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MFN 08-453

Docket No. 52-010

May 2, 2008

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. 148 Related to ESBWR Design Certification Application – Nuclear Boiler System - RAI Numbers 5.2-70 and 5.2-71

Enclosure 1 contains the GE Hitachi Nuclear Energy (GEH) response to the subject NRC RAI transmitted via the Reference 1 letter.

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

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

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 08-158, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 148 Related to ESBWR Design Certification Application*, February 19, 2008

Enclosure:

1. MFN 08-453 - Response to Portion of NRC Request for Additional Information Letter No. 148 Related to ESBWR Design Certification Application – Nuclear Boiler System - RAI Numbers 5.2-70 and 5.2-71

cc:	AE Cubbage	USNRC (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	GB Stramback	GEH/San Jose (with enclosures)
	RE Brown	GEH/Wilmington (with enclosures)
	eDRF	0000-0076-5641, RAI 5.2-70 and RAI 5.2-71

Enclosure 1

MFN 08-453

Response to Portion of NRC Request for Additional Information Letter No. 148 Related to ESBWR Design Certification Application

Nuclear Boiler System

RAI Numbers 5.2-70 and 5.2-71

Verified DCD changes associated with this RAI response are identified in the enclosed DCD markups by enclosing the text within a black box. The marked-up pages may contain unverified changes in addition to the verified changes resulting from this RAI response. Other changes shown in the markup(s) may not be fully developed and approved for inclusion in DCD Revision 5.

NRC RAI 5.2-70:

In Section 5.2.3.2.2, "BWR Chemistry of Reactor Coolant," of ESBWR DCD, Revision 4, the applicant stated that, "Originally introduced on past BWR designs to control IGSCC, if connected, a HWCS is also beneficial in avoiding IASCC."

Please address the following:

1. *There is significant industry experience with IASCC of shroud and other reactor vessel internals in the operating fleet of reactors. This one statement does not adequately address this operating experience in the context of whether hydrogen water chemistry could alleviate this problem. Please revise the DCD to explain/ expand this statement to include your plan of mitigating the IGSCC and IASCC of the core shroud.*

2. *At the ACRS meeting on January 17, 2008, several other options to mitigate the IASCC were discussed with the ACRS members, i.e., (a) solution annealing of core shroud, (b) forged core shroud, and (c) additional inspection of core shroud. Please revise the DCD and discuss other mitigating device(s) that you will be using in addressing the IGSCC and IASCC concerns of the core shroud.*

GEH Response:

The one statement, last sentence at the end of DCD Tier 2 rev. 4 Subsection 5.2.3.2.2, will be removed and replaced with a discussion that will address concerns of reactor water chemistry and Irradiation Assisted Stress Corrosion Cracking (IASCC) raised by the Advisory Committee on Reactor Safeguards (ACRS), during the ACRS November 1-3, 2007 meeting regarding IASCCand reactor water chemistry controls.

A HWCS is not part of the ESBWR Standard Plant design as stated in Subsection 1.2.2.12.13. However, provisions will be provided as part of the design to allow an HWCS to be connected if desired.

Discussion of core support structure design and manufacturing methods to mitigate IGSCC and IASCC will be added to DCD Tier 2 Subsection 4.5.2.1 and Table 4.5-1.

DCD Impact:

DCD Tier 2, Subsections 5.2.3.2.2 and 4.5.2.1, and Table 4.5-1 will be revised as noted in the attached markup.

NRC RAI 5.2-71:

Due to increased susceptibility to stress corrosion cracking in austenitic stainless steels and nickel based alloy components exposed to reactor coolant as a result of post weld grinding, the staff requests that GEH make the following modifications to the ESBWR DCD:

1. *Modify the ESBWR DCD to describe controls placed on welding operations, in addition to ASME Code requirements and recommendations of NRC regulatory guides, which minimize the potential for welding defects that would require grinding on stainless steel and nickel based alloy components that will be exposed to reactor coolant.*

