AUDIT REPORT OF THE ECONOMIC
SIMPLIFIED BOILING WATER REACTOR
STEAM DRYER DESIGN METHODOLOGY
SUPPORTING CHAPTER 3 OF ESBWR
DESIGN CONTROL DOCUMENT

On March 21-23, 2012, the U.S. Nuclear Regulatory Commission (NRC) conducted an audit at the General Electric Hitachi (GEH) facility in Wilmington, NC, to review the GEH documents pertaining to the ESBWR licensing topical reports (LTRs) referenced in Chapter 3, Section 3.9.5, "Reactor Vessel Internals," of the Design Control Document (DCD) GEH submitted to the NRC in support of the ESBWR design certification application. The audit plan is provided in an NRC letter dated March 12, 2012, to GEH (ADAMS Accession package number ML120790437). Based on its review of the ESBWR LTRs during the evaluation of the Grand Gulf Nuclear Station (GGNS) Extended Power Uprate (EPU) license amendment request (which referenced these LTRs), the NRC staff determined that additional information is needed from GEH to support the NRC staff's conclusions in the ESBWR Final Safety Evaluation Report (FSER) and LTR SERs. During the March 2012 audit, the NRC staff reviewed GEH documents related to the steam dryer design methodology and to needed to support the ESBWR FSER and LTR SER conclusions. Below is a summary of the audit.

1.0. BACKGROUND

On November 15, 2011, the U.S. Nuclear Regulatory Commission (NRC) informed GEH that the staff was preparing the final ESBWR Design Certification (DC) rule package for submission to the NRC, and we provided a schedule for completing the ESBWR rulemaking. We estimated delivery of the rule to the Commission in January 2012, and provided the Commission affirmed the final certification, publication in May 2012.

Through the NRC's review of the Grand Gulf Extended Power Uprate (EPU), issues have been identified that are relevant to the conclusions in the staff's March 9, 2011, Final Safety Evaluation Report (FSER) issued in support of the ESBWR DC rulemaking. Specifically, errors have been identified in the benchmarking GEH used as a basis for determining fluctuating pressure loading and stresses/strains on the steam dryer, and errors have been identified in a number of GEH's modeling parameters. The staff has concluded these errors may affect the conclusions in the Safety Evaluation Reports prepared for the four LTRs, which were the basis of the safety conclusions in the staff's FSER and need to be addressed before we complete the ESBWR DC Rulemaking.

The staff's FSER for ESBWR relied on GEH licensing topical reports (LTRs) NEDE-33312P-A, "ESBWR Steam Dryer Acoustic Load Definition," Revision 1, NEDE-33313P-A, "ESBWR Steam Dryer Structural Evaluation," Revision 2, NEDC-33408P-A, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," Revision 1, and NEDC-33408 Supplement 1P "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," Revision 1. The issues identified may affect the basis for the staff's approval of these LTRs and, accordingly, the basis for the staff's ESBWR safety evaluation. These issues are described in the enclosure to NRC's letter to GEH dated January 19, 2012 (ML120170273).

The four LTRs describe the analytical methods for computing oscillating pressure loads acting on the steam dryers in the ESBWR design. The methods include a state-of-the-art acoustic load definition model, as well as a demonstration of that model through benchmarking to data

from the Quad Cities (QC2) and Susquehanna nuclear power plants. The NRC's conclusions in its safety evaluation of these four LTRs, referenced in Section 3.9.5 of the ESBWR FSER, are based on the review of both the model and the benchmarking to show that the method is acceptable. The FSER was completed in March 2011.

The five key errors were discussed with GEH during a public meeting held at the NRC offices on January 31, 2012. GEH indicated there is additional documentation that has not been included or submitted on the docket, which demonstrates that the steam dryer design methodology approved in the topical reports is acceptable.

In addition, to the five key errors identified in the letter, new information has prompted the NRC to identify three additional concerns with Susquehanna Steam Electric Station (SSES) structural finite element model and conservatism. The staff has identified information that it would like to review directly related to these three additional concerns during the audit.

2.0. PURPOSE

The purpose of this on-site audit was to review documentation presented by the GE Hitachi (GEH) staff that addresses key errors and additional concerns in four Economic Simplified Boiling-Water Reactor (ESBWR) licensing technical reports (LTRs) for determining fluctuating pressure loading on the steam dryer and determine what additional information needs to be submitted by GEH on the docket to support approval of the LTRs and the ESBWR Design Certification.

3.0 AUDIT DETAILS

The agenda for the audit is provided in Section 3.3 of this report. Other documents that will be submitted by the applicant on the docket were also reviewed. A list of documents reviewed and/or discussed during the audit is provided in Attachment 1 of this report. The action items resulting from the audit are included in Section 4.0 of this report.

3.1 Audit Logistics

Date: March 21 - 23, 2012
Location: GE Hitachi Nuclear Energy Offices, Wilmington, North Carolina

3.2 Audit Attendees

- NRC: Chakrapani Basavaraju, Joseph Colaccino, David Misenhimer, Thomas Scarbrough, Terri Spicher
- NRC Contractors: Dr. Stephen A. Hambric, Richard Morante
- GEH: Jerry Head, Patricia Campbell, Tim Niggel, Dan Pappone, Tao Wu, Tim Enfinger, Jon McLamb, Scott Bowman, Glen Watford, Brian Johnson, Jerry Deaver, Richard Bodily, David Keck,Timothy Jones, Mark Elliott, Larry Tucker, Zhichao Wang, Leray Dandy, Wei Ren, Peter Yandow,
- GEH Contractors: Enrico Betti, Abbas Selmane, Michael Heger

3.3 Audit Agenda

The NRC staff and its contractors discussed and evaluated the eight agenda items listed below with members of GEH. This discussion is summarized in Section 3.4 of this report.

March 21, 2012

1:00 PM	Audit Entrance Briefing
1:30 PM	NRC Concern #1 (SSES structural model)
3:00 PM	NRC Staff Caucus / Review of Information
3:30 PM	NRC Concern #3 (SSES structural model)
5:00 PM	NRC Staff Caucus / Review of Information
5:30 PM	Status Briefing - Review of open and resolved items identified in Day 1
6:00 PM	Conclusion of Day 1

March 22, 2012

7:30 AM	NRC Key Error #1(QC2 coarse acoustic mesh)
9:30 AM	NRC Staff Caucus / Review of Information
10:00 AM	NRC Key Error #5 (Strain gage errors)
12:00 Noon	Lunch
1:00 PM	NRC Staff Caucus / Review of Information
1:30 PM	NRC Key Error #4 (SSES end-to-end benchmarks)
4:00 PM	NRC Staff Caucus / Review of Information
5:00 PM	Status Briefing - Review of open and resolved items identified in Day 2
6:00 PM	Conclusion of Day 2

March 23, 2012

7:30 AM	NRC Concern #2 (Conservatism)
8:30 AM	NRC Staff Caucus / Review of Information
9:00 AM	NRC Key Error #3 (Load transfer)
9:30 AM	NRC Staff Caucus / Review of Information
10:00 AM	NRC Key Error #2 (Main steam line (MSL) nozzle areas/locations)
11:00 AM	NRC Staff Caucus / Review of Information
12:00 Noon	Lunch
1:00 PM	Status Briefing - Review of open and resolved items identified in Day 3
1:30 PM	Audit Exit Briefing
2:30 PM	Conclusion of Audit

3.4 Audit Discussion on Agenda Items

During the audit, GEH provided relevant documentation regarding each error and concern for the audit team per the agenda. This included presentations, review of calculations and computational data, and other information determined to be relevant but not currently on the docket. GEH also identified docketed information it believed addressed the staff's concerns. The NRC team reviewed this material. Listed below is a summary of each agenda item. Section 4 contains a consolidated summary and action items.

NRC Error #1: QC2 Coarse Acoustic Mesh

GEH provided information on QC2 acoustic finite model. Specifically, additional comparisons were presented for acoustic transfer functions computed using the original QC2 acoustic mesh and a refined mesh that was used in sensitivity studies. The refined mesh is valid to a higher frequency than the coarse mesh. However, neither mesh density is valid to the full frequency range. The comparisons demonstrated that the denser mesh produces generally higher loads, but also shows that coarser models produce acoustic cavity resonance frequencies that are too high. GEH also stated that the original QC2 mesh was based on computer aided design (CAD) files for a scale model test (SMT) dryer and reactor pressure vessel (RPV) mockup, and that an updated QC2 mesh was being generated based on actual plant drawings.

GEH discussed updating the mesh such that it is valid for frequencies for full frequency range. GEH also proposed to address the QC2 error by the use of SSES as an alternate acoustic benchmark instead of QC2.

NRC Error #2: Main Steam Line (MSL) Area and Nozzle Location

GEH provided information that addressed the geometric differences between the actual and modeled locations. The errors were vertical and radial. Actual GGNS drawings were presented and reviewed. Also, GEH provided data that describes the MSL area error in regards to the mathematical terms used for the plant based load evaluation (PBLE) methodology as described in the LTRs.. GEH discussed updating the geometric errors for QC2. Additionally, GEH proposed to address the QC2 error by use of SSES as an alternate acoustic benchmark instead of QC2.

NRC Error #3: Load Transfer

GEH explained the mathematical procedure for mapping loads to the structural finite element model of the steam dryer in order to determine the steam dryer alternating stresses. Nodal plots were described and reviewed by the staff. Since there is a difference in the number of nodes in the models, the relationship and transfer was discussed.

NRC Error #4: SSES End-to-End Benchmarks

The staff had extensive discussions with GEH on end-to-end benchmarking. The current benchmarks are based on bias and uncertainties using several different approaches summed together. GEH presented an approach with the conservatism of their overall dryer stress simulation. The plots reviewed had clear overestimates of all strain gage spectra on this

instrumented dryer. GEH proposed to demonstrate an alternate benchmarking approach which will establish the suitability of their PBLE methodology for the ESBWR prototype dryer.

GEH also discussed modifying their benchmarking of PBLE to reflect SSES, no longer relying on the flawed QC2-based benchmarks, due to issues with mesh resolution and geometric errors.

NRC Error #5: Strain Gage Errors

GEH presented information, submitted under the GGNS docket, which shows that the QC2 (and SSES) strain gage calibration errors may be accounted for using in-lab derived calibration factors, as well as in-plant static pressurization test data. These calibration corrections are included in the GGNS steam dryer analysis. GEH also discussed on-dryer strain gage testing currently being performed in Japan. The strain gages are sources of bias and uncertainties that are required for analysis.

NRC Additional Concern #1: SSES Structural Model

GEH presented the staff with SSES hammer test measurements report results and their comparison to SSES finite element (FE) calculations. The report shows that the SSES FE model (and presumably future models constructed using similar techniques) underestimates and overestimates frequency responses. Determination of natural frequencies is used for predictive analysis design verification.

NRC Additional Concern #2: Conservatism

GEH presented several sources of conservatism in the design of steam dryers. This included instrumenting the first ESBWR steam dryer and conformance with American Society of Mechanical Engineers (ASME) Code NG, excluding ASME weld and fatigue factors.
A complete list of conservatism was presented on the GGNS docket.

NRC Additional Concern #3: SSES Structural Model

GEH and the staff reviewed several aspects of the structural finite element ANSYS analysis used in the ESBWR LTRs. In particular they discussed and reviewed: (1) which completed ANSYS structural analysis serves as the best benchmark for the ESBWR analysis methodology, (2) reviewed the modeling information and analysis results for GGNS, confirmed that the locations and magnitudes of critical stresses have been accurately predicted, (3) reviewed how the ANSYS stress results are used in the fatigue evaluation, (4) reviewed the step-by-step procedure used to develop the peak stresses for the Code-acceptance check, and (5) the technical basis for concluding that FIV loads will not initiate fatigue cracks and premature failure of the steam dryer..

4.0 ACTION ITEMS

Based on the information reviewed during the audit, the staff will prepare requests for additional information (RAI). GEH estimated that they can answer all RAIs within 2 months of receipt of final RAIs.

5.0 CONCLUSION

The staff's audit covered all the key errors and additional concerns identified by the staff prior to the audit. The staff concluded that there are errors and omissions in the LTRs that necessitate GEH to clarify or support the application. The staff will utilize the information reviewed during the audit to request additional information. Based on the feedback provided by the staff during the audit, GEH stated they will respond to the issues regarding its PBLE methodology to support the ESBWR design certification by using information from the SSES instrumented steam dryer and main steam lines to validate the methodology for the ESBWR steam dryer rather than Quad Cities data. GEH also stated for questions related to the structural model, they will use an alternate benchmark to address the stated structural modeling errors and concerns.

Attachment 1

Item	Document Number	Rev	Date
1	GENE-0000-0083-7694-R3	3	June 2008
2	GENE-0000-0039-5860-01-P	1	May 2005
3	GENE-0000-0041-1656-01-P	0	May 2005
4	GE-NE-0000-0056-9958-R0-P	0	October 2006
5	0000-0095-2113-P-R0	0	February 2009
6	0000-0099-0973-P-R0	0	August 2009
7	PRC 11-71 Evaluation		1/25/2012
8	CAR 54821 with Root Cause Investigation		CAR - 4/22/2011 RCI - Nov 2011
9	MFN 09-509		7/31/2009
10	MFN 09-435		7/6/2009
11	MFN 08-895		11/13/2008
12	N/A		
13	0000-0075-7016 / 0000-0081-8783		9/3/2007
14	GHNE-0000-0094-0291-R0	0	March 2009
15	26A7365, Table 1	0	December 2007
16	26A7365, Table 2	0	December 2007
17	26A7365, Table 3	0	December 2007
18	NEDC-33408 Supplement 1P-A, Figure 10	2	October 2010
19	NEDC-33408 Supplement 1P-A, Figure 11	2	October 2010
20	NEDC-33408 Supplement 1P-A, Figure 12	2	October 2010
21	NEDC-33408 Supplement 1P-A, Table 4	2	October 2010
22	NEDC-33408 Supplement 1P-A	2	October 2010
23	CAR 49314		3/19/2012
24	MFN 09-363		6/8/2009
25	MFN 09-459		
26	MFN 05-516 (TAC MC0761)		
27	N/A		
28	GNRO-2012/0006		2/6/2012
29	DRF 0000-0087-2787 / Section 0000-0087-2786	0	9/20/2008
30	CAR 57911		2/27/2012
31	CAR 57759		2/10/2012
32	CAR 57681		2/7/2012
33	CAR 57960		3/3/2012
34	CAR 57839		2/20/2012
35	CAR 57840		2/20/2012

Attachment 1 (continued)

Item	Document Number	Rev	Date
36	CAR 57841		2/20/2012
37	CAR 57464		1/10/2012
38	CAR 57770		2/13/2012
39	MFN 09-392		
40	NEDE-33313P-A	2	October 2010
41	GE-NE 0000-0039-4817-1	1	April 2005
42	Various		
43	BANK to Bank tie bar submodel, Figure 3		
44	DRF 0000-0131-0351		
45	DRF- 0000-4904/ section 0144-4905		
46	DRF 0000-0145-4002		
47	Stress level results		
48	DRF 0000-0140-5070		
49	DRF 0000-0145-3110/Section 0000-0145-4002		
50	Bulletin 432		
51	ASME 2001 Section III Div 1 - NG		
52	DRF 0000-0142-4505/Section 0000-0142-4562		
53	GGNS-2011/000107 RAI #2		
54	2005 paper on Exelon Replacement dryers.		
55	MFN 09-392, MFN 09-459		
56	DRF 0000-0139-4817		
57	TAC MC0761		
58	MFN-05-16		