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

Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 2

Ref. 1: Letter, Sandra M. Sloan (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 265, Supplement 1," NRC:09:132, December 17, 2009.

In Reference 1, AREVA NP Inc. (AREVA NP) provided a response to RAI No. 265, Questions 03.06.03-20 through 03.06.03-26 regarding the Leak-Before-Break (LBB) for the U.S. EPR. In a telecon with the NRC on April 7, 2010, NRC provided comments regarding this RAI response. The NRC comments concerned the AREVA NP response to Question 03.06.03-20 regarding dynamic strain aging (DSA), Question 03.06.03-21 on thermal aging, and Question 03.06.03-26 regarding the finite element analysis (FEA). The enclosure provides:

1) the original NRC questions 03.06.03-20 and 03.06.03-21;
2) the original AREVA NP responses provided in Reference 1;
3) the NRC comments on the AREVA NP responses to Questions 03.06.03-20 and 03.06.03-21; and
4) the AREVA NP responses to the NRC comments.

Regarding the NRC comment on Question 03.06.03-26, AREVA NP is revising the allowable load limit (ALL) diagrams for the pressurizer surge line (SL) consistent with the methodology performed for the SL dissimilar metal weld (DMW) fusion line location described in Attachment 3 to the Response to RAI 265 Supplement 1. The revised ALL diagrams are anticipated to be submitted to NRC by July 31, 2010.

The enclosed response consists of the following:

Question #	Start Page	End Page
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RAI 265 — 03.06.03-21	5	10

AREVA NP considers some of the material contained in the enclosure to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support the withholding of the information from public disclosure. Proprietary and non-proprietary versions of the enclosure to this letter are enclosed.

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AREVA NP INC.
An AREVA and Siemens company

3315 Old Forest Road, P.O. Box 10935, Lynchburg, VA 24506-0935
Tel.: (434) 832-3000 - Fax: (434) 832-3840

NRO

If you have any questions related to this submittal, please contact me by telephone at 434-832-2369 or by e-mail at sandra.sloan@areva.com.

Sincerely,

Sandra M. Sloan

Sandra M. Sloan, Manager
New Plants Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: G. Tesfaye
Docket No. 52-020

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Sandra M. Sloan. I am Manager, New Plants Regulatory Affairs for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in "Response to Request for Additional Information No. 265, Supplement 2" and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information".

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Sandra M. Sloan

SUBSCRIBED before me this 3rd

day of June, 2010.

Kathleen A. Bennett

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2011

KATHLEEN ANN BENNETT
Notary Public
Commonwealth of Virginia
110684
My Commission Expires Aug 31, 2011

Response to

Request for Additional Information No. 265, Supplement 2

9/16/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.06.03 - Leak-Before-Break Evaluation Procedures
Application Section: 03.06.03

QUESTIONS for Component Integrity, Performance, and Testing Branch 1
(AP1000/EPR Projects) (CIB1)

Original NRC Question 03.06.03-20:

Follow-up to RAI Question 03.06.03-3

During the 6/09/2009, audit, the staff reviewed information related to Dynamic Strain Aging (DSA) and recommendations regarding metallurgical and heat treatment specifications as well as improvements to production welding procedures for ferritic base metals that would minimize the concern for dynamic strain aging. AREVA is requested to formally submit this material so the staff can review the recommendations and AREVA's approach.

Original AREVA NP Response to Question 03.06.03-20:

The AREVA NP presentation material from the NRC audit related to impact of DSA on leak-before-break (LBB) analysis was formally submitted to the NRC on July 1, 2009 (reference Accession Number ML091900197). Additional information as requested by the NRC regarding DSA is provided in this response.

Based on Reference 1, DSA can be minimized in carbon steel by minimizing the amount of nitrogen and carbon dissolved in the ferrite, which depends on the steel grade, the deoxidation practice, and the heat treatment.

The steel grade controls the chemical composition of the material, which affects the final properties. One method of minimizing the amount of nitrogen and carbon in solution is to limit the amount in the heat of material. Carbon cannot be reduced without decreasing the strength of the material because it is the main hardening agent. However, SA-106 typically contains a small amount of strong carbide formers (i.e., chromium, vanadium and molybdenum), which remove some of the free carbon from solution, decreasing its role in strain aging. Nitrogen does not provide a significant benefit to the mechanical properties, so it should be held as low as reasonably achievable through modern steel making practices to minimize its role in strain aging (Reference 2).