2. *For those situations where grinding is unavoidable the staff requests that GEH modify the DCD to state the following: For ASME Code components, including reactor vessel internals, in the ESBWR design exposed to reactor coolant, the following steps will be taken to mitigate the effects of cold working: Any surfaces of austenitic stainless steels or nickel based alloy components that have been cold worked by machining, grinding, or other mechanical processes, that will be exposed to BWR coolant, shall be evaluated for acceptability for the service application and/or locally or fully re-solution annealed. Some of the techniques that may be used for mitigation of surface cold work include flappers, controlled machining in accordance with demonstrated procedure, mechanical polishing or electro polishing as well as other appropriately qualified methods.*

GEH Response:

(1) GEH agrees that control of welding operations is necessary for quality welds, such that repair and associated grinding operations are minimized. GEH will use qualified suppliers that have a demonstrated quality program with appropriate controls on welding. Qualification will include review of the fabrication process to assure that the supplier has the capability of achieving quality welds while minimizing grinding. In addition, the number of weld joints will be minimized to reduce the need for grinding. GEH will revise Subsections 4.5.2.2 and 5.2.3.4.2.

(2) For those cases where grinding is necessary, GEH will control grinding through the use of qualified procedures and personnel, such that the effects of cold work from grinding are minimized. GEH will incorporate the grinding controls recommended by the staff, and will revise Sections 4.5.2.4 (reactor internals austenitic stainless steel fabrication), 4.5.2.5 (reactor internals nickel base alloy fabrication) and 5.2.3.4.1(reactor coolant pressure boundary stainless steel).

DCD Impact:

DCD Tier 2, Subsections 4.5.2.2, 4.5.2.4, 4.5.2.5, 5.2.3.4.1 and 5.2.3.4.2 will be revised as noted in the attached markup.

The degree of surface cleanliness obtained by these procedures meets the requirements of Regulatory Guide 1.37.

4.5.2 Reactor Internal Materials

4.5.2.1 Material Specifications

The reactor internal materials are selected to be resistant to corrosion and stress corrosion cracking in the BWR steam/water environment. Improved material specifications and fabrication techniques will reduce the probability that reactor internal components will experience IGSCC and IASCC. The austenitic stainless steel material for internals construction has a low carbon content to resist Intergranular Stress Corrosion Cracking (IGSCC). Wrought materials have a 0.02% maximum carbon content, and large diameter forgings and cast materials have a 0.03% maximum carbon content. Reactor core structural components are designed to be below fluence thresholds of exposure and/or stress to avoid IASCC (also see Subsection 5.2.3.2.2). One design step to address SCC concerns is to avoid crevices. For example, eliminating crevices from the top guide and core plate designs in order to prevent the synergistic interaction with IGSCC or IASCC. Component processing can reduce manufacturing induced stresses. For example, the use of forgings or welded construction followed by solution annealing of the core shroud, are methods that could reduce the effects of cold work and weld residual stresses.

RAI 5.2-70

Reactor internal material specifications are provided in Table 4.5-1. All core support structures are fabricated from ASME specified materials, and designed in accordance with requirements of ASME Code Section III, Subsection NG. The other reactor internals are non-code, and they may be fabricated from American Society of Testing Methods (ASTM) or American Society of Mechanical Engineers (ASME) specification materials or other equivalent specifications.

Steam dryers will be constructed from wrought 300 series and XM-19 stainless steel, and Grade CF3 stainless steel castings. Except for the steam dryer vane material, the maximum carbon content of the wrought stainless steel is limited to 0.02% and the maximum hardness of wrought 300 series stainless steel is limited to Rockwell B92.

4.5.2.2 Controls on Welding

Welding is performed in accordance with Section IX (Welding and Brazing Qualification) and Section II Part C (Welding Rod Electrode and Filler Metals) of the ASME B&PV Code. Welded austenitic stainless steel assemblies require solution annealing to minimize the possibility of sensitization. However, welded assemblies are exempt from this requirement when the assemblies are of material of low carbon content (less than 0.020%). These controls are employed in order to comply with the intent of Regulatory Guide 1.44.

The welding processes for austenitic stainless steel and nickel base alloys shall be controlled to ensure acceptable welds. The controls include the following:

- Prior to welding, the joint surfaces and the base metal within 2 inches [51 mm] of the joint shall be thoroughly cleaned. Such surfaces shall be free of moisture, phosphates, carbonaceous materials such as oil, grease, oxides, paint and marking materials, halogens and all other foreign materials, except that an anti-spatter compound may be applied to the adjacent base metal.

