Enclosure 2

MFN 12-086, Revision 2

GEH Final Response to RAI 3.9-277

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 3.9-277

Summary

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.

Full RAI

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 steam dryer design [[ ]]. The staff noted that this is inconsistent with NEDE 33313P, Rev 2. Please provide clarification if [[ ]] in the ESBWR steam dryer.

GEH Response

1.0 REFERENCES

1.) AWS A3.0:2001 "Standard Welding Terms and Definitions".

2.) Letter from Richard E. Kingston, (GEH), to NRC, "Response to Portion of NRC RAI Letter No. 220 Related to ESBWR Design Certification Application - DCD Tier 2, Section 3.9 - Mechanical Systems and Components; RAI Number 3.9-214," January 30, 2009. (ADAMS Accession No. ML090340672).

3.) Letter from Richard E. Kingston, (GEH), to NRC, "Response to Portion of NRC RAI Letter No. 392 Related to ESBWR Design Certification Application - DCD Tier 2, Section 3.9 - Mechanical Systems and Components; RAI Number 3.9-214 S02," December 4, 2009.

4.) Letter from Richard E. Kingston, (GEH), to NRC, "Subject: Response to NRC Report of the August 25, 2009, and September 9, 2009, Regulatory Audit of Reactor Pressure Vessel Internals of the Economic Simplified Boiling Water Reactor," October 8, 2009 (ADAMS Accession No. ML092860177).

5.) NEDE-33313P-A, Rev. 2, "ESBWR Steam Dryer Structural Evaluation", October 2010.

6.) Letter from Richard E. Kingston, (GEH), to NRC, "Subject: Response to Portion of NRC RAI Letter No. 339 Related to ESBWR Design Certification Application – DCD Tier 2, Section 3.9 - Mechanical Systems and Components; RAI

Number 3.9-215 S01 Parts A, B, C & D (revised) and 3.9-244 S01 (revised)," July 10, 2009 (ADAMS Accession No. ML091950502).

7.) 26A6642AN, Rev. 9 ESBWR DCD Tier 2, Chapter 3, "Design of Structures, Components, Equipment and Systems", Appendices 3G – 3L.

8.) 26A6642AP, Rev. 9 ESBWR DCD Tier 2, Chapter 4, "Reactor".

9.) ASME Boiler & Pressure Vessel Code (BPVC), Section III "Rules for Construction of Nuclear Facility Components", Division 1.

   a. Subsection NB "Class 1 Components", 2001 Edition with Addenda to and including 2003.

   b. Subsection NG "Core Support Structures", 2001 Edition with Addenda to and including 2003.

   c. Subsection NG "Core Support Structures", 1973 Winter Addenda.

   d. Subsection NB "Class 1 Components", 1971 Edition.

10.) ASME Boiler & Pressure Vessel Code (BPVC), Section VIII "Rules for Construction of Pressure Vessels, Division 1, 1974 Edition.

11.) Letter from Jerald G. Head, (GEH), to NRC, "NRC Requests for Additional Information (RAI) Related to the Audit of ESBWR Steam Dryer Design Methodology Support Chapter 3 of the ESBWR DCD – Final Responses for RAIs 3.9-289, 3.9-290 and 3.9-291," January 30, 2013.

12.) ASME Boiler & Pressure Vessel Code (BPVC), Section IX "Welding and Brazing Qualifications", 2001 Edition with Addenda to and including 2003.

13.) NUREG/CR-6909 "Effect of LWR Coolant Environments on the Fatigue Life of Reactor Materials", February 2007.

14.) Letter from L. Crider to G. Watford, G. Barkley, subject: "Root Cause Investigation for SSES Unit 2 Steam Dryer Cracking Near 4^{o} Seismic Block" Non-Proprietary Information – Class I, dated 2/21/2012.

15.) 26A6642AK, Rev. 9 ESBWR DCD Tier 2, Chapter 3, "Design of Structures, Components, Equipment and Systems", Sections 3.9 – 3.11.

16.) Letter from Jerald G. Head, (GEH), to NRC, "Economic Simplified Boiling Water Reactor (ESBWR) Steam Dryer Design Methodology Supporting Chapter 3 of the ESBWR Design Control Document", December 12, 2012.

17.) NUREG-0307 "Review and Assessment of Research Relevant to Design Aspects of Nuclear Power Plant Piping Systems", Battelle Columbus Labs., OH, July 1977.

18.) W. Pilkey, Peterson's Stress Concentration Factors, 2nd Ed., Wiley-Interscience.

2.0 TYPES OF WELDS

2.1 ESBWR Steam Dryer Welds

The specific types of welds (ref. 1) used in ESBWR steam dryer design are groove welds and fillet welds. Note the other two basic types of welds; plug or slot welds, and intermittent welds; are not used in ESBWR steam dryer design. This does not include the vane assemblies used for moisture removal which may contain [[ ]]. The types of joints (ref. 1) used in design may include butt joint, corner joint, T joint, and lap joint; although an edge joint will not be considered as explained later in this section.

