RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**447-8548**
SRP Section:	**05.02.03 – Reactor Coolant Pressure Boundary Materials**
Application Section:	**05.02.03**
Date of RAI Issue:	**03/21/2016**

Question No. 05.02.03-20

In the Response to RAI No. 335-8351, Question No. 05.02.03-8 (dated January 13, 2016, ML16013A482) it was stated that δ-ferrite was limited in accordance with the CASS thermal aging susceptibility screening criteria of the NRC License Renewal Issue No. 98-0030 with the exception that a screening criteria of 500°F (260°C) is acceptable for APR-1400 according to the precedent set in the CESSAR-DC. The staff does not concur that this precedent applies as this precedent has been superseded by License Renewal Issue No. 98-0030.

Additionally the response noted that the applicant considers the use of ASTM A800/A800M to be equivalent to using Hull's method for calculation of δ-ferrite and cites the superseded CESSAR-DC precedent. The ASTM A800/800M method is known to under predict δ-ferrite, particularly within the range of 12 to 25% δ-ferrite where such predictions are needed. The applicant cited the NRC acceptance of the Advanced Light Water Reactor Utility Requirements Document as justification. However, the staff does not concur that this precedent applies as it has been superseded by License Renewal Issue No. 98-0030. The staff notes that detailed information has been submitted to the NRC specifically undermining the use of ASTM A800/A800M for the subject application, for example in NUREG/CR-7185, “Effects of Thermal Aging and Neutron Irradiation on Crack Growth Rate and Fracture Toughness of Cast Stainless Steels and Austenitic Stainless Steel Welds” (ADAMS Accession No. ML15202A007).

License Renewal Issue No. 98-0030 represents the current NRC position and is applied to all applications currently under review. Use of ASTM A800/A800M is not currently accepted by the staff. The staff requests that the applicant either provide revisions to the DCD complying fully with License Renewal Issue No. 98-0030 and the use of Hull's equivalent factors or provide a full and detailed technical evaluation supporting the 500°F criteria and ASTM A800/A800M

Response

The delta ferrite content of cast austenitic stainless steel will be determined using the Hull's equivalent factor. DCD Section 5.2.3.4.5 will be revised to reflect this change as attached.

Impact on DCD

DCD 5.2.3.4.5 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical or Environmental Report.

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b. NRC RG 1.34

NRC RG 1.34 is addressed in Subsection 5.2.3.3.

c. NRC RG 1.71

NRC RG 1.71 is addressed in Subsection 5.2.3.3.

5.2.3.4.5 Toughness of Cast Austenitic Stainless Steels or Welds

Reasonable assurance of the fracture toughness of cast stainless steels is provided by limiting the delta ferrite in the materials as follows:

a. For normal operating temperatures less than or equal to 260 °C (500 °F): 8 percent to 30 percent

Add
", determined using the Hull's equivalent factor,"

b. For normal operating temperatures above 260 °C (500 °F): 8 percent to 20 percent

c. Static cast stainless steel of CF8: 14 percent maximum

Revise
"CF3M or CF8M: "

Reasonable assurance of the fracture toughness of stainless steel welds is provided by limiting the delta ferrite in the weld materials as follows:

a. Singly and combined stainless steel weld filler metals: 8FN-15FN (8FN-16FN for Type 309 (L)) with no reading below 5FN as deposited.

5.2.3.4.6 Nondestructive Examination

Nondestructive examinations of austenitic stainless steel tubular products for components of RCPB are carried out in accordance with ASME Section III, Subsection NB-2500, under their construction, and Section XI during inservice inspections. Additional testing and inspection for major components are explained in Subsections 5.3.1.3, 5.4.1.4, 5.4.2.3, 5.4.3.4, and 5.4.10.4.

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Question No. 05.02.03-21

In the Response to RAI No. 335-8351, Question No. 05.02.03-12, (dated January 13, 2016, ML16013A482) several proposed revisions and explanations were proffered. The revisions are factually incorrect and the explanations are insufficient. The first revision states that the materials noted do not sensitize; the staff notes that these materials may sensitize but not to a critical extent provided the conditions listed are met. The staff believe that the second revision should become a simple deletion of the original statement.

In addition there appears to be confusion between the term "Type" and "Grades" with regards to the listing "Type 308, 309, 312, 316." Table 5.2-2 does not contain any components having the material of type 308 (UNS S30800), 309 (UNS S30900), or 312 (no UNS code for this non-standard alloy). Type 308 and 309 may be intended to reference ER308 and ER309 which are weld filler materials; however this is otherwise irrelevant as weld materials are not considered susceptible to the subject form of sensitization due to the microstructure of the weldment.

It is the understanding of the staff that if both revised statements and the surrounding paragraphs were to be deleted then:

- Welding of cast materials (CF3, CF3M, CF8, and CF8M) would require the same programmatic controls as the wrought austenitic material. Specifically: maximum interpass temperature, heat input, and carbon content. This requirement is already stated in the DCD. This change would reduce the possibility of sensitization of the bulk material and areas of localized low ferrite concentration.
- Furnace or bulk heat treatments would require monitoring to ensure that the material is not exposed to sensitization temperatures.
- The weld materials would be defined as austenitic.