RAI 5.2-71 (1)

- Protective gas back purging shall be used for full penetration single side welded joints of stainless steel until a minimum of 4.8 mm (3/16 inch) of weld thickness is completed. Before welding, joints shall be back purged. This back purge is not required where the backside is fully accessible for cleaning and liquid penetrant examination; and when the cleaning and liquid penetrant examination are performed.
- The SMAW process shall not be used on the root pass.
- Each welding pass shall be visually examined for defects and bead shape prior to applying the next pass. The weld bead and the surfaces heated during welding shall be cleaned between passes to remove oxides. Porosity, slag, lack of fusion, cracks, and other defects shall be removed by grinding, machining, or chipping prior to depositing subsequent passes. Removal of cracks, other than crater cracks, shall be verified by a liquid penetrant examination.
- Grinding shall be controlled per Subsection 4.5.2.4.

RAI 5.2-71 (1)

Core support structures are fabricated in accordance with requirements of ASME Code Section III, Subsection NG-4000, and the examination and acceptance criteria shown in NG-5000. The internals, other than the core support structures meet the requirements of the industry standards, for example, ASME or American Welding Society (AWS), as applicable. ASME Boiler & Pressure Vessel (B&PV) Code Section IX qualification requirements are followed in fabrication of core support structures. All welds are made with controlled weld heat input.

Electroslag welding is not applied for structural welds.

ESBWR fully complies with Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal", including application of the following provisions to all stainless steel weld filler metal applied to reactor internal components: The delta ferrite content for weld materials used in welding austenitic stainless steel assemblies is verified on undiluted weld deposits for each heat or lot of filler metal and electrodes. The delta ferrite content is defined for weld materials as 5.0 Ferrite Number (FN) minimum, 8.0FN average and 20FN maximum for 308L and 16FN for 316L. Ferrite content is determined by use of magnetic instruments calibrated according to AWS A4.2. This ferrite content is considered adequate to prevent any micro-fissuring (Hot Cracking) in austenitic stainless steel welds. This procedure complies with the requirements of Regulatory Guide 1.31.

4.5.2.3 Non-Destructive Examination

Materials for core support structures are in conformance with and certified to ASME Section III, Subsection NG. Examination of materials (examination methods and acceptance criteria) is specified in NG-2500. Examination methods and acceptance criteria for core support structure weld edge preparations and welds are provided in NG-5000. Tubular products that are pressure boundary components (CRD and in-core housings) are examined as outlined in Subsection 5.2.3.3.3 ~~according to ASME Section III, NB-2500, and associated pressure retaining welds are examined according to NB-5000~~. For non-ASME Code reactor internal structures and associated welds, examinations are established based on relevant design and analysis information, and take guidance from NG-2500 and NG-5000 respectively.

4.5.2.4 Fabrication and Processing of Austenitic Stainless Steel—Regulatory Guide Conformance

Fabrication process controls are applied to minimize the degradation of material properties by forming, cold working, etc. Susceptibility to stress corrosion cracking is limited by careful control of solution heat treatment, sensitization testing and testing for intergranular attack (IGA). Significantly cold-worked stainless steels are not used in the reactor internals except for vanes in the steam dryers. During fabrication, cold work is controlled by applying ~~Applying~~ limits on hardness ~~controls cold work~~, bend radii and surface finish on ground surfaces. For components exposed to reactor coolant, the following steps will be taken to mitigate the effects of cold working: Any surface that is cold worked by machining, grinding, or other mechanical processes, shall be evaluated for an acceptable surface condition. The evaluation shall address the service application and/or cold work mitigation. Some of the techniques that may be used for mitigation of surface cold work include locally or fully re-solution annealing, flappers, controlled machining in accordance with demonstrated procedure, mechanical polishing or electropolishing as well as other appropriately qualified methods. ~~Furnace sensitized material are not allowed. Electroslag welding is not applied for structural welds. ESBWR fully complies with Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal", including application of the following provisions to all stainless steel weld filler metal applied to reactor internal components: (RAC275)The delta ferrite content for weld materials used in welding austenitic stainless steel assemblies is verified on undiluted weld deposits for each heat or lot of filler metal and electrodes. The delta ferrite content is defined for weld materials as 5.0 Ferrite Number (FN) minimum, 8.0FN average and 20FN maximum. Ferrite content is determined by use of magnetic instruments calibrated according to AWS A4.2.(RAC276) This ferrite content is considered adequate to prevent any micro fissuring (Hot Cracking) in austenitic stainless steel welds. This procedure complies with the requirements of Regulatory Guide 1.31.~~