In the response to RAI 3.9-214 (ref. 2) GEH states that the ESBWR steam dryer design maximizes the use of full penetration welds. 26A6642AN section 3L.2.3 (ref. 7) discusses weld joint design and how to avoid stress concentrations. Although fillet welds are easier to fit-up and weld, and are therefore more economical, groove welds are used in favor of fillet welds. In the response to RAI 3.9-214S02 (ref. 3) GEH provided examples where joints were redesigned to increase the use of full penetration welds from BWR/6 to ABWR and then to ESBWR and BWR replacement steam dryers. In line with this design development philosophy, for the ESBWR steam dryer, GEH [[ ]].

Paragraph NG-3352 of ASME Boiler & Pressure Vessel Code (BPVC), Section III "Rules for Construction of Nuclear Facility Components" (ref. 9b) provides description of joints used in core support structures. GEH also references these same NG-3352 weld types (i.e. Types I through VIII) for internal structures such as the steam dryer, for example in NEDE-33313P-A (ref. 5) section 4.0. With respect to weld joint design philosophy, the following explains how weld joints are considered and selected for ESBWR steam dryer design:

a.) Butt joints, NG-3352 Type I. Butt joints are full penetration groove welds, Figures 1(a) and 1(c). [[ ]].

b.) Corner joints, NG-3352 Type III and some Type V. Corner joints are constructed using groove welds or fillet welds. As indicated in DCD 26A6642AN section 3L.2.3 (ref. 7), joints are designed [[

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]]

c.) T-joint, NG-3352 Type III, some Type V and some Type VII. T-joints are constructed using groove welds or fillet welds.

- Type III T-joints will use full penetration groove welds, Figure 1(l), [[

-

-

-

]]

d.) Lap joint, NG-3352 Type V. All lap joints will be [[

]].

e.) Edge joint, NG-3352 Type VI. This joint design, Figure 1(o) is not used since the edge joint [[

]].

f.) Plug or slot welds and intermittent welds, NG Type VIII will not be used in ESBWR steam dryer design. Figure 1(w) shows a lap joint with a fillet weld and plug weld similar to that used in some thin wall vessels. Plug and slot welds [[

]]. An intermittent fillet weld is shown in Figure 1(y). [[

]]

Table 2.1a summarizes weld types and steam dryer weld joint use.

Table 2.1a: Types of Welds, Steam Dryer Application and Corresponding Requirements
[[

]]

Notes:

1.) The "Figure 1" column provides references to an example of the joint type.

2.) The "Steam Dryer Use" column indicates whether each design is used or not used in the ESBWR steam dryer design and refers to (a) through (f) above in the preceding paragraph, describing joints considered in ESBWR steam dryer design. [[

]]

3.) The "GEH quality factor" and "GEH fatigue factor" columns contain information from NEDE-33313 (ref. 5) addressing those factors for secondary structural non-load bearing welds. Primary structural load bearing welds use quality and fatigue factors as given in Article NG-3000 (as stated in section 3.9.5 of ref. 15). See response for

RAI 3.9-289 (ref. 11) for descriptions of primary and secondary welds. For justification of GEH quality and fatigue factors, see section 3.0 below.

4.) For NG types, NG quality factors and location (i.e. category), see Table 2.1b; see NG-3350 for definitions. [[ ]]

NEDE-33313P-A addresses each of the welds that the ESBWR steam dryer will use. Weld joint types that are not discussed in NEDE-33313P-A are not used in ESBWR design. For example, in RAI 3.9-215 S01(C), (ref. 6), a BWR replacement steam dryer document [[ ]]. In that RAI, the NRC Staff question concerned a T-joint with fillet welds on each side where the weld is not wrapped around the plate's ends. In the response, GEH stated "[[ ]]

In summary, the welds used in ESBWR steam dryer design are controlled [[ ]].

Table 2.1b: 2001 Edition of Core Support Structures Quality and Fatigue Factors (ref. 9b)

TABLE NG-3352-1
PERMISSIBLE WELDED JOINTS AND DESIGN FACTORS

Type of Welded Joint	Permissible for Category Shown Below	Quality Factor and Fatigue Factor[1] RT or UT[2] and PT or MT Examination NG-5220	Progressive PT or MT Examination NG-5231	Root and Final PT or MT Examination NG-5232	Surface PT or MT Examination NG-5233	Surface Visual Examination NG-5260
I. Full penetration	A,B,C,D,E	$n = 1.0$ $f = 1$	$n = 0.9$ $f = 1$	$n = 0.75$ $f = 1$	$n = 0.65$ $f = 1$	$n = 0.5$ $f = 1$
II. Full penetration	A,B,C,D,E	$n = 1.0$ $f = 2$	$n = 0.9$ $f = 2$	$n = 0.75$ $f = 2$	$n = 0.65$ $f = 2$	$n = 0.5$ $f = 2$
III. Full penetration	C,D,E	$n = 1.0$ $f = 1$	$n = 0.9$ $f = 1$[3]	$n = 0.75$ $f = 1$[3]	$n = 0.65$ $f = 1$[3]	$n = 0.5$ $f = 1$[3]
IV. Double groove (RT not applicable)	A,B,C	$n = 0.5$ $f = 4$	$n = 0.45$ $f = 4$	$n = 0.4$ $f = 4$	$n = 0.35$ $f = 4$	$n = 0.25$ $f = 4$
	D,E	$n = 0.9$ $f = 4$	$n = 0.8$ $f = 4$	$n = 0.7$ $f = 4$	$n = 0.6$ $f = 4$	$n = 0.4$ $f = 4$
V. Double fillet (RT not applicable)	B,C	$n = 0.5$ $f = 4$	$n = 0.45$ $f = 4$	$n = 0.4$ $f = 4$	$n = 0.35$ $f = 4$	$n = 0.25$ $f = 4$
	D,E	$n = 0.9$ $f = 4$	$n = 0.8$ $f = 4$	$n = 0.7$ $f = 4$	$n = 0.6$ $f = 4$	$n = 0.4$ $f = 4$
VI. Single groove (RT not applicable)	D,E	$n = 0.6$ $f = 4$	$n = 0.55$ $f = 4$	$n = 0.45$ $f = 4$	$n = 0.4$ $f = 4$	$n = 0.35$ $f = 4$
VII. Single fillet (RT not applicable)	D,E	$n = 0.6$ $f = 4$	$n = 0.55$ $f = 4$	$n = 0.45$ $f = 4$	$n = 0.4$ $f = 4$	$n = 0.35$ $f = 4$
VIII. Intermittent fillet or plug	E	Not applicable	$n = 0.45$ $f = 4$	$n = 0.4$ $f = 4$	$n = 0.35$ $f = 4$	$n = 0.3$ $f = 4$