Carbon steel is killed by adding deoxidizing agents such as silicon and aluminum, which form nitrides and remove nitrogen from the ferrite lattice. This deoxidation practice decreases nitrogen's contribution to strain aging. Steels that are deoxidized with both aluminum and silicon are most resistant to dynamic strain aging (Reference 2). ASME SA-106 requires that the steel be killed with silicon. Based on Reference 2, the SA-106 Grade C piping will be killed with 0.15-0.25 wt percent silicon and 0.03-0.08 wt percent aluminum. This will reduce the susceptibility to strain aging while not significantly affecting the mechanical properties.

The strain aging response of carbon steel is also a function of heat treatment. For the SA-106 Grade C carbon steel to meet the minimum mechanical property requirements of the MSL piping, it must be quenched and tempered. The rapid cooling during the quenching process traps carbon and nitrogen interstitials in sites too small for the size of these atoms, straining the crystal lattice. At operating temperatures, these interstitial atoms may segregate to dislocations and impede their movement, which contributes to DSA. Tempering causes carbon atoms to form carbide precipitates, which, unlike carbon interstitials, do not increase DSA susceptibility. Tempering temperature has a larger role in carbide precipitation compared to time. The same is true for the stress relief heat treatment because the stress relief temperature is the same as the tempering temperature. As stated in Reference 1, the lowest susceptibility will be associated with treatments that provide precipitation of nitrides and carbides, namely, extended treatment near 600°C (1110°F) followed by slow cooling.

The impact of the welding process on the DSA susceptibility of the base metal was also considered. DSA susceptibility could potentially be increased if a sharp notch near the weld was formed due to a fabrication defect. This is not a concern because such a defect would be found and removed during required post weld inspection. The adverse impact of the welding process on the DSA susceptibility of the base metal is the creation of residual stress in the weld heat affect zone. These stresses will be removed during the post fabrication stress relief heat treatment or the post weld heat treatment. The welding process will not adversely impact base metal DSA susceptibility.

Additionally, the following actions will further minimize the potential for DSA:

- The composition of SA-106 Grade C that will be used for the U.S. EPR MSL piping to reduce the susceptibility to dynamic strain aging is:

  Si: 0.15-0.25 percent.
  Al: 0.03-0.08 percent.
  N: As low as reasonably achievable.

  This composition will decrease the total amount of nitrogen in the material and minimize the amount of free nitrogen by encouraging the formation of nitrides.

- The SA-106 Grade C heat treatment that will be used for the U.S. EPR (MSL) piping is:

Heat Treatment:	1600-1650°F held for two to three hours and water quenched.
Temper:	1100-1150°F held for four hours and air cooled.
Stress Relief:	1100-1150°F held for 30 hours and furnace cool to 600°F.

  This heat treatment is consistent with the recommendations for minimizing susceptibility to DSA in Reference 1 and is also consistent with heat treatment of SA-106 Grade C pipe in service at operating nuclear facilities.

References for Original AREVA NP Response to Question 03.06.03-20:

1. Marschall, C. W., et al., “Effect of Dynamic Strain Aging on Fracture Resistance of Carbon Steels Operating at Light-Water Reactor Temperatures,” Fracture Mechanics: Twenty-First Symposium, ASTM STP 1074, J. P. Gudas, J. A. Joyce, and E. M. Hackett, Eds., American Society for Testing and Materials, Philadelphia, 1990, pp. 339-360.
2. Leslie, W. C., et al., “Influence of Aluminum and Silicon Deoxidation on the Strain Aging of Low-Carbon Steels,” Transactions AIME, Journal of Metals, Aug. 1953, pp. 1021-1031.

NRC Comment on AREVA NP Response to Question 03.06.03-20:

Based on a telecon with NRC on April 7, NRC provided the following comment regarding the AREVA NP Response to Question 03.06.03-20:

One issue of potential concern is that a fabrication defect (a sharp notch near a weld) could increase DSA susceptibility. AREVA does not perceive this to be a problem as they indicate that it will be found and removed during post weld inspection. The MSL is ASME Code Class 2 and Section III rules apply with Radiography as the primary NDE technique required for fabrication inspection. Appendix VIII of Section XI is not applicable. How effective is the required Section III inspection at detecting sharp notches?

