Enclosure 2

MFN 12-047, Revision 1

GEH Final Response to RAI 3.9-275

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 3.9-275

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 Response

Introduction and Summary

Scheduled visual inspections of the Susquehanna Steam Electric Station (SSES) Unit 2 replacement steam dryer, conducted in April 2011 after one 2-year cycle of operation at Extended Power Uprate (EPU)[1] conditions revealed a crack indication in the vicinity of the 4° seismic block location. In order to support SSES and the Grand Gulf Nuclear Station (GGNS) power uprate licensing submittal (which was underway at the time), GEH performed a comprehensive investigation that encompassed the design, analysis, and manufacture of the SSES replacement dryer. As part of the review of the GGNS submittal, GEH responded to a series of questions related to the crack. GEH has stated that the fatigue crack was not the result of a deficient analysis.

In summary, the investigation determined [[

]] Information provided to the NRC staff in prior RAI responses has been supplemented and assimilated in Reference 1, which is summarized in this RAI response in order to answer the staff's request.

Detailed Response:

Analysis Overview

Upon discovery of the skirt crack adjacent to the seismic block, further Flow-Induced Vibration (FIV) evaluations were performed to support the root cause evaluation for this crack. [[

[1] Susquehanna is approved to operate at 120% Original Licensed Thermal Power (OLTP).

]] This analysis used the same PBLE acoustic pressure loads from the on-dryer measurements as the Reference 2 analysis. The results of these analyses were used in subsequent evaluations. [[

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Global Model Evaluation (Load Basis)

For this evaluation, the global model analysis provides the transient boundary conditions used to drive the more detailed submodel for the seismic block and skirt region. Highlights of the analysis include the following:

- The structural Finite Element (FE) model used in the global analysis was "upgraded" to be consistent with improvements and lessons learned from other projects. [[

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- The PBLE-based analysis [2] was used in the seismic block analysis because there was less uncertainty in the loads. It was based on actual on-dryer measurements (test condition 3D) instead of the more remote main steam line measurements, and the [[

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- The PBLE-based analysis takes into account bias and uncertainty terms developed benchmarking against the SSES on-dryer instrumentation; therefore, it represents bounding predicted dryer stresses. [[

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Figure 1 Strain gage measurement versus model prediction

Detailed Submodel Evaluation

A submodel of the seismic block region was developed for the analysis. [[

]] The submodel is shown in Figure 2.

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Figure 2 Submodel of the seismic block area

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The submodel results were benchmarked to the global model results in order to determine if the [[

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The results of the as-built submodel analysis are provided in Table 1. [[

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Table 1 Stress intensity in the as-built skirt and seismic block weld

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Fracture Mechanics Evaluation

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Conclusions

Several conclusions can be drawn from the Reference 1 evaluation, which have been summarized in this response:

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Additional Discussion

The initial GEH response to this RAI [5] did not fully address NRC staff concerns. Additional points requiring clarification were discussed during a teleconference and are summarized (and paraphrased) below.

1. GEH should provide a more detailed explanation about [[

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2. On page 3, the third bullet of the draft response states that the [[

   ]] Can GEH confirm that the original analysis involved the acoustic circuit model for calculating the pressure loads in the dryer? If so, please provide a comparison between the pressure loads predicted by PBLE and ACM methods.
3. Regarding benchmarking of the [[

   ]] GEH should provide results supporting these statements.
4. Table 2 provides stress at the [[

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5. GEH needs to explain why its QA process did not prevent this error, i.e., [[

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6. How will lessons learned be included in Licensing Topical Reports (LTRs)?
7. How far away was the closest instrument (i.e., strain gauge) from the crack location (distance)?
8. The discussion should address the weld quality factor.
9. Expand the discussion of other evidence that supports the conclusion that [[ ]]

Each of these items is addressed below.

Additional Discussion Item #1

Figures 3 and 4 are provided for illustration purposes. Figure 3 shows a side view of the SSES steam dryer. This figure shows the scale of the dryer in comparison to the blocks. The seismic blocks are located along the support ring (dryer mid-section). Figure 4 shows the 4° seismic block detail and the crack location. Figure 5 is a photograph of the SSES 4° seismic block showing the wear pattern. Using the photograph information (and simple scaling), the submodel was run considering a [[

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Figure 3 Steam dryer profile showing seismic blocks

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Figure 4 Seismic block detail (side view)

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Figure 5 – View from under the seismic block showing the crack (circled) and the wear pattern

Additional Discussion Item #2

The Susquehanna replacement dryer was evaluated in 2007 [6]. This dryer was instrumented and treated as a prototype, consistent with Regulatory Guide (RG) 1.20 Revision 3. The replacement dryer evaluation leveraged a benchmark study based on in-plant strain gage data taken in 1985. The benchmark study included comparisons between predicted and measured pressures at the pressure drum and outer hood locations. A more detailed comparison was also made of the predicted strains versus measured strains at specific strain gauge locations. This work provided a basis for the loads. The studies [[

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[3] The Reference 6 report provides a reference for the loads (CDI Report No. 06-22 Rev. 0 dated September 2006). However, GEH's rights with respect to this information are limited. A direct comparison of PBLE-based loads versus the 2006 SSES acoustic model is not available.

Additional Discussion Item #3

Mesh refinement studies supporting this analysis demonstrated [[

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The submodel was benchmarked against the original global model [[

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Additional Discussion Item #4

Nodal “raw” stresses taken from the original SSES global model, in the 0° area (near the location of the 4° block), range from [[

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[[

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Figure 6 – M25 load case skirt elements near the crack initiation area

Additional Discussion Item #5

The results presented in this response are based on a submodel study that includes the detailed features of the seismic block. In general, considering the GEH modeling approach, [[

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The key issues relative to quality assurance were identified in the GEH (internal) Root Cause Analysis (RCA). [[

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Additional Discussion Item #6

Lessons learned are generally incorporated into all processes (e.g., procurement, design, manufacturing, etc.) under the GEH quality assurance program as described in Reference 8. If changes due to lessons learned resulted in a need to update a licensing topical report, a revised or new report would be submitted for review as part of the appropriate regulatory change process (e.g., license amendment, Section VIII of design certification rule, or addressed in a COL application).

Additional Discussion Item #7

Figure 7 from Reference 4 shows the location of the closest strain gauge, S9, located on the dryer skirt (on the drain channel). It is approximately [[
]].

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Figure 7 – The 0° view of the SSES Unit 1 instrumented replacement steam dryer showing sensor locations

Additional Discussion Item #8

Weld quality factors are addressed in the response to RAI 3.9-277.

Additional Discussion Item #9

The introduction to this RAI response was revised relative to the original draft [5] to (1) remove the references to prior (GGNS) RAI responses, (2) provide a summary in place of the referenced responses, as well as more explicit details concerning the RCA findings, and (3) highlight the fact that the RCA was comprehensive, covering the design, analysis, and manufacture of the SSES replacement steam dryer. The early draft of the response was almost solely focused on the stress and fracture mechanics evaluation [1], which is responsive to the

question, but presumes that the reader is familiar with the background concerning the investigation.

References:

1. GEH Technical Report 0000-0136-8710P, *Replacement Steam Dryer Analysis of Skirt Crack Indication*, Class III, Revision 2, February 2012.
2. GEH Technical Report 0000-0099-0973-P-R0, *Susquehanna Replacement Steam Dryer Fatigue Stress Analysis Using PBLE Methodology*, Class III, Revision 0, August 2009.
3. GEH Technical Report 0000-0095-2113-P-R0, *Susquehanna Replacement Steam Dryer Updated Stress Analysis at Extended Power Uprate Conditions*, Class III, Revision 0, February 2009.
4. Engineering Report GE-NE 0000-0085-2413 P-R0, *Susquehanna Unit 1 Replacement Steam Dryer Vibration Instrument Program NRC Summary Test Report*, Class III, Revision 0, July 2008.
5. MFN 12-047, Jerald Head (GEH) to David Misenhimer (NRC)," 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 – Draft Response for RAI 3.9-275," July 25, 2012.
6. Engineering Report GE-NE-0000-0061-0595-R1, *Susquehanna Replacement Steam Dryer Fatigue Analysis*, Class III, June 2007.
7. Engineering Report 0000-0095-2113-P-R0, *Susquehanna Replacement Steam Dryer Updated Stress Analysis at Extended Power Uprate Conditions*, Class III, February 2009.
8. NEDO-11209-A, *GE Hitachi Nuclear Energy Quality Assurance Program Description*, Rev. 9, August 2011, Class I.

Licensing Basis Changes:

No change is proposed for the DCD or referenced Engineering Reports.