August 11, 2009

U.S. NUCLEAR REGULATORY COMMISSION (NRC)
OFFICE OF NEW REACTORS
DIVISION OF ENGINEERING
REGULATORY AUDIT REPORT

Docket No.:	052-000020
Applicant:	AREVA NP, INC. AREVA BETHESDA OFFICE 1700 Rockville Pike, Suite 400 Rockville, MD, 20852
Applicant Contact:	Russ Wells Advisory Engineer, New Plants AREVA NP, Inc. 3315 Old Forest Road, P.O. Box 10935 Mail Stop OF-34 Lynchburg, VA 24506-0935 Phone: 434-832-3884
Application and Section:	U.S. EPR Design Certification Application Section 3.6.3
Audit Dates:	June 09, 2009
NRC Audit Reviewers:	Eric Reichelt, Technical Reviewer (NRO/DE/CIB1) Jay Patel, NRC Project Manager (NRO/DNRL/NARP)
Approved by:	David Terao, Branch Chief Component Integrity, Performance & Testing Brach1 (NRO/DE/CIB1)

EXECUTIVE SUMMARY

AREVA NP, INC.
Docket No. 052-000020

This audit was held as a result of a telecon between the NRC staff, Engineering Mechanics Corporation of Columbus (EMC2), and AREVA NP, Inc. (AREVA) on March 11, 2009. AREVA had agreed to re-run their leak-before-break (LBB) confirmatory analyses using the PICEP and KRAKFLO codes considering the EPRI/GE method with an elliptical crack opening shape and considering the equivalent number of turns/inch as provided in NUREG/CR-6004 for the air-fatigue crack morphology. The purpose of this audit was to review AREVA's updated case on the LBB confirmatory analysis on the U.S. EPR Surge Line (SL) and compare the methodology and results of the updated LBB leakage curves with EMC2. Additionally, results were compared and reviewed for the specific input variables for the leak-rate analysis for PICEP, KRACKFLO and SQUIRT. The comparison of results on specific input variables for leak-rate analysis and flaw stability analysis were performed, and discussions/clarifications on Requests for Additional Information (RAI) still considered open were held.

The results of the audit are summarized below:

The NRC staff successfully reviewed AREVA's input/results to the confirmatory LBB analyses using the PICEP and KRAKFLO codes. Discussions on open RAI's regarding Section 3.6.3 were held, and as a result, follow-up RAI's will be issued to ensure that information needed for the staff's safety decision is properly included in the U.S. EPR docket file. These questions will be sent to AREVA as RAI 3358, Questions 03.06.03-20, 03.06.03-21, 03.06.03-22, 03.06.03-23, 03.06.03-24, 03.06.03-25 and 03.06.03-26. As a result of the audit, AREVA will re-run their LBB analyses using the parameters discussed during the audit, and future telecons/audits will be held as necessary to ensure agreement on the results of the updated confirmatory analysis.

REPORT DETAILS

AUDIT SCOPE/SUMMARY:

The overall scope of the audit was to accomplish the following:

- Obtain agreement on the methodology and results for the confirmatory analysis on the updated Leak-Before-Break (LBB) leakage curves for the U.S. EPR Surge Line
- Resolve NRC concerns on Dynamic Strain Aging (DSA)
- Discuss unresolved RAI's and path forward

Members present at the audit are provided within Attachment 1 of this audit report. The purpose of the audit was to discuss the updated LBB analysis for the U.S. EPR Surge Line. AREVA had performed the updated leak rate analysis using SQUIRT, PICEP and KRAKFLO considering EPRI/GE method with an elliptical crack opening shape and considering the equivalent number of turns/inch as provided in NUREG/CR-6004 for the air-fatigue crack morphology. An overview of the analysis was provided for the staff to review and the methodology and results were discussed. A discussion of dynamic strain aging (DSA) was also provided by both AREVA and EMC2. Unresolved RAI's were discussed and follow-up RAI's will be issued to ensure the adequate information was provided to close each RAI.

OBSERVATIONS AND FINDINGS:

AREVA made a presentation describing their updated U.S. EPR LBB confirmatory analyses.
During the presentation, the NRC staff asked specific questions regarding the parameters used and the results presented. The assumptions regarding the crack morphology parameters, especially the number of turns/inch of crack length, had the most significant effect on the LBB analysis and the resulting Allowable Limit Load (ALL) diagrams. During the audit there was much discussion between AREVA and NRC concerning the comparison data between KRACKFLO (AREVA) and SQUIRT (