AREVA NP Response to NRC Comment:

Radiography performed in accordance with ASME, Section III is able to detect sharp notches or other abrupt discontinuities. Therefore, it is unlikely that such a flaw would go undetected during fabrication.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this NRC comment.

Original NRC Question 03.06.03-21:

Follow-up to RAI Question 03.06.03-6

RAI Question 03.06.03-6 requested AREVA to provide details for the J-R curves used for ALL the calculations as none were provided in the original FSAR. AREVA provided the requested information during an audit conducted on June 26, 2008. The information presented to the staff during the audit indicated that for SST pipe and welds the toughness was reduced by 30% to account for thermal aging. In the formal response to RAI Question 03.06.03-6, dated 9/18/2008, AREVA indicated that the reduction in toughness was to account for heat to heat variations. The staff requests AREVA to provide the justification and the basis for the 30% reduction.

Original AREVA NP Response to Question 03.06.03-21:

As noted in the Response to RAI 48, Question 03.06.03-6, the material constants for the main coolant loop (MCL) stainless steel base metal were reduced by 30 percent to account **[**

] . There is no reduction to account for thermal aging of the stainless steel base metal.

The basis for the 30 percent reduction of the stainless steel weld material as a result of thermal aging concerns is provided in this response.

AREVA NP has reviewed the parameters that primarily affect thermal aging of austenitic stainless steels and identified the applicable data for aging of austenitic stainless steel welds. One set of data found in Reference 1 shows lower bound properties in comparison to the parameters used in the U.S. EPR welds. The material, welding process, aging time, and temperature for this set of data are similar or more conservative than the parameters used for the U.S. EPR. The welding process for the data in Reference 1 is unknown, but it is assumed to be the gas tungsten arc weld (GTAW) based on the retention of toughness after extensive aging. Welds made by the GTAW process demonstrate higher toughness than gas metal arc welding (GMAW), submerged arc welding (SAW), and shielded metal arc welding (SMAW) aged welds because the ferrite phase can withstand sizeable deformation prior to fracture, increasing the toughness value in comparison to SMAW or SAW. The material for the data set in Reference 1 is 16-8-2, which is a similar weld material to 316 stainless steel weld material. The data for this set was aged for 100,000 hours at 900°F, which is an order of magnitude greater than the typical aging times from Reference 1. **[**

]. Because of its greater aging time and temperature, the data set from Reference 1 is a lower bound toughness data set for 316 GTAW/TIG welds. Four sets of public data (Reference 1 through Reference 4) fall below the data in Reference 1 (16-8-2 material aged for 100,000 hours at 900°F) as shown in Figure 03.06.03-21-1.

Table 03.06.03-21-1 categorizes the four sets of data from Reference 1 through Reference 4. These four sets of data include at least one of the five groupings (size of test specimen, welding process type, amount of delta ferrite present in the welding material, aging temperature, length of aging) that is different from the desired properties **[**

]. The four J-R curves from

Reference 1 through Reference 4, shown in Table 03.06.03-21-1, are bounded by Huang's 16-8-2 data set, as shown in Figure 03.06.03-21-1.

The use of J evaluated at a crack extension length of 0.008 in (0.2 mm) is not the most effective way to predict the effect of thermal aging on fracture toughness values for stainless steel welds. Using dJ/da alone can not realistically determine the average percent reduction for aged materials. Combining both $J_{0.2}$ (or J_{IC}) and dJ/da to construct a J-R curve beyond the 0.008 in (0.2 mm) crack extension by assuming a two-straight line model provides a more reasonable average percent reduction. From this model, a J value can be obtained at a given crack extension and the percent reduction of fracture toughness at a certain crack extension can be obtained by ratioing aged J versus unaged J. Huang's data was not used in this evaluation because of its unknown welding type. The data from Reference 2 through Reference 5 and the

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This value has been rounded to 30 percent to be conservative and provides the basis for the reduction due to thermal aging for stainless steel welding materials used for the U.S. EPR.