NOTES:
(1) See NG-3352 for definitions.
(2) Electroslag butt welds shall be examined by radiography. Electroslag welds in ferritic material shall also be examined for their full length by the ultrasonic method after a grain refining heat treatment, when performed, or after a postweld heat treatment.
(3) A minimum fatigue strength reduction factor of 1.0 is permitted when both sides of weld are examined; otherwise a factor of 2.0 must be used in analysis for cyclic operation.

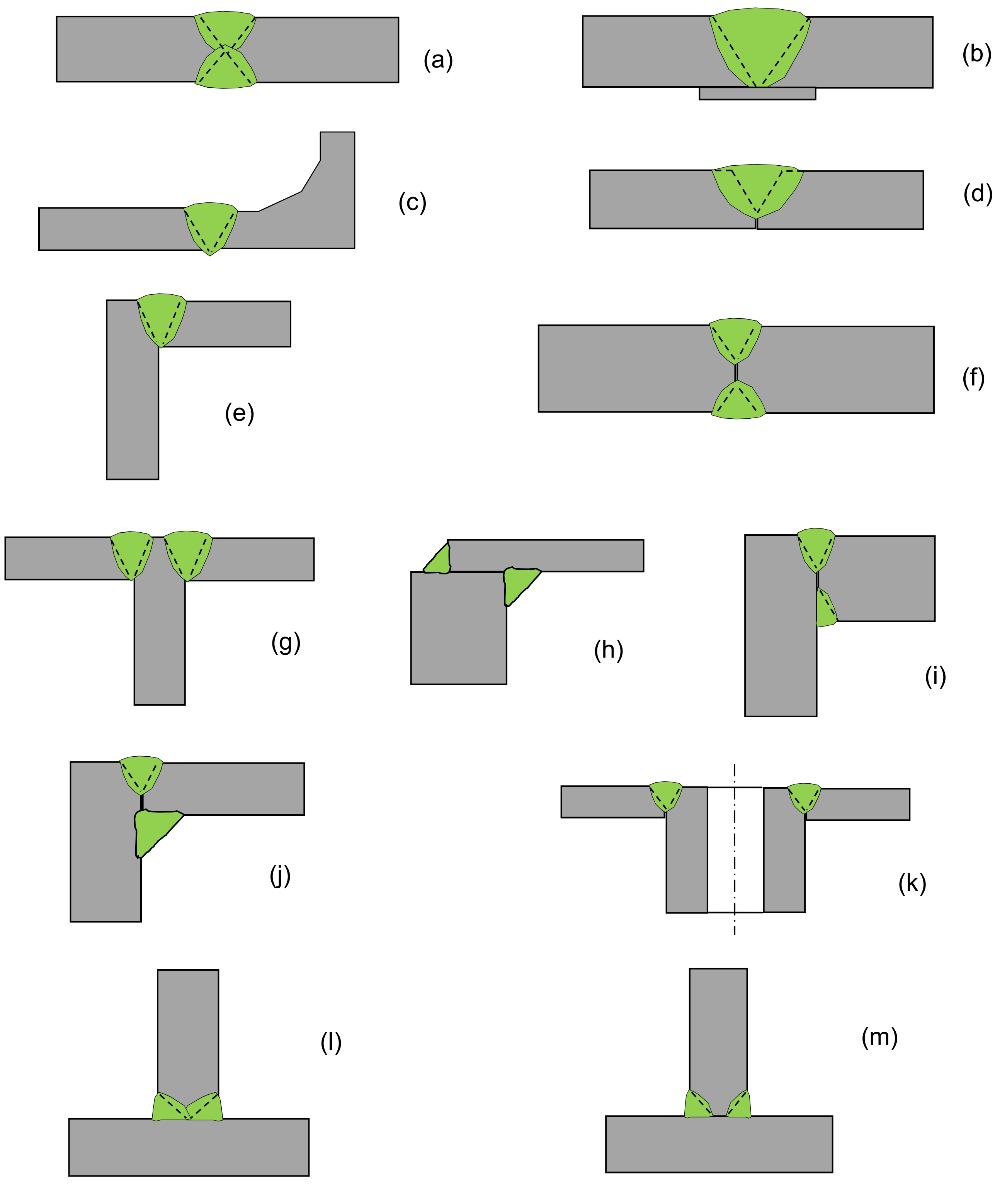

Figure 1 - Typical Weld Joints

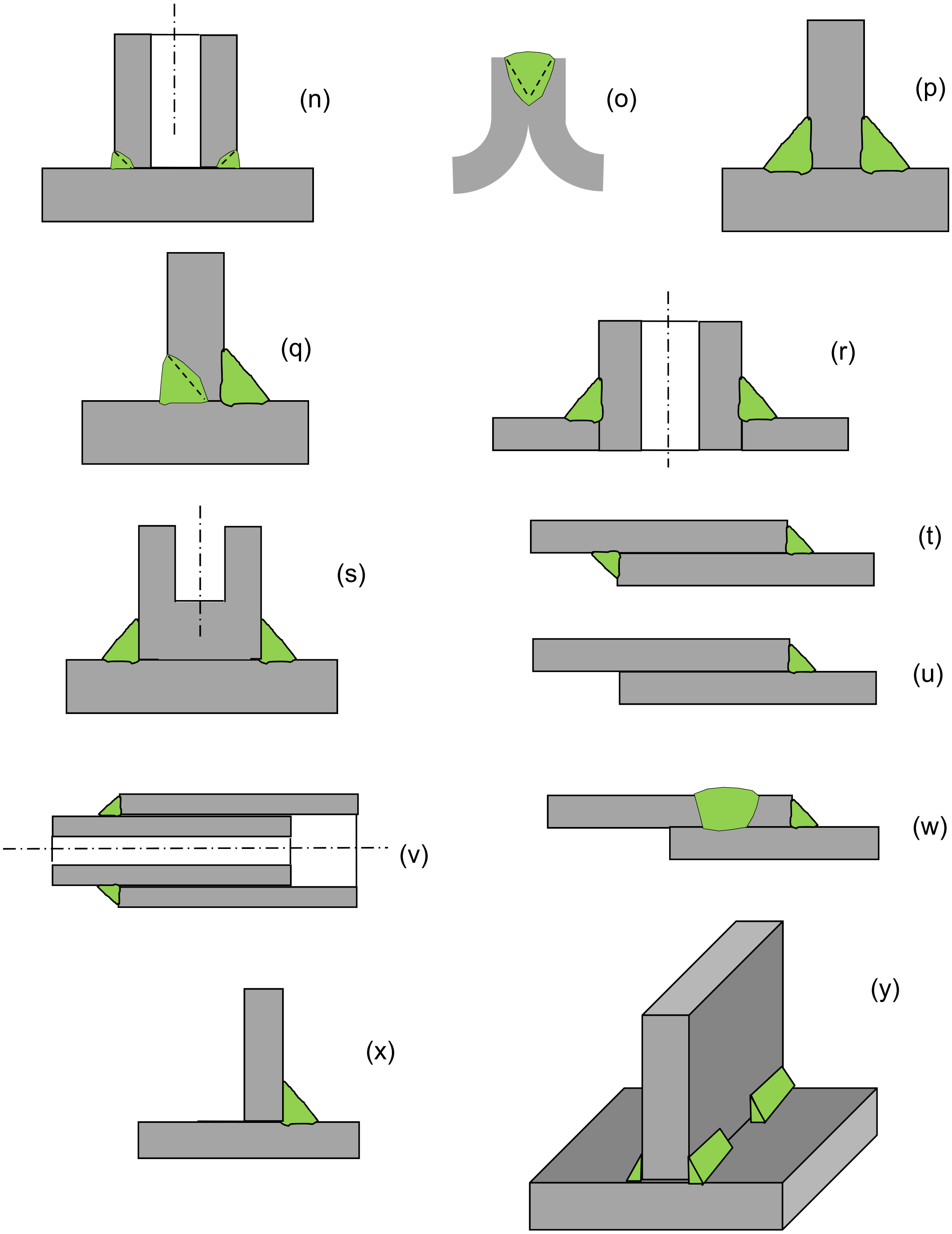

Figure 1 - Typical Weld Joints (continued)

2.2 Discussion of Partial Penetration Welds in Steam Dryer Reports

In reviewing GEH ESBWR licensing basis documents, NEDE-33313P-A (ref. 5) is the only Steam Dryer report that mentions partial penetration welds. Table 2.2 below specifically reviews NEDE-33313P-A for use of partial penetration welds.

Table 2.2: NEDE-33313P-A discussion of Partial Penetration Welds

Report Section	Subject	Addresses Partial Penetration welds ?
2.0	Steam Dryer Description	No
4.0, 4.1	Design Criteria – Fatigue	No
4.0, 4.2	Design Criteria – Weld Quality Factor	No, partial penetration, fillet and some groove welds are provided as examples of welds where the weld root is difficult to inspect. See paragraph below for further explanation.
Figure 4-1	Weld Fatigue Factor Flow Diagram	No, only “Full Penetration Welds” and “Fillet Welds”.
5.0	Steam Dryer FEA Model and Applied Loads	No
6.0	Vibration Analysis and Predicted Component Stresses	No
7.0	Fatigue Prediction	No

NEDE-33313P-A section 4.1 “Fatigue Criteria”, states, [[

]], only full penetration welds.