RAI 5.2-71 (2)

The limitation placed upon the delta ferrite in austenitic stainless steel castings is 8% minimum and a maximum value of 20%. The maximum limit is used for those castings designed for a 60-year life such as the fuel support pieces, in order to limit the effects of thermal aging degradation.

Furnace sensitized materials are not allowed. Proper solution annealing of the 300 series austenitic stainless steel is verified by testing per ASTM-A262, "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels." ~~Welding of austenitic stainless steel parts is performed in accordance with Section IX (Welding and Brazing Qualification) and Section II Part C (Welding Rod Electrode and Filler Metals) of the ASME B&PV Code. Welded austenitic stainless steel assemblies require solution annealing to minimize the possibility of the sensitizing. However, welded assemblies are exempt from this requirement when the assemblies are of material of low carbon content (less than 0.020%). These controls are employed in order to comply with the intent of Regulatory Guide 1.44.~~

Careful control of all cleaning materials and process materials that contact stainless steel during manufacture and construction prevent exposure to contaminants. Any inadvertent surface contamination is removed to avoid potential detrimental effects.

Special care is exercised to insure removal of surface contaminants prior to any heating operation. Water quality for rinsing, flushing, and testing is controlled and monitored.

The degree of cleanliness obtained by these procedures meets the requirements of Regulatory Guide 1.37.

4.5.2.5 Other Materials

Hardenable martensitic stainless steel and precipitation hardening stainless steels are not used in the reactor internals.

Materials, other than Type-300 stainless steel, employed in reactor internals are:

- Type or Grade XM-19 stainless steel,
- Niobium modified Alloy 600 per ASME Code Case No. N-580-1, and
- N07750 (Alloy X-750) or equivalent.

All Niobium modified Alloy 600 material is used in the solution annealed condition.

Alloy X-750 components are fabricated in the annealed and aged condition. Where maximum resistance to stress corrosion is required, the material is used in the high temperature (1093°C) annealed plus single aged condition.

Hard chromium plating surface is applied to austenitic stainless steel couplings.

All materials used for reactor internals are selected for their compatibility with the reactor coolant as shown in ASME Code Section III, NG-2160 and NG-3120. The fabrication and cleaning controls preclude contamination of nickel-based alloys by chloride ions, fluoride ions, sulfur, or lead.

All materials referenced in this subsection have been successfully used for many years in BWR applications.

For nickel based alloy components exposed to reactor coolant, the steps outlined in Subsection 4.5.2.4 will be taken to mitigate the effects of cold working.

RAI 5.2-71 (2)

Use of Alloy 182 is prohibited in contact with reactor ~~water~~coolant.

4.5.3 COL Information

None.

4.5.4 References

None.

