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U.S. Nuclear Regulatory Commission
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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 325 Related to ESBWR Design Certificatin Application – RAI Number 6.1-12 S02**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) responses to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC letter No. 325 (Reference 1). GEH response to RAI Number 6.1-12 S02 is addressed in Enclosure 1.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

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Vice President, ESBWR Licensing

Reference:

1. MFN 09-229, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 325 Related to ESBWR Design Certification Application*, dated April 2, 2009.

Enclosure:

1. MFN 09-110 S01, Response to Portion of NRC Request for Additional Information Letter No. 325 Related to ESBWR Design Certification Application – RAI Number 6.1-12 S02

cc:	AE Cubbage	USNRC (with enclosure)
	JG Head	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRFs	0000-0101-2307

Enclosure 1

MFN 09-110 S01

Response to Portion of NRC Request for

Additional Information Letter No. 325

Related to ESBWR Design Certification Application

RAI Number 6.1-12 S02

NRC RAI 6.1-12 S02

In RAI 6.1-12 S01 the staff requested that the applicant provide additional information related to the cladding of A709 HPS 70W with stainless steel and dissimilar metal weld between HPS 70W and type 304L stainless steel.

The applicant responded on February 11, 2009 and stated that to ensure adequate corrosion resistance of the finished welds, Type E309 weld metal with a maximum carbon content of 0.03% will be used for the dissimilar metal welds. The wet areas of A709 liner plates will be clad in accordance with SA-264 specified in DCD Tier 2, Revision 5, Subsection 3.8.1.6.4 and Figure 3G.1-48. The exact cladding method (roll bonding, welding, etc.) will be determined in the construction phase.

In order for the staff to complete its review, the staff requests that the applicant address the following:

A. *The applicant stated that it will use E309 weld metal to perform dissimilar metal welds but did not discuss the history of joining HPS 70W to 304L using E309 or any other filler metal as requested by the staff. The staff notes that HPS 70W is a high performance steel generally used in bridge building. The staff is unaware of any testing of HPS 70W to stainless steel welds or any commercial applications that requires these two materials to be joined together. Therefore the staff requests that the applicant discuss the history of welding these two materials together. If no history is available, discuss your technical basis for welding these materials and confirmatory weld testing that you have performed.*

B. *The applicant's February 11, 2009 response stated that A709 HPS 70W liner plates will be cladded in accordance with SA-264. The applicant also stated that the exact cladding method (roll bonding, welding, etc.) will be determined in the construction phase. The staff notes that SA-264 does not address cladding of materials by welding other than cladding repairs. Therefore, the staff requests that the applicant address this inconsistency. In addition, describe the final heat treatment of the finished clad product and identify the testing requirements to ensure that the HPS 70W material retains its mechanical properties and the stainless steel cladding retains its corrosion resistance.*

GE Response

(A) GEH concurs that, to date, there have been no commercial applications of HPS 70W to 304 L stainless steel components. However, GEH considers HPS70W to be a technically acceptable material for the welded containment structure as discussed below.

The application of high performance steel (HPS) grades for bridge construction has steadily increased over the last several years because of weldability. HPS grades have been developed to greatly improve weldability and to minimize need for pre- and post-heating processes. HPS 70W itself has a very low carbon equivalent number, meaning it is resistant to cold cracking and hardening in the heat affected zone after welding. HPS 70 W steel has improved toughness (compared to standard grades of 70W) to

retard the growth of the discontinuities in the weld metal (weld cracking,). The Shielded Metal Arc Welding process (SMAW) and Submerged Arc Welding (SAW) process have been extensively used during welding of HPS 70W steel. HPS 70W contains low levels of carbon, making it easy to weld under a variety of conditions. Although no confirmatory weld testing has been performed, the technical basis for welding these materials is presented below. However, a confirmatory test of the dissimilar metal weld will be performed prior to issue of construction documents. Also additional macro examination with 10X magnification of the welded coupon will also be performed to check for any visual defects.

Welding of austenitic 300 series stainless steel grades to carbon or low alloy steels is a common practice. In welding of austenitic stainless steels to carbon or low alloy steels, it is customary to use a Type 309L stainless-steel filler metal. Type 309L stainless steel is sufficiently high in total alloy (Ni and Mn) content to prevent martensite formation when diluted with carbon or low alloy steel during welding, while at the same time, preserving residual amounts of ferrite to counteract the tendencies for hot cracking during welding.

Several studies have been conducted to define the effect of combining alloy additions. One of the most recognized of these is the Schaeffler diagram [1]. The Schaeffler diagram can be used to predict the likely outcome of weld metal constituents when welding stainless steels to carbon steels. For example; the ESBWR containment design will require the joining of ASTM A 240 Type 304L [3] austenitic stainless steel A 709 HPS 70W plate per code case N-763. To determine the suitability of a Type 309L electrode [6] for this application, the Schaeffler Diagram is used in combination with the chemistry of the materials of construction. The chemical compositions are given for the plates and welding filler metal in Table 1 (Values are maximums, unless a range is specified).

