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MFN 06-260 Docket No. 52-010

August 7, 2006

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 41 Related to ESBWR Design Certification Application – Reactor Coolant Pressure Boundary Materials – RAI Numbers 5.2-36 through 5.2-49**

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Reference:
1. MFN 06-220, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 41 Related to ESBWR Design Certification Application,* July 10, 2006

Enclosure:
1. MFN 06-260 – Response to Portion of NRC Request for Additional Information Letter No. 41 Related to ESBWR Design Certification Application – Reactor Coolant Pressure Boundary Materials – RAI Numbers 5.2-36 through 5.2-49

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Enclosure 1

MFN 06-260

Response to Portion of NRC Request for

Additional Information Letter No. 41

Related to ESBWR Design Certification Application

Reactor Coolant Pressure Boundary Materials

RAI Numbers 5.2-36 through 5.2-49

NRC RAI 5.2-36

SRP Section 5.2.3, Revision 2, July 1981. states that the specifications be reviewed for pressure-retaining ferritic materials, nonferrous metals and austenitic stainless steels, including weld materials, that are used for each component (e.g., vessels, piping, pumps, and valves) of the reactor coolant pressure boundary. DCD Tier 2, Table 5.2-1 is not complete because it does not list components in systems that are considered to be part of the reactor coolant pressure boundary (RCPB). There are inconsistencies in materials listed in DCD Tier 2 Tables 5.2-4 and 6.1-1 for the isolation condenser. Provide material type, specification and grade, for all pressure boundary materials, including weld material specifications and grades that make up the RCPB.

GE Response

Based on the discussion topic, it is assumed reference to Table 5.2-1 in this RAI was intended to be Table 5.2-4. Table 5.2-4 will be corrected and expanded to include all RCPB components and materials, including weld metals.

Table 5.2-4 will be revised in the next DCD update. See attached draft revision.

NRC RAI 5.2-37

DCD Tier 2 Section 3E.2.2 states that SA 672 Gr. C70 is one of the carbon steels used in the ESBWR RCPB piping but this material is not listed in DCD Tier 2 Table 5.2-4 "Reactor Coolant Pressure Boundary Materials". Provide clarification.

GE Response

SA-672 Gr. C70 was listed in error in DCD Section 3E.2.2. This material is not used in the ESBWR reactor coolant pressure boundary. SA-672 Gr. C70 is rolled and welded pipe. All RCPB piping will be seamless.

DCD Section 3E.2.2 will be revised to delete reference to SA-672 Gr. C70 as follows:

3E.2.2 Carbon Steels and Associated Welds

The carbon steels used in the ESBWR reactor coolant pressure boundary piping are SA-106 Gr. B or SA-333 Gr. 6. The first specification covers seamless pipe and the second one pertains to both seamless and seam-welded pipe, although only seamless pipe will be used for ESBWR reactor coolant pressure boundary piping. The corresponding material specifications used for carbon steel flanges, fittings and forgings are equivalent to the piping specifications.

NRC RAI 5.2-38

Given that cast austenitic stainless steel (CASS) can be susceptible to thermal aging embrittlement, please discuss the following for any CASS component that acts as a RCPB: (1) the impact of this aging effect on the integrity of the components, (2) the consideration of the thermal embrittlement mechanism in the design and material selection for RCPB components, (3) the need for inspections to detect this aging effect, and (4) verify that ä-ferrite content is calculated using Hull's equivalent factors or a method producing an equivalent level of accuracy.

GE Response

See GE response to RAI 4.5-3 with respect to performance of cast stainless steel in the BWR environment and control of ferrite and carbon content as a means to control thermal embrittlement of cast austenitic stainless steel. (1) As described in RAI Response 4.5-3, there is virtually no thermal aging of cast stainless steel at BWR operating temperatures (288°C maximum) for Grades CF3/CF3A when ferrite content is limited to 20% maximum. (2) and (3) Consideration of these items is not necessary based on Item (1) response. (4) Delta ferrite will be determined in accordance with ASTM A 800, which is considered to have adequate accuracy.