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Table 4.5-1

Reactor Internals Material Specifications

Component	Form	Material	ASME Specification
Materials Used for the Core Support Structure:			
~~Shroud~~ Support Leg	Plate or Forging	Columbium[1)] modified Ni-Cr-Fe Alloy	~~Modified~~ SB-168 and SB-564 Nickel Alloy 600 as modified per ASME Code Case N-580-1
Shroud and Support Ring	Plate or Forging	Stainless Steel[2)]	SA-240, and SA-182/SA-182M, Type or Grade Type 304 / 304L / 316 / 316L
Core Plate	Plate ~~and~~ or Forging	Stainless Steel[2)]	SA-240 and SA-182/SA-182M, Type or Grade 304 / 304L / 316 / 316L
Top Guide	Plate ~~and~~ or Forging	Stainless Steel[2)]	SA-240 and SA-182/SA-182M, Type or Grade 304 / 304L / 316 / 316L
Peripheral Fuel Supports	~~Forging~~Bar	Stainless Steel[2)]	SA-~~182~~479/SA-~~182~~479M, ~~Grade~~ Type 304 / 304L / 316 / 316L
Orificed Fuel Support	Casting	Stainless Steel	SA-351/SA-351M, Grade CF3
Core Plate and Top Guide Studs, Nuts, and Sleeves	Bar	Stainless Steel[2)]	SA-479/SA-479M, Type 304 / 304L / 316 / 316L and XM-19
Control Rod Drive Housing	~~Forging~~Seamless Pipe	Stainless Steel[2)]	SA-~~336~~312/SA-~~336~~312M Type~~es~~ ~~SA-182/SA-182M Grade~~ 304 /304L or 316 / 316L
Control Rod Guide Tube	Pipe, Bar and Forging	Stainless Steel[2)]	SA-312/SA-312M and SA-479/SA-479M, Type 304 / 304L / 316 / 316L and XM-19
Control Rod Drive Penetration Stub Tubes	Forging	Columbium[1)] modified Ni-Cr-Fe Alloy	~~Modified~~ SB-564 Nickel Alloy 600 as modified per ASME Code Case N-580-1
Materials Used for the Internal Structures:			
Chimney, Chimney Partitions and Chimney Restraints	Plate and Bar	Stainless Steel[2)]	SA-240 and SA-479/SA-479M, Type 304 / 304L / 316 / 316L. The equivalent ASTM specification "A-" acceptable
Chimney Head and Steam Separator Assembly	Plate and Bar	Stainless Steel[2)]	SA-240 and SA-479/SA-479M, Type 304 / 304L / 316 / 316L. The equivalent ASTM specification "A-" acceptable

Reactor Water Dissolved Hydrogen - If a HWCS is connected, a direct measurement of the dissolved hydrogen content in the reactor water serves as a cross check against the hydrogen gas flow meter in the injection system to confirm the actual presence and magnitude of the hydrogen addition rate.

Main Steamline Radiation Level - The major activity in the main steamline is N^{16} produced by a (n, p) reaction with O^{16} in the reactor water. If a HWCS is connected, the fraction of the N^{16} that volatilizes with the steam increases with increased dissolved hydrogen. The main steamline radiation monitor readings increase with the hydrogen addition rate.

The major impurities expected in the ESBWR under certain operating conditions are listed in Table 5.2-5.

To support water quality specifications flow-assisted corrosion resistant low alloy steels are to be used in susceptible steam extraction and drain lines. Stainless steels are considered for baffles, shields, or other areas of severe duty. Provisions are made to add nitrogen gas to extraction steamlines, feedwater heater shells, and drain piping to minimize corrosion during layup. Alternatively, the system may be designed to drain while hot so that dry layup can be achieved.

The potential deterioration of ESBWR carbon steel piping from flow-assisted corrosion due to high velocity single-phase water flow and two-phase steam/water flow is addressed by appropriate control of hydrodynamic and environmental conditions.

Water quality specifications for the ESBWR require the condenser to be designed and erected to minimize tube leakage and to facilitate maintenance. Condenser tubes and tube sheets are made of titanium or stainless steel alloys. Appropriate features are incorporated to detect leakage and segregate the source. The valves controlling the cooling water to the condenser sections are required to be operable from the control room so that a leaking section can be sealed off quickly.

Irradiation Assisted Stress Corrosion Cracking (IASCC) Considerations

Based on current knowledge, it is well known that reactor coolant does have direct effects on stress corrosion cracking and specifically intergranular stress corrosion cracking (IGSCC). As documented in the industry guidelines, reactor coolant impact includes the effects of corrosion potential as well as conductivity. Irradiated assisted stress corrosion cracking (IASCC) is associated with degradation that occurs as austenitic stainless steel material in the core region experiences material changes due to the effects of radiation. These effects include material hardening as well as radiation induced segregation. It is accepted that the threshold for IASCC degradation occurs when components are subjected to a combination of cumulative fluence greater than $5x10^{20}$ n/cm^2 (E>1 MeV) with applied stress levels in the component(s). Extensive tests have also shown that IASCC has not occurred at fluence levels below $5x10^{20}$ n/cm^2 (E>1 MeV) even at high stress levels in the component(s). In summary, experiments indicate that as fluence increases above this threshold of $5x10^{20}$ n/cm^2 (E>1 MeV), the stress to initiate IASCC decreases.