In NEDE-33313P-A, section 4.2, “Weld Quality Factor” provides justification for the factors used for static applications. The 3rd paragraph discusses the difficulty of inspecting the root side weld joints. As part of the justification for a quality factor of n=1, GEH stated, [[

]].

3.0 JUSTIFICATION FOR FATIGUE AND QUALITY FACTORS

As described in DCD Tier 2 Subsection 3.9.5.4 (Ref. 15), the reactor internal structures classified as nonsafety-related in Section 3.9.5 are not ASME B&PV Code components, but their design complies with the requirements of ASME B&PV Code Section III, Article NG-3000, except for the weld quality and fatigue factors for secondary structural non-load bearing welds. Primary structural load bearing welds use quality and fatigue factors as given in Article NG-3000. This section provides justification for those factors used for secondary welds in the steam dryer, a nonsafety-related structure. To provide this distinction, NEDE-33313P-A will be revised with additional guidance.

The fatigue factors (f) and quality factors (n), used for the ESBWR steam dryer welds are described in NEDE-33313P-A section 4.0 and Figure 4-1. The fatigue factors are also known as fatigue strength reduction factors (FSRF).

Table NG-3352-1 values have not changed since the Table was issued with the ASME BPV Code Winter 1973 Addenda; see Table 3.0 below compared to Table 2.1b.

- FSRFs listed in Table NG-3352-1 are dependent on the joint type and the potential for inspection (not the inspection method), see Table 3.1.
- Weld quality factors are dependent on joint type, inspection method and the weld's location in the component, see Table 3.2a.

Table 3.0: Original Core Support Structure Quality and Fatigue Factors (ref. 9c)

TABLE NG-3352-1

Type of Welded Joint	Permissible for Category Shown Below	Quality Factor & Fatigue Factor[1] RT or UT[3] & PT Examination NG-5220		UT[4] & PT Examination NG-5220		Progressive PT Examination NG-5230		Root & Final PT Examination NG-5240		Surface PT Examination NG-5250		Surface Visual Examination NG-5260	
I. Full Penetration	A, B, C, D, E	n=1.0	f=1	n=.9	f=1	n=.9	f=1	n=.75	f=1	n=.65	f=1	n=.5	f=1
II. Full Penetration[5]	A, B, C, D, E	n=1.0	f=2	n=.9	f=2	n=.9	f=2	n=.75	f=2	n=.65	f=2	n=.5	f=2
III. Full Penetration	C, D, E	n=1.0	f=1	n=.9	f=1[2]	n=.9	f=1[2]	n=.75	f=1[2]	n=.65	f=1[2]	n=.5	f=1[2]
IV. Double Groove (RT Not Applicable)	A, B, C	n=.5	f=4	n=.45	f=4	n=.45	f=4	n=.4	f=4	n=.35	f=4	n=.25	f=4
	D, E	n=.9	f=4	n=.8	f=4	n=.8	f=4	n=.7	f=4	n=.6	f=4	n=.4	f=4
V. Double Fillet (RT Not Applicable)	B, C,	n=.5	f=4	n=.45	f=4	n=.45	f=4	n=.4	f=4	n=.35	f=4	n=.25	f=4
	D, E	n=.9	f=4	n=.8	f=4	n=.8	f=4	n=.7	f=4	n=.6	f=4	n=.4	f=4
VI. Single Groove (RT Not Applicable)	D, E	n=.6	f=4	n=.55	f=4	n=.55	f=4	n=.45	f=4	n=.4	f=4	n=.35	f=4
VII. Single Fillet (RT Not Applicable)	D, E	n=.6	f=4	n=.55	f=4	n=.55	f=4	n=.45	f=4	n=.4	f=4	n=.35	f=4
VIII. Intermittent Fillet or Plug	E	Not Applicable		n=.45	f=4	n=.45	f=4	n=.4	f=4	n=.35	f=4	n=.3	f=4

NOTE:
1. See NG-3352 for definitions.
2. A minimum fatigue strength reduction factor of 1.0 is permitted when both sides of weld are examined—otherwise a factor of 2.0 must be used in analysis for cyclic operation.
3. Ultrasonically examine weldment in accordance with XVI-3400 using the *acoustical equivalency* test.
4. Ultrasonically examine weldment in accordance with IX-3400. *Acoustical equivalency* test not required.
5. See NG-3352.2 for fatigue factor special case NB-3352.4(d).

3.1 Fatigue Strength Reduction Factors

Per 2001 Edition / 2003 Addenda ASME BPV Code Section III NG-3213.13 (ref. 9b), a FSRF is a “stress intensification factor which accounts for the effect of a local structural discontinuity (stress concentration) on the fatigue strength.” These FSRFs were adopted from Subarticle NB-3300 Vessel Design (ref. 9d) when NG was issued in the 1973 Winter Addenda (ref. 9c).

FSRFs listed in Table NG-3352-1 are dependent on the joint design. See Table 3.1 where only the FSRFs are shown.

