Enclosure 2

MFN 12-077, Revision 3

GEH Revised Response to RAI 3.9-285 and

Response to RAI 3.9-285 S01

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 show here [[ ]].

NRC RAI 3.9-285

Summary: The staff's question is in regard to clarifying the "peak" stress from the shell model.

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* [[ ]]

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 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 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.*

<u>GEH Revised Response</u>

<u>References</u>

1. MFN 12-059, Revision 1, Jerald Head (GEH) to US Nuclear Regulatory Commission, “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.
2. Deleted.
3. Deleted.
4. NEDE-33313P, Revision 4, “ESBWR Steam Dryer Structural Evaluation,” September 2013.

<u>Response</u>

As stated in the staff’s supplemental Request for Additional Information (RAI), the initial response to Economic Simplified Boiling Water Reactor (ESBWR) RAI 3.9-285 did not adequately address the Nuclear Regulatory Commission’s (NRC’s) concern regarding the General Electric-Hitachi (GEH) methodology for determining the peak stress intensity in a parallel fillet weld configuration. The examples provided are 3-D; this approach was chosen because the dryer model is 3-D, and the methodology for this simplified case study should be indicative of the actual process used in the steam dryer finite element analysis (FEA) as described in Engineering Report NEDE-33313P [4]. The 2-D plane strain elements are treated consistent with solid elements of infinite length, and would not illustrate the GEH methodology. However, the issue with using a 3-D shell model is that Poisson’s effects exist at the model’s edges. The previous version of this response included these effects in the FEA calculations used for illustration of Method 1 and Method 2 (see Table 1 below). In retrospect, an improved approach to address the staff's question would have been to either use results from the center of the model, away from the edges (i.e., consistent with the staff proposed 2-D case); or, use 2-D cases and acknowledge the difference in the ANSYS element formulation compared to the GEH methodology. The GEH interpretation of the staff's question is related to [[ ]] in lieu of traditional methods that use a [[ ]] The revised FEA results (below) therefore were evaluated at the weld joint center using 3-D shell models to be consistent with the staff-proposed 2-D case while maintaining congruency with the GEH methodology.

Detailed Discussion of the Case Study Approach and Methods

A brief description of the various methods to determine the fatigue stress in fillet welds is provided in Table 1. Method 0[1] (zero) utilizes a traditional weld sizing calculation methodology; [[ ]] The response to this RAI, in conjunction with the response to RAI 3.9-286, demonstrates the adequacy of [[ ]]

The approaches used for the illustrative calculations are consistent with the procedures of Engineering Report NEDE-33313P [4] for fillet welds. As discussed above, the comparisons are made using an element near the center of the weld span.
The baseline stress is calculated using traditional methods (Method 0 ("zero") in Table 1). The scope of this work covers only [[ ]] is discussed in the response to ESBWR RAI 3.9-286.

[1] Method 0 is included in the table to discern it from the [[ ]]

Table 1– Methods used to determine the Fatigue Stress in Fillet Welds

Method Number	Method Description	Application	Comment or Example
0	Traditional weld calculation using an FSRF of 4.0 (baseline method for comparisons)	This is a direct application of ASME-S-N based calculation using FSRFs. The stress is determined from traditional weld area method calculations (e.g., a calculation similar to what one will find in “Design of Welded Structures” by O.W. Blodgett).	This method would be employed during the design phase to size the weld that would connect two parts together given an assumed set of loads. This method is not used for final fatigue stress calculation for the steam dryer, but used as the baseline for the GEH Methods 1 and 2 (in this RAI response), and Method 3 (in the RAI 3.9-286 response).
[[			
			]]

The geometry for the case studies presented in this response is based on a T-joint configuration as shown in Figure 1. Also shown in the figure are the edges that are pinned, the edge that is loaded, and the coordinate system convention used in the calculations. The plate nomenclature is that the continuous plate is the reactionary plate (show as vertical in the figure) and the intersecting plate is the loaded plate (shown as horizontal in the figure).

[[ ]]

Figure 1: [[ ]]

Analysis

The stress is calculated in three manners; a nominal stress using the traditional weld design method, [[

]] Table 2 provides the configurations of plate thicknesses and weld sizes used for this parametric study. For all cases the [[

]]

Table 2[2]: Geometric Configurations for the Case Study

[[			
			]]

For all cases, [[

]] All loads are assumed to be distributed evenly along the intersecting plate's loaded edge.