References for Original AREVA NP Response to Question 03.06.03-21:

1. F. H. Huang, DOE Document No. WHC-SD-FF-TRP-019, Rev. 0, "Effect of Long Term Thermal Aging on the Fracture Toughness of Austenitic Stainless Steel Base and Weld Metals," September 27, 1995.
2. W. J. Mills, "Fracture Toughness of Aged Stainless Steel Primary Piping and Reactor Vessel Materials," Transactions of the ASME, Volume 198, November 1987.
3. G. E. Hale and S. J. Garwood, "Effect of Aging on Fracture Behavior of Cast Stainless Steel and Weldments," Materials Science and Technology, Volume 6, 1990.
4. P. Ould, P. Balladon, Y. Meyzaud, "Fracture Toughness Properties of Austenitic Stainless Steel Welds," International Seminar on Stainless Steels, Task Group for the Study of Steels, Technical Faculty of MONS, April 27-28, 1988.
5. F. Faure, P. Ould, and P. Balladon, "Effect of Long Term Aging on the Mechanical Properties of Stainless Steel Welds in PWR," Trends in Welding Research, Gatlinburg, TN, 1992.

NRC Comment on AREVA NP Response to Question 03.06.03-21:

Based on a telecon with NRC on April 7, NRC provided the following comment regarding the AREVA NP Response to Question 03.06.03-21:

The 30-percent reduction seems to be in reasonable agreement with NUREG/CR-6428 ("Effects of Thermal Aging on Fracture Toughness and Charpy-Impact Strength of Stainless Steel Pipe Welds" by Argonne.) However, AREVA needs to review NUREG/CR-6428 and include their assessment of the NUREG and the level of support that the NUREG provides to their response.

AREVA NP Response to NRC Comment:

Review of NUREG/CR-6428

For three different type 304/308 pipe weldments as defined in the Material Characterization Section of NUREG/CR-6428 (i.e., PWWO, PWCE and PWER), the fracture toughness J-R curve tests were conducted at both room temperature and at an operating temperature of 290°C (554°F). Although the welding process was not specified, these large diameter pipe welds were assumed in NUREG/CR-6428 to be prepared by a shielded metal arc weld (SMAW) process. The ferrite content of these welds was relatively low (ranging from 4 percent to 6 percent). The effect of thermal aging on the fracture toughness J-R curves showed that, for all of the welds, the decrease in fracture toughness due to thermal aging is relatively small at room temperature and at 290°C (554°F).

NUREG/CR-6428 also summarizes unaged fracture toughness J-R curve data compiled in the Pipe Fracture (PIFRAC) database as well as data from other published sources. The unaged data are shown in Figure 15 of NUREG/CR-6428 for both room and operating temperatures (288°C to 427°C (550°F to 800°F). These results indicated that the fracture toughness properties are insensitive to filler metal; however, they are sensitive to the welding process used with gas tungsten arc weld (GTAW) exhibiting higher toughness than SMAWs or SAWs. The available fracture toughness J-R curves for aged SMAWs, submerged arc welds (SAW), and GTAWs are shown in Figure 16 of NUREG/CR-6428 for both room and operating temperature of 288°C (550°F). In these studies the aging time and temperature was sufficient to achieve saturation. It is the effect of thermal aging at operating temperature that is of particular interest. At operating temperature, Figure 16 NUREG/CR-6428 only provides aged J-R curves for the SMAW welding process. There are four sets of aged J-R curves presented on this figure. These aged data are than compared against what are considered to be the corresponding unaged data from Figure 15 of NUREG/CR-6428 and shown in Figure 03.06.03-21-1. The results of Figure 03.06.03-21-1 show that a 25 percent reduction due to thermal aging (for operating temperature condition) best describes the data from NUREG/CR-6428.

In Reference 1, the NRC stated that the Japanese nuclear pipe flaw evaluation codes (JSME) and Japanese pipe fracture tests has shown that the GTAW toughness is comparable to SMAW welds. Based on this information, it is reasonable to consider the aged SMAW weld data of NUREG/CR-6428 for the U.S. EPR stainless steel welds even though it uses the GTAW process. It is concluded that to account for the effects of thermal aging of the U.S. EPR stainless steel welds, the J-R curve at operating temperature needs to be reduced by at least 25 percent.

Literature Review of Aged and Unaged Austenitic Stainless Steel Welds

As noted in the Response to Question 03.06.03-21, AREVA NP also performed a literature review of aged and unaged austenitic stainless steel welds (i.e., References 1 through 5 of the Response to Question 03.06.03-21) whose results are summarized in the RAI Response to Question 03.06.03-21. As a result of this review, in the Response to Question 03.06.03-21, AREVA NP determined that a 30 percent reduction of unaged J-R data is appropriate to account for the effects of thermal aging, and this percent reduction is used for the U.S. EPR.

Experimental J-R Test Data for Aged Stainless Steel Weld

In addition to the NUREG/CR-6428 and literature review study, AREVA NP performed an experimental thermal aging program on the 308 stainless steel GTAW joints. Prior to testing, these materials were aged for[ ] hours at [ ]°F. The aged 1.5T CT weld metal (B9 and C8) J-R curves are compared against the projected lower bound J-R curve (30 percent reduction of lower bound unaged data) as shown in Figure 03.06.03-21-2. These power law curves are not meant to be lower bounding in the early portion (Δa less than 0.15 inches) of the J-R curve. For crack extensions less than or equal to 0.5 inches, the applicable lower bound curve is defined as [ ]. For crack extensions less than or equal to 0.9 inches, the applicable lower bound curve is defined as [ ]. Note that the actual aged 1.5T CT weld data follows the [ ] curve up to Δa of approximately 0.5 inches. Beyond a crack extension of 0.5 inches, the experimental data is bounded by the [ ] curve.

References

6. E-mail, Getachew Tesfaye (NRC) to Martin C. Bryan, et al (AREVA NP Inc.), "EMC2 comments to AREVA response to RAI 265, Questions 20-26," March 30, 2010.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this NRC comment.

Figure 03.06.03-21-1—Comparison between Aged and Unaged Data

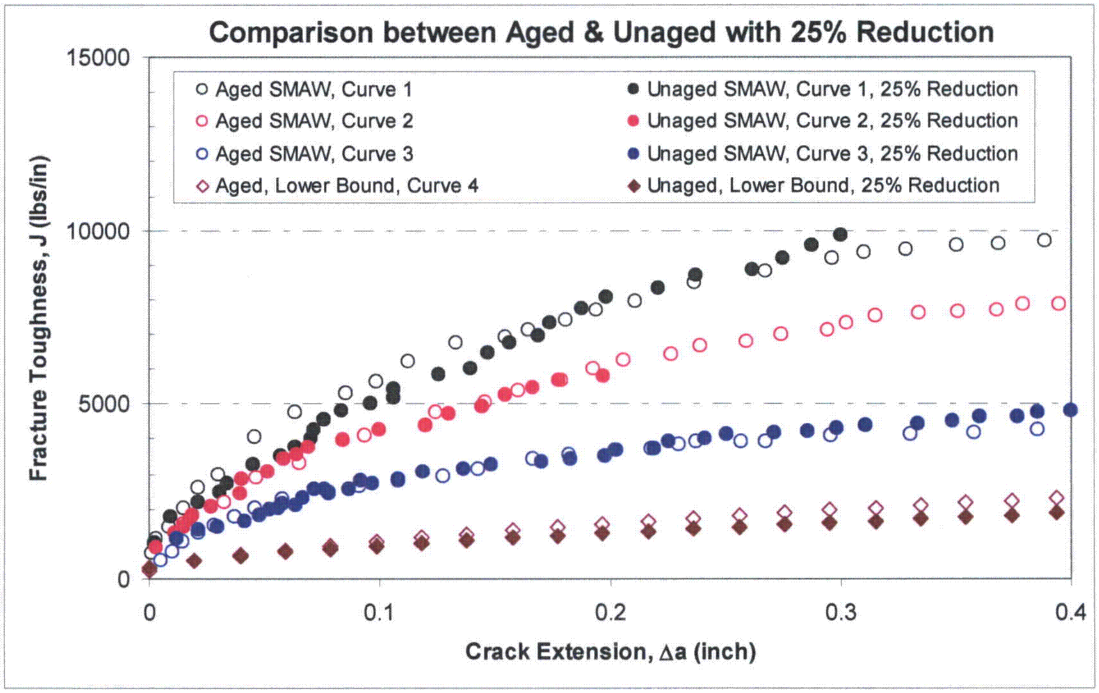

Figure 03.06.03-21-2—Comparison of the Aged 1.5T CT Weld Metal J-R Curves to the Projected Lower Bound J-R Curve