It is known that the material causal factors that are important for IASCC, material hardening and segregation, are the same factors that lead to IGSCC; therefore the effects of water chemistry are similar. Improvement of reactor water chemistry to limit the susceptibility to IGSCC will have an indirect beneficial effect on subsequent IASCC as well. Additionally, for material that has been subjected to fluences greater than $5x10^{20}$ n/cm^2 (E>1 MeV), improved water chemistry will

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also have a beneficial effect on cracking behavior. Therefore, water quality in accordance with current industry guidelines is beneficial to control IGSCC as well as IASCC.

Several approaches are being used to prevent IASCC. These include measures to prevent IGSCC early in life such as material selection, fabrication and process controls, water chemistry controls, and measures to prevent IASCC later in life such as design measures to locate welds away from the highest fluence regions and those items listed above to mitigate IGSCC (see also Subsection 4.5.2.1).

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~~Plant experience and laboratory tests indicate that irradiation assisted stress corrosion cracking (IASCC) can be initiated in solution annealed stainless steel above certain stress levels after exposure to radiation.~~

~~Extensive tests have also shown that IASCC has not occurred at fluence levels below ~$5x10^{20}$ neutron/cm^2 (E > 1 MeV) even at high stress levels. Experiments indicate that as fluence increases above this threshold of $5x10^{20}$ neutron/cm^2, there is a decreasing threshold of sustained stress below which IASCC has not occurred.~~

~~Reactor core structural components are designed to be below these thresholds of exposure and/or stress to avoid IASCC. In addition, crevices have been eliminated from the top guide design in order to prevent the synergistic interaction with IASCC.~~

~~In areas where the $5x10^{20}$ neutron/cm^2 threshold of irradiation is not practically avoided, the stress level is maintained below the stress threshold. High purity grades of materials are used in control rods to extend their life. Originally introduced on past BWR designs to control IGSCC, if connected, a HWCS is also beneficial in avoiding IASCC.~~

5.2.3.2.3 Compatibility of Construction Materials with Reactor Coolant

The construction materials exposed to the reactor coolant consist of the following:

- Solution-annealed austenitic stainless steels (both wrought and cast), Types 304, 304L, 316, 316L and XM-19;
- Nickel-based alloy (including niobium modified Alloy 600 and X-750);
- Carbon steel and low alloy steel;
- Some 400-series martensitic stainless steel (all tempered at a minimum of 595°C (1103°F));
- Colmonoy and Stellite hardfacing material (or equivalent); and
- Precipitation hardening stainless steels, 17-4PH and XM-13 in the H1100 condition.

All of these construction materials are resistant to stress corrosion in the BWR coolant. General corrosion on all materials except carbon and low alloy steel is negligible. Conservative corrosion allowances are provided for all exposed surfaces of carbon and low alloy steels.

The requirements of GDC 4 relative to compatibility of components with environmental conditions are met by compliance with the applicable provisions of the ASME Code and by compliance with the recommendations of Regulatory Guide 1.44.

These RCPB components meet 10 CFR 50 Appendix B requirements and the ASME Code requirements, thus assuring adequate control of quality for the products.

5.2.3.4 Fabrication and Processing of Austenitic Stainless Steels

Austenitic stainless steels in a variety of product forms are used for construction of a limited number of pressure-retaining components in the reactor coolant pressure boundary. Process controls are exercised during various stages of component manufacturing and reactor construction to avoid severe sensitization of the material and to minimize exposure of the stainless steel to contaminants that could lead to stress corrosion cracking.

5.2.3.4.1 Avoidance of Stress/Corrosion Cracking

Avoidance of Significant Sensitization

When austenitic stainless steels are heated in the temperature range 427°C - 982°C (801°F - 1800°F), they are considered to become "sensitized" or susceptible to intergranular corrosion. The ESBWR design complies with Regulatory Guide 1.44 and with the guidelines of Generic Letter 88-01 and NUREG-0313 Revision 2, to avoid sensitization through the use of reduced carbon content and process controls.