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

NRC RAI 5.2-39

DCD Tier 2, Section 5.2.3.2.2 indicates that Nuclear Grade Stainless steel is used in the ESBWR design. Please provide a specification for Nuclear Grade stainless steel used in the ESBWR design for RCPB components and identify the components.

GE Response

"Nuclear Grade" is not an ASME designation. It is a GE designation to identify Types 304/316 stainless steels that are ordered with special requirements. Paragraph 2.1.1 of NUREG-0313 Rev. 2 recognizes 304NG and 316NG as being resistant to IGSCC. The primary distinction from ordinary Types 304/316 is that the carbon content is limited to 0.02% maximum while maintaining the strength of Types 304 or 316. Strength is maintained by addition of nitrogen (up to the maximum allowed for these alloys by ASTM/ASME). An example of a typical "Nuclear Grade" specification is shown in an appendix to the final report on development of alternate alloys for BWR service*.

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

*Reference: "Alternative Alloys for BWR Pipe Applications", EPRI Report NP-2671-LD, October 1982.

NRC RAI 5.2-40

Given the issues of susceptibility to stress corrosion cracking and welding fabrication flaws, associated with the performance of dissimilar metal welds (DMWs), provide a description of all DMWs in the RCPB and discuss the selection of filler metals and welding processes and process controls for DMWs in the ESBWR design. Also explain the inconsistencies between DCD Tier 2, Section 5.2.3.2.2 which indicates Alloy 82 will be used in the ESBWR design and DCD Tier 2, Section 3E.3.4 which indicates Alloy 182 will be used for bimetallic welds in the RCPB. If Alloy 182 is used, provide a basis given that it has been known to be susceptible to stress corrosion cracking.

GE Response

Dissimilar metal welds are primarily used in the RCPB to join carbon steel to stainless steel piping components. These joints are generally made by buttering a layer or layers of 309L or 309MoL onto the carbon steel weld preparation followed by completion of the groove weld using 308L, 316L, 309L or 309MoL. Ferrite in these weld metals is controlled to 8-20 FN. Post weld heat treatment of the carbon steel after buttering is performed if dictated by ASME NB-4600. Alternately, the dissimilar metal weld may be completed using Nickel Alloy 82 for the entire weld. Dissimilar metal welds between nickel alloy and either carbon/low alloy steel or stainless steel are performed using Alloy 82. Post weld heat treatment of stainless steel base metal is not allowed (a weld butter on carbon/low alloy steel may be applied and post weld heat treated followed by attachment of the stainless steel component). These weld metals are selected for good weldability in contact with carbon/low alloy steel, stainless steel, and nickel alloy, a high level of SCC resistance, and tolerance of post weld heat treatment if required. All of these alloys are currently in BWR service with no incidences of stress corrosion cracking or other problems being observed. Weld application is generally by mechanized GTAW although other welding processes such as GMAW, SMAW, and PAW are allowed (excepting that SMAW is not allowed for nickel alloy welds). All pressure-retaining RCPB dissimilar metal welds are subject to volumetric examination, both at fabrication or installation, and in-service in accordance with ASME Sections III and XI respectively.

Alloy 182 is not used in RCPB welds and was listed in DCD Section 3E.3.4 in error.

DCD Section 3E.3.4 will be revised at the next update to delete reference to Alloy 182 as follows:

3E.3.5 Bimetallic Welds

For joining austenitic stainless steels to ferritic steels, Ni-Cr-Fe Alloy 82 is generally used for weld metal (in selected cases stainless steel types 309L/308L may be used). Note: (The balance of the paragraph is unchanged.)

NRC RAI 5.2-41

DCD Tier 2, Section 5.2.3.2.3 indicates that XM-13 is used in the RCPB. Provide a description of the components fabricated from XM-13, the basis for selection of XM-13, and any proposed thermal treatment. Include any history of its use in light water reactors (LWRs).

GE Response

In actuality XM-13 is not used in the RCPB of ESBWR. Since compatibility of materials with reactor coolant was being discussed in Section 5.2.3.2.3, all alloys in contact with coolant were listed regardless of whether they were used for pressure boundary components or internals.