Table 1 – Filler Metal and Plate Chemistry

Chemical	304 L		309L		HPS 70W
Element	%		%		%
C	0.03		0.04		0.11
Cr	18-20		22-25		.45-.7
Mn	2		.5-2.5		1.10-1.35
Ni	8-12		12-14		.25 -.40
P	0.045		0.04		0.02
S	0.03		0.03		0.006
Si	0.75		0.9		.3-0.5
Mo			0.75		.02-.08
Cu			0.75		.25-0.4
V					.04-.08
Al					.010- .040
N2	0.1				0.015

The weld composite zone will encompass a mixture of weld filler metal and base metal. For the SMAW process, an approximately 30% base metal dilution is expected. Therefore, the resultant weld metal would be 70% filler metal chemistry with 15% HPS 70W plate chemistry and 15% 304 L Plate chemistry assuming equal fusion of base materials (Note: A 50/50 mixture is a common assumption as shown in AWS Handbook, Vol. 4, Ch 6) [2].)

To determine the weld metal constituents, the chromium and nickel equivalents tabulated in Tables 2A, 2B and 2C for filler metal and base metals for the welded joint are calculated as follows. The Chromium and Nickel equivalents are plotted in the Schaeffler diagram shown in Figure 1.

Cr Equivalent

309L

Element	%
Cr	25
Mo	0.75
Nb	0
Si	0.9
Ti	0

Ni Equivalent

309L

Element	%
Ni	14
C	0.04
Mn	2.5

Table 2 A

Cr Eq 27.1

Ni Eq 16.45

Cr Equivalent

304L

Element	%
Cr	20
Mo	0
Nb	0
Si	0.75
Ti	0

Ni Equivalent

304L

Element	%
Ni	12
C	0.03
Mn	2

Table 2 B

Cr Eq 21.125

Ni Eq 13.9

Cr Equivalent

HPS 70 W

Element	%
Cr	0.7
Mo	0.08
Nb	0
Si	0.5
Ti	0

Ni Equivalent

HPS 70 W

Element	%
Ni	0.4
C	0.11
Mn	1.35

Table 2C

Cr Eq	1.53
Ni Eq	4.375

For an E 309 L electrode weldments nickel equivalent would be

Cr equivalent = 0.7 (27.1) + 0.15 (21.125) + 0.15 (1.53) = 22.368 (Max)

Ni equivalent = 0.7 (16.45) + 0.15 (13.9) + 0.15 (4.375) = 14.256 (Max)

Cr equivalent = 0.7 (24.1) + 0.15 (19.125) + 0.15 (0.92) = 19.876 (Min)

Ni equivalent = 0.7 (13.15) + 0.15 (9.9) + 0.15 (1.7) = 10.945 (Min)

When the Cr and Ni equivalents are plotted on the Schaeffler diagram the weld deposit structure for the E309L electrode is austenite, and approximately 7 % ferrite with 30% dilution, (4% ferrite with 40% dilution). The expected dilution rate for Metal Arc Welding is 25- 40% and for SAW is 25-40%. Based on this evaluation, an E309L electrode is suitable for the joining of austenitic stainless steel to HPS 70W steel using SAW, SMAW or flux core welding processes.

