Enclosure 3

MFN 12-065, Revision 1

GEH Final Response for RAI 3.9-293

Public Version

This is a non-proprietary version of Enclosure 1, 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 [[ ]].

NRC RAI 3.9-293

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 EPU license amendment request.

GEH Response

Summary

The RAI-referenced letter regarding the GGNS EPU license amendment request (Reference 1, Entergy letter dated October 10, 2011) explains many of the same conservatisms associated with the ESBWR steam dryer assessment methodology, because the GGNS replacement steam dryer assessment methodology is based largely on the ESBWR methodology, adapted as necessary for a replacement dryer in an operating plant as compared to the ESBWR steam dryer for new reactor deployment. The conservatisms that are inherent in the ESBWR steam dryer assessment methodology identified in the DCD and referenced Engineering Reports are described below. For additional conservatisms in the predictive analysis, GEH is adding to the ESBWR design certification licensing basis a 2.0 minimum alternating stress ratio to the predictive analysis to ensure structural integrity of the steam dryer.

NOTE: Where specific sections of certain references are listed, the final revisions to the ESBWR licensing basis may change the location of the information (i.e., sections in certain references may be renumbered). A roadmap/change list will be provided in response to RAI 3.9-292 to identify section number changes.

Detailed Response

References 2 through 5 provide a comprehensive description of the fatigue calculations and associated methodology for assessing the ESBWR prototype and non-prototype steam dryers. These references describe the detailed development of the dryer analysis methodology and, where applicable, identify where conservatism is introduced into specific models and correlations. However, in most cases, the impact of these individual models or design choices is quantified through the benchmark comparisons, which represent an integral assessment of predictive capability in terms of key parameters (i.e., stress and strain). Given this premise, rather than evaluating the merits of individual models, the discussion presented here focuses on two aspects of the analysis: (1) a brief discussion of the benchmarking results, which provides an expectation of accuracy when the Plant Based Load Evaluation (PBLE) and structural Finite Element (FE) based method is applied to other plants; and, (2) conservatisms associated with the analysis technique that are expected, but not quantified, through the benchmark analysis.

End-to-End Benchmarking:

GEH conducted an evaluation of PBLE and FE analysis bias and uncertainty based on a comparison of predicted versus measured data from the Susquehanna Steam Electric Station (SSES) steam dryer. See Enclosure 2 of Reference 7, Table 6, pg. 23 of 27. This evaluation was also provided in Reference 1. However, with the revised PBLE end-to-end benchmark process documented in Reference 5, the conservatism reported in Table 6 of Reference 7 is no longer applicable to the revised analysis process that will be used for the ESBWR steam dryer.

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- Bias and Uncertainty Treatment – The fatigue stress bias and uncertainty evaluation and the determination of the maximum adjusted stress intensity are performed on a component-by-component basis using the two methods described in Reference 4. [[

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<u>Analysis Approach:</u>

The items below represent conservatisms in the steam dryer analysis methodologies that are expected, though not quantified, through the benchmark analyses.

- Fatigue Design Limit – The GEH steam dryer methodology utilizes the design fatigue curve and fatigue life evaluation guidance for austenitic steels as described in Regulatory Guide 1.207 (Reference 10) as the acceptance criterion for the predicted alternating stress. The limit from the design fatigue curve is 13.6 ksi based on 10^{11} cycles assumed over the 60-year design life of the dryer. In determining the acoustic pressures acting on the dryer, [[ ]] so that the FIV loads determined by the stress analysis will have considered the peak stress intensities that occur at frequencies as low as 1 cycle per 100 seconds, or less than $2x10^7$ cycles over the life of the dryer. Therefore, the design limit is conservative in that the peak load cycles are assumed to occur at a much higher rate than actual in-service conditions would indicate (i.e., compared to on the on-dryer measurement).

Based on plant measurements, the fatigue usage is expected to accumulate at a lower rate over the 60-year design life of the ESBWR steam dryer. Therefore, there is margin available to accommodate higher loading and still remain within a fatigue usage factor of 1.0 over the life of the steam dryer.