Fatigue Strength Reduction Factors

[[

]]

[[

]]

Traditional Weld Stress Calculation (Method 0)

The traditional method assumes that the plates are rigid bodies and that the load from the intersecting plate is distributed evenly through the entire length of the weld and reacted out of the weld into the continuous plate. The continuous plate is assumed to be perfectly rigid. The basic equations used for the nominal stress calculations are as follows (see Figure 2 for a schematic):

[[

]]

For the nominal calculation using the traditional method, the only loads acting at the weld are [[ ]] Therefore the stress terms that include [[ ]] for the traditional method.

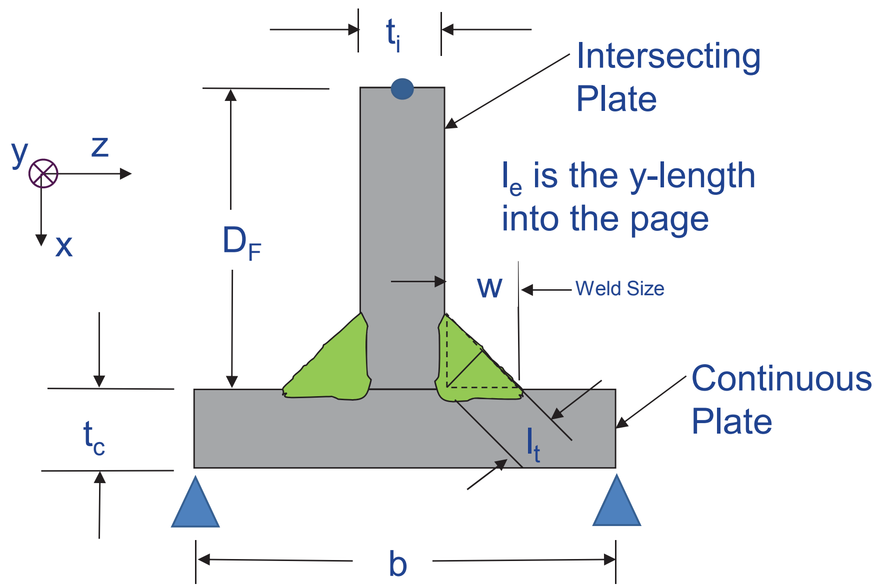

Figure 2: Schematic of Weld Joint showing Geometric Nomenclature

Nominal Stress using FEA Forces and Moments (Method 1)

[[

]]

This process is consistent with Section 4.1 of NEDE 33313P.

[[

]]

[[ ]]

Figure 3: [[ ]]

The following provides [[

]]

Case Study Model

Shell models of geometric proportions to Figure 1 were constructed using the plate thicknesses listed in Table 2. [[ ]] The mesh grid sizes used for these models were [[

]]

[[ ]]

Figure 4: Case Study FE Model ([[ ]]**)**

Results

The following details the results for the three manners in which the weld fatigue stress values were determined at the weld location.

Traditional Weld Sizing Calculation (Method 0)

[[

Table

]]

Table: 3 [[

]]

Finite Element Analysis Shell Stress ([[ ]])

[[

]]

Table 4: [[

						]]

Table 5: [[

						]]

Table 6: [[

						]]

Table 7: [[

]]

Table 8: [[

]]

Table 9: [[

]]

Discussion Regarding Direct Load Cases

The reason that the results of [[

]]

To illustrate the effect of the [[ ]] on the calculation of the stress in the weld line, the [[

]]

The [[ ]] is provided in Table 10. For completeness, all loading types are shown. As can be seen in the ratio of the FEA results to the traditional method results, [[
]]

The [[ ]] is provided in Table 11. Again, for completeness, all loading types are shown. [[

]]

Table 10: [[

						]]

Table 11: [[

						]]

Table 12: [[

											]]

Conclusions

[[

]]

<u>RESPONSES TO COMMENTS FROM NRC STAFF</u>

Reference:

MFN 12-077, Revision 2, Letter from Jerald G. Head, GEH, to USNRC, Subject: 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 – GEH Final Responses to RAIs 3.9-285 and 3.9-286, dated February 15, 2013

In the above reference, Section 7.0, GEH addressed nine (9) NRC staff comments received during a follow-on teleconference on November 14, 2012. GEH believes the revised response to RAI 3.9-285 (above) and response to RAI 3.9-285 S01 (below) are responsive to the staff's concerns, thus obviating the comments and GEH's associated responses. The prior responses can be viewed in MFN 12-077, Revision 2 (ML13052A161).

<u>ESBWR Licensing Basis Impact</u>

See GEH's response to RAI 285 S01 below for the combined licensing basis impact.

<u>NRC RAI 3.9-285 S01</u>

Summary: The staff's question is in regard to GEH's response to RAI 3.9-285.

GEH submitted the final response to RAI-285 on 02/15/2013. This RAI response provides a comparison of GEH Method 1, GEH Method 2, and a traditional strength of materials approach, for fatigue evaluation of fillet welds. GEH defined 10 typical configurations of double fillet welded T connections for this study. The staff reviewed the RAI-285 response, and discussed it with GEH during telephone calls on 02/27/2013 and 03/06/2013. The staff further discussed it with GEH during the meeting at NRC on 03/19/2013. GEH informed the staff that the demonstration [[ ]] *was inappropriately calculated. A corrected calculation indicates that* [[ ]] *The staff noted that this new information would be considered in preparing the final follow-up RAI-285 S01.*

Based on the information provided in the RAI-285 final response, and the three (3) subsequent discussions with GEH, the staff finds that the final response does not adequately address all of the staff comments previously provided to GEH on November 14, 2012.

- *Regarding staff comment 2 from November 14, 2012: GEH informed the staff on 03/19/2013, that a* [[ ]] *in the RAI-285 study. Since the typical steam dryer global shell model has element sizes in t*[[ ]] *range, it is not clear to the staff how GEH ensures that Method 2 produces conservative results for fatigue evaluation of fillet-welded T-joints in actual steam dryer applications.*

  a) The staff requests that GEH submit quantitative information that establishes Method 2 solution convergence for the largest shell element size currently used in the global shell model, at the locations of interest (i.e. double fillet-welded T-connections).

  b) Also describe in detail how the ESBWR global shell model will be evaluated, to ensure convergence of Method 2 at all locations where it will be applied to assess fillet welded T-connections.

- *Regarding staff comment 3 from November 14, 2012: GEH provided a brief description of the approach used in past convergence studies to meet a specified* [[ ]] *criterion. The staff needs additional information to better understand how the convergence study described specifically applies to convergence of Method 2 results for assessment of fillet-welded T-connections.*

Therefore, the staff requests GEH to

a) *Confirm that the* [[ ]] *criterion is applied to local FEA shell stresses that are used in Method 2; if not, identify where the* [[ ]] *criterion is applied, and explain why this is applicable to the local FEA shell stresses used in Method 2.*

b) *Based on previous convergence studies, identify the maximum shell element mesh size, at locations of interest for application of Method 2 to fillet-welded T-connections, that meets the* [[ ]] *criterion.*

- *Regarding staff comment 5 from November 14, 2012: GEH is requested to address the following:*

1) *From the results reported in Table 5.5.1b of the RAI-285 response, Method 1 does not converge until the mesh size approaches* [[ ]] *sizes, the predicted results are consistent with the traditional calculation for fillet welds. The staff notes that the change in the Method 1 prediction, between a* [[ ]] *mesh, as presented in Table 5.5.2 of the RAI-285 response, is very significant. The* [[ ]] *mesh results are at least* [[ ]] *mesh results, and* [[ ]] *for several cases. Therefore, it would appear that the use of Method 1 for* [[ ]] *Therefore, GEH is requested to explain how Method 1 will be applied in a typical steam dryer fatigue evaluation, if the shell mesh* [[ ]] *Will GEH refine the mesh locally in areas where Method 1 is to be used? Will a separate local model be used to obtain the converged membrane and bending resultants for use in Method 1?*

2) *From the results presented in Table 5.5.1b of the RAI-285 response, the Method 2 results for a* [[ ]]*evaluation results and the converged Method 1 results. However, there is a lack of consistency in the conservatism of the Method 2 results. There is* [[ ]] *A review of these configurations indicates that they share a common attribute; namely, that all have a* [[ ]] *Method 2 results are closer to the traditional results and the converged Method 1 results.*

During the 02/27/2013 telephone call with GEH, the staff requested GEH to review these Method 2 results for possible errors in the table, or to provide a technical explanation for the validity of these Method 2 results.