All austenitic stainless steels are supplied in the solution heat treated condition and special sensitization tests are applied to confirm and assure proper heat treatment. For applications where stainless steel surfaces are exposed to reactor water at temperatures above 93°C (199°F) in welded applications where solution heat treatment is not performed, nuclear grade materials (carbon content ≤ 0.02%) are used.

During fabrication, any heating operation (except welding) above 427°C (801°F) is avoided, unless followed by solution heat treatment. During welding, heat input is controlled. The interpass temperature is also controlled. Where practical, shop welds are solution heat treated. ~~In general, weld filler material used for austenitic stainless steel base metals is Type 308L/316L/309L/309MoL with an average ferrite content not less than 8 FN (ferrite number).~~

Process Controls to Minimize Exposure to Contaminants

Process controls are exercised during all stages of component manufacturing and construction to minimize contaminants. Cleanliness controls are applied prior to any elevated temperature treatment. Exposure to contaminants capable of causing stress/corrosion cracking of austenitic stainless steel components are avoided by carefully controlling all cleaning and processing materials which contact the stainless steel during manufacture, construction, and installation.

Special care is exercised to insure removal of surface contaminants prior to any heating operations. Water quality for cleaning, rinsing, flushing, and testing is controlled and monitored. Suitable protective packaging is provided for components to maintain cleanliness during shipping and storage. The degree of surface cleanliness obtained by these procedures meets the requirements of Regulatory Guides 1.37 and 1.44.

Cold-Worked Austenitic Stainless Steels

Cold worked austenitic stainless steels are not used for RCPB components. Cold work controls are applied for ASME Code components made of austenitic stainless steel and follow the same

RAI 5.2-71 (2)

requirements outlined in Subsection 4.5.2.4. During fabrication, cold work is controlled by applying limits in hardness, bend radii and surface finish on ground surfaces.

RAI 5.2-71 (2)

5.2.3.4.2 Control of Welding

General Welding Controls

For general welding controls on austenitic stainless steel and nickel base alloy components, refer to Subsection 4.5.2.2.

RAI 5.2-71 (1)

Avoidance of Hot Cracking

Regulatory Guide 1.31 describes the acceptable method of implementing requirements with regard to the control of welding when fabricating and joining austenitic stainless steel components and systems.

Written welding procedures that are approved by GEH are required for all primary pressure boundary welds performed for material fabrication and plant construction. These procedures shall comply with the requirements of Sections III and IX of the ASME Code and applicable NRC Regulatory Guides.

All austenitic stainless steel weld filler materials are required by specification to have ~~a~~ an average minimum delta ferrite content of 8 FN (ferrite number) and a maximum of 20 FN for 308L and 16 FN for 316L as determined on undiluted weld pads by magnetic measuring instruments calibrated in accordance with American Welding Society (AWS) Specification A4.2.

Regulatory Guide 1.34: Electroslag Welds

See Regulatory Guide 1.34 in Subsection 5.2.3.3.2.

Regulatory Guide 1.71: Welder Qualification for Areas of Limited Accessibility

Regulatory Guide 1.71 requires that weld fabrication and repair for wrought low-alloy and high-alloy steels or other materials such as static and centrifugal castings and bimetallic joints comply with fabrication requirements of Sections III, VIII and IX of the ASME Code. It also requires additional performance qualifications for welding in areas of limited access.

All ASME Section III welds are fabricated in accordance with the requirements of Sections III and IX of the ASME Code. There are few restrictive welds involved in the fabrication of ESBWR components. Welder qualification for welds with the most restrictive access is accomplished by mockup welding. Mockups are examined by sectioning and radiography (or UT).

The Acceptance Criterion II.3.b(3) of SRP Subsection 5.2.3 is based on Regulatory Guide 1.71. The ESBWR design meets the intent of this regulatory guide by utilizing the following alternate approach.

When access to a non-volumetrically examined ASME Section III production weld (1) is less than 300 mm (11.8 in.) in any direction and (2) allows welding from one access direction only, such weld and repairs to welds in wrought and cast low alloy steels, austenitic stainless steels and high nickel alloys and in any combination of these materials shall comply with the fabrication requirements specified in ASME Code Section III and with the requirements of Section IX invoked by Section III, supplemented by the following requirements: