changes Roadmap

Public Version

This is a non-proprietary version of Enclosure 2, from which the proprietary information has been removed. Portions of the document that have been removed are identified by white space within double brackets, as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS DOCUMENT

Please Read Carefully

NRC RAIs and Licensing Basis Changes Roadmap[1]

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
3.9-269	*The staff's question is in regard to submitting an end-to-end frequency-dependent steam dryer strain simulation validation using steam dryer loads computed using the GEH Plant-Based Load Evaluation (PBLE) method 1, along with described adjustments to the methodology and/or bias and uncertainty to ensure the strain gage spectra for an instrumented steam dryer are bounded.*	MFN 12-043, Rev. 1 (02/07/2013)	Yes	*GEH is requested to submit an end-to-end frequency-dependent steam dryer strain simulation validation using steam dryer loads computed using the GEH Plant-Based Load Evaluation (PBLE) method 1 [[ ]], along with described adjustments to the methodology and/or bias and uncertainty to ensure the strain gage spectra for an instrumented steam dryer are bounded.*	Report NED-33408 Rev. 2 contains the PBLE01 model description (entire report) and an end-to-end frequency-dependent steam dryer strain simulation validation using steam dryer loads for the GGNS replacement steam dryer [[ ]] (Section 3). Report NED-33408 Rev. 2 describes adjustments to the methodology and/or bias and uncertainty to ensure the strain gauge spectra for an instrumented steam dryer are bounded. See Sections 3.1 (pg. 23) and 4.4.4. Figures 20 and 21 show plots of mean biases and uncertainties at GGNS EPU conditions. Also see Appendix F. See response to **RAI 3.9-292** for NED-33313 changes for **RAI 3.9-269**.
3.9-269 (cont.)				*Specifically, GEH is requested to plot the upper envelopes of the simulated strain spectra at several locations on a steam dryer (based on calculations*	Report NED-33408 Rev. 2 includes plots that show comparisons of projected versus measure power spectral density (PSD):

[1] This roadmap is a tool for reviewers of RAI responses. It is not a separate quality record, but includes information excerpted from quality records. Please refer to the separate RAI responses for the quality record.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				spanning [[ ]], *augmented with PBLE, finite element (FE), and all other bias errors and uncertainties, and show that the measured strain spectra are bounded. The spectra for each time-shifted calculation should be shifted upward and downward in frequency accordingly* [[ ]], *and an upper bound generated. The upper bound should then be adjusted according to all bias errors and uncertainties and compared to the measurements.*	Section 3.1 and Appendix A: To monitor the steam dryer pressure loads, the GGNS steam dryer was instrumented with 15 pressure transducers (PTs). The location of the pressure transducers is described in Appendix A. The regional layout of the GGNS PT sensors is also shown in Appendix A. The layout was selected to be well distributed to capture the pressure response over the entire dryer. The regional locations were also selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. According to Section 4.4.4, the end-to-end bias values are based on the comparison of the measured PSD data over the projected PSD data at each of the on-dryer sensor locations. Section 3.2 and Appendix B: Steady state data was obtained at CLTP conditions during the GGNS startup. The [[ ]] data was then used to define acoustic loads on the steam dryer. Appendix B shows the comparison between the PBLE01 predicted pressure loads and the measured pressures for each of the on-dryer pressure sensors at CLTP condition. As explained in Section 3.4, in general, the comparison plots in Appendix B demonstrate that the PBLE01 methodology is capable of adequately capturing the frequency content across the dryer face. In general, at CLTP conditions [[ ]], the predicted loads are [[ ]].

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					Section 3.3 and Appendix C: Steady state data was obtained at EPU conditions during the GGNS startup. The [[ ]] data was then used to define acoustic loads on the steam dryer. Appendix C shows the comparison between the PBLE01 predicted pressure loads and the measured pressures for each of the on-dryer pressure sensors at EPU condition. As explained in Section 3.4, the comparison plots in Appendix C demonstrate that the PBLE01 methodology is capable of adequately capturing the frequency content across the dryer face at EPU conditions. Section 4.4.4 and Appendices E and F: Appendix E shows the projected versus measured PSD acceleration and strain at GGNS EPU conditions, with the plots showing the end-to-end comparison across the frequency range. PSD comparisons of the ANSYS predictions from the GGNS EPU conditions and the measured data for the analysis time interval are included in Appendix E for each sensor. Appendix F provides tabular values of the [[ ]] end to end bias and uncertainty as a function of frequency.
3.9-269 (cont.)				*In the event the strains are not bounded, GEH is requested to provide and describe adjustments in bias error/uncertainty and/or the methodology to ensure they are bounded.*	Report NED-33408 Rev. 2 Section 4.4.4 explains biases and uncertainties. Section 4.4.4 and Appendices E and F:

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					Appendix E shows the projected versus measured PSD acceleration and strain at GGNS EPU conditions, with the plots showing the end-to-end comparison across the frequency range. PSD comparisons of the ANSYS predictions from the GGNS EPU conditions and the measured data for the analysis time interval are included in Appendix E for each sensor. Appendix F provides tabular values of the [[ ]] end to end bias and uncertainty as a function of frequency.
3.9-269 (cont.)				*Also, GEH is requested to provide a pictorial set of links between the steam dryer strain gages and all high stress regions to establish the relevance of the benchmark.*	Section 3.1 and Appendix A: To monitor the steam dryer pressure loads, the GGNS steam dryer was instrumented with 15 pressure transducers (PTs). The location of the pressure transducers is described in Appendix A. The regional layout of the GGNS PT sensors is also shown in Appendix A. The layout was selected to be well distributed to capture the pressure response over the entire dryer. The regional locations were also selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. According to Section 4.4.4, the end-to-end bias values are based on the comparison of the measured PSD data over the projected PSD data at each of the on-dryer sensor locations. Section 4.4.4: To monitor the dryer dynamic response six (6) accelerometers and seven (7) strain gauges were installed. The

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					accelerometer and strain gauge locations were selected to monitor the global response of the hoods and the dryer stress in high stress regions. The strain and acceleration instruments are well distributed over different dryer regions. Where possible, locations were selected where the sensor would see higher amplitudes and be in areas with low gradients at the frequencies that most significantly contribute to high stress. The regional layout of the GGNS accelerometers and strain gauge sensors is summarized in Appendix A. The installed locations were selected to provide good correlation with dryer high stress areas and redundancy such that multiple instruments will have good correlation with the high stress regions. Table A1 lists the sensors and locations. Figures A-1 through A-6 show the sensors and locations on various steam dryer views.
3.9-269 (cont.)				*Finally, if the steam dryer analysis for the* [[ ]] *EPU license amendment is used as the end-to-end platform to support the ESBWR design certification application, GEH should submit the reasons why fatigue cracks occurred near the* [[ ]].	N/A. The [[ ]] steam dryer is not used as the benchmark.
3.9-269 (cont.)				NRC provided feedback on 10/31/2012 to confirm the GGNS FE model is the updated version reflecting the as-built dryer. Confirm that the dryer FE model approved is identical to that which will be used for ESBWR.	Report NED-33408 Rev. 2 explains in Sections 3 and 4 that the GGNS replacement steam dryer is used as the validation benchmark. Section 1 explains that the report contains the model description that is established as the version of the ESBWR model (also see GEH response to **RAI 3.9-271**):

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					The PBLE01 (Plant Based Load Evaluation) is an analytical tool developed by GEH to perform the prediction of fluctuating pressure loads on the steam dryer. This report provides the theoretical basis of the PBLE01 method that will be applied for determining the fluctuating loads on the ESBWR steam dryer, describes the PBLE01 analytical model, determines the biases and uncertainties of the PBLE01 formulation and describes the application of the PBLE01 method to the evaluation of the ESBWR steam dryer.
3.9-269 (cont.)				NRC provided feedback on 10/31/2012 to demonstrate PBLE method 1 [[ ]].	Report NED-33408 Rev. 2 includes the plots that should the comparisons of projected versus measure power spectral density (PSD): Section 3.1 and Appendix A: To monitor the steam dryer pressure loads, the GGNS steam dryer was instrumented with 15 pressure transducers (PTs). The location of the pressure transducers is described in Appendix A. The regional layout of the GGNS PT sensors is also shown in Appendix A. The layout was selected to be well distributed to capture the pressure response over the entire dryer. The regional locations were also selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. According to Section 4.4.4, the end-to-end bias values are based on the comparison of the measured PSD data over the projected PSD data at each of the on-dryer sensor locations.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					Section 3.2 and Appendix B: Steady state data was obtained at CLTP conditions during the GGNS startup. The [[ ]] data was then used to define acoustic loads on the steam dryer. Appendix B shows the comparison between the PBLE01 predicted pressure loads and the measured pressures for each of the on-dryer pressure sensors at CLTP condition. As explained in Section 3.4, in general, the comparison plots in Appendix B demonstrate that the PBLE01 methodology is capable of adequately capturing the frequency content across the dryer face. In general, at CLTP conditions [[ ]], the predicted loads are [[ ]]. Section 3.3 and Appendix C: Steady state data was obtained at EPU conditions during the GGNS startup. The [[ ]] data was then used to define acoustic loads on the steam dryer. Appendix C shows the comparison between the PBLE01 predicted pressure loads and the measured pressures for each of the on-dryer pressure sensors at EPU condition. As explained in Section 3.4, the comparison plots in Appendix C demonstrate that the PBLE01 methodology is capable of adequately capturing the frequency content across the dryer face at EPU conditions. Section 4.4.4 and Appendices E and F:

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					Appendix E shows the projected versus measured PSD acceleration and strain at GGNS EPU conditions, with the plots showing the end-to-end comparison across the frequency range. PSD comparisons of the ANSYS predictions from the GGNS EPU conditions and the measured data for the analysis time interval are included in Appendix E for each sensor. Appendix F provides tabular values of the [[ ]] end to end bias and uncertainty as a function of frequency.
3.9-269 (cont.)				NRC provided feedback on 10/31/2012 and 11/07/2012 to demonstrate method 2 in the same manner. [[ ]]	N/A. GEH has deleted Method 2 from the ESBWR design certification. See GEH response to **RAI 3.9-270**.
3.9-269 (cont.)				NRC provided feedback on 10/31/2012 to apply both methodologies to both 100% CLTP test conditions- with the original plant static pressure [[ ]]	Report NED-33408 Rev. 2 Section 3.2 and Appendix B: Steady state data was obtained at CLTP conditions during the GGNS startup. The [[ ]] data was then used to define acoustic loads on the steam dryer. Appendix B shows the comparison between the PBLE01 predicted pressure loads and the measured pressures for each of the on-dryer

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					pressure sensors at CLTP condition. Note that Method 2 has been deleted from the ESBWR design certification. See GEH response to **RAI 3.9-270**. Therefore, Method 2 is not discussed in Report NED-33408 Rev. 2.
3.9-269 (cont.)				NRC provided feedback on 10/31/2012 to commit to formally updating [[ ]]	Report NED-33408 Rev. 2 explains in Sections 3 and 4 that the GGNS replacement steam dryer is used as the validation benchmark. Section 1 explains that the report contains the model description that is established as the version of the ESBWR model (see GEH response to **RAI 3.9-271** for the potential need for and control of updates to the methodology): The PBLE01 (Plant Based Load Evaluation) is an analytical tool developed by GEH to perform the prediction of fluctuating pressure loads on the steam dryer. This report provides the theoretical basis of the PBLE01 method that will be applied for determining the fluctuating loads on the ESBWR steam dryer, describes the PBLE01 analytical model, determines the biases and uncertainties of the PBLE01 formulation and describes the application of the PBLE01 method to the evaluation of the ESBWR steam dryer.
3.9-269 (cont.)				Other changes in Response to RAI 3.9-269	Table 1.6-1 to change reference to updated report NED-33408 Rev. 2. Section 3L.4.1 is modified to remove the reference to BWR/4 plants, as these plants have not been found to have abnormally high pressure loads under extended power uprate operating

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					conditions. Section 3L.4.4 is revised to remove references to 3L-9. **(RAI 3.9-270.)** Section 3L.4.4 is revised to remove the last two sentences, which refer to Method 2. **(RAI 3.9-270.)** Section 3L.4.6 is modified to reflect removal of PBLE Method 2. **(RAI 3.9-270.)** Section 3L.6 references are updated and Reference 3L-9 is deleted. **(RAI 3.9-270.)**
3.9-269 (cont.)				Specific changes to NED-33408 from Rev. 1 to Rev. 2.	-Cover Page Copyright date updated with 2013 -General Replaced "gage" with "gauge" in multiple places for consistency -S2.1 Removed reference to use of "steam line pressure data" to define acoustic loads -S2.1 Added text from NEDC-33408 Supplement 1P-A, Revision 2 section 2.3 stating that alternate FE programs can be used as described in new Appendix D. Figure 2 Replaced Quad Cities 2 acoustic mesh figures with acoustic mesh figures used for the Grand Gulf EPU benchmark. -S2.2.2 and Figure 3 Revised description of typical vessel model to reflect expected range of mesh elements (500,000 to 1,000,000) and deleted discussion of Quad Cities 2 drain channel sensitivity along with Figure 3.