- f = 1, full penetration groove welds, welded from both sides, e.g. figures 1(a) and 1(l).
- f = 1, full penetration groove welds, welded from one side, provided the component design has allowed the backside to be accessible for inspection, figure 1(c).
- f = 2, full penetration from 1 side where backing is used, figure 1(b).
- f = 2, full penetration groove welds such as figures 1(e) and 1(g), if the component design has not allowed weld backside inspection capability.
- f = 4, partial penetration welds
- f = 4, fillet welds

With the exception of corner joints, the FSRF does not change with respect to the method of inspection or level of inspection, that is if the joint is volumetrically inspected (e.g. RT and UT) versus surface only (e.g. PT and VT).

Table 3.1: Weld Joint Type and FSRFs (ref. 9b)

[[

]]

3.1.1 Groove Welds

Full penetration groove welded butt joints, corner joints and T-joints: NG-3352 Types I and III:

- for primary weld's FEA or when traditional strength of materials formulas are applied [[ ]]. This is consistent with ASME BPV Section III Subsection NG requirements.
- for secondary weld where FEA is used, [[ ]].

3.1.2 Fillet Welds

Fillet welded T-joints and lap joints: NG-3352 Type V and VII:

- for primary weld's FEA or when traditional strength of materials formulas are applied [[ ]]. This also applies to secondary welds when traditional strength of materials formulas are applied. This SCF is consistent with ASME BPV Section III Subsection NG requirements.
- for secondary weld's FEA [[ ]].
- for secondary weld's FEA [[ ]].

3.1.3 Application of FSRFs in Analysis

The fatigue factors (f) are included in the fatigue stress calculations obtained from fatigue loading and then compared to the 6,800 psi acceptance criteria. This is obtained by reducing the 13,600 psi endurance limit of the stainless steel fatigue design curve in NUREG/CR-6909 (ref. 13) by 50%.

3.2 Weld Quality Factor

When Subsection NG was issued in the 1973 Winter Addenda, NG adopted the joint type philosophy from Section VIII Division 1 “Rules for Construction of Pressure Vessels” (ref. 10). These vessel joint types were assigned joint efficiencies which were multiplied by, and thereby reduced, the allowable stress based level of inspection. Subsection NG changed “joint efficiencies” to a more descriptive label “weld quality factors” since the factor depended on the ability to inspect the weld’s attributes.

Table 3.2a: Weld Joint Type and Quality Factors (ref. 9b)

[[

]]

The basis for GEH weld quality factor, [[ ]], for steam dryer analysis is discussed below. The discussion is limited to the steam dryer design and processes:

a.) Only weld Types I, III, V and VII from section 2.1 above will be addressed, i.e. full penetration groove welds and fillet welds.

b.) Material is [[ ]].

c.) [[ ]].

Table 3.2b shows the applicable steam dryer weld types [[
]].

Table 3.2b: Table 3.2a with applicable steam dryer joints

[[

]]

For steam dryers, [[

]]

Table 3.2c: Table 3.2b with [[ ]]

[[

]]

3.2.1 Steam Dryer Weld Qualifications

Based on the [[

]]. Essential variables are those process variables which must be controlled in procedure qualifications.

Table 3.2.1: Steam Dryer Weld Procedure Qualification Requirements

[[

]]

Notes:

1.) Any P8 type base metal = material listed in QW-422, for example, Types 304, 304L, 316, 316H, 310, 347, 312, etc.

2.) Info only = information is required to be provided, although the specific parameters (i.e. non-essential variables) do not need to be followed during qualification.

Currently all variables associated with joints (QW-402, ref. 12) are nonessential variables in the ASME BPV Code WPS. Regardless, the manufacturer must state the types of joints permitted to provide guidance to the welder, although the manufacturer can have several different joint designs on the same weld procedure without welding each joint design. [[

]]

For example, if using only ASME BPV Code requirements, a weld procedure specification for welding Type 312 stainless steel plates together in a butt joint with a single V groove joint preparation, [[ ]] then tested for mechanical properties.

For a GEH example, to be qualified to weld Type 304L stainless steel steam dryer parts together in a T-joint, the coupons [[ ]]. To meet Section IX qualification requirements, additional coupons are welded, or another weld qualification made available to meet the ASME BPVC mechanical testing requirements. Similarly for butt joints, to qualify plates in a butt joint [[ ]].

GEH also [[ ]].

In summary, [[ ]]. ASME BPVC allows one joint configuration to qualify for multiple joint configurations. ASME BPVC does not require the supplier's weld procedure to show capability of meeting design requirements for the same joint configuration used in production. In contrast, the GEH weld qualification requirements, described in NEDE-33313P-A will be used [[ ]].

3.2.2 Weld Subsurface Flaws Defect Potential

The [[ ]] are reviewed below for Type I, III, V and VII joints.

- Porosity – this flaw gives a rounded indication and would reduce the weld area. This defect is [[

  ]].

- Lack of Penetration – this flaw has potential for those single sided full penetration groove welds where visual inspection of the backside of the weld is difficult. This defect also has potential in fillet welds where the weld may not consume the joint root. This defect could be caused by [[

  ]]. Lack of penetration is more common in fillet welds than full penetration groove welds. For all GEH steam dryer welds the [[

  ]]. This joint specific qualification provides confidence in achieving required penetration in fillet welds. ASME BPVC Section IX allows a weld procedure qualified [[

  ]]. This helps assure groove weld penetration where the inspection of the weld backside is difficult.