If such a deletion occurred, the following text would remain to be corrected in 5.2.3.4.1.c,

> The unstabilized grades of austenitic stainless steels with carbon content of more than 0.03 percent used for components of the RCPB are Type 304 and Type 316. These materials are furnished in the solution-annealed condition. Completed or partially fabricated components are not exposed to temperatures from 427 °C (800 °F) to 816 °C (1,500 °F).
>
> CF8M, CF8 Cast stainless steel: delta ferrite 8 percent to 30 percent, 8 percent to 20 percent for normal operating temperature above 260 °C (500 °F) [The staff disputes this temperature criteria], 14 percent maximum for static cast stainless steel of CF8M
>
> Type 308, 309, 312, 316 Singly and combined stainless steel weld filler metals: delta ferrite controlled to 8FN-15FN (8FN-16FN for Type 309 (L)) with no reading below 5FN as deposited

The staff request that Section 5.2.3.4.1.c be revised to address the noted deficiencies.

Response

DCD Section 5.2.3.4.1 c. will be revised to delete the description of two paragraphs regarding duplex stainless steel. However, the severe or excessive sensitization of the materials in the form of castings and weld metal can be properly controlled by maintaining at least 5% of delta ferrite contents in them, which is allowed in accordance with Reg. Guide 1.44 Positions 4 and 5. We believe that welding of casting would not require the same programmatic controls as wrought austenitic stainless steel as described in Section 5.2.3.4.1 d. It should be noted that Section 5.2.3.4.1 d. is applied to unstabilized wrought austenitic stainless steels.

Impact on DCD

DCD 5.2.3.4.1 c will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical or Environmental Report.

procedures on the susceptibility of unstabilized Type 300 series stainless steels to sensitization induced intergranular corrosion. Only the procedures and/or practices demonstrated not to produce a sensitized structure are used in the fabrication of RCPB components. ASTM A262 Practices A or E is the criterion used to determine susceptibility to intergranular corrosion. The test has shown excellent correlation with a form of localized corrosion peculiar to sensitized stainless steels. As such, ASTM A262 Practice A or E is used as a go/no-go standard for acceptability.

As a result of the above test, a relationship was established between the carbon content of Type 304 stainless steel and weld heat input. This relationship is used to avoid weld-heat-affected-zone sensitization as described in Item d below.

c. Unstabilized austenitic stainless steel

Revise
"Austenitic stainless steels containing a certain quantity of delta ferrite (weld metal, cast metal, weld deposit buttering) do not sensitize,"

The unstabilized grades of austenitic stainless steels with carbon content of more than 0.03 percent used for components of the RCPB are Type 304 and Type 316. These materials are furnished in the solution-annealed condition. Completed or partially fabricated components are not exposed to temperatures from 427 °C (800 °F) to 816 °C (1,500 °F).

Duplex, austenitic stainless steels containing a certain quantity of delta ferrite (weld metal, cast metal, weld deposit overlay) are not considered unstabilized because these alloys do not sensitize, meaning they do not form a continuous network of chromium-iron carbides. Alloys in this category are:

CF8M, CF8	Cast stainless steel: delta ferrite 8 percent to 30 percent, 8 percent to 20 percent for normal operating temperature above 260 °C (500 °F), 14 percent maximum for static cast stainless steel of CF8M
Type 308, 309, 312, 316	Singly and combined stainless steel weld filler metals: delta ferrite controlled to 8FN-15FN (8FN-16FN for Type 309 (L)) with no reading below 5FN as deposited

Delete paragraph

In duplex, austenitic/ferritic alloys, chromium-iron carbides are precipitated preferentially at the ferrite/austenitic interfaces during exposure to temperatures ranging from 427 to 816 °C (800 to 1,500 °F). This precipitate morphology precludes intergranular penetrations associated with sensitized Type 300 series stainless steels exposed to oxygenated or fluoride environments.

Revise
"In austenitic stainless steel containing a certain quantity of delta ferrite alloys, chromium-iron carbides are precipitated preferentially at the ferrite/austenitic interfaces during"

Delete paragraph

d. Avoidance of sensitization

Exposure of unstabilized austenitic Type 300 serie
ranging from 427 to 816 °C (800 to 1,500 °F)
The degree of carbide precipitation, or sensitization, depends on the temperature, the amount of time at that temperature, and the carbon content. Severe sensitization is defined as a continuous grain boundary chromium-iron carbide network. This condition induces susceptibility to intergranular corrosion in oxygenated aqueous environments, as well as those containing fluorides. Such a metallurgical structure rapidly fails the ASTM A262 Practice A or E Test. Discontinuous precipitates (i.e., an intermittent grain boundary carbide network) are not susceptible to intergranular corrosion in a PWR environment.

Weld-heat-affected-zone sensitized austenitic stainless steels are avoided by carefully controlling:

1) Weld heat input to less than 23.6 kJ/cm (60 kJ/in)

2) Interpass temperature to 176.7 °C (350 °F) maximum

3) Carbon content to 0.065 percent maximum

Homogeneous or localized heat treatment in the temperature range from 427 to 816 °C (800 to 1,500 °F) is prohibited for unstabilized austenitic stainless steel with a carbon content greater than 0.03 percent used in components of the RCPB. When stainless steel safe ends are required on component nozzles, fabrication techniques and sequencing require that the stainless steel piece be welded to the component after final stress relief. This is accomplished by welding a NiCrFe overlay on the end of the nozzle. Following final stress relief of the component,