A rain-flow cycle counting analysis was performed using the strain amplitudes measured on the instrumented SSES and Quad Cities Unit 2 replacement steam dryers. Figure 1 shows the upper (hood region) and lower (skirt region) dryer instrument histograms (cycles versus strain amplitude) for both dryers. While the upper and lower sensors show consistent curve characteristics, there is marked difference between QC2 (dominated by high frequencies) and SSES (dominated by low frequencies). Figure 2 shows the highest 20% of the strain range from Figure 1. While the analysis was performed assuming the 40 year design life for the replacement dryers, the distribution of the number of cycles versus strain amplitude is determined by the pressure loading and structural response of the dryer, which is not affected by the number of years of operation.

Therefore, the trends shown and conclusions are applicable to the 60 year design life of the ESBWR dryer.

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Figure 1 – Strain Histogram SSES and QC2 Replacement Dryers

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Figure 2 – Strain Histogram SSES and QC2 Replacement Dryers High Amplitude Strain

For low frequency plants such as SSES, GGNS, and ESBWR, [[

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Other conservatisms in the methodology include:

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  ]]. Also see NEDE-33312P-A, Section 4.1, Reference 3.

- As described in Reference 3, the acoustic load definition that will be used in the design of the ESBWR dryer includes [[

  ]]. The ESBWR main steamline geometry will be designed to preclude these loads. These design changes are further described in the response to RAI 3.9-290 in Reference 9.

- For additional conservatisms in the predictive analysis, GEH is adding to the ESBWR design certification licensing basis a 2.0 minimum alternating stress ratio of the predictive analysis results to the fatigue acceptance criterion in order to ensure the structural integrity of the steam dryer. With the incorporation of the 2.0 minimum alternating stress ratio for the dryer, [[

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GGNS EPU Observations

Two significant observations were made during the Grand Gulf Nuclear Station (GGNS) EPU power ascension testing of the instrumented replacement steam dryer. The GGNS EPU license amendment was not approved when the plant started up from the refueling outage that implemented the EPU system changes. The plant ascended to the previous licensed power level and reactor operating pressure while waiting for the EPU approval. When the EPU was approved, the plant reduced the reactor system pressure in preparation for the power ascension to full EPU power (GGNS was implementing a constant pressure power uprate where the reactor dome pressure at EPU is kept the same as the previous licensed power). [[

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The second observation was found during an evaluation of the on-dryer structural measurements (both strain gauge and accelerometers) taken during the power ascension. The measurements showed [[

]] were evaluated in the final EPU stress analysis for the GGNS replacement dryer (Reference 11).

ESBWR Evaluation

An evaluation of the GGNS EPU power ascension observations was performed to determine the potential implications for the ESBWR steam dryer structural response and stress analyses. The primary effects that are evaluated are the stress responses to changes in [[ ]]. Also discussed is a related issue of the pressure regulator setpoint tolerance on the dryer fatigue assessment.

The ESBWR is a natural circulation plant and there is no active control of the core flow as in the forced circulation plants. Nominally, the core flow at full power is a single value; however, there will be some variation in the core flow due to the power distribution changes over the fuel cycle and due to the feedwater temperature variations used to control reactor power.

Core Exposure Effect

The rated Reactor Heat Balance for 100% power (Figure 1.1-3a in Reference 12) provides a core flow range of 31553 to 37352 t/hr or ±8.4% of the nominal core flow 34452 t/hr (the average of 31553 and 37352). This range considers both the uncertainties in the predicted core flow and the effect of core exposure. Table 2.2-1 of Reference 13 provides an example of the nominal core flow variation over the fuel cycle at rated power and feedwater conditions (i.e., constant steam flow). The core flow varied from a low of 35042 t/hr to 36144 t/hr or approximately 3%. Therefore, most of the core flow range shown on Figure 1.1-3a reflects the uncertainty in the core flow prediction. The uncertainty in the predicted core flow is [[

]] The final dryer stress analysis predictions will be benchmarked against on-dryer measurements taken during the prototype plant startup at the core flow achieved at full power operation.

Table 2.2-1 of Reference 13 provides an example of the nominal core flow variation over the fuel cycle at rated power and feedwater conditions (constant steam flow). The core flow varied from a low of 35042 t/hr to 36144 t/hr or 3%. The difference between the nominal core flow in the design heat balance and the maximum core flow in Table 2.2-1 is 4.9%. For comparison, the full power core flow window for GGNS is from 104.4 to 118.1 Mlb/hr or 92.8-105% of rated core flow. The ESBWR core flow range of 3-5% is much smaller than the 12% range for GGNS. Therefore, [[

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Core Power/Feedwater Temperature Operating Map

The ESBWR core flow will also vary as the final feedwater temperature is varied. The feedwater temperature is varied as a means of changing core power level without the moving control rods and is used as the functional equivalent of changing power with recirculation flow in a forced circulation plant. The defined operating range of core power as a function of feedwater temperature is shown in Figure 4.4-1 of Reference 14. The reactor heat balance conditions for the feedwater temperature operating range are shown in Figures 2.1-1 and 3.1-1 and Table 3.2-1 of Reference 15.

The dryer stresses are expected to [[

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Reactor Pressure and Pressure Regulator Setpoint Tolerance

The dryer response measurements taken during the GGNS EPU power ascension showed [[

]] The pressure setpoint readjustment during the final GGNS EPU power ascension was unusual and was the result of the mid-cycle EPU license amendment approval and implementation. Under normal circumstances, the pressure regulator setpoint is adjusted early in the reactor system pressurization so that the reactor will be at nominal pressure when full power is achieved and is not readjusted during the cycle. In addition, the plant thermal efficiency (electrical generation as a function of thermal power) is maximized by operating the reactor system at the high end of the allowable pressure range, which, [[

]] It is not likely that the plant will be operated at full power at lower reactor system pressures for any longer than would be necessary. Therefore, consideration of a [[

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Licensing Basis Changes:

Changes to the ESBWR licensing basis are as described above and as noted in the references below. Revisions to References 2 and 3 to incorporate the methodology modifications identified in Reference 16 are shown Attachment 1. Refer to RAI 3.9-292 for the final licensing basis changes.

References:

1. GNRO-2011/00088, Entergy Operations, Inc., to U.S. Nuclear Regulatory Commission, “Request for Additional Information Regarding Extended Power Uprate, Grand Gulf Nuclear Station, Unit 1, Docket No. 50-416, License No. NPF-29,” October 10, 2011.
2. 26A6642AK Rev. 9 “ESBWR DCD Tier 2, Chapter 3 Design of Structures, Components, Equipment and Systems”, Sections 3.9 – 3.11, and Appendix 3L. NOTE: This document is being revised.
3. NEDE-33312P-A Rev. 2, “Steam Dryer - Acoustic Load Definition,” October 2010. NOTE: This report is being revised.
4. NEDE-33313P-A Rev. 2, “Steam Dryer - Structural Evaluation,” October 2010. NOTE: This report is being revised.
5. NEDC-33408P-A Rev. 1, “ESBWR Steam Dryer - Plant Based Load Evaluation Methodology,” October 2010. NOTE: This report is being revised.
6. Deleted.
7. MFN 09-509, “Response to Portion of NRC RAI Letter No. 220 and 339 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.9 – Mechanical Systems and Components; RAI Numbers 3.9-213 and 3.9-217 S01,” Richard Kingston to USNRC Document Control Desk, July 31, 2009.
8. Deleted.
9. MFN 12-066, Revision 2, "NRC Requests for Additional Information (RAI) 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 for RAIs 3.9-289, 3.9-290 and 3.9-291," Jerald Head to USNRC, January 30, 2013.
10. Regulatory Guide 1.207, “Guidelines for Evaluating Fatigue Analyses Incorporating the Life Reduction of Metal Components Due to the Effects of the Light-Water Reactor Environment for New Reactors,” March 2007.
11. NEDC-33765 Supplement 4, “Grand Gulf Nuclear Station Replacement Steam Dryer EPU Full Re-Analysis and Benchmarking Report,” December 2012.
12. 26A6642AD Rev. 9, “ESBWR Design Control Document, Tier 2, Chapter 1 Introduction and General Description of Plant, Sections 1.1 – 1.11,” December 2010. Note This document is being revised.

13. NEDO-33337 Rev. 1, "ESBWR Initial Core Transient Analyses," April 2009.

14. 26A6642AP Rev. 9, ""ESBWR Design Control Document, Tier 2, Chapter 4 Reactor," December 2010.

15. NED0-33338 Rev.1, "ESBWR Feedwater Temperature Operating Domain Transient and Accident Analysis," May 2009.

16. MFN 12-130, "Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document," Jerald Head (GEH) to USNRC Document Control Desk, December 12, 2012.