- Lack of Fusion – This is a groove weld subsurface defect [[

  ]]. The cleanliness is addressed in GEH welding procedures that meet DCD 26A6642AP section 4.5.2.2 “Controls on Welding” where the [[

  ]].

- Cracks – Austenitic stainless steel is susceptible to solidification cracking if the delta ferrite is not maintained at an acceptable level during the welding process. Section IX qualification [[

]] Regulatory Guide 1.31, "Control of Delta Ferrite in Stainless Steel Weld Metal" as stated in DCD 26A6642AP section 4.5.2.2 "Controls on Welding".

- Inclusions, Rounded – Inclusions could be due to [[ ]].
- Inclusions, Sharp – This indication is normally caused by [[ ]].

During the development of Subsection NG as discussed in section 3.2 of this response, the working group had concerns about the quality control and integrity of the core support structures and internal structures. The concern was based on fabrication practices prior to 1973. These components were built prior to published guidance such as RG 1.31 "Control of Ferrite Content in Stainless Steel Weld Metal" and RG 1.44 "Control of the Use of Sensitized Stainless Steel". Due to the Subsection NG working group's concerns, additional margin was added to the weld efficiency factors prior to implementing weld quality factors. [[ ]]

3.2.3 Replacement Steam Dryer Weld Performance

The steam dryer failures were discussed in GEH's response to RAI 3.9-215S01 (ref. 6). The metallurgical evaluations that supported the conclusions above were summarized and presented in the RAI response. More recently a 2011 steam dryer skirt crack was reported (ref. 14). [[ ]]

3.2.4 Weld Joint Categories

The joint locations (i.e. categories) adopted in Subsection NG were similar to those used in vessels. Category E was added to address the different joint configurations found in the core support structures.

Categories are locations of the joints in CSS components:

- Category A = longitudinal weld in cylinder
- Category B = circumferential weld in cylinder
- Category C = cylinder to flange circumferential weld
- Category D = nozzle to cylinder
- Category E = joints at the ends of beams or webs

Paragraph NG-3351 states joints whose design functions are neither to restrain nor support the core do not fall into any category. This statement applies to steam dryers. As an example, the skirt weld [[

]] of the steam dryer to meet the Code rule of an internal structure in Paragraph NG-1122, i.e. not to affect adversely the integrity of core support structures.

Since the weld categories are not applicable to the steam dryer, the designer is left to select the appropriate quality factor. Those welds that are [[

]].

Table 3.2.4: Table 3.2c with selected quality factors removed

[[

]]

3.2.5 Inspection Level

As can be observed in Table 3.2a, the weld quality factor starts its highest value for volumetric inspection and PT, then is reduced incrementally based on the level of inspection until VT weld quality factor is approximately half of the volumetric value. Per NEDE-33313P-A the [[

]], reference 26A6642AP section 4.5.2.2 “Controls on Welding”.

GEH concentrates efforts [[

]], reasonable confidence is based on:

[[

]].

replacement steam dryer performance in 3.2.3.

Once all welds are [[

]] of quality factors.

Table 3.2.5: Table 3.2.4 with [[ ]]

[[

]]

3.2.6 Joint Type

The method of inspection determines the level or degree of a weld’s inspection, and in the case of fillet welds, [[

]].

Table 3.2.5 shows that full penetration groove welds (Types I and III) have the highest weld quality factor for a given level of inspection and the allowable stress is reduced 10% for double fillet welds. This reduction is not necessary for Type V welds [[

]].

Table 3.2.6: Table 3.2.5 accounting for [[ ]]

[[

]]

3.2.7 Application of Quality Factors in Static Analysis

The weld quality factors are multiplied by the allowable stress limit. [[ ]]

The reason for using [[ ]]. The GEH reactor internal structure's [[ ]].

4.0 DESIGN ITERATIONS

As stated in NEDE-33313P-A section 4.1, if [[ ]].

5.0 CONCLUSION

The specific types of welds used in ESBWR steam dryer design and the approach for analysis has not changed since responding to NRC staff RAI 3.9-214 with supplements, therefore GEH believes the final safety evaluation of NEDE-33313P-A (ref. 5) remains valid in regard to weld types. Also, to clarify the topic of partial penetration welds, the ESBWR steam dryer design will not contain this type of weld.

6.0 RESPONSES TO COMMENTS FROM NRC STAFF

In a teleconference November 7, 2012, the NRC Staff provided 3 comments on the above sections 1.0 through 5.0. The comments are shown below in *italics* with the GEH response below each comment.

1.) *Based on review of 2004 edition of NB3600 table NB-3681(a)-1 the selection of a 1.8 weld fatigue factor for filet welds is not justified. The only filet weld entry in the table is "girth filet weld to socket weld". K1 is 3.0 for internal pressure, and K2=2.0 for moment loading. The staff notes that the applied moment loading is on a pipe circular cross section, not a plate section. The code states that C and K indices can be determined by test for components/configurations not covered in the table. The dominant filet weld connection in the steam dryer is a double filet welded T-joint. This joint is not addressed in NB-3600, which is specific to pressure retaining piping. Provide additional technical justification in the RAI response, other than NB-3600, for using a 1.8 weld factor for filet welds. Ideally this would include relevant test results.*

The information below is justification for the selection of 1.8 fatigue factor for fillet welds.