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					-S2.3.1 Delete reference to Quad Cities 2 benchmarking using eight pressure sensors in Sections 3.2 and 3.3. -S2.4.3 Added new section to describe vane upstream droplet wetness correlation previously documented in NEDC-33408 Supplement 1P-A, Revision 2. Figure 9 Delete reference to Quad Cities 2 and specific pressure transducer nomenclature since figure is provided as illustrative purpose only. -S3.0 Replaced references to Quad Cities 2 with Grand Gulf Nuclear Station. -S3.1.1 Corrected section number to 3.1. Section replaced with new text describing GGNS PBLE01 validation procedure. -S3.2 Section replaced with new text describing GGNS PBLE01 validation at CLTP. -S3.3 Section replaced with new text describing GGNS PBLE01 validation at EPU. -S3.4 Delete QC2 Benchmark Conclusions section and replace with GGNS PBLE01 validation conclusions. -S4.2.1 RG 1.20 Section 2.1.(1)(b) PBLE01 conformance revised to reflect use of GGNS end-to-end benchmark. -S4.2.1 RG 1.20 Section 2.1.(3) PBLE01 conformance revised to reflect use of GGNS end-to-end Benchmark -S4.4.1 Correct incorrect reference to figure. -S4.4.1 Deleted reference to "if model size allows it the upper frequency limit for the meshing requirements should be 150% of the highest frequency considered in the analysis. This statement should be removed, as it does not apply to PBLE01. The

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					PBLE01 acoustic FRFs are calculated thru a Direct Response frequency analysis (as opposed to a solution using Modal Superposition, which is inadequate when there is frequency-dependent damping and boundary conditions). The 150 % applies only to the modal superposition, which is not used in PBLE01. -S4.4.1 Delete paragraph preceding Figure 18 which refers to Quad Cities 2 benchmark analysis which have been deleted. -S4.4.2 Delete reference to Quad Cities 2 benchmark. -S4.4.2 Add information on calibration of on-dryer sensors in response to NRC **RAI 3.9.274**. -S4.4.4 Delete entire section that refers to sensitivity studies performed on the Quad Cities 2 acoustic model and replace with summary of GGNS EPU end-to-end benchmarks. -Figure 20 Figure added to show end-to-end bias and uncertainty for GGNS EPU benchmark for the upper dryer region. -Figure 21 Figure added to show end-to-end bias and uncertainty for GGNS EPU benchmark for the lower dryer region. -S4.5 Delete entire section that refers to Quad Cities 2 benchmarks. -S5.0 Replace references to Quad Cities 2 benchmarks with references to GGNS EPU end-to-end benchmarks. -Appendix A Delete QC2 benchmark results and replace with GGNS dryer instrumentation descriptions.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					-Appendix B Delete QC2 benchmark results and replace with GGNS PBLE01 validation plot comparisons at CLTP. -Appendix C Delete QC2 uncertainty assessment and replace with GGNS PBLE01 validation plot comparisons at EPU. -Appendix D Add new Appendix that defines requirements for PBLE01 finite element program (Appendix J from NEDC-33408 Supplement 1P-A). -Appendix E Add new Appendix that provides comparison of predicted and measured on-dryer sensor response (strain gage and accelerometers). -Appendix F Add new Appendix that provides a summary table of end to end bias and uncertainties.
3.9-270	*The staff's question is in regard to submitting an updated PBLE method 2 benchmark that resolves the errors and concerns raised by the NRC regarding the QC2 benchmark.*	MFN 13-003 (01/21/2013)	Yes	*GEH is requested to submit an updated PBLE method 2* [[ ]] *benchmark that resolves the errors and concerns raised by the NRC regarding the QC2 benchmark (such as* [[ ]], *geometric modeling errors, and nozzle errors). As part of this submittal, GEH is requested to provide the "Susquehanna* [[ ]] *Summary Statistics using [[ ]]," and GEH Engineering Calculation Sheet DRF 0000-0117-4341R0 (dated September 30, 2010). If the SSES platform is used for this benchmark, GEH should ensure that the nozzle area and other SSES issues are resolved. GEH is requested to provide both* [[ ]] *data, including plots of simulated and measured point pressure spectra.*	Table 1.6-1 is updated to indicate that NED-33408 Supplement 1 is deleted. Section 3.9.2.3 is revised to remove Method 2 information and to indicate how subsequent steam dryers will be monitored. Sections 3L.1, 3L.2.2, 3L.4.4, and 3L.4.6 are revised to adjust references.

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				The NRC staff provided feedback on the initial draft response to RAI 3.9-270 (which was combined with RAI 3.9-269). GEH has since determined that PBLE Method 2 would be deleted from the ESBWR design certification.	
3.9-271	*The staff's question is in regard to confirming that the PBLE method 1 and 2 benchmarks are performed using the same version of PBLE that will be used for the ESBWR certified design.*	MFN 12-045, Rev. 1 (02/08/2013).	No	The NRC asked GEH to include in the licensing basis the PBLE version and specified assumptions for that version used for the benchmark's analysis and load definition.	Revised NEDE-33408P (in response to **RAI 3.9-269**) represents the PBLE01 model description that is the ESBWR PBLE method version that is used for the benchmark and load definition and that will be used for the ESBWR steam dryers. For **RAI 3.9-271**, no changes to the ESBWR licensing basis are proposed.
3.9-272	*The staff's question is in regard to submitting the performance and results of the ongoing strain gage calibration studies.*	MFN 12-046, Rev. 2 (01/24/2013)	Yes	*GEH is requested to submit the performance and results of the ongoing strain gage calibration studies, with adjustments to the bias errors and uncertainties for strain gages.*	See GEH response to **RAI 3.9-272**, Sections 1 – 4.
3.9-272 (cont.)				*Accordingly, GEH is requested to specify applicable ESBWR Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) to confirm the accuracy of the strain gages prior to plant startup.*	See GEH response to **RAI 3.9-272**, Sections 6-7.
3.9-272 (cont.)				NRC provided feedback on 11/07/2012. [[ ]]	See GEH response to **RAI 3.9-272**, Sections 1 – 4.
3.9-272				NRC provided feedback on 11/07/2012 that GEH is	As described in the response to **RAI 3.9-272** (Sections 6 and10),

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
(cont.)				requested to document the strain gauge static pressure calibration procedures in an ESBWR licensing basis document.	Section 3L.4.6 is revised to include information on the strain gauge static pressure calibration procedures as they will be employed in the ESBWR processes. Also, information on calibration of strain gauges is added to NED-33408 Rev. 2 Section 4.4.2 (see response to **RAI 3.9-269**).
3.9-273	*The staff's question is in regard to describing the performance and results of the hammer tests on the SSES steam dryer.*	MFN-12-038, Rev. 1 (06/01/2012)	No	*GEH is requested to describe the performance and results of the hammer tests on the SSES steam dryer, and the lessons learned for the FE model of the steam dryer.*	The hammer test was provided in response to **RAI 3.9-273**, as requested. No changes to the ESBWR licensing basis are proposed. The NRC feedback 11/07/2012 was that the response is adequate as submitted (in final).
3.9-274	*The staff's question is in regard to resolving the main steam line (MSL) strain gage calibration errors.*	MFN-12-040, Rev. 2 (01/24/2013)	Yes	*GEH is requested to describe the resolution of the main steam line (MSL) strain gage calibration errors in support of the ESBWR design certification application. GEH should include the 'pipe and beam' calibration report and the procedure used to correct for differences between benchmark and future plant strain gage models and installation configurations. GEH is requested to specify applicable ITAAC to confirm the accuracy of the strain gages prior to plant startup.*	To the extent that **RAI 3.9-274** relates to [[ ]] instruments for Method 2, GEH has deleted Method 2 from the ESBWR design certification (see **RAI 3.9-270** response). The response to **RAI 3.9-274** addresses each of the items in the RAI.
				NRC feedback on 05/16/2012: The NRC asked GEH to add comments about rust and scale on the mounting surface for installation of strain gauges.	GEH addressed this NRC feedback in response to related **RAI 3.9-272**. GEH considered the comment and determined to address appropriate surface preparations for strain gauge installation. Information is added to DCD Section 3L.4.6 to address this feedback, as follows:

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					Strain gauge manufacture installation procedures are followed to duplicate previous installations. Care is taken to assure surface preparation (attachment surface area polish), spot weld welding energy, and weld strength recommendations are followed for each gauge.
3.9-274 (cont.)				NRC feedback on 11/07/2012: GEH is requested to document the in plant static pressure MSL strain gauge procedure in an ESBWR Licensing Basis Document since GEH identified an additional MSL steam gauge B&U for the PBLE methodology as described and used in the GGNS analysis.	Report NED-33408 Rev. 2 Section 4.4.2 includes the description of the calibration of strain gauges, as described in response to **RAI 3.9-274**.
3.9-275	*The staff's question is in regard to evaluating the strain measured on the SSES steam dryer during EPU operation in comparison to the strain calculated from the SSES steam dryer analysis.*	MFN 12-047, Rev 1 (02/13/2013)	No	*GEH is requested to provide an evaluation of the strain measured on the SSES steam dryer during EPU operation in comparison to the strain calculated from the SSES steam dryer analysis. As part of this evaluation, GEH should address the failure of the skirt (and vessel support) on the SSES steam dryer during EPU operation, including an assessment of the stress in the region of the failure, and the lateral and torsional loading on the steam dryer. GEH should describe the lessons learned regarding the steam dryer design and the assessment methodology from the measured SSES steam dryer data.*	GEH addresses the NRC questions in response to **RAI 3.9-275**. No changes to the ESBWR licensing basis resulted from this response.
3.9-275 (cont.)				In a conference call conducted 08/15/2012, the NRC provided feedback on the draft response to RAI 3.9-275. Specifically, the NRC provided 9 items that should be addressed in a final response.	NRC feedback provided in the 08/15/2012 conference call is addressed in the response to **RAI 3.9-275** under the header "Additional Discussion."

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3.9-275 (cont.)				On 11/07/2012, the NRC provided feedback that the response to RAI 3.9-275 or RAI 3.9-277 need to discuss weld quality factors [[ ]].	**RAI 3.9-275** includes discussion under Addition Discussion Item #5 regarding [[ ]]. **RAI 3.9-275** addresses weld quality factors in Additional Discussion Item #8 as follows: Weld quality factors are addressed in the response to **RAI 3.9-277.**
3.9-276	*The staff's question is in regard to providing a specific analysis of the MSL nozzle location and size for the QC2 acoustic model and the SSES acoustic model.*	MFN 12-048, Rev. 1 (01/23/2013)	No	*GEH is requested to provide a specific analysis of the MSL nozzle location and size for the QC2 acoustic model and the SSES acoustic model, including the impact on the results of the analysis from the modeling errors in the location and size of the MSL nozzles.* The NRC discussed this RAI on 07/25/2012 and had no specific feedback beyond the question in the RAI.	GEH response to **RAI 3.9-276** addresses the NRC questions on the MSL nozzle location and size. No information is added to the ESBWR licensing basis.
3.9-277	*The staff's question is in regard to the use of specific types of welds in the ESBWR steam dryer and the justification for fatigue and quality factors for each weld type.*	MFN 12-086, Rev 2 (02/11/2013)	Yes	*GEH is requested to discuss the use of specific types of welds in the ESBWR steam dryer and the justification for fatigue and quality factors for each weld type. In addition, GEH is requested to discuss the [[ ]] in the ESBWR steam dryer as described in NEDE 33313P, Rev 2. During the audit, the staff asked GEH to address the [[ ]] in the ESBWR steam dryer design, and how the [[ ]] will be conducted. At the audit, GEH made a definitive statement that the ESBWR*	The response to **RAI 3.9-277** responds to the RAI questions. No DCD changes were identified. Changes to technical report NED-33313 to address this RAI are as follows (see response to **RAI 3.9-292** for NED-33313): Section 4.0, 1st paragraph, last sentence: From: The steam dryer is not an ASME Code component, but the design shall comply to the applicable requirements of ASME Code Subsection NG-3000 except for the weld quality and fatigue factors as discussed in Subsections 4.1 and 7.

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				steam dryer design [[ ]]. The staff noted that this is inconsistent with NEDE 33313P, Rev 2. Please provide clarification if [[ ]] in the ESBWR steam dryer.	To: The steam dryer is not an ASME Code component, but the design shall comply to the applicable requirements of ASME Code Subsection NG-3000 for primary structural welds. For [[ ]]. Section 4.2, 3rd paragraph, 5th sentence: From: [[ ]]. To: [[ ]].
3.9-277 (cont.)				On 11/07/2012, the NRC provided specific feedback for which information and clarification on several items was	Response to **RAI 3.9-277** restates the specific NRC feedback and responds to each item. See Section 6 of the response to

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				requested.	**RAI 3.9-277**.
3.9-277 (cont.)				On 11/07/2012, the NRC provided feedback that the response to RAI 3.9-275 or RAI 3.9-277 need to discuss weld quality factors [[ ]].	**RAI 3.9-275** includes discussion under Addition Discussion Item #5 regarding [[ ]]. **RAI 3.9-275** addresses weld quality factors in Additional Discussion Item #8 as follows: Weld quality factors are addressed in the response to **RAI 3.9-277.** **RAI 3.9-277** addresses weld quality factors.
3.9-278	*The staff's question is in regard to describing the potential for loose parts resulting from the failure of welds.*	MFN 12-049, Rev. 1 (01/31/2013)	No	*GEH is requested to discuss the potential for loose parts resulting from the failure of welds (such as partial penetration welds). GEH is requested to discuss the design criterion that the steam dryer must retain its structural integrity without the generation of loose parts in the reactor coolant and main steam systems. GEH is requested to discuss this design criterion in comparison to its evaluation of the report dated January 24, 2012, reviewed during the audit.*	GEH addresses the NRC questions in response to **RAI 3.9-278**. No changes to the ESBWR licensing basis are made as a result of this response.
3.9-278 (cont.)				NRC feedback 06/27/2012: -Rephrase the sentences in "conclusions" regarding safety significance of a loose part and FEMA. The point of the question was how loose parts are avoided. -In the conclusions, inspections "should" and regulatory requirements "should" be adequate needs to be changed to "are" as more positive statements. -Figure 1-1 was confusing (and raised weld quality	GEH response to **RAI 3.9-278** addresses these specific comments. No changes to the ESBWR licensing basis are made as a result of this response. -The response conclusions section is reworded to address how loose parts are avoided. -The response conclusions section is reworded to "are". The response is revised to explain that Figure 1-1 shows the

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				concerns) until GEH explained it was the original SSES SD showing an unwelded joint that did not propagate cracks in its 20-year operation. GEH indicated it would note that the figure is for the original SSES SD.	original SSES steam dryer.
3.9-279	*The staff's question is in regard to describing the welds in the SSES structural model used as the validation benchmark.*	MFN 12-050, Rev. 1 (01/24/2013)	No	*GEH is requested to describe the welds in the SSES structural model used as the validation benchmark. Additionally, describe how the fatigue assessment of the partial penetration welds is performed and accounted for in the fatigue assessment of the SSES dryer.* The NRC did not provide specific feedback on this RAI.	GEH response to **RAI 3.9-279** addresses the RAI. No changes are made to the ESBWR licensing basis as a result of this response.
3.9-280	*The staff's question is in regard to providing a description of the transition interface modeling.*	MFN 12-051, Rev. 2 (02/15/2013)	Yes	*GEH is requested to provide a description of the [[ ]], including a description of how the dimensions (length and thickness) of the layer plate elements, [[ ]], is determined. GEH is also requested to clearly describe the criterion for how the [[ ]], is determined. Additionally, GEH should address [[ ]] concerns identified in letters from Entergy in support of the Grand Gulf EPU license amendment and [[ ]].*	GEH response to **RAI 3.9-280** addresses the RAI. No changes are made to the ESBWR licensing basis as a result of this response. The response to **RAI 3.9-280** also addresses specific NRC feedback in the "Additional Questions" sections of the response.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
3.9-281	*The staff's question is in regard to describing SSES dryer components requiring further post evaluation to determine the stress reduction factors.*	MFN-12-052, Rev. 1, 06/12/2012	No	*GEH is requested to provide a description for SSES dryer components requiring further post evaluation to determine the stress reduction factors (SRF). If applicable, GEH is requested to describe sub-model analysis and [[ ]] approach. GEH should also explain whether sub-modeling and/or [[ ]] approach always provides [[ ]]. Additionally, GEH is requested to describe if the [[ ]].* The NRC did not provide specific feedback on this RAI.	GEH response to **RAI 3.9-281** addresses the RAI. No changes are made to the ESBWR licensing basis as a result of this response.
3.9-282	*The staff's question is in regard to providing justification for applying dynamic analysis to unconnected nodes in CAR# 57911.*	MFN-12-070 06/05/2012	No	During the audit, the staff reviewed Corrective Action Report (CAR) 57911 that pertains to a submodel that contained two unconnected nodes. The staff noted that the justification for the unconnected nodes was based on a study using [[ ]]. The staff requests justification based on applying the applicable dynamic flow induced vibration (FIV) loading, and the appropriate cut boundary conditions to the submodel mentioned in CAR# 57911. The NRC did not provide specific feedback on this RAI.	GEH response to **RAI 3.9-282** addresses the RAI. No changes are made to the ESBWR licensing basis as a result of this response.

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
3.9-283	*The staff's question is in regard to providing additional justification for the submodel analysis used in GGNS if a similar approach was applied to SSES steam dryer or validate the conclusion based on additional submodels.*	MFN 12-054, Rev. 1 (02/14/2013)	No	*During the audit, the staff discussed with GEH the GGNS summarized [[ ]] approach resulted in higher stress with a difference greater than [[ ]] for the following several dryer components: [[ ]] Entergy justified these high stress areas by performing a [[ ]] However, that location is not the higher stress location in terms of magnitude [[ ]] or the higher percentage difference location [[ ]]. If a similar approach was applied to SSES steam dryer, GEH is requested to provide additional justification for the other significant locations noted above for the applicability of the submodel analysis conclusion, or validate the conclusion based on additional submodels.*	GEH response to **RAI 3.9-283** addresses the RAI. No changes are made to the ESBWR licensing basis as a result of this response.
3.9-283 (cont.)				NRC feedback on 11/14/2012 indicated that information related to the GGNS approach should be on the ESBWR docket.	To address this specific NRC feedback, the response to **RAI 3.9-283** has an addendum that includes the GGNS information.
3.9-284	*The staff's question is in regard to clarifying information included in Table 1 (on sheet 4 of DRF 0000-0087-2787, "SSES Dryer FEM with Superelement Vane Bundle*	MFN 12-055, Rev. 2 (02/14/2013)	No	*During the audit, the staff inquired about changes made to the SSES ANSYS structural model during the SSES benchmarking effort. Following the exit meeting for the audit, the staff had the opportunity to review DRF 0000-0087-2787, "SSES Dryer FEM with [[*	GEH response to **RAI 3.9-284** addresses the RAI. The response states that no changes are made to the ESBWR licensing basis as a result of this response. However, information is added to NED-33313, Section 5.1 (see response to **RAI 3.9-292** for NED-33313 changes).

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
	Representations and Other Modifications").			*]] Representations and Other Modifications", dated 09/20/2008. Based on its review, the staff sheet 4 of the document):* *(1) Element Nos. 99 and 199 are specified as [[ ]]. In a subsequent table, the element thicknesses are listed as [[ ]]. There is no information about stiffness or mass associated with these elements. Based on the complete description, it appears that these [[ ]]. The staff requests GEH to* *(2) describe in detail the purpose of these elements and why they are needed; (2) confirm the thickness and specify the stiffness (E, nu) and mass density; (3) describe in detail the technical basis for determining that these [[ ]] do not affect the structural response of the steam dryer; and (4) if they do affect the structural response, provide the detailed technical basis for why this is acceptable.* *(2) Element No. 5 is specified as [[ ]], and is used to enforce*	

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				moment transfer between shell and solid elements. The staff could not find information about the thickness, stiffness or mass associated with these elements. The staff requests GEH to (1) describe in detail the implementation of this technique to enforce moment transfer; (2) specify the thickness, stiffness (E, nu) and mass density for these elements; (3) describe in detail the technical basis for determining that these elements do not affect the structural response of the steam dryer; and (4) if they do affect the structural response, provide the detailed technical basis for why this is acceptable. *(3) GEH is requested to provide the purpose for utilizing any fictitious overlay elements in regions other than solid-to-shell transitions, and their impact on the SSES stresses.* *(4) GEH is requested to specifically describe the extent to which the elements identified in items (1) and (2) above will be implemented in the ANSYS structural analysis of the ESBWR steam dryer. GEH should also discuss any planned changes for ESBWR, and the technical basis for the changes.*	
3.9-284 (cont.)				NRC feedback 11/07/2012: The following clarifications and additional information	The first item is addressed in response to **RAI 3.9-284**. The second item is addressed in response to **RAI 3.9-280**.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				are needed: 1) Explain in detail the ANSYS process that deletes the dummy shell elements from solution at each time step, after the instantaneous nodal forces on the solid elements are calculated from the instantaneous pressures on the shell elements. 2) Shell overlay elements 2 and 4 to enforce rotational compatibility between shell elements and solid elements are described in detail in the response to RAI 280 and are reviewed there.	
3.9-285	*The staff's question is in regard to clarifying the "peak" stress from the shell model.*	MFN 12-077, Rev. 2 (02/15/2012)	Yes	*During the audit, the staff and GEH discussed at length the calculation methods identified in Section 4.1 and Figure 4-1 of Reference 1, related to the prediction of the alternating peak stress intensity for the fatigue evaluation of fillet welds. As an example, GEH described in detail its response to a GGNS RAI that addressed the same issue. The response to the GGNS RAI provided a single comparison between 2 methods discussed in NEDE 33313P, Rev 2 for fillet welds. These are method (1) calculation of a* [[ ]]; *and method (2)* [[ ]].	The NRC questions are addressed in response to **RAI 3.9-285**. In addition, the response to **RAI 3.9-285** addresses NRC feedback provided 11/14/2012 in Section 7 of the response. (see response to **RAI 3.9-292** for NED-33313) **<u>ESBWR DCD Changes:</u>** The following changes will be made to Section 3.9 of the ESBWR DCD: • Section 3.9.2.3, change "peak component stress" to "highest component stress", one place. • Section 3.9.2.3, change "peak stress" to "highest stress", three places. The following changes will be made to Appendix 3L of ESBWR

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				The staff requested clarification of the peak stress from the shell model. GEH explained that this [[ ]]. In the example presented by GEH, there are [[ ]] sharing the target node. The local geometry is very complex. GEH [[ ]]. This value is compared directly to the material fatigue endurance limit [[ ]]. *Based on the one example presented, method (2) produced an acceptable result, compared to method (1). GEH has developed a post-processing procedure (which is discussed in the LTR on page 5 of 37) to calculate [[ ]], for use in method (1).* *There was no theoretical basis presented for method (2). Based on GEH's response to staff questions at the audit, there does not appear to be one. GEH apparently developed method (2) based on comparison of a very limited sample set. At this time, the staff is seeking a more comprehensive, quantitative technical basis for*	DCD: • Section 3L.3.3, change "peak stress" to "highest stress", one place. • Section 3L.5.2, change "peak stresses" to "highest stresses", two places. • Section 3L.5.5.2.1, change "peak stress" to "highest stress", two places. • Section 3L.5.5.2.2, change "peak stress" to "highest stress", one place. **<u>Engineering Report Changes (see response to RAI 3.9-292 for NED-33313):</u>** • The following changes will be made to NEDE-33313P-A (ref. 2). • Section 4.1, 2nd paragraph, change "peak stress" to "highest stress", two places. • Section 4.1, 3rd paragraph, change "peak stress" to "highest stress", one place. • Section 4.1, 7th paragraph: FROM: The [[ ]] TO:

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				GEH's conclusion that method (2) provides equal or greater conservatism, compared to method (1). To this end, the staff requests GEH to perform a series of simple confirmatory analyses that the staff can reference in its safety evaluation of this issue. *The basic model is a T-connection of 304 stainless steel plates, which may be considered to be of infinite longitudinal length. A unit strip may be used, reducing the problem to 2-D. The basic loading is in-plane membrane force and out-of-plane bending moment applied to the free end of the vertical (web) plate. The horizontal (flange) plate is constrained at both ends.* *The staff requests the applicant to conduct a parametric study, varying the lengths and thicknesses of the 2 plates, and the ANSYS shell element refinement. The shell element refinement should be varied by a factor of ten, and should envelope typical shell element lengths used in the steam dryer shell models. For each configuration, analyze a "unit" membrane force, a "unit" bending moment, and both applied simultaneously.* *Using the shell element stress results from the ANSYS analyses, calculate the peak alternating stress intensities using method (1) and method (2), for each permutation. In the method (1) calculation, assume a range of acceptable fillet weld sizes, based on the*	A [[ ]] • Section 4.1, 8th paragraph, item A: FROM: - [[ ]] TO: - [[ ]] • Section 4.1, 9th paragraph, change "peak stress" to "highest stress", two places. • Section 4.1 10th paragraph: FROM: [[

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				thicknesses of the plates being joined. In the method (2) calculation, tabulate the results with [[ ]] *defined in the last paragraph on page 5 of 37 of Reference 1. Given the simplicity of the model and loading, an extensive parametric study should be designed and implemented, to confirm the validity of method (2). In addition, as a check on the implementation of method (1), compare the results of method (1) to alternating stress intensity predictions "using traditional weld stress formulas", as defined in B. on page 5 of 37, assuming complete load reversal* [[ ]], *for a representative subset of cases.*	]] TO: [[ ]] • Section 4.1, 11th paragraph, change "peak stress" to "highest stress", one place. • Section 4.1, 13th paragraph, change "peak stress" to "highest stress", one place. • Figure 4.1, change "peak stress" to "highest stress", one place. • Section 5.1, change "peak stress" to "highest stress", one place. • Section 5.2.2, change "peak stress" to "highest stress", three places. • Section 5.2.4, change "peak stress" to "highest stress", 21 places. • Section 5.2.4, change "peak stresses" to "highest stresses", two places. • Section 9.1, change "peak stress location" to "highest

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					stress location", one place. • Section 9.2, change "peak stress" to "highest stress", nine places. • Section 9.2, change "peak alternating stress" to "highest alternating stress", one place.
3.9-286	*The staff's question is in regard to developing alternating peak stress intensity predictions using the solid element submodel approach for a representative set of cases, and to compare the results with the corresponding method (1) and method (2) results.*	MFN 12-077, Rev. 2 (02/15/2012)	No	During the audit, the staff and GEH also discussed the solid element submodel approach identified in Section 4.1 and Figure 4-1 of Reference 1, for predicting the alternating peak stress intensity for the fatigue evaluation of fillet welds. This method is applied when [[ ]] (top of page 6 of 37). In prior RAI responses, GEH has stated that the submodel approach is used when [[ ]], and that the submodel approach leads to reduced stresses. The staff inquired how many submodels are typically developed. GEH indicated that for GGNS, there are [[ ]] developed. Alternating peak stress intensity at all other locations are based on the shell model results. In a solid element submodel, the fillet is added. The fillet representation in the submodel is textbook – triangular with the design leg length. While multiple solid elements are used [[ ]]. As stated in Reference 1, top of page 6 of 37, "...,	GEH response to **RAI 3.9-286** addresses the questions in the RAI. In addition, the response to **RAI 3.9-285** addresses NRC feedback provided 11/14/2012 in Section 7 of the response. No changes to the ESBWR licensing basis are made as a result of the response.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				[[ ]]." As an adjunct to the parametric study comparing methods (1) and (2) for shell models (see Question 4), the staff requests GEH to develop alternating peak stress intensity predictions using the solid element submodel approach for a representative set of cases, and to compare the results with the corresponding method (1) and method (2) results. Include one example calculation that demonstrates the procedure defined in the statement quoted in the preceding paragraph.	
3.9-287	*The staff's question is in regard to describing the structural finite element model for the additional benchmark.*	MFN 12-058, Rev. 1 (02/14/2013)	No	*GEH is requested to describe the structural finite element model for the SSES steam dryer for use in benchmarking the ESBWR steam dryer analysis in support of the ESBWR design certification application. GEH should address concerns identified during review of the Grand Gulf EPU license amendment request and issues raised during the March audit. For example, GEH should discuss (a) resolution of unconnected nodes, (b) partial penetration welds, (3) dummy elements, and (d) load transfer concerns. Additionally, GEH is requested to update the dryer stresses to address the recently found errors (e.g., disconnected nodes, partial penetration welds, use of overlay) in the finite element model of SSES.*	GEH response to **RAI 3.9-287** addresses the questions in the RAI. As it notes, the response to **RAI 3.9-284** discusses the "dummy elements" in SSES FE model. The revised benchmark is addressed in **RAI 3.9-269**. Partial penetration welds are addressed in response to **RAI 3.9-279**. Regarding impacts on the ESBWR licensing basis, because the revised benchmark is based on GGNS, any impact on the benchmarking for these issues is covered. Refer to RAI **3.9-269** and **RAI 3.9-292** for changes to the ESBWR licensing basis for the GGNS replacement steam dryer benchmark.

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
3.9-287 (cont.)				NRC feedback on 11/07/2012: "GEH is requested to document the technical discussions in this RAI plus additional relevant technical discussions referenced in several GGNS responses in an ESBWR Licensing document."	With the change to the GGNS benchmark (response to **RAI 3.9-269**), and the responses to **RAI 3.9-279** and **RAI 3.9-284**, this NRC feedback is addressed by the response to **RAI 3.9-287** and these other RAI responses. No ESBWR licensing basis changes specific to the response to RAI 3.9-287 are necessary.
3.9-288	*The staff's question is in regard to submitting GEH's proposed technical approach to ensure that the ESBWR steam dryer shell model has a sufficiently refined mesh to accurately respond at the highest loading frequency of interest.*	MFN 12-059, Rev. 1 (02/08/2013)	No	*NEDE-33313P, Rev 2, does not directly address how the modal properties of the ANSYS global shell model of the steam dryer will be evaluated to ensure that the mesh is sufficiently refined to produce an acceptably accurate response up to the highest frequency of interest. On page 10, NEDE-33313P discusses a mesh sensitivity study to ensure that the design-basis response to the dynamic loading has no more than a 5 percent error. This maximum 5 percent error is then applied to the results as a "bias". While the [[ ]], ensuring that the structural model can adequately respond to the highest dynamic input frequency is equally necessary. On page 14, NEDE-33313P identifies this frequency to be [[ ]]. During the audit, GEH presented preliminary results of a hand calculation based on the Grand Gulf ANSYS shell model, and indicated that the ESBWR steam dryer shell model would have comparable mesh refinement. The staff requests GEH to submit its proposed technical approach to ensure that the ESBWR steam dryer shell model has a sufficiently*	GEH response to **RAI 3.9-288** addresses the questions in the RAI. No changes to the ESBWR licensing basis are made as a result of the response.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				refined mesh to accurately respond at the highest loading frequency of interest [[ ]]. On 11/07/2012, the NRC provided feedback that this response is adequate.	
3.9-289	*The staff's question is in regard to describing the process for the combined license (COL) licensee to satisfy ESBWR DCD Tier 1, Table 2.1.1-3, "ITAAC for the Reactor Pressure Vessel and Internals," in ITAAC 8.b.*	MFN-12-066, Rev. 2 (01/30/2013)	No	*ESBWR DCD Tier 1, Table 2.1.1-3, "ITAAC for the Reactor Pressure Vessel and Internals," specifies in ITAAC 8.b that the steam dryer will meet the requirements of ASME Boiler & Pressure Vessel Code, Subsection NG-3000 (except for weld quality and fatigue factors for secondary structural non-load bearing welds). GEH is requested to describe the process for the combined license (COL) licensee to satisfy this ITAAC.* On 11/07/2012, the NRC provided feedback that this response is acceptable.	GEH response to **RAI 3.9-289** addresses the NRC questions in the RAI. No changes are made to the ESBWR licensing basis as a result of this response.
3.9-290	*The staff's question is in regard to describing the process for the COL licensee to satisfy ESBWR DCD Tier 1, Table 2.1.2-3, "ITAAC for the Nuclear Boiler System," in ITAAC 36 and the process for the COL licensee to identify and resolve low frequency.*	MFN-12-066, Rev. 2 01/30/2013	Yes	*ESBWR DCD Tier 1, Table 2.1.2-3, "ITAAC for the Nuclear Boiler System," specifies in ITAAC 36 that the MSL and safety relief valve (SRV) and relief valve (RV) branch piping geometry precludes first and second shear layer wave acoustic resonance conditions from occurring and avoids pressure loads on the steam dryer at plant normal operating conditions. GEH is requested to describe the process for the COL licensee to satisfy this ITAAC. GEH is also requested to address the process for the COL licensee to identify and resolve low frequency loads, such as those occurring at SSES*	GEH addresses the NRC questions in response to **RAI 3.9-290.** Based on NRC feedback, DCD Tier 2 is revised to include a new sub-heading at the end of current DCD Tier 2 Subsection 3.9.5.3 entitled "Steam Dryer Acoustic Loading Effects from Safety-Relief Valve Standpipes and Main Steam Piping." The response describes the added content.

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				during EPU operation. On 11/07/2012, the NRC asked GEH to include more specificity on concepts for SRV and RV resonances and incorporate in the ESBWR Licensing Basis Document.	
3.9-291	*The staff's question is in regard to specifying the provision that will require the COL applicant to demonstrate that the FEA and post-processing of peak stress has been performed to confirm that the ESBWR steam dryer is structurally acceptable as part of a COL Information Item.*	MFN-12-066, Rev. 2, 01/30/2013	Yes	*ESBWR DCD Tier 2, Appendix 3L, "Reactor Internals Flow Induced Vibration Program," states in Section 3L.4.5, "Structural Evaluation," that a finite element analysis (FEA) is performed to confirm that the ESBWR steam dryer is structurally acceptable for operation. GEH is requested to specify the provision that will require the COL applicant to demonstrate that the FEA and post processing of peak stress has been performed to confirm that the ESBWR steam dryer is structurally acceptable as part of a COL Information Item.* On 11/07/2012, the NRC provided feedback, which is quoted in the GEH supplemental response to RAI 3.9-291.	GEH addresses the question in the RAI and NRC feedback in response and supplemental response to **RAI 3.9-291**. Several changes are described in the RAI response to the following sections of the ESBWR DCD: -Tier 1, Section 2.1.1 and Table 2.1.1-3. -Tier 2 Table 1.9-21 -Tier 2, Section 3.9.2.4 -Tier 2, Section 3L
3.9-292	*The staff's question is in regard to describing the changes that will be made to the topical reports (or DCD).*	MFN 13-007 (02/19/2013)	Yes	*The staff's question is in regard to describing the changes that will be made to the [ESBWR licensing basis documents]. GEH is requested to describe the changes to the topical reports for ESBWR steam dryer analysis that will be made to rely on the SSES steam dryer data to benchmark the steam dryer analysis in support of the ESBWR design certification application.*	GEH response to **RAI 3.9-292** is a compilation of ESBWR licensing basis changes that have resulted from responses to **RAIs 3.9-269 through 3.9-293**. The response contains a change list for the ESBWR Design Control Document and this roadmap.
3.9-292					Changes in NED-33313 (which is submitted with **RAI 3.9-292**):

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
(cont.)					S1.0 - Added overview of dryer structural evaluation process. S4.0 - Revised in response to **RAI 3.9-277** (MFN 12-086 Rev. 2) S4.1, 1st para, last sentence - Revised to reflect MASR = 2.0 per MFN 12-130, dated December 12, 2012 and response to **RAI 3.9-293**. S4.1, 2nd para, last sentence - Deleted steam line pressure measurements consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012 and response to **RAI 3.9-270**. S4.1, 3rd para - Revised to use on-dryer instrumentation for subsequent plants per MFN 12-130 dated December 12, 2012 and response to **RAI 3.9-270**. S4.1 - Revised to include changes identified in response to **RAI 3.9-285**. S4.2 - Revised in response to **RAI 3.9-277** (MFN 12-086 Rev. 2) S5.1 - Added shell-to-solid element interface modeling per response to **RAI 3.9-284**. Added changes for **RAI 3.9-285**. S5.2.2 - Revised to be consistent with the end-to-end benchmark documented in NEDC-33408 Rev. 2 (see response to **RAI 3.9-269**). Added changes for **RAI 3.9-285**. 5.2.3 - Deleted references to PBLE benchmarking in NEDC-33408 Supplement 1. 5.2.4, 3rd para, item 1 - Revised to use on-dryer instrumentation for subsequent plants per MFN 12-130 dated December 12,

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					2012 and response to **RAI 3.9-270**. 5.2.4, 3rd para, items 1 and 2 - Deleted steam line pressure measurements consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012 and response to **RAI 3.9-270**. 5.2.5 - Revised to be consistent with the end-to-end benchmark documented in NEDC-33408 Rev. 2 (see response to **RAI 3.9-269**). S8.3 - Corrected section reference. S9.1 - Deleted steam line pressure measurements consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012 and response to **RAI 3.9-270**. S9.1 - Revised to use on-dryer instrumentation for subsequent plants per MFN 12-130 dated December 12, 2012 and response to **RAI 3.9-270**. S9.2 - Deleted obsolete reference for fatigue endurance limit. Added changes for **RAI 3.9-270, RAI 3.9-285**, and **RAI 3.9-293**. S11.0 – Deleted Ref. 7 for **RAI 3.9-270**. Attachment 1 – Deleted (this was NRC SER for previous revision).
3.9-293	*The staff's question is in regard to describing the conservatisms in the steam dryer assessment.*	MFN 12-065, Rev. 1 (02/08/2013)	Yes	*GEH is requested to describe the conservatisms in the steam dryer assessment methodology in support of the ESBWR design certification application. For example, GEH should address conservatisms such as described in a letter from Entergy dated October 10, 2010 [actual date: October 10, 2011], in support of the Grand Gulf*	GEH response to **RAI 3.9-293** addresses conservatisms in the steam dryer assessment methodology in support of ESBWR design certification. The response also addresses lessons learned from GGNS replacement steam dryer power ascension testing and analysis.

RAI Number	*RAI Summary*	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
				EPU license amendment request.	
3.9-293 (cont.)				On 11/07/2012, the NRC requested that GEH add information to the ESBWR licensing basis and to document, in an ESBWR licensing basis document, lessons learned from the GGNS Power Ascension 90-day report since testing and analysis provide additional conservatisms in the steam dryer assessment methodology in support of the ESBWR Design Certification application.	The GEH response includes a revision to Report NED-33312 to include the following changes: -Deletion of PBLE Method 2 -Addition of minimum alternating stress ratio of 2.0 Specific changes are as follows: -Page vii Updated the revision number of NEDE-33312P referenced in the ABSTRACT. -S1.0 3rd bullet – deleted [[ ]] per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S1.0 Added 4th bullet for MASR of 2.0; see MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S1.0 Revised 6th bullet to be consistent with application of MASR of 2.0 in dryer design. -S1.0 Corrected 7th bullet from “steam dome pressure” to “dryer pressure loads.” -S1.0 Revised 8th bullet from “invessel instruments” to “on-dryer instruments” -S1.0 Deleted 9th bullet consistent with deletion of PBLE “Method 2” per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S1.0 10th bullet – deleted “and steam line” consistent with deletion of PBLE “Method 2” per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)**

RAI Number	RAI Summary	RAI Final Response Letters and Date	Changes to Licensing Basis	RAI and NRC Questions via Feedback on Draft Responses	Response (see Footnote 1)
					-S1.0 Revised 12th bullet to be consistent with revised end-to-end benchmark process in References 2 and 3. **(RAI 3.9-269.)** -S1.0 Revised last bullet to use on-dryer instrumentation for subsequent plants per MFN 12-130 dated December 12, 2012. **(RAI 3.9-270.)** -S2.2 [[ ]] consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S3.1 Included reference to Reference 3 in first paragraph. -S4.1 First paragraph - deleted "and steam line" consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S4.1 Added statement that the load projections in Figure 4.1-1 are illustrative of the design load definitions that will be used for the ESBWR dryer design. -S4.1 Deleted references to Reference 4 (NEDC-33408 S1 PBLE Method 2) consistent with MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -S4.1 Edited 7th and 8th paragraphs for clarification. -S4.1 Included reference to Reference 3 in 9th paragraph. -S6.0 Updated References 2 and 3 to be consistent with revisions to these reports. -S6.0 Deleted Reference 4 consistent with deletion of PBLE "Method 2" per MFN 12-130, dated December 12, 2012. **(RAI 3.9-270.)** -Attachment 1 Deleted. NOTE: Attachment 1 was the NRC Safety Evaluation Report for its initial approval of the Report.

Enclosure 6

MFN 13-007

ESBWR Design Control Document Marked-Up Pages

IMPORTANT NOTICE REGARDING CONTENTS OF THIS DOCUMENT

Please Read Carefully

2.1.1 Reactor Pressure Vessel and Internals

Design Description

The RPV and Internals generate heat and boil water to steam in a direct cycle. The functional arrangement of the RPV and Internals includes the reactor core and reactor internals (see Figure 2.1.1-1). The chimney provides an additional elevation head (or driving head) necessary to sustain natural circulation flow through the RPV. The chimney also forms an annulus separating the subcooled recirculation flow returning downward from the steam separators and feedwater from the upward steam-water mixture flow exiting the core. The steam is separated from the steam-water mixture by passing the mixture sequentially through an array of steam separators attached to a removable cover on the top of the chimney assembly, and through the steam dryer, resulting in outlet dry steam. The water mixes with the feedwater as it comes into the RPV through the feedwater nozzle. RPV internals consist of core support structures and other equipment.

The RPV is located in the containment. Internal component locations are shown on Figure 2.1.1-1.

The reactor core contains a matrix of fuel rods assembled into fuel assemblies using structural elements. Control rods in the reactor perform the functions of power distribution shaping, reactivity control, and scram reactivity insertion for safety shutdown response. The core is designed for 1132 fuel bundles and 269 control rods arranged as shown in Figure 2.1.1-2.

(1) The functional arrangement of the RPV and Internals is as described in the Design Description of this Subsection 2.1.1, Table 2.1.1-1 and Figure 2.1.1-1.

(2) The key dimensions (and acceptable variations) of the as-built RPV are as described in Table 2.1.1-2.

(3) a1. The RPV and its components identified in Table 2.1.1-1 (shroud, shroud support, top guide, core plate, control rod guide tubes and fuel supports) as ASME Code Section III are designed in accordance with ASME Code Section III requirements.

a2. The RPV and its components identified in Table 2.1.1-1 (shroud, shroud support, top guide, core plate, control rod guide tubes and fuel supports) as ASME Code Section III shall be reconciled with the design requirements.

a3. The RPV and its components identified in Table 2.1.1-1 (shroud, shroud support, top guide, core plate, control rod guide tubes and fuel supports) as ASME Code Section III

are fabricated, installed, and inspected in accordance with ASME Code Section III requirements.

(4) Pressure boundary welds in the RPV meet ASME Code Section III non-destructive examination requirements.

(5) The RPV retains its pressure boundary integrity at its design pressure.

(6) The equipment identified in Table 2.1.1-1 as Seismic Category I can withstand Seismic Category I loads without loss of safety function.

(7) RPV surveillance specimens are provided from the forging material of the beltline region and the weld and heat affected zone of a weld typical of those adjacent to the beltline region. Brackets welded to the vessel cladding at the location of the calculated peak fluence are provided to hold the removable specimen holders and a neutron dosimeter in place.

(8) a. The RPV internal structures listed in Table 2.1.1-1 (chimney and partitions, chimney head and steam separators assembly, and steam dryer assembly) must meet the limited provisions of ASME Code Section III regarding certification that these components maintain structural integrity so as not to adversely affect RPV core support structure.

b. The RPV internal structures listed in Table 2.1.1-1 (chimney and partitions, chimney head and steam separators assembly, and steam dryer assembly) meet the requirements of ASME B&PV Code, Subsection NG-3000, except for the weld quality and fatigue factors for secondary structural non-load bearing welds.

(9) The initial fuel to be loaded into the core will withstand flow-induced vibration and maintain fuel cladding integrity during operation.

(10) The fuel bundles and control rods intended for initial core load have been fabricated in accordance with the approved fuel and control rod design.

(11) The reactor internals arrangement conforms to the fuel bundle, instrumentation, neutron sources, and control rod locations shown on Figure 2.1.1-2.

(12) The number and locations of pressure sensors installed on the steam dryer for startup testing ensure accurate pressure predictions at critical locations.

(13) The number and locations of strain gages and accelerometers installed on the steam dryer for startup testing are capable of monitoring the most highly stressed components, considering accessibility and avoiding discontinuities in the components.

(14) The number and locations of accelerometers installed on the steam dryer for startup testing are capable of identifying potential rocking and of measuring the accelerations resulting from support and vessel movements.

(15) The initial fuel to be loaded into the core will be able to withstand fuel lift and seismic and dynamic loads under normal operation and design basis conditions.

~~(15)~~(16) The as-built steam dryer predicted peak stress is below the fatigue limit. 3.9-291

Table 2.1.1-3

ITAAC For The Reactor Pressure Vessel and Internals

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
15. The initial fuel to be loaded into the core will be able to withstand fuel lift and seismic and dynamic loads under normal operation and design basis conditions.	An analysis of the fuel lift and seismic and dynamic loads will be performed on the fuel bundle design that will be loaded into the ESBWR initial core.	The initial fuel to be loaded into the core will have primary stresses and maximum fuel bundle lift out of the fuel support piece that do not exceed the allowable values provided in the approved Fuel Assembly Mechanical Design Report.
16. The as-built steam dryer predicted peak stress is below the fatigue limit.	Analyses using NRC-approved methodologies are performed.	Fatigue analyses of the as-built steam dryer verify that the maximum calculated alternating stress intensity provides at least a Minimum Alternating Stress Ratio of 2.0 to the allowable alternating stress intensity of 93.7 MPa (13,600 psi).

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Table 1.6-1

Referenced GE / GEH Reports

Report No.	Title	Section No.
NEDO-33306	GE Hitachi Nuclear Energy, "ESBWR Severe Accident Mitigation Design Alternatives," NEDO-33306, Class I (Non-proprietary), Revision 4, October 2010.	19.2
NEDE-33312P~~-A~~ NEDO-33312~~-A~~	GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Acoustic Load Definition," NEDE-33312P~~-A~~, Class III (Proprietary), Revision ~~2~~3, ~~October~~ February 201~~0~~3, and NEDO-33312~~-A~~, Class I (Non-Proprietary), Revision ~~2~~3, ~~October~~February 201~~0~~3.	3L
NEDE-33313P~~-A~~ NEDO-33313~~-A~~	GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDE-33313P~~-A~~, Class III (Proprietary), Revision ~~2~~3, ~~October~~ February 2013~~0~~, and NEDO-33313~~-A~~, Class I (Non-Proprietary), Revision ~~2~~3, ~~October~~ February 201~~0~~3.	3.9, 3L
NEDC-33326P-A NEDO-33326-A	*[Global Nuclear Fuel, "GE14E for ESBWR Initial Core Nuclear Design Report," NEDC-33326P-A, Revision 1, Class III (Proprietary), and NEDO-33326-A, Revision 1, Class I (Non-proprietary), September 2010.]**	4.3, 4.4, 4A, 4D, 15.0, 15.2, 15.3, 15.5
NEDO-33337	GE Hitachi Nuclear Energy, "ESBWR Initial Core Transient Analyses," NEDO-33337, Class I (Non-proprietary), Revision 1, April 2009.	4.4, 4D, 15.0, 15.2, 15.3, 15.5, 15D
NEDO-33338	GE Hitachi Nuclear Energy, "ESBWR Feedwater Temperature Operating Domain Transient and Accident Analysis," NEDO-33338, Class I (Non-proprietary), Revision 1, May 2009.	1.1, 4.4, 4D, 6.2, 6.3, 15.0, 15.2, 15.3, 15.5, 15D Chapter 16, Sect. 5.6.3
NEDO-33373-A	GE-Hitachi Nuclear Energy, "Dynamic, Load-Drop, and Thermal-Hydraulic Analyses for ESBWR Fuel Racks," NEDO-33373-A, Revision 5, Class I (Non-proprietary), October 2010.	9.1

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Table 1.6-1

Referenced GE / GEH Reports

Report No.	Title	Section No.	
NEDC-33374P-A NEDO-33374-A	[*GE-Hitachi Nuclear Energy, "Safety Analysis Report for Fuel Storage Racks Criticality Analysis for ESBWR Plants," NEDC-33374P-A, Revision 4, Class III (Proprietary) September 2010, and NEDO-33374-A, Revision 4, Class I (Non-proprietary), September 2010.*]*	9.1	
NEDE-33391	GE Hitachi Nuclear Energy, "ESBWR Safeguards Assessment Report," NEDE-33391, Revision 3, March 2010 – Safeguards Information.	13.6	
NEDC-33408P~~-A~~ NEDO-33408~~-A~~	GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDC-33408P~~-A~~, Class III (Proprietary), Revision ~~1~~2, ~~October~~ February 201~~0~~3, and NEDO-33408~~-A~~, Class I (Non-proprietary), Revision 2~~1~~, ~~October~~February 2013~~0~~.	3L	3.9-269
~~NEDC-33408 Supplement 1P-A~~ ~~NEDO-33408 Supplement 1-A~~	~~GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," NEDC-33408 Supplement 1P-A, Revision 2, Class III (Proprietary), October 2010, and NEDO-33408 Supplement 1-A, Revision 2, Class I (Non-proprietary), October 2010.~~	~~3L~~	3.9-269 and 3.9-292

Table 1.9-21

NRC Regulatory Guides Applicability to ESBWR

RG No.	Regulatory Guide Title	Appl. Rev.	Issued Date	ESBWR Appli-cable?	Comments
1.9	Selection, Design, Qualification and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants	3	07/1993	No	No safety-related Diesel Generators for ESBWR. URD intent – see Table 1.9-21a
1.11	Instrument Lines Penetrating Primary Reactor Containment (Safety Guide 11) and Supplement to Safety Guide 11, Backfitting Considerations	0	03/1971	Yes	Supplement issued 02/1972
1.12	Nuclear Power Plant Instrumentation for Earthquakes	2	03/1997	Yes	
1.13	Spent Fuel Storage Facility Design Basis	1	12/1975	Yes	URD Intent – see Table 1.9-21a. See also proposed Rev 2 published 12/1981 as CE 913-5.
1.14	Reactor Coolant Pump Flywheel Integrity	1	08/1975	No	PWR only
1.16	Reporting of Operating Information – Appendix A Technical Specifications	4	08/1975	—	COL
1.17	Protection of Nuclear Power Plants Against Industrial Sabotage	1	06/1973	No	Withdrawn 7/5/1991
1.20	Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing	~~2~~3	0~~5~~3/~~1976~~ 2007	Yes	Performed During Power Ascension Testing

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bolts or other suitable fastening strong enough to prevent overturning or sliding. The effect of friction on the ability to resist sliding is neglected. The effect of upward dynamic loads on overturning forces and moments is considered. Unless specified otherwise, anchorage devices are designed in accordance with the requirements of the ASME B&PV Code, Subsection NF, or ANSI/AISC-N690 and ACI 349.

Dynamic design data are provided in the form of acceleration response spectra for each floor area of the equipment. Dynamic data for the ground or building floor to which the equipment is attached are used. For the case of equipment having multiple supports with different dynamic motions, an upper bound envelope of all the individual response spectra for these locations is used to calculate maximum inertial responses of items with multiple supports.

Refer to Subsection 3.9.3.5 for additional information on the dynamic qualification of valves.

Supports

Subsections 3.9.3.7 and 3.9.3.8 address analyses or tests that are performed for component supports to assure their structural capability to withstand seismic and other dynamic excitations.

3.9.2.3 Dynamic Response of Reactor Internals Under Operational Flow Transients and Steady-State Conditions

[*The major reactor internal components within the vessel are subjected to extensive testing, coupled with dynamic system analyses, to properly evaluate the resulting FIV phenomena during normal reactor operation and from anticipated operational transients.*

In general, the vibration forcing functions for operational flow transients and steady-state conditions are not predetermined by detailed analysis. The vibration forcing functions for operational flow transients and steady state conditions are determined by first postulating the source of the forcing function, such as forces due to flow turbulence, symmetric and asymmetric vortex shedding, pressure waves from steady state and transient operations. Based on these postulates, prior startup and other test data from similar or identical components are examined for the evidence of the existence of such forcing functions. Special analysis of the response signals measured for reactor internals of many similar designs is performed to obtain the parameters, which determine the amplitude and modal contributions in the vibration responses. Based on these examinations, the magnitudes of the forcing functions and response amplitudes are derived. These magnitudes are then used to calculate the expected ESBWR responses for each component of interest during steady state and transient conditions. This study provides useful predictive information for extrapolating the results from tests of components with similar designs. This vibration prediction method is appropriate where standard hydrodynamic theory cannot be applied due to complexity of the structure and flow conditions. Elements of the vibration prediction method are outlined as follows:

- *Dynamic modal analysis of major components and subassemblies is performed to identify vibration modes and frequencies. The analysis models used for Seismic Category I structures are similar to those outlined in Subsection 3.7.2.*
- *Data from previous plant vibration measurements are assembled and examined to identify predominant vibration response modes of major components. In general, response modes are similar but response amplitudes vary among Boiling Water Reactors (BWRs) of differing size and design.*

- *Parameters are identified which are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions.*
- *Correlation functions of the parameters are developed which, multiplied by response amplitudes, tend to minimize the statistical variability between plants. A correlation function is obtained for each major component and response mode.*
- *Predicted vibration amplitudes for components of the prototype plants are obtained from these correlation functions based on applicable values of the parameters for the prototype plants. The predicted amplitude for each dominant response mode is stated in terms of a range, taking into account the degree of statistical variability in each of the correlations. The predicted mode and frequency are obtained from the dynamic modal analyses.*

The dynamic modal analysis forms the basis for interpretation of the initial startup test results (Subsection 3.9.2.4). Modal stresses are calculated and relationships are obtained between sensor response amplitudes and peak component stresses for each of the lower normal modes.

Details of the special signal analyses of the vibration sensors are given below:

The test data from sensors (accelerometers, strain gages, and pressure sensors) installed on reactor internal components are first analyzed through signal processing equipment to determine the spectral characteristics of these signals. The spectral peak magnitudes and the frequencies at the spectral peaks are then determined. These spectral peak frequencies are then classified as natural frequencies or forced frequencies. If a spectral peak is classified as being from a natural frequency, its amplitude is then determined using a band-pass filter if deemed necessary. The resultant amplitude is then identified as the modal response at that frequency. This process is used for all frequencies of interest. Thus the modal amplitudes at all frequencies of interest are determined. If a spectral peak is identified as being from a forced frequency, the source (such as the vane passing frequency of a pump) is identified. Again, its magnitude is determined using a band-pass filter if deemed necessary.

The modal amplitudes and the forced response amplitudes are then used to calculate the expected ESBWR amplitudes for the same component. These ESBWR expected amplitudes are determined by calculating the expected changes in the forcing function magnitudes from the test component to the ESBWR component. For example, for flow turbulence excited components, the magnitudes are determined by ratio with the flow velocity squared.

A flow chart of the above process is shown in Figure 3.9-6.

The allowable vibratory amplitude in each mode is that which produces a peak stress amplitude of ±68.95 MPa (±10,000 psi). For the steam dryer and its components, a higher allowable peak stress limit is used as explained in the following paragraphs.

Vibratory loads are continuously applied during normal operation and the stresses are limited to ±68.95 MPa (±10,000 psi), with the exception of the steam dryer, in order to prevent fatigue failure. Prediction of vibration amplitudes, mode shapes, and frequencies of normal reactor operations are based on statistical extrapolation of actual measured results on the same or similar components in reactors now in operation.

Extensive predictive evaluations have been performed for the steam dryer loading and structural evaluation. These evaluations are described in Appendix 3L.4. In the dryer design and in the development of the initial strain and accelerations acceptance limits used during startup, the fatigue analysis performed for the ESBWR steam dryer uses a fatigue limit stress amplitude of 93.7 MPa (13,600 psi). For additional conservatism in the predictive analysis, the analysis stress results will also meet a minimum alternating stress ratio of 2.0 between the analysis results and the fatigue acceptance limit. ~~For the outer hood component, which is subjected to higher pressure loading in the region of the main steamlines, the fatigue limit stress amplitude is 74.4 MPa (10,800 psi).~~ Following the startup testing of the first unit or if an acceptance limit is reached during power ascension, the ~~load~~ FIV load definition is defined from the recorded dryer pressure ~~or dryer pressure and steam line~~ data. ~~The load definition bias and uncertainty is benchmarked against the dryer pressure sensor data.~~ A structural assessment is performed to benchmark the FE model strain and acceleration predictions against the measured data. The dryer peak stress based on test data, adjusted for ~~load, FE model, and instrument~~ end-to-end benchmark bias and uncertainties, is then calculated and maintained less than 93.7 MPa (13,600 psi). The subsequent ESBWR steam dryers ~~includes~~ will follow the same ~~dryer~~ FIV monitoring ~~via~~ process using ~~main steam line~~ on-dryer instruments. The acceptance limits for subsequent plants is based on assuring that the stresses remain less than 93.7 MPa (13,600 psi) allowable stress. The limit is justified because first steam dryer is heavily instrumented, subsequent plants is also monitored for FIV loads, and the load and response is explicitly evaluated based on test data with consideration of bias and uncertainty. The steam dryer is a nonsafety-related component, performs no safety-related functions, and is only required to maintain its structural integrity (no loose parts generated) for normal, transient and accident conditions.

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The dynamic loads caused by FIV of the steam separators have been determined using a full-scale separator test under reactor conditions. During the test, the flow rate through the steam separator was 226,000 kg/hr (499,000 lbm/hr) at 7% quality. This is higher than the ESBWR maximum separator flow of 100,700 kg/hr (222,000 lbm/hr) at rated power. Test results show a maximum FIV stress of less than 49.6 MPa (7200 psi), well below the GEH acceptance criterion of 68.9 MPa (10,000 psi). Thus it can be concluded that separator FIV effects are acceptable. Jet impingement from feedwater flow has no significant effect on the steam separator assembly since the separator outer-most cylindrical structure (also referred to as the separator "skirt") is above the feedwater flow impingement area.]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior Nuclear Regulatory Commission (NRC) approval is required to change.

3.9.2.4 Initial Startup Flow Induced Vibration Testing of Reactor Internals

A reactor internals vibration measurement and inspection program is conducted only during initial startup testing. This meets the guidelines of RG 1.20 with the exception of those requirements related to preoperational testing which cannot be performed for a natural circulation reactor.

Initial Startup Testing

Vibration measurements are made during reactor startup at conditions up to 100% rated flow and power. Steady state and transient conditions of natural circulation flow operation are evaluated.

- *Parameters are identified which are expected to influence vibration response amplitudes among the several reference plants. These include hydraulic parameters such as velocity and steam flow rates and structural parameters such as natural frequency and significant dimensions.*
- *Correlation functions of the parameters are developed which, multiplied by response amplitudes, tend to minimize the statistical variability between plants. A correlation function is obtained for each major component and response mode.*
- *Predicted vibration amplitudes for components of the prototype plants are obtained from these correlation functions based on applicable values of the parameters for the prototype plants. The predicted amplitude for each dominant response mode is stated in terms of a range, taking into account the degree of statistical variability in each of the correlations. The predicted mode and frequency are obtained from the dynamic modal analyses.*

The dynamic modal analysis forms the basis for interpretation of the initial startup test results (Subsection 3.9.2.4). Modal stresses are calculated and relationships are obtained between sensor response amplitudes and ~~peak~~highest component stresses for each of the lower normal modes. 3.9-285

Details of the special signal analyses of the vibration sensors are given below:

The test data from sensors (accelerometers, strain gages, and pressure sensors) installed on reactor internal components are first analyzed through signal processing equipment to determine the spectral characteristics of these signals. The spectral peak magnitudes and the frequencies at the spectral peaks are then determined. These spectral peak frequencies are then classified as natural frequencies or forced frequencies. If a spectral peak is classified as being from a natural frequency, its amplitude is then determined using a band-pass filter if deemed necessary. The resultant amplitude is then identified as the modal response at that frequency. This process is used for all frequencies of interest. Thus the modal amplitudes at all frequencies of interest are determined. If a spectral peak is identified as being from a forced frequency, the source (such as the vane passing frequency of a pump) is identified. Again, its magnitude is determined using a band-pass filter if deemed necessary.

The modal amplitudes and the forced response amplitudes are then used to calculate the expected ESBWR amplitudes for the same component. These ESBWR expected amplitudes are determined by calculating the expected changes in the forcing function magnitudes from the test component to the ESBWR component. For example, for flow turbulence excited components, the magnitudes are determined by ratio with the flow velocity squared.

~~*A flow chart of the above process is shown in Figure 3.9-6.*~~

The allowable vibratory amplitude in each mode is that which produces a ~~peak~~highest stress amplitude of ±68.95 MPa (±10,000 psi). For the steam dryer and its components, a higher allowable ~~peak~~highest stress limit is used as explained in the following paragraphs. 3.9-285

Vibratory loads are continuously applied during normal operation and the stresses are limited to ±68.95 MPa (±10,000 psi), with the exception of the steam dryer, in order to prevent fatigue failure. Prediction of vibration amplitudes, mode shapes, and frequencies of normal reactor *operations are based on statistical extrapolation of actual measured results on the same or similar components in reactors now in operation.*

Extensive predictive evaluations have been performed for the steam dryer loading and structural evaluation. These evaluations are described in Appendix 3L.4. In the dryer design and in the development of the initial strain and accelerations acceptance limits used during startup, the fatigue analysis performed for the ESBWR steam dryer uses a fatigue limit stress amplitude of 93.7 MPa (13,600 psi). For additional conversavism in the predictive analysis, the analysis stress results will also meet a minimum alternating stress ratio of 2.0 between the analysis results and the fatigue acceptance limit. ~~For the outer hood component, which is subjected to higher pressure loading in the region of the main steamlines, the fatigue limit stress amplitude is 74.4 MPa (10,800 psi).~~ Following the startup testing of the first unit or if an acceptance limit is reached during power ascension, the ~~load~~ FIV load definition is defined from the recorded dryer pressure ~~or dryer pressure and steam line~~ data. ~~The load definition bias and uncertainty is benchmarked against the dryer pressure sensor data.~~ A structural assessment is performed to benchmark the FE model strain and acceleration predictions against the measured data. The dryer ~~peak~~highest stress based on test data, adjusted for ~~load, FE model, and instrument~~ end-to-end ~~benchmark~~ bias and uncertainties, is then calculated and maintained less than 93.7 MPa (13,600 psi). The subsequent ESBWR steam dryers ~~includes~~ will follow the same ~~dryer~~ FIV monitoring ~~via~~ process using ~~main steam line~~ on-dryer instruments. The acceptance limits for subsequent plants is based on assuring that the stresses remain less than 93.7 MPa (13,600 psi) allowable stress. The limit is justified because first steam dryer is heavily instrumented, subsequent plants is also monitored for FIV loads, and the load and response is explicitly evaluated based on test data with consideration of bias and uncertainty. The steam dryer is a nonsafety-related component, performs no safety-related functions, and is only required to maintain its structural integrity (no loose parts generated) for normal, transient and accident conditions.

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The dynamic loads caused by FIV of the steam separators have been determined using a full-scale separator test under reactor conditions. During the test, the flow rate through the steam separator was 226,000 kg/hr (499,000 lbm/hr) at 7% quality. This is higher than the ESBWR maximum separator flow of 100,700 kg/hr (222,000 lbm/hr) at rated power. Test results show a maximum FIV stress of less than 49.6 MPa (7200 psi), well below the GEH acceptance criterion of 68.9 MPa (10,000 psi). Thus it can be concluded that separator FIV effects are acceptable. Jet impingement from feedwater flow has no significant effect on the steam separator assembly since the separator outer-most cylindrical structure (also referred to as the separator "skirt") is above the feedwater flow impingement area.]*

* Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2*. Prior Nuclear Regulatory Commission (NRC) approval is required to change.

3.9.2.4 Initial Startup Flow Induced Vibration Testing of Reactor Internals

A reactor internals vibration measurement and inspection program is conducted only during initial startup testing. This meets the guidelines of RG 1.20 with the exception of those requirements related to preoperational testing which cannot be performed for a natural circulation reactor.

3.9.2.4 Initial Startup Flow Induced Vibration Testing of Reactor Internals

A reactor internals vibration measurement and inspection program is conducted only during initial startup testing. This meets the guidelines of RG 1.20 with the exception of those requirements related to preoperational testing which cannot be performed for a natural circulation reactor.

Initial Startup Testing

Vibration measurements are made during reactor startup at conditions up to 100% rated flow and power. Steady state and transient conditions of natural circulation flow operation are evaluated. The primary purpose of this test series is to verify the anticipated effect of single- and two-phase flow on the vibration response of internals. Details of the initial startup vibration test program are described in Subsection 3L.4.6 for the steam dryer and Section 3L.5 for other reactor internals. A brief summary is given below.

Vibration sensor types may include strain gauges, displacement sensors (linear variable transformers), and accelerometers.

Accelerometers are provided with double integration signal conditioning to give a displacement output. Sensor locations are provided in Appendix 3L.

In all plant vibration measurements, only the dynamic component of strain or displacement is recorded. Data are recorded and provision is made for selective on-line analysis to verify the overall quality and level of the data. Interpretation of the data requires identification of the dominant vibration modes of each component by the test engineer using frequency, phase, and amplitude information for the component dynamic analyses. Comparison of measured vibration amplitudes to predicted and allowable amplitudes is then to be made on the basis of the analytically obtained normal mode that best approximates the observed mode.

The visual inspections conducted prior to and remote inspections conducted following startup testing are for damage, excessive wear, or loose parts. At the completion of initial startup ~~testing, remote inspections of major components are performed on a selected basis. The remote~~ inspections cover the steam dryer, chimney, chimney head, core support structures, the ~~peripheral CRD and incore housings. Access is provided to the reactor lower plenum for these~~ inspections. #9 3.9-292

The analysis, design and equipment that are to be utilized for ESBWR comply with RG 1.20, as explained below.

RG 1.20 describes a comprehensive vibration assessment program for reactor internals during preoperational and initial startup testing. The vibration assessment program meets the requirements of Criterion 1, Quality Standards and Records, Appendix A to 10 CFR 50. This RG is applicable to the core support structures and other reactor internals.

Vibration testing of reactor internals is performed on all GE-BWR plants. Since the original issue of RG 1.20, test programs for compliance have been instituted for preoperational and startup testing. The first ESBWR plant is instrumented for testing. However, it can be subjected to startup flow testing only to demonstrate that FIVs similar to those expected during operation do not cause damage. Subsequent plants, which have internals similar to those of the first plant, are also tested in compliance with the requirements of RG 1.20. GEH is committed to confirm the satisfactory vibration performance of the internals in these plants through startup flow testing followed by inspection. Extensive vibration measurements in prototype plants together with satisfactory operating experience in all BWR plants have established the adequacy of reactor internal designs. GEH continues these test programs for subsequent plants to verify structural integrity and to establish the margin of safety. The FIV evaluation program pertaining to reactor internal components is addressed in Appendix 3L. As part of the initial implementation of the vibration assessment program, RG 1.20 guidance in Section 2.4 states that if inspection of the reactor internals reveals defects, evidence of unacceptable motion, or excessive or undue wear; if results from the measurement program fail to satisfy the specified test acceptance criteria; or if results from the analysis, measurement, and inspection programs are inconsistent, then further evaluations, modifications, or other actions are taken to justify the structural adequacy of the reactor internals. Such results and actions are reported to the NRC as part of the final report documentation of results of the comprehensive vibration assessment program following testing.

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3.9.5.3 Loading Conditions

Events to be Evaluated

Examination of the spectrum of conditions for which the safety-related design bases (Subsection 3.9.5.4) must be satisfied by core support structures and safety-related internal components reveals three significant load events:

- RPV Line Break Accident — a break in any one line between the reactor vessel nozzle and the isolation valve (the accident results in significant pressure differentials across some of the structures within the reactor and RBV caused by suppression pool dynamics).
- Earthquake — subjects the core support structures and reactor internals to significant forces as a result of ground motion and consequent RBV.
- SRV or DPV Discharge — RBV caused by suppression pool dynamics and structural feedback.

The faulted conditions for the RPV internals are discussed in Subsection 3.9.1.4. Loading combination and analysis for safety-related reactor internals including core support structures are discussed in Subsection 3.9.5.4.

Reactor Internal Pressure Differences

For reactor internal pressure differences, the events at normal, upset, emergency and faulted conditions are considered.

The TRACG computer code is used to analyze the transient conditions within the reactor vessel following AOOs, infrequent events and accidents (e.g., LOCA). The analytical model of the vessel consists of axial and radial nodes, which are connected to the necessary adjoining nodes by flow paths having the required resistance and inertial characteristics. The program solves the energy and mass conservation equations for each node to give the depressurization rates and pressures in the various regions of the reactor.

In order to determine the maximum pressure differences across the reactor internals, a two sigma statistical uncertainty study is performed to determine the upper bound pressure difference adders that are applied to the nominal pressure differences.

Table 3.9-3 summarizes the maximum pressure differentials that result from the limiting events among the AOOs, infrequent events and accidents (e.g., LOCA).

Seismic and Other RBV Events

The loads due to earthquake and other RBV acting on the structure within the reactor vessel are based on a dynamic analysis methods described in Section 3.7.

Steam Dryer Acoustic Loading Effects from Safety-Relief Valve Standpipes and Main Steam Piping

The safety relief valves (SRV) and safety valves (SV) standpipes and main steam branch lines in the ESBWR are specifically designed to preclude first and second shear layer wave acoustic resonance conditions from occurring and to avoid pressure loads on the steam dryer at plant normal operating conditions. Appropriate selection of SRV standpipes vertical height between main steam piping and the valves, along with selection of valve entrance effects, minimizes vortex generation. Design of piping is based on Strouhal numbers outside the range for which adverse impacts due to acoustic resonance would occur (based on resonance frequency determined using velocity at the speed of sount). Calculations performed as described below show that design features and selections can acceptable eliminate first and second shear wave resonances in SRV/SV standpipes and main steam piping.

For standpipe configuration, main steam and SRV/SV configuration (dimensions and arrangement) and attachment of standpipes to the main steam piping are considered. System geometry and flow rates are used to calculate critical Strouhal ranges. Then the Strouhal values for flow at 100% and 102% power levels are calculated to ensure that the values at normal operating flow rates are not within the critical range and that additional margin is provided.

As shown on Figure 5.2-2, the ESBWR main steam system has two longer main steam lines with 5 SRV/SVs, and two shorter main steam lines with 4 SRV/SVs, mounted perpendicular to the main steam pipe centerline. For eliminating main steam flow acoustic frequency at branchline connections, boundary conditions at the connections are evaluated to ensure flow disturbances are not on the same order as acoustic waves that may pass through the system. Design features such as dimensions, diameter ratios, lengths of piping from reactor vessel nozzles, entrance effects, and flow rate effects are considered in the evaluation.

Acceptance criteria are to demonstrate through the evaluation that the final as-built design of the main steam line and SRV/SV branch piping geometry precludes first and second shear layer wave acoustic resonance conditions from occurring and results in no significant pressure loads on the steam dryer at plant normal operating conditions. This is demonstrated by analysis showing that the final design maximum velocity, Strouhal range, and power level are outside the critical range of values where first and second shear resonances would occur. See Subsection 3.9.2.1 for piping vibration and dynamics effects testing during preoperational and startup testing. 3.9-290

3.9.10 References

3.9-1 General Electric Company, "BWR Fuel Channel Mechanical Design and Deflection," NEDE-21354-P, September 1976 (GE proprietary) and NEDO-21354, September 1976 (Non-proprietary).

3.9-2 General Electric Company, "BWR Fuel Assembly Evaluation of Combined Safe Shutdown (SSE) and Loss-of-Coolant Accident (LOCA) Loadings (Amendment No. 3)," NEDE-21175-3-P-A, October 1984 (GE proprietary) and NEDO-21175-3-A, October 1984 (Non-proprietary).

3.9-3 General Electric Company, "General Electric Environmental Qualification Program," NEDE-24326-1-P, Proprietary Document, January 1983.

3.9-4 M.A. Miner, "Cumulative Damage in Fatigue," Journal of Applied Mechanics, Vol. 12, ASME, Vol. 67, pages A159-A164, September 1945.

3.9-5 American Society of Mechanical Engineers Code for Operation and Maintenance of Nuclear Power Plants, 2001 Edition with 2003 Addenda.

3.9-6 (Deleted)

3.9-7 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Structural Evaluation," NEDE-33313P~~-A~~, Revision ~~2~~3, Class III (Proprietary), ~~October~~ February ~~2010~~2013, and NEDO-33313~~-A~~, Revision ~~2~~3, Class I (Non-Proprietary), ~~October~~ February ~~2010~~2013. 3.9-292

3.9-8 American Society of Mechanical Engineers OM-S/G-1990, Standards and Guides for Operation and Maintenance of Nuclear Power Plants

3L.1 INTRODUCTION

A flow-induced vibration (FIV) analysis and testing program of the reactor internal components of the ESBWR initial plant demonstrates that the ESBWR internals design can safely withstand expected FIV forces for reactor operating conditions up to and including 100% power and core flow. The ESBWR FIV program is considered to be a prototype per Reference 3L-1. This will require analysis, measurement and full inspection of reactor internals of the first plant. The ESBWR internals are similar to the Advanced Boiling Water Reactor (ABWR) internals; therefore, analyses and measurements from the ABWR FIV program are used to the extent possible. The ESBWR FIV program includes an initial evaluation phase that has the objective of demonstrating that the reactor internals are not subject to FIV issues that can lead to failures due to material fatigue. Throughout this part of the program, the emphasis is placed on demonstrating that the reactor components will safely operate for the design life of the plant. The results of this evaluation are shown in Reference 3L-1. This evaluation does not include the steam dryer since it is separately evaluated in References 3L-5, 3L-6, 3L-7 and 3L-8~~ and 3L-9~~; however, an overview of the steam dryer evaluation program is explained in Section 3L.4. The 3.9-270 second phase of the program is focused on preparing and performing the startup test program that demonstrates through instrumentation and inspection that no FIV problems exist. This part of the program meets the requirements of Regulatory Guide 1.20 with the exception of those requirements related to preoperational testing that are not applicable to a natural circulation plant.

3L.2.2 Evaluation Process – Part 2

The next phase of the evaluation program performed additional work to demonstrate the adequacy of the components where Part 1 determined additional evaluations were required. The objective of this phase completes a more quantitative evaluation and documents the existing facts regarding the individual components. This part of the evaluation focuses on the following:

(1) Similarities and differences of the ESBWR component design configurations as compared to prior designs. In most cases the comparison design is ABWR components.

(2) A review of prior calculations for the components being evaluated, to establish the mode shapes and natural frequencies. Calculation of the ESBWR component natural frequencies is determined based on this data.

(3) Prior plant startup instrumentation data from the prototype ABWR plant is reviewed to establish the magnitude and frequency of the measured vibration data, and to review the resulting calculated stress for the components that were instrumented.

(4) A comparison of the flow paths and characteristics of the ESBWR design to prior BWR designs where a startup vibration test program was conducted.

Using the results of the above items, an assessment as to the likelihood of FIV issues is completed and documented in Reference 3L-1. This report does not include the steam dryer since it was evaluated in separate reports (see references 3L-5, 3L-6, 3L-7, 3L-8 ~~and 3L-9~~). The evaluations for the chimney components and SLC lines are included in this report, but alternate methods to those described above have been used to evaluate FIV since these are new BWR components. This report concludes that FIV evaluations have been completed and that none of the reactor internal components are susceptible to FIV. 3.9-270

During the evaluation phase, the process as identified in Subsection 3.9.2.3 was followed to prepare finite element analysis (FEA) models per the details shown in Subsection 3L.5.5.1. This information will then be used as the basis for the instrumentation in the ESBWR startup test program. It should be noted that the SLC internal piping, steam dryer and chimney have already been identified in Section 3L.2.1 for inclusion in the startup test program.

3L.3.3 Testing and Two-phase Flow Analysis

For the ESBWR, the chimney partition assembly constitutes a structure that has a unique vibration evaluation program as part of the ESBWR reactor internals. In order to assess its capability to maintain structural integrity under plant operating conditions, a flow induced vibration evaluation is performed in which the fluctuating fluid force acting on the partition plates is evaluated by a combination of scale tests and two-phase flow analysis.

The test scope comprised a 1/6-scale (100 mm × 100 mm [4 in x 4 in]), a 1/12-scale (50 mm × 50 mm [2 in x 2 in]) and one almost full scale (500 mm × 500 mm [20 in x 20 in]) chimney. Tests use a mixture of air and water to simulate two-phase flow testing inside the chimney. The velocities of the gas and liquid components of the two-phase flow were adjusted to be consistent with ESBWR values to simulate the actual two-phase flow pattern. Different inlet flow conditions in the smaller scale models were used to investigate the influence of inlet mixing within the partition to simulate different power conditions. Pressure fluctuation was measured on the inner surface of the partition wall with pressure transducers. The 1/6-scale model was later divided into four cells for investigating the pressure fluctuations between cells (Reference 3L-1).

The scale model tests were used to investigate the effect of model size on the magnitude of pressure fluctuations acting on the partition wall in steam-water conditions.

A structural analysis of the chimney and partition design was then conducted using finite element methods. First, an eigenvalue analysis determined that the lowest natural frequency of the chimney structure is approximately 54 Hz. This was sufficiently greater than the predominant frequency of pressure fluctuation determined by testing (2 Hz) that a static analysis of the structure was concluded to be proper. Based on the results of that static analysis, a maximum stress of 32.8 MPa (4,760 psi), with a fatigue strength reduction factor of 2, was calculated near the edge of the partition plate joint. This stress value is bounded by the allowable vibration ~~peak~~highest stress amplitude of 68.9 MPa (10,000 psi) specified in Subsection 3.9.2.3.

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3L.4.4 Fluid Loads on the Steam Dryer

During normal operation, the steam dryer experiences a static differential pressure loading across the steam dryer plates resulting from the pressure drop of the steam flow across the vane banks. The steam dryer also experiences fluctuating pressure loads resulting from turbulent flow across the steam dryer and acoustic sources in the vessel and main steamlines. During transient and accident events, the steam dryer also experiences acoustic and flow impact loads that result from system actions (e.g., turbine stop valve closure) or from the system response (e.g., the two-phase level swell following a main steamline break).

Of particular interest are the fluctuating acoustic pressure loads that act on the steam dryer during normal operation that have led to fatigue damage in previous steam dryer designs. In the low frequency range, these pressure loads have been correlated with acoustic sources driven by the steam flow in the outer hood and vessel steam nozzle region. In the high frequency range, acoustic resonances in the stagnant steamline side branches (e.g., relief valve standpipes) are coupled to the vessel, thus imparting a pressure load on the steam dryer. Vessel acoustic modes may also be excited by sources inside and outside the vessel, resulting in additional acoustic pressure loads in the middle frequency range.

A detailed description of the pressure load definition for the ESBWR steam dryer is provided in Reference 3L-5. The load definition is based on the Plant Based Load Evaluation Methodology described in Reference 3L-8. References 3L-8 ~~and 3L-9~~ provides the theoretical basis of the methodology, describes the analytical model and provides benchmark and sensitivity comparisons of the methodology predictions with measured pressure data taken from instrumented steam dryers. The fluctuating load definition is based on the load definitions based on in-plant measurements that were developed for the steam dryer structural analyses in several extended power uprates. These load definitions provide a fine-mesh array of pressure time histories that are consistent with the structural finite element model nodalization. Multiple load definitions are used in the ESBWR steam dryer analysis in order to evaluate the steam dryer response over a wide frequency range. These load definitions include the limiting low and high frequency loads observed in plants with instrumented steam dryers. Based on the unique plant configurations (e.g., dead legs in the main steamlines that may amplify the low frequency acoustic response) and operating conditions (e.g., high steam line flow velocities) in these instrumented plants, the load definitions from these plants are expected to provide a robust load definition for the ESBWR. The load definitions developed for the ESBWR are also benchmarked against the instrumented steam dryer measurements taken during startup testing for the lead ABWR. The ESBWR and ABWR have the same vessel diameter and vessel steam nozzle design (with flow restricting venturi), and similar main steamline layouts; therefore, it is expected that the frequency content of the ESBWR steam dryer pressure loads will be similar to those measured on the ABWR.

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~~Reference 3L-9 provides the results of benchmarking and sensitivity studies of the pressure load definition methodology against measured pressure data taken during power ascension testing of a replacement steam dryer installed at an operating nuclear plant. Reference 3L-9 concludes that, based on comparisons of model predictions to actual measurements, the methodology predicts good frequency content and spatial distribution, and the safety relief valve resonances are well captured. The methodology provides accurate predictions of main steamline phenomena~~ 3.9-270

~~occurring downstream of the main steamline sensors, valve whistling (safety relief valve branch line) and broadband excitations (venturi, main steam isolation valve turbulence). The methodology also accurately predicts the dryer pressure loads resulting from vessel hydrodynamic phenomena.~~

3L.4.6 Instrumentation and Startup Testing

The ESBWR steam dryer is instrumented with temporary vibration sensors to obtain flow induced vibration data during power operation. The primary function of this vibration measurement program is to confirm FIV load definition used in the structural evaluation is conservative with respect to the actual loading measured on the steam dryer during power operation, and to verify that the steam dryer can adequately withstand stresses from flow induced vibration forces for the design life of the steam dryer. The instrumentation and startup testing program for the ESBWR steam dryer follows NRC regualtory guidance in Reference 3L-10, as described below. The detailed objectives are as follows: 3.9-291

- Determine the as-built frequency response parameters: This is achieved by frequency response testing the steam dryer components. The results yield natural frequencies, mode shapes and damping of the components for the as-built steam dryer. These results are used to verify portions of the steam dryer analytical model.
- Confirm FIV loading: In order to confirm loading due to turbulence, acoustics and other sources, dynamic pressure sensors are installed on the steam dryer. These measurements will provide the actual pressure loading on the steam dryer under various operating conditions.
- Verify the design: Based on past knowledge gained from different steam dryers, as well as information gleaned from analysis, selected areas are instrumented with strain gages and accelerometers to measure vibratory stresses and displacements during power operation. The measured strain values are compared with the allowable values (acceptance criteria) obtained from the analytical model to confirm that the steam dryer alternating stresses are within allowable limits.

The objective of the steam dryer frequency response test is to identify the as-built frequencies and mode shapes of several key components of the steam dryer at ambient conditions. Different components of the steam dryer have different frequencies and mode shapes associated with them. The areas of interest are the drain channel, the outer hood panel, the inner hood panel, the side panel, and the skirt. These results are used to verify portions of the finite element model of the steam dryer.

The concern is that local natural frequencies may coincide with existing forcing functions to cause resonance conditions. The resonance could cause high stresses to occur in localized areas of the steam dryer. A finite element frequency response analysis can calculate the frequency and mode shape of a component, but they are only ideal approximations to the real values due to variations such as plate thickness, weld geometries, configuration tolerances and residual stresses that affect the assumed boundary conditions in the finite element model. The mode shapes and frequencies determined by the frequency response test are used to validate the finite element frequency response analysis and determine the uncertainty in the finite element model predictions of the frequency response. The FE model and experimental transfer functions are then used to derive frequency dependent amplitude bias and uncertainty of the FE model for key areas of the dryer. This is described further in Reference 3L-6.

The frequency response test is performed following final assembly of the steam dryer. The tests are performed with the steam dryer resting on simulated support blocks similar to the way the steam dryer is seated inside the reactor vessel.

Two types of impact tests are performed on the steam dryer: (1) Dry frequency response test, and (2) Wet frequency response test with the steam dryer skirt and drain channels partially submerged in different water levels (to approximate in-reactor water level). Both tests are conducted in ambient conditions. Temporary bondable accelerometers are installed at predetermined locations for these tests. An instrumented input force is used to excite the steam dryer at several pre-determined locations and the input force and the structural responses from the accelerometers are recorded on a computer. The data is then used to compute experimental transfer functions mode shape, frequency and damping of the instrumented steam dryer components using appropriate software. The temporary sensors are then removed and the steam dryer is cleaned prior to installation in to the reactor vessel The steam dryer vibration sensors consist of strain gages, accelerometers and dynamic pressure sensors, appropriate for the application and environment. A typical list of vibration sensors with their model numbers is provided in Table 3L-3. The selection and total number of sensors is based on past experience of similar tests conducted on other BWR steam dryers. These sensors are specifically designed to withstand the reactor environment. The pressure instrument locations are selected to provide a good measure of the acoustic loading through the frequency range of interest. A proper distribution of the steam dryer pressure instruments facilitates accurate assessments of FIV loads. The layout of the steam dryer pressure instrument locations is evaluated using the RPV acoustic FEA Model. ~~The distribution of steamline instruments is determined using the Plant Based Load Evaluation model (Reference 3L-8) to provide an adequate measure of the acoustic loading through the frequency range of interest. The instrument layout permits steam dryer load development with steam dryer data alone, steamline data alone, or a combination using both sets of data.~~ The approach used to determine the number and locations of pressure instruments is described in Subsections 2.3.2 and 4.4.2 of Reference 3L-8 ~~and Subsections 4.4.3.1 and 4.4.4 of Reference 3L-9~~. 3.9-270

The steam dryer startup test and monitoring power ascension limits are developed on a similar basis as the monitoring limits used for recent extended power uprate replacement steam dryers. The power ascension limits are based on the final FIV analysis performed for the as-built steam dryer. Strain gages and accelerometers are used to monitor the structural response during power ascension. Accelerometers are also used to identify potential rocking and to measure the accelerations resulting from support and vessel movements. The approach used to determine the number and locations of the strain gages and accelerometers is described in Section 9.0 of Reference 3L-6. Specific information utilized to verify the FIV load definition during startup testing is described further in References 3L-5 and 3L-6.

Each of the sensors ~~are~~is pressure tested in an autoclave prior to assembly and installation on the steam dryer. An uncertainty analysis is performed to calculate the expected uncertainty in the measurements. 3.9-292

Prior to initial plant start-up, strain gages are resistance spot-welded directly to the steam dryer surface. Accelerometers are tack welded to pads that are permanently welded to the steam dryer surface. Surface mounted pressure sensors are welded underneath a specially designed dome cover plate to minimize flow disturbances that may affect the measurement. The dome cover plate with the pressure transducer ~~are~~is welded to an annular pad that is welded permanently to the steam dryer surface. The sensor conduits are routed along a mast on the top of the steam dryer and fed through the RPV instrument nozzle flange to bring the sensor leads out of the ~~pressure boundary. Sensor leads are routed through the drywell to the data acquisition area~~ outside the primary containment. 3.9-292

Pressure transducers and accelerometers are typically piezoelectric devices, requiring remote charge converters that are located in junction boxes inside the drywell. The data acquisition system consists of strain gages, pressure transducers and accelerometer signal conditioning electronics, a multi-channel data analyzer and a data recorder. The vibration data from all sensors is recorded on magnetic or optical media for post processing and data archival. The strain gages, accelerometer and pressure transducers are field calibrated prior to data collection and analysis. This calibration includes the addition of natural strain gauge factors based on the specific vendor supplied calibration sheets and their effects on the final stress tables.

The locations of the gauges are more distributed than BWR EPU gauge locations. The locations are selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. The final pressure transmitter locations are evaluated using the PBLE model with multiple combinations of Frequency Response Function (FRF) sets corresponding to different transmitter locations. The resulting data are used to find locations that provide redundancy and minimize singularities over the frequency ranges of interest, with special consideration at frequencies critical to high stress locations in the dryer. The sensitivity of locations to dimensional tolerances is also considered. Strain gauge manufacturer installation procedures are followed to duplicate previous installations. Care is taken to assure surface preparation (attachment surface area polish), spot weld welding energy, and weld strength recommendations are followed for each gauge. Applicable lessons learned from manufacturer's recommendation were also incorporated into the GEH welding procedure specification. Furthermore, knowledge is passed to the welders by holding pre-job briefs and discussing the proper technique for applying the gauges, emphasizing the uniform placement of spot welds at approximately 0.7 – 0.8 mm intervals. Afterwards, the welders will practice on shims until peel tests are successfully completed. Quality Control personnel are present to accept the weld process. The temporary vibration sensors are removed after the first outage. 3.9-272

~~In addition to the instrumentation on the steam dryer, the main steamlines are instrumented in order to measure the acoustic pressures in the main steamlines.~~ The ~~main steamline pressure measurements with the~~ steam dryer pressure measurements are used as input to an acoustic model for determining the pressures acting on the steam dryer in order to provide a pressure load definition for use in performing confirmatory structural evaluations. 3.9-270

In addition to the elements described above, NRC regulatory guidance (Reference 3L-10) describes elements of the comprehensive vibration assessment program that is implemented prior to and through startup testing. The following regulatory positions for prototype steam dryers address the program elements applicable to the ESBWR steam dryers: 3.9-291

- Position 2.1 provides a description of the vibration and stress analysis program, including specific items that should be included in the vibration and stress analysis submittal prior to implementation of the vibration measurement program.

- Position 2.2 provides a description of the vibration and stress measurement program, which is to verify the structural integrity of reactor internals, determine the margin of safety, and confirm results of the vibration analysis.
- Position 2.3 describes the inspection program for inspection both prior to and following plant operation.
- Position 2.4 describes documentation of results of the program.
- Position 2.5 describes the schedule for conducting the vibration assessment program.

COL Information Item 3.9.9-1-A implements the vibration assessment program. For each of the regulatory positions above, the NRC guidance (Reference 3L-10) explains how the program is to be conducted, how the processes assure structural integrity of the steam dryer, and identifies information and reports that are to be prepared and when the information and reports should be submitted. Steps in the process for the regulatory positions include the following key elements:

Position 2.1: The steam dryer analysis and modeling methodologies for performing a vibration and stress analysis are described in References 3L-5, 3L-6, and 3L-8. NRC guidance specifies that a summary of the vibration analysis program should be submitted to the NRC at least 60 days prior to submission of the description of the vibration measurement and inspection programs (or 120 days if submitted with a description of the vibration measurement and inspection phases description). Thus, a summary of the as-built steam dryer structural analysis with the applied acoustic loads would be developed and submitted to the NRC. In addition, the supporting information will be available for NRC review for assuring acceptance criteria are met in accordance with ESBWR DCD Subsections 3.9 and 14.3. This analysis is used to correlate results obtained through vibration measurements during power ascension.

Position 2.2: Details of the steam dryer monitoring program are described above and in References 3L-5, 3L-6, and 3L-8. According to NRC guidance, a description of the vibration measurement and inspection phases of the comprehensive vibration assessment program should be submitted to the NRC in sufficient time to permit utilization of the staff's related recommendations (allowing 90 days for staff's review and comment period). This submittal would be focused on the as-built steam dryer monitoring and instrumentation to be used for obtaining vibration measurements, with details of the data acquisition and reduction system (e.g., transducer types, transducer position, measures to maximize quality of data, online data evaluation system, procedures, and bias errors associated with the instruments). During power ascension, the steam dryer instrumentation (strain gages, accelerometers and dynamic pressure transducers) is monitored against established limits to assure the structural integrity of the steam dryer is maintained. If resonant frequencies are identified and the vibrations increase above the pre-determined criteria, power ascension is stopped. The acceptability of the steam dryer for continued operation is evaluated by revising the load definition based on the measured loading, repeating the structural analysis using the revised load definition, and determining revised operating limits based on the results of the structural analysis. 3.9-291

~~It is expected that subsequent ESBWR units will be monitored using the main steam lines pressure data. Additional information on power ascension testing, acceptance criteria, benchmarking loads, and benchmarking of the FE model for the first and subsequent ESBWR units is included in references 3L-5 and 3L-6.~~ 3.9-270

Position 2.3: Specific steam dryer inspection recommendations for the ESBWR steam dryer design are developed based on the final as-built design and structural analysis results. The steam dryer inspection recommendations are consistent with Reference 3L-2, and consistent with Boiling Water Reactor Vessel Internals Program guidance issued by the BWR owners group specific to reactor internals vibration. According to NRC guidance, a description of the inspection phase would be included in the submittal with a description of the vibration measurement program. This description would identify any inspections that are to be performed prior to and following operation during power ascension, and describe procedures and method of inspections, if any, of the steam dryer.

Position 2.4: According to NRC guidance, results of the comprehensive vibration assessment program should be reviewed and correlated to determine the extent to which test acceptance criteria are satisfied. The preliminary report following startup testing should compare preliminary comparison of data to test acceptance criteria and identify anomalous data that could bear on the steam dryer structural integrity. If results are acceptable, the final report should include a description of any deviations, comparison between measured and analytically determined modes of structural response and hydraulic response for verifying analytical technique, determination of margins of safety, and evaluation of unanticipated observations or measurements that exceeded acceptable limits not specified as test acceptance criteria (as well as disposition of such deviations). If testing or inspections reveal defects or unacceptable results, the final report should also include an evaluation and description of the modifications or actions planned to justify the structural adequacy of the steam dryer.

Position 2.5: A schedule for conducting the elements of the comprehensive vibration assessment program is inherent in COL Information Item 3.9.9-1-A. NRC guidance specifies that the steam dryer be classified as prototype or non-prototype; that a commitment be made in the DCD or COL application regarding the scope of the comprehensive vibration assessment program; and that certain submittals be made describing the program and results with suggested schedules for the submittals.

With the detailed description above and implementation of COL Information Item 3.9.9-1-A, the instrumentation and startup testing program elements are consistent with NRC regulatory guidance and adequately ensure steam dryer structural integrity.

3L.5.2 Sensor Locations

Having determined the components to instrument during the test, sensor locations on those structures are determined based upon the analytically predicted mode shapes for each structure, or calculated maximum stress locations or, sensor locations based on computational fluid dynamics modeling, and in some cases, based upon the location of past FIV-related failures. Strain gages and accelerometers are used for monitoring vibration levels. Strain gages measure local strain from which local stress can be calculated. Based on knowledge of the natural mode shapes of the structure or calculated stress distribution, ~~peak~~ highest stresses at other locations on the structure are determined from these data. Accelerometers (with double integration of the output signal) provide measurements of local structural displacement. This information, together with knowledge of the natural mode shapes of the structure or calculated stress distribution, allows the ~~peak~~ highest stresses to be calculated at other locations. Pressure sensors are also utilized at various locations in the vessel. These are not used to measure structural vibration directly, but rather to measure the pressure variation that is often a forcing function that causes the structural vibration. These pressure sensor data are very useful for determining the source of any excessive vibration amplitudes, if they are to occur during testing. Sensor types and locations are listed in Table 3L-4. 3.9-285

3L.5.5.1.3 Steam Dryer

The design of the steam dryer assembly for the ESBWR plant is similar to ABWR.

However, the total steam flow rate of the ESBWR plant is different from past designs. These differences warrant a detailed vibration analysis and test monitoring to assure the adequacy of the new design to withstand the FIV.

In the ABWR initial plant FIV test program of the steam dryer assembly, accelerometers were located on the cover plate and several locations on the skirt, and strain gages were located directly on the skirt, drain channels and hoods (Reference 3L-5). In addition, pressure sensors were used to measure the pressure differentials between the inside and outside of the upper skirt adjacent to the front hood and the lower skirt. The differential pressure fluctuation across the hoods and skirt is the primary forcing function causing vibration of the steam dryer structure.

A dynamic finite element model of the steam dryer assembly is developed using the ANSYS computer code (References 3L-3 and 3L-6). Due to the complicated geometry and the large size of the analytical model, major components may be modeled with coarse meshes such that their dynamic contributions are accounted for in the whole steam dryer assembly vibration responses. Separate refined dynamic finite element models of the major components are then developed to provide a high resolution of the component's response calculation.

The structural material properties and density for the steam dryer components at temperature are used in the model. The effect of the water on the dynamic responses is accounted for by explicitly modeling the dynamic properties of the fluid in the submerged portions of the skirt, drain channels, and the base ring.

Prior analytical models have predicted that the vibration modes are closely spaced. The final as-built structural predictive vibration analysis is performed prior to startup testing for correlation to final measurement results of acoustic loads measured on the steam dryer during startup testing, as elements of a comprehensive vibration assessment program described in Subsection 3L.4.6. 3.9-291

3L.5.5.2.1

The next two steps are identical for Methods I and II.

- A weighting factor is determined by the strain energy method, which begins by obtaining the solution to the following equation based on the expected forcing function:

$$\{U\} = q_1\{\phi\}_1 + q_2\{\phi\}_2 + \ldots = \sum_{i=1}^{N} q_i\{\phi\}_i$$

where

$\{U\}$ = A vector representing the displacement response of the structure when subjected to the expected forcing function shape. This displacement response to an input forcing function is calculated from the finite element model on the computer.

$\{\phi\}_i$ = Mass normalized mode shape for vibration mode i. Mode shapes were determined from modal analysis of the finite element model. The mode shapes are normalized such that the generalized mass, $\{\phi\}_i^T[M]\{\phi\}_i$, is unity (where [M] is the mass matrix).

q_i = Mode i response, dependent on load distribution. These coefficients are calculated from the previously calculated {U} and $\{\phi\}_i$ using formulas derived from the generalized Fourier Theorem.

This is an application of the generalized Fourier Theorem, which establishes that a displacement function such as {U} can be represented by a linear sum of the eigenfunctions, $\{\phi\}_i$. The theory and methods for calculation of these coefficients may be found in text books on the subject of basic vibration analysis, such as Reference 3L-4.

- The strain energy contribution, e_i, for each mode is then calculated:

$$e_i = \frac{1}{2} \cdot q_i^2 \cdot \{\phi\}_i^T \cdot [K] \cdot \{\phi\}_i$$

where

[K] = The structural stiffness matrix (For a more detailed explanation of the theory and calculation methods, see text books on the subject vibration analysis, such as Reference 3L-4.)

- This step is similar for both Methods I and II, the only difference being that Method I includes the entire frequency range in one group, while Method II uses several groups of frequency ranges. Then the strain energy weighted allowable strain vibration amplitude is calculated over a given frequency range by combining the weighted strain allowable values for each mode as follows:

For

$$\omega_I < \omega_1, \omega_2, \ldots, \omega_n \leq \omega_{II}$$

$$\varepsilon_{II,allowed} = \frac{e_1 \cdot \varepsilon_{1,allowed} + e_2 \cdot \varepsilon_{2,allowed} + \ldots + e_n \cdot \varepsilon_{n,allowed}}{e_1 + e_2 + \ldots + e_n}$$

where

$\varepsilon_{II,allowed}$ = Allowable strain value between ω_I and ω_{II}, which includes the SCF

It should be noted that this step conservatively assumes that the ~~peak~~highest stress of each mode occurs at the same physical location on the structure. In reality, the maximum stress locations for different modes may occur at different locations. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add this conservatism. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases. 3.9-285

The strain value in the above equation is the allowable strain used during the actual execution of the test. It represents the strain level at the sensor location when the maximum stress on the structure is 68.9 MPa (10,000 psi).

- Step 9 is the same for both Methods I and II, except that it is applied to each of the multiple frequency ranges associated with Method II; whereas, Method I is only for one frequency range. The combined shape factor is derived to relate the maximum zero-to-peak strain value measured at the sensor location to the corresponding maximum zero-to-peak stress intensity value on the structure.

$$\sigma_{II,\max} = \frac{\varepsilon_{II,measured,\max}}{\varepsilon_{II,allowed}} \cdot (68.9\,MPa) = \varepsilon_{II,measured,\max} \cdot CSF$$

where

$CSF = \dfrac{(68.9\ MPa)}{\varepsilon_{II,allowed}}$ = Combined Shape Factor with the SCF included.

$\sigma_{II,max}$ = Maximum zero-to-peak stress value anywhere on the structure for modes within the frequency range of ω_I to ω_{II}.

$\varepsilon_{II,measured,max}$ = Maximum measured zero-to-peak strain (one-half of maximum measured p-p) from time history of sensor band pass filtered over the frequency range ω_I to ω_{II}.

This is the maximum zero-to-peak stress value anywhere on the structure as determined by Method I. For Method I, this value is compared to 68.9 MPa (10,000 psi) for determination of acceptability.

- One additional step remains for Method II. The maximum stress values for each frequency band are added together using the absolute sum method to determine the overall maximum stress on the structure for comparison to the 68.9 MPa (10,000 psi) limit for the material.

$$\sigma_{MAX} = \sigma_{II,\max} + \sigma_{III,\max} + \ldots + \sigma_{N,\max}$$

where

σ_{MAX} = Maximum overall zero-to-peak stress anywhere on structure as determined by Method II.

$\sigma_{N,\max}$ = Maximum zero-to-peak stress anywhere on structure within the frequency range of ω_{N-1} to ω_N (N-1 frequency ranges total).

σ_{MAX} is compared to the 68.9 MPa (10,000 psi) limit in order to determine acceptability under Method II.

It should be noted that this step conservatively assumes that the ~~peak~~highest stress of each mode occurs at the same time. In reality, the maximum stress occurs at different times. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add this conservatism. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases. 3.9-285

3L.5.5.2.2 Method III

Method III uses the mode shape factor from Step 3, the SCF and the measured strain value to determine the maximum stress amplitude anywhere on the structure for each natural mode. Picking up after Step 5 from Subsection 3L.5.5.2:

(1) Maximum stress in the structure is calculated from the measured strain value at the sensor location.

$$\sigma_{i,MAX} = \varepsilon_{i,measured,\max} \cdot E \cdot MSF_i \cdot SCF_i$$

where

$\sigma_{i,MAX}$	=	Maximum zero-to-peak stress anywhere on structure for mode i.
$\varepsilon_{i,measured,max}$	=	Maximum zero-to-peak strain for mode i as determined from power spectrum from sensor signal.
E	=	Young's Modulus
MSF_i	=	Mode Shape Factor for mode i.
SCF_i	=	Stress Concentration Factor as applicable for maximum stress location for mode i.

(2) The maximum stress values for each mode are added together using the absolute sum method to determine the overall maximum stress on the structure for comparison to the 68.9 MPa (10,000 psi) limit for the material.

$$\sigma_{MAX} = \sigma_{1,MAX} + \sigma_{2,MAX} + \ldots + \sigma_{n,MAX}$$

where

σ_{MAX}	=	Maximum overall zero-to-peak stress anywhere on structure as determined by Method III.
$\sigma_{i,MAX}$	=	Maximum zero-to-peak stress anywhere on structure for mode i (n total dominant modes).

σ_{MAX} is compared to the 68.9 MPa (10,000 psi) limit in order to determine acceptability under Method III.

It should be noted that this step conservatively assumes that the ~~peak~~highest stress of each mode 3.9-285 occurs at the same physical location on the structure and at the same time. In reality, the maximum stress locations for different modes may occur at different locations and at different times. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add these conservatisms. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases.

In summary, all three methods involve two significant conservatisms:

- The assumption of the maximum stresses occurring at the same location in a component, and

- The assumption that the maximum stresses for different modes occur at the same time.

Inclusion of these two significant conservatisms results in significantly higher calculated stresses.

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In summary, all three methods involve two significant conservatisms:

- The assumption of the maximum stresses occurring at the same location in a component, and
- The assumption that the maximum stresses for different modes occur at the same time.

Inclusion of these two significant conservatisms results in significantly higher calculated stresses.

3L.5.5.3 (Deleted)

3L.6 REFERENCES

3L-1 GE Hitachi Nuclear Energy, "Reactor Internals Flow Induced Vibration Program", NEDE-33259P-A, Revision 3, Class III (Proprietary), October 2010, and NEDO-33259-A, Revision 3, Class I (Non-proprietary), October 2010.

3L-2 General Electric Company, "BWR Steam Dryer Integrity", Service Information Letter (SIL) 644 Revision 2, August 30, 2006.

3L-3 ANSYS Engineering Analysis System User's Manual, see Table 3D.1-1 for the applicable revision.

3L-4 Elements of Vibration Analysis, Leonard Meirovitch, McGraw Hill Book Co., 1975.

3L-5 GE Hitachi Nuclear Energy, "Steam Dryer - Acoustic Load Definition," NEDE-33312P~~-A~~, Revision ~~2~~3, Class III (Proprietary), ~~October~~ February ~~2010~~2013, and NEDO-33312, Revision ~~2~~3, Class I (Non-Proprietary), ~~October~~ February ~~2010~~2013. 3.9-293

3L-6 GE Hitachi Nuclear Energy, "Steam Dryer - Structural Evaluation," NEDE-33313P~~-A~~, Revision ~~2~~3, Class III (Proprietary), ~~October~~ February ~~2010~~2013, and NEDO-33313, Revision ~~2~~3, Class I (Non-Proprietary), ~~October~~ February ~~2010~~2013. 3.9-292

3L-7 (Deleted)

3L-8 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDC-33408P~~-A~~, Revision ~~1~~2, Class III (Proprietary), ~~October~~February 201~~0~~3, and NEDO-33408, Revision ~~1~~2, Class I (Non-proprietary), ~~October~~February 201~~0~~3. 3.9-269

~~3L-9~~ (Deleted)~~GE Hitachi Nuclear Energy, "ESBWR Steam Dryer - Plant Based Load Evaluation Methodology Supplement 1," NEDC-33408, Supplement 1P-A, Revision 2, Class III (Proprietary), October 2010, and NEDO-33408, Supplement 1-A, Revision 2, Class I (Non-Proprietary), October 2010.~~ 3.9-269 and 3.9-270

3L-10 Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program For Reactor Internals During Preoperational and Initial Startup Testing," Revision 3, March 2007. 3.9-291

Table 3L-5

***Applicable Data Reduction Method for Comparison to Criteria*[(2)(3)]**

Component	Sensor Type	Applicable Data Reduction Method	Frequency Bandwidth (Hz)[(1)]
Shroud	Strain Gages	Time History	0-100
Steam Dryer Skirt	Strain Gages	Time History	0-200
Steam Dryer Skirt	Accelerometer (Displacement)	Time History	0-100
Steam Dryer Drain Channels	Strain Gages	Time History	0-100, 100-200
Steam Dryer Hoods	Strain Gages	Time History	0-100, 100-200
Steam Dryer Support Ring	Accelerometer	Time History	0-1600 0-80, 80-200
Separator Top	Accelerometer	Time History	0-100
Chimney	Accelerometer	Time History	0-200
Standby Liquid Control Lines	Strain Gages, Accelerometer	Time History	0-100

(1) It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program is adjusted to bound the range of frequencies determined for the final SRV standpipe design.

(2) Pressure sensors data reduction from steam dome, steam dryer skirt, and steam dryer hood are not included in this table. The pressure data from these components ~~and the main steamlines~~ are discussed in Subsection 3L.4.6. 3.9-270

(3) For Method III, the spectrum method may be used in place of the Time History Method in cases with sufficient margin.