During the 03/06/2013 telephone call with GEH, GEH indicated that the results are correct, and explained why the level of conservatism changes with the w/t_v *ratio. To better understand any possible limitations, the staff requested GEH to analyze a configuration* [[ ]] *GEH agreed to do this.*

The staff subsequently reviewed the data in light of GEH's clarification, and reached the conclusion that for [[ ]]*, the Method 2 results are nonconservative, when compared to the traditional results and the converged Method 1 results.*

Therefore, the staff requests GEH to explain how Method 2 will be implemented (e.g., imposing a restriction on the minimum [[ ]]*, in order to ensure that the Method 2 results are conservative, when compared to the traditional results and the converged Method 1 results.*

3) *Table 5.5.3b of the RAI-285 response shows that Method 2, with* [[ ]] *the traditional results and the converged Method 1 results. The 3 configurations analyzed (4s, 5s and 9s) all have* [[ ]] *GEH noted the nonconservatism of the results in a Table footnote.*

The staff discussed this observation with GEH during the 02/27/2013 and 03/06/2013 telephone calls. GEH responded that configurations 4s, 5s, and 9s are not representative of fillet weld details used in the steam dryer, and had identified this in a different part of the RAI-285 response. According to GEH, this analysis was conducted just to satisfy a staff request. The staff noted that it had not requested any specific analysis and left the choice of "representative" configurations to GEH.

The staff requests GEH to define the restriction on w/t_v *ratio that will be imposed on the ESBWR steam dryer design. Demonstrate the conservatism of Method 2 for the* [[ ]] *consistent with the GEH response to item (2) directly above.*

GEH Response

References

1. MFN 12-059, Revision 1, Jerald Head (GEH) to US Nuclear Regulatory Commission, "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.
2. Deleted.
3. Deleted.
4. NEDE-33313P, Revision 4, "ESBWR Steam Dryer Structural Evaluation," September 2013.

RAI

- *Regarding staff comment 2 from November 14, 2012: GEH informed the staff on 03/19/2013, that a* [[ ]] *in the RAI-285 study. Since the typical steam dryer global shell model has element sizes in* [[ ]] *range, it is not clear to the staff how GEH ensures that Method 2 produces conservative results for fatigue evaluation of fillet-welded T-joints in actual steam dryer applications.*

  a) *The staff requests that GEH submit quantitative information that establishes Method 2 solution convergence for the largest shell element size currently used in the global shell model, at the locations of interest (i.e. double fillet-welded T-connections).*

GEH Response

The adequacy of Method 2 is demonstrated in the revised response to RAI 3.9-285 (above). The global model stress convergence is discussed in the response to RAI 3.9-292 S02.

RAI

b) *Also describe in detail how the ESBWR global shell model will be evaluated, to ensure convergence of Method 2 at all locations where it will be applied to assess fillet welded T-connections.*

GEH Response

The topic of global model stress convergence is discussed in the response to RAI 3.9-292 S02.

RAI

- *Regarding staff comment 3 from November 14, 2012: GEH provided a brief description of the approach used in past convergence studies to meet a specified* [[ ]] *criterion. The staff needs additional information to better understand how the convergence study described specifically applies to convergence of Method 2 results for assessment of fillet-welded T-connections.*

  Therefore, the staff requests GEH to

  1) *Confirm that the* [[ ]] *criterion is applied to local FEA shell stresses that are used in Method 2; if not, identify where the* [[ ]] *criterion is applied, and explain why this is applicable to the local FEA shell stresses used in Method 2.*

GEH Response

The topic of global model mesh convergence is discussed in RAI 3.9-292 S02.

RAI

2) *Based on previous convergence studies, identify the maximum shell element mesh size, at locations of interest for application of Method 2 to fillet-welded T-connections, that meets the* [[ ]] *criterion.*

GEH Response

The topic of global model mesh convergence is discussed in the response to RAI 3.9-292 S02.

RAI

- *Regarding staff comment 5 from November 14, 2012: GEH is requested to address the following:*

  1) *From the results reported in Table 5.5.1b of the RAI-285 response, Method 1 does not converge until the mesh size approaches* [[ ]] *sizes, the predicted results are consistent with the traditional calculation for fillet welds. The staff notes that the change in the Method 1 prediction, between a* [[ ]] *mesh, as presented in Table 5.5.2 of the RAI-285 response, is very significant. The* [[ ]] *mesh results are at least* [[ ]] *mesh results, and* [[ ]] *for several cases. Therefore, it would appear that the use of Method 1 for* [[ ]]. *Therefore, GEH is requested to explain how Method 1 will be applied in a typical steam dryer fatigue evaluation, if the shell mesh* [[ ]]. *Will GEH refine the mesh locally in areas where Method 1 is to be used? Will a separate local model be used to obtain the converged membrane and bending resultants for use in Method 1?*

GEH Response

Based on the analysis presented for the revised response to RAI-3.285, [[ ]]

RAI

2) *From the results presented in Table 5.5.1b of the RAI-285 response, the Method 2 results for a* [[ ]] *evaluation results and the converged Method 1 results. However, there is a lack of consistency in the conservatism of the Method 2 results. There is* [[ ]] *A review of these configurations indicates that they share a common attribute; namely, that all have a* [[ ]] *Method 2 results are closer to the traditional results and the converged Method 1 results.*

   During the 02/27/2013 telephone call with GEH, the staff requested GEH to review these Method 2 results for possible errors in the table, or to provide a technical explanation for the validity of these Method 2 results.

During the 03/06/2013 telephone call with GEH, GEH indicated that the results are correct, and explained why the level of conservatism changes with the w/tv ratio. To better understand any possible limitations, the staff requested GEH to analyze a configuration [[ ]] *GEH agreed to do this.*

The staff subsequently reviewed the data in light of GEH's clarification, and reached the conclusion that for [[ ]] *the Method 2 results are nonconservative, when compared to the traditional results and the converged Method 1 results.*

Therefore, the staff requests GEH to explain how Method 2 will be implemented (e.g., imposing a restriction on the minimum [[ ]]*, in order to ensure that the Method 2 results are conservative, when compared to the traditional results and the converged Method 1 results.*

<u>GEH Response</u>

GEH has revised the response to RAI 3.9-285. The revised response to RAI 3.9-285 demonstrates [[ ]] relative to traditional weld calculation methods with the defined configuration limitations referenced in the revised response to RAI 3.9-285.

<u>RAI</u>

3) Table 5.5.3b of the RAI-285 response shows that Method 2, with [[ ]] *the traditional results and the converged Method 1 results. The 3 configurations analyzed (4s, 5s and 9s) all have* [[ ]] *GEH noted the nonconservatism of the results in a Table footnote.*

The staff discussed this observation with GEH during the 02/27/2013 and 03/06/2013 telephone calls. GEH responded that configurations 4s, 5s, and 9s are not representative of fillet weld details used in the steam dryer, and had identified this in a different part of the RAI-285 response. According to GEH, this analysis was conducted just to satisfy a staff request. The staff noted that it had not requested any specific analysis and left the choice of "representative" configurations to GEH.

The staff requests GEH to define the restriction on w/tv ratio that will be imposed on the ESBWR steam dryer design. Demonstrate the conservatism of Method 2 for the [[ ]]*, consistent with the GEH response to item (2) directly above.*

GEH Response

[[

]]

GEH has revised the response to RAI 3.9-285. The revised response to RAI 3.9-285 demonstrates [[ ]] relative to traditional weld calculation methods with these defined configuration limitations.

ESBWR Licensing Basis Impact

The following changes have been made to Engineering Report NEDE-33313 [4].

Section 4.0 last 2 sentences:

FROM:
The steam dryer design specification shall specify which welds are primary structural welds or secondary structural welds. Partial penetration welds are prohibited for steam dryer design use.

TO:
The steam dryer design specification shall specify which welds are primary structural welds or secondary structural welds. The section properties of the weld(s) shall be equivalent to or greater than the members to which they are joined. Partial penetration groove welds are prohibited for steam dryer design use.

Section 4.1 Seventh Paragraph

From:

[[

A.

-

-

-

-

-

B.

-

-]]

- Multiply the nominal stress intensity by 4.0.

To:

[[

]]

Section 4.1 Eighth Paragraph

From:
The stress may also be obtained from the [[

]]

To:
The stress may also be obtained from the [[

]]

Section 4.1 Ninth Paragraph

FROM:
[[

]]

TO:

[[

]]

Figure 4-1

FROM:

[[

]]

TO:

[[ ]]