The only application of XM-13 is a single component in the control blades (if the pin/roller design is used). The component is a small diameter pin that holds the roller ball on the control blade wing. The original design for early BWRs used a cobalt base alloy for this component. In an effort to eliminate cobalt base alloys wherever practical, XM-13 was qualified as a replacement in the early 1980s. All GE-supplied control blades have used this alloy for this part since that time.

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

NRC RAI 5.2-42

In DCD Tier 2, Table 5.2-4 under Main Steam Piping, the specification for the contour nozzle indicates the class of material but not the Grade. Provide the appropriate Type/Grade of material.

GE Response

This omission will be corrected as part of the overall revision of Table 5.2-4 in response to RAI 5.2-36.

Table 5.2-4 will be revised in the next DCD update. See attached draft revision.

NRC RAI 5.2-43

Provide a description of corrosion allowances for all unclad low alloy and carbon steel surfaces in the RCPB.

GE Response

Corrosion allowances for unclad carbon and low alloy steels are defined for both external (air exposure) and internal (wetted) surfaces. The 60 year allowance for external surfaces is 0.8 mm and the allowance for internal surfaces is 1.6 mm.

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

NRC RAI 5.2-44

DCD Tier 2, Section 5.2.3.3.2 indicates that the guidelines of Regulatory Guide (RG) 1.50 may not be followed. Please provide a description of the portions of RG 1.50 that will not be followed and a description of the steps that will be taken to ensure delayed cracking of the weld metal or heat affected zone will not occur. Explain in detail, the process methods, temperature monitoring and post weld bake out to be performed.

GE Response

Regulatory Guide 1.50 requires that all low alloy steel welds be maintained at the minimum preheat temperature until post weld heat treatment is performed. As described in DCD Section 5.2.3.3.2, in some cases the reactor vessel will be allowed to cool to ambient temperature after application of post weld baking to remove any hydrogen that may be present. This same allowance has been included in previous BWR licensing documents including the ABWR SSAR and accepted[1]. The specific post weld baking parameters are dictated by the type of weld involved, the welding process (e.g. inert gas shielded), and prior qualification testing. For example, drop of preheat is allowed for narrow gap, GTAW or GMAW joints where the weld is subjected to post weld baking for 2 hours at 300°C, or 4 hours at 200°C. With gas shielded welding there is little potential for introduction of hydrogen into the weld zone in any case. In accordance with the Regulatory Guide, all such welds are subjected to volumetric examination to confirm the absence of delayed cracking. All such joints are subsequently subjected to post weld heat treatment. Therefore, the intent of the Regulatory Guide is met by a combination of post weld baking and inspection. This process has been successfully applied to operating BWR reactor vessels.

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

Reference 1: Final Safety Evaluation Report Relating to Certification of the Advanced Boiling Water Reactor, NUREG 1503 Vol. 1, July 1994.

NRC RAI 5.2-45

DCD Tier 2, Section 5.2.3.4.2 indicates that the ESBWR design meets the intent of RG 1.71. In order to assess the applicants alternative, please discuss the specific portions of RG 1.71 that the ESBWR design does not conform to and provide an explanation as to how the ESBWR alternative meets the intent of RG 1.71.

GE Response

Regulatory Guide 1.71 deals with qualification of welders who perform welds with limited access. The Guide specifically requires that for welds performed with less than 12 to 14 inches of access in any direction from the joint, the welder performance qualification include a similar access restriction. However, the precise method for implementation of this guidance is open to interpretation and refinement. GE considers that the intent of the Regulatory Guide is that welds with restricted access be performed to the same level of quality as unrestricted welds, consistent with weld quality required by ASME Section III. As a way to practically achieve this objective (described in some detail in DCD Section 5.2.3.4.2), restricted access qualifications are required when access to a non-volumetrically examined production weld, (1) is less than 305 mm (~12 inches) in any direction, and (2) allows welding from one access direction only. Requalification is required if the production weld is more restricted than the welder's performance qualification. This position was previously approved for certification of the ABWR (See Reference 1 for RAI Response 5.2-44.). The rationale for this interpretation is as follows:

a. If a RCPB weld is subject to volumetric inspection, the inspection method and acceptance criteria will be according to ASME Section III, Subsection NB. If the weld passes this inspection, the weld quality is considered acceptable irrespective of the access restriction. Therefore the intent of the Regulatory Guide is met by inspection. The fabricator or installer must produce welds that satisfy the Code irrespective of any access restrictions.
b. The Regulatory Guide indicates restrictions of 12 to 14 inches. Since this is insufficiently definitive from a specification and quality assurance point of view, GE selected 12 inches as the defined limit.
c. Practically, even though a restriction may exist in one direction from the weld, this is not necessarily the only direction from which the welder may approach the weld. Therefore, if the welder can freely approach the weld from another direction with no access restrictions, the restricted access performance qualification is not required.

It is further noted that in the ESBWR design, there are few, if any, RCPB welds that truly have restricted access. Additionally, much of the welding is performed with mechanized welding systems where physical access for a welder is not relevant to the ultimate weld quality.

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

NRC RAI 5.2-46

DCD Tier 2, Section 5.2.3.3.3 indicates that wrought tubular products of the RCPB are subject to the requirements of NB-2550. Verify that the ESBWR design complies with the requirements of NB-2560 or NB-2570.

GE Response

ESBWR reactor coolant pressure boundary components will comply fully with ASME Subsection NB and be certified accordingly. Consequently, if NB requires specific materials to be inspected according to NB-2560 or NB-2570, such inspections will be performed and certified. However, it is recognized that for completeness, DCD Section 5.2.3.3.3 can be clarified to indicate that welded tubular products will be examined according to NB-2560 and cast tubular products will be examined according to NB2570.

DCD Section 5.2.3.3.3 will be revised at the next update as follows:

5.2.3.3.3 Nondestructive Examination of Tubular Products

Wrought tubular products that are used for pressure-retaining components of the RCPB are subject to the examination requirements of ASME Code Section III, Subsection NB. Seamless tubular products shall be examined according to NB-2550, welded tubular products according to NB-2560, and cast tubular products according to NB-2570. These RCPB components meet 10 CFR 50 Appendix B requirements and the ASME Code requirements, thus assuring adequate control of quality for the products.

NRC RAI 5.2-47

Provide a description of the heat input and interpass temperature controls used during welding of stainless steel components.

GE Response

First recognize that all welded austenitic stainless steels in the RCPB are low carbon types with carbon limited to 0.02% maximum. Consequently, the time required at temperature to sensitize these materials is much longer than for conventional high carbon stainless steels. While ordinary Type 304 material can be sensitized in as little as three minutes at 650°C (~1200°F), low carbon 316/316L requires 20 to 30 hours to sensitize. Therefore, welding heat input controls and interpass temperature controls are much less critical as a means to control sensitization in the materials used for ESBWR. Nevertheless, GE conservatively continues to apply the same heat input controls that were instigated for high carbon materials. Specifically, the welding heat input is required to be as low as practical for the welding process being applied, and in no case higher than 20,000 joules/cm (~50,000 j/in.). Interpass temperature in all cases is limited to 180°C (~350°F) maximum.

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

NRC RAI 5.2-48

Provide a description of the "special sensitization test" that will be applied to ensure the proper solution heat treatment of stainless steel components.

GE Response

A modified version of ASTM A 262 Practice A is applied. There are two aspects to the modifications to the ASTM standard dealing with retest and acceptance criteria. With respect to retest, A 262 allows material failing the Practice A screening test to be retested by Practice E. If the material passes Practice E, it is accepted. In the GE version, Practice A is strictly a pass/fail test with no option to pass the material by Practice E. The second modification to Practice A involves the acceptance criteria. ASTM defines "ditching" as a single grain completely surrounded by etched grain boundaries. In the GE version, the examiner is required to evaluate the entire field of view of the micrograph and ratio the length of etched grain boundaries to the total grain boundary length. Any etching of grain boundaries is defined as "ditching" and no more than 5% ditching is allowed. This acceptance criterion is significantly more severe than the ASTM version in that, by the GE definition, a sample could be 50% ditched, but if no grains were completely surrounded by ditches, A 262 Practice A would pass the material. In addition, the GE modified Practice A is applied across the entire thickness of the material with special attention to the presence or absence of surface ditching.