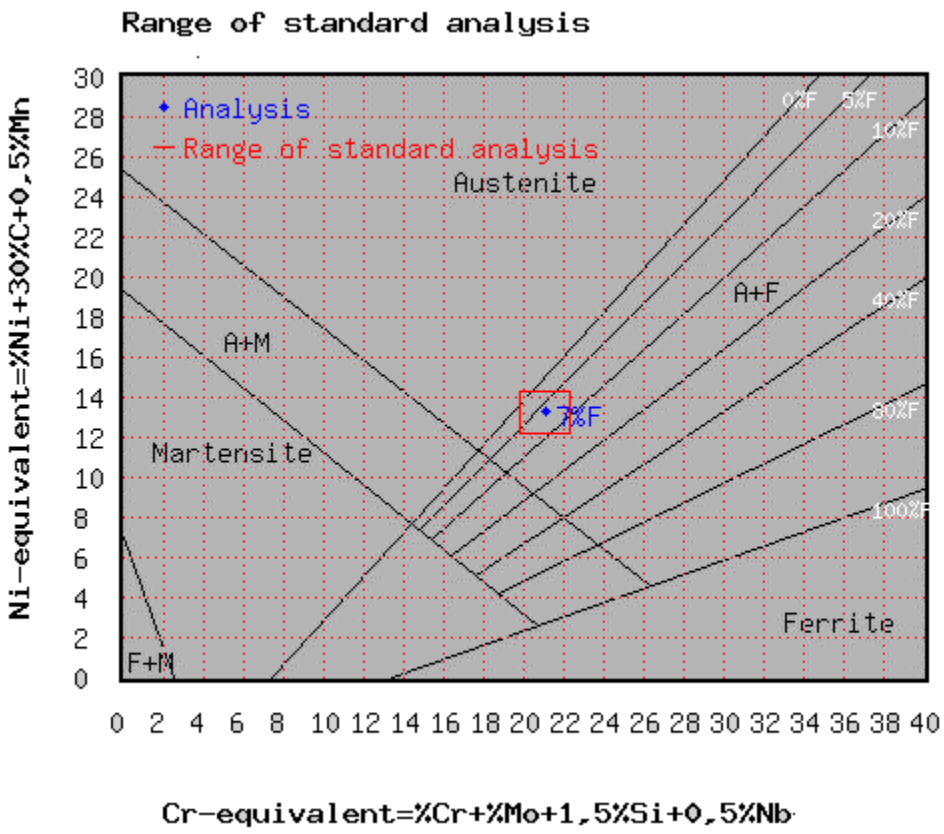

Figure 1: Schaeffler Diagram

(B) As noted in the February 11, 2009 response, the exact method for cladding of the HPS 70W will be determined at the construction phase. The two methods for forming of the clad steel plate are discussed below.

(1) Roll bonding: The composite steel plate will be in accordance with ASME SA-264 [4], Corrosion resisting Chromium- nickel steel clad plate, Sheet, and strip. The roll cladding operation occurs prior to the required heat treatment for properties. The heat treatment of the clad plate is specified in ASTM A 709, and the mechanical properties of the clad plate will be tested in accordance with the requirements of SA-264. Given that the heat treatment range specified in ASTM A 709 for HPS 70W [5] may result in carbide precipitation in standard grade 300 series stainless steel, L-grade stainless steel will be used for the stainless steel clad material.

(2) Explosive bonding: In the case of explosively bonded plate, the material will also be supplied in accordance with the requirements of SA-264. Since the explosion cladding bonding process occurs at a very rapid rate, there is minimal time for thermodynamic reaction products such as inter metallic layers or diffusion of base into cladding and vice versa that could affect the mechanical properties of the plate. Therefore, the heat treatment for properties of the HPS 70W will occur prior to the explosion cladding process. Given that the cladding will not see the potentially sensitizing heat treatment of the base material, the corrosion resistance of the clad material is considered acceptable.

<u>Weld cladding</u>: GEH agrees that the SA-264 does not address weld overlay of 304 L material by welding. If the weld overlay method is used to fabricate portions of the containment structure, HPS 70W material will be clad in accordance with the requirements of the applicable codes and standards.

Figure 2 is a schematic of typical weld joints used in the fabrication of clad steel plates.

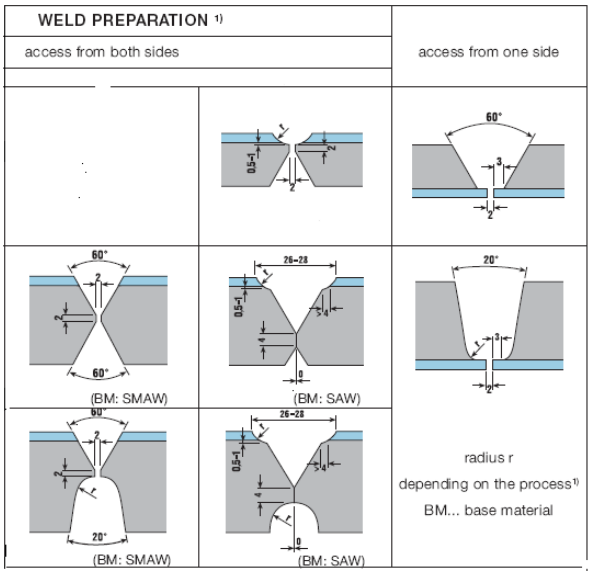

Figure 2: Typical Weld Edge Preparation for Composite Plate.

References

[1] A.L. Schaeffler, Constitution Diagram for Stainless Steel Weld Metal, *Met. Prog.,* Vol 56 (No. 11), 1949, p 680-680B.

[2] Welding Handbook. Vol. 4, CH 6 8th ed. Miami, FL: American Welding Society, 1998.

[3] ASTM Specification for Heat-Resisting Chromium and Chromium – Nickel stainless steel plate, sheet, and strip for pressure vessels, SA 240-99a. Annual Book of ASTM Standards, Philadelphia, PA

[4] ASTM Specification for Stainless Chromium- Nickel steel-clad plate, sheet, and strip, SA-264-98. Annual Book of ASTM Standards, Philadelphia, PA

[5] ASTM Standard Specification for Structural Steel for Bridges, A 709/A 709M-06 Annual Book of ASTM Standards. Philadelphia, PA

[6] ASME Section 2C Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding, SFA 5.4, ASME B&PV Code 2001, 2003 addenda.

DCD Impact

No DCD changes will be made in response to this RAI.