Test results obtained from Chapter 4 of NUREG-0307 (ref. 17) state a sound weld machined flush on both sides has a fatigue strength essentially equal to un-welded plate. After discussing the testing in welded plates, the NUREG also indicates the C_2K_2 value for welds in plate may be taken as 1.0.

[[

]].

[[

]]

Figure 1: Fatigue Strengths of Various Welds (ref. 17).

2.) The selection of a weld quality factor of 1.0 for both full penetration welds and filet welds, when NDE consists of PT of root and final passes, is a major exception to Subsection NG. While GEH has developed welding procedures that generally will produce high quality welds, there is no confirmation without volumetric NDE. The technical basis for the staff to accept a weld quality factor of 1.0 appears to be that the steam dryer is a non-safety component; the weld in question are "non-structural"; the provisions of NG do not apply; and failure of any of these welds possesses no safety threat.
There appears to be three categories of weld:

a.) "structural" welds that are designed to all the provisions of NG, including weld factor fatigue and weld quality factor

b.) "non-structural" welds whose failure could generate loose parts, that are designed with the exception, to NG for both weld fatigue factor and quality *weld factors, but with the code endurance limit alternating stress intensity reduced by 20% (10800 psi vs. 13600 psi) and*

c.) balance of the "non-structural" welds that are designed with the exceptions to NG for both weld fatigue factors and weld quality factors and code endurance limit alternating stress intensity of 13,600 psi.

To assist staff in technical evaluation, please augment the RAI response to confirm or correct the above definitions (3 categories): clearly identify on drawings of typical steam dryer (e.g. prototype ESBWR design) which welds fall into each of three category; indicate whether they are full penetration or filet welds; and provide an estimate of the number and/or total length of the total (full penetration or filet weld) in each category.

NEDE-33313P-A will be revised to show how GEH addresses primary structural welds and secondary structural welds.

GEH submitted reference 16 to the NRC committing to apply a minimum alternating stress ratio (MASR) of 2.0. Therefore, the weld groupings would be classified as:

a.) [[

b.)

c.)

]].

Table 6.1: Estimated total length of welds in each Steam Dryer weld class.

[[

{3}]]

[[

]]

Figure 6.2: Typical drawing of [[

]].

All steam dryer [[

]] as can be observed in Table 6.1.

[[

]]

Figure 6.3: Typical drawing of [[

]].

[[

]]

Figure 6.4: Typical drawing of [[

]].

The weld's purpose is to keep the bolt from turning, a nonstructural function.

3.) *The draft RAI response states in section 3.1.1 "Full penetration groove welded butt joints, corner joints and T-joints: NG-3352 Types I and III:*

- for primary weld's FEA or when traditional strength of materials formulas are applied [[

]]. This is consistent with ASME BPV Section III Subsection NG requirements.

- for secondary weld where FEA is used, [[

]].

If GEH is consistently following NG 4424 and NG 4426, it appears to be unnecessary to apply a 1.4 weld fatigue factor to "secondary" full penetration welds, in recognition of "the local discontinuity present at the toe of the groove weld due to weld reinforcement." As noted in the response, NG specifies 1.0. Please provide an explanation for this apparent inconsistency. Also, confirm or correct staff's understanding that GEH has committed to NG including NG 4424 and NG 4426, with the only exception being the weld fatigue factors and the weld quality factor applied to "non-structural" welds.

NG-4420 Rules for Making Weld Joints

In DCD 26A6642AK (ref. 15) section 3.9.5, GEH committed to the design of reactor internals structures classified as non-safety related as complying with the requirements for ASME BPV Code Article NG-3000 except for the weld quality and fatigue factors for secondary structural welds. Therefore, [[

]].

Shell Model's Groove Weld Fatigue Factor Discussion

The [[

]] of the groove weld.

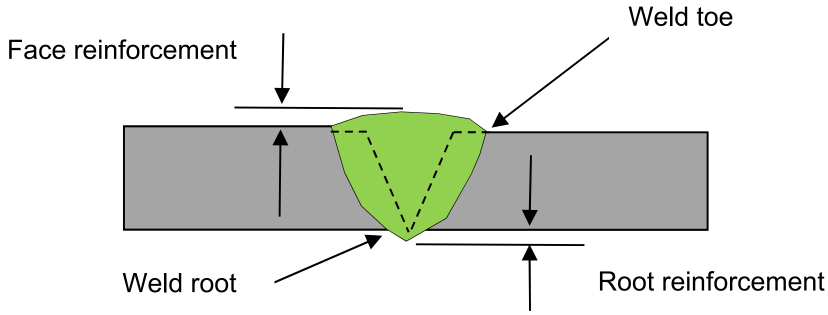

Figure 6.5: Groove weld geometry and nomenclature (ref. 1).

[[

]]

Figure 6.6: [[ ]]

[[

]]

Figure 6.7: [[

]].

DCD Impact

None.

Engineering Report Impact

The following changes will be made to NEDE-33313P-A revision 2:

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.

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:
[[

]].