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

NRC RAI 5.2-49

Provide a description of the solution heat treatment requirements for austenitic stainless steel components and welds.

GE Response

Consistent with most of the ASTM/ASME materials specifications for wrought austenitic stainless steels, the minimum annealing temperature is specified to be 1900°F. Holding time at temperature is required to be 15 minutes per inch of thickness (metal temperature) and 15 minutes minimum regardless of thickness. Solution heat treatment must be immediately followed by quenching in circulating water. Alternate holding times are allowed for continuous heat treatment furnaces provided material heat treated by such a process is demonstrated to be capable of passing the GE sensitization test. Likewise, alternate quenching methods such as water spray or air (or inert gas) quench are allowed provided the process is qualified by sensitization testing. This solution heat treatment practice is consistent with that described in Regulatory Guide 1.44 and NUREG 0313 Revision 2.

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

Table 5.2-4

Reactor Coolant Pressure Boundary Materials

Component	**Form**	**Material**	**Specification* (ASTM/ASME)**
Main Steam Isolation Valves (MSIVs)			
Valve Body	Cast	Carbon steel	SA-352, Grade LCB
Cover	Forged	Carbon Steel	SA-350, Grade LF2
Poppet	Forged	Carbon Steel	SA-350, Grade LF2
Valve stem	Rod	Precipitation-hardened steel	SA–564 Gr 630 (H1100)
Body bolt	Bolting	Alloy steel	SA–540, Gr B23 CL5
Hex nuts	Bolting Nuts	Alloy steel	SA–194 GrR 7
Safety/-Relief and Depressurization Valves			
Body (SRV)	Forging or Casting	Carbon steel Carbon steel	ASME SA–350, Gr LF2 ASME SA–352, Gr LCB
Body (DPV)	Forging or Casting	Stainless Steel	SA–182, Gr F304L or F316L
Bonnet (yoke)	Forging or Casting	Carbon steel Carbon steel	ASME SA–350, Gr LF2 ASME SA–352, Gr LCB
Nozzle (seat)	Forging or Casting	Stainless steel Carbon steel	ASME SA–182, Gr F316 ASME SA–350, Gr LF2
Body to bonnet stud	Bar/rod	Alloy steel	ASME SA–193, Gr B7
Body to bonnet nut	Bar/rod	Alloy steel	ASME SA–194, Gr 7
Disk	Forging or Casting	Nickel alloy Stainless steel	ASME SA–637, Gr 718 ASME SA–351, CF 3A

Table 5.2-4

Reactor Coolant Pressure Boundary Materials

Component	Form	Material	Specification* (ASTM/ASME)
Spring washer and Adjusting Screw or Setpoint adjustment assembly	Forging Forgings	Carbon steel ~~Alloy steel~~Martensitic Stainless Steel Carbon and alloy steel parts	ASME SA–105 ASME SA–193 Gr B6 Multiple specifications
Spindle (stem)	Bar	Precipitation-hardened steel	ASTM A 564, Gr 630 (H1100)
Spring	Wire or Bellville washers	Steel Alloy steel	ASTM A 304, Gr 4161 N 45 Cr Mo V67
Main Steam Piping			
Pipe	Seamless	Carbon steel	SA–333, Gr. 6
Contour nozzle	Forging	Low alloy steel	SA–508, ~~Class~~ Grade 3, Class 1
200 mm 1500 lb. large groove flange	Forging	Carbon steel	SA–350, Gr LF 2
50 mm special nozzle	Forging	Carbon steel	SA–350, Gr LF 2
Elbow	Seamless Fitting	Carbon steel	SA–420, Gr WPL-6
Head fitting/penetration piping	Forging	Carbon steel	SA–350, Gr LF 2

CRD			
Middle flange	Forging	Stainless steel	SA-182~~, Type~~ or SA-336, ~~Class~~ Grades F304/F304L/F316/F316L
Spool piece	Forging	Stainless steel	SA-182~~, Type~~ or SA-336 ~~Class~~ Grades

			F304/F304L/F316/F316L
Mounting bolts	Bolting	Alloy steel	SA-193, Grade B7
Reactor Pressure Vessel			
Shells and Heads	Plate	Mn-1/2 Mo-1/2 Ni Low Alloy Steel	SA-533, ~~Type~~ Grade B, Class 1
	Forging	3/4 Ni-1/2 Mo-Cr-V Low alloy steel	SA-508, Grade 3, Class 1
Shell and Head Flange	Forging	3/4Ni-1/2Mo-Cr-V Low alloy steel	SA-508, Grade 3, Class 1
Main Closure Bolting	Bolting	Low Alloy Steel	SA-540, Grade B23 or B24, Class 3
Standard Flange Bolting	Bolting	Low Alloy Steel	SA-193, Grade B7 or SA-540, Grade B23, Class 3
Nozzles	Forging	3/4Ni-1/2Mo-Cr-V Low alloy steel	SA-508, Grade 3, Class 1
Nozzle Safe Ends	Forging	Carbon Steel	SA-350, Grade LF2 or SA-508, Grade 1
Drain Nozzles	Forging	Cr-Ni-Mo Stainless steel	SA-182~~, Type~~ or SA-336, ~~Class~~ Grade F304/F304L/F316/F316L
Instrumentation Nozzles	Forging	Cr-Ni-Mo Stainless steel and Ni-Cr-Fe	SA-182~~, Type~~ or SA-336, ~~Class~~ Grades F304/F304L/F316/F316L and Code Case N-580-1
Stub Tubes	Bar, Smls. Pipes Forging	Ni-Cr-Fe	Code Case N-580-1
Isolation Condenser			
Steam pipe	Seamless	Carbon steel	SA-333, Grade 6
Steam pipe fittings	Forging or	Carbon steel	SA-350, Grade LF2 or SA-508, Grade 1

	Fitting	Carbon steel	SA-420, Grade WPL-6
Condensate pipe	Seamless	Stainless steel	Type 316L
Condensate pipe fittings	Forging or Fitting	Stainless steel	SA-182 or SA-336, Grades 304/304L/316/316L or SA-403, Grades 304/304L/316/316L
Feedwater Piping			
Pipe	Seamless	Low Alloy	SA-335, Grade P22
Fittings	Forging	Low Alloy	SA-336, Grade F22
Reactor Water Cleanup/Shutdown Cooling Piping			
Cleanup Piping	Seamless Pipe	Carbon steel	SA-333, Grade 6
Fittings	Forging or Fitting	Carbon steel	SA-350, Grade LF2 or SA-508, Grade 1 SA-420, Grade WPL-6
Drain Line Piping	Seamless Pipe	Stainless steel	SA-312 or SA-376, Grades 304/304L/316/316L
Fittings	Forging or Fitting	Stainless steel	SA-182 or SA-336, Grades 304/304L/316/316L SA-403, Grades 304/304L/316/316L
Gravity Driven Cooling (See Table 6.1-1)			
SLC			
Piping	See Table 6.1-1		
Weld Filler Metals			
Carbon Steel Filler	Covered Electrodes or Filler Wire	Carbon Steel	SFA-5.1 SFA-5.17 or SFA-5.18
Low Alloy Steel Filler	Covered Electrodes or Filler Wire	Low Alloy Steel	SFA-5.5 SFA-5.23 or SFA-5.28

Stainless Steel Filler	Covered Electrodes or Filler Wire	Stainless Steel	SFA-5.4, Grades E308L/E316L or E309L SFA-5.9, Grades ER308L/ER316L or ER309L
Nickel Alloy Filler	Filler Wire	Nickel Alloy	SFA-5.14, Grade ERNiCr-3

*Note: Carbon content of all RCPB wrought austenitic stainless steel (304/304L/316/316L) is 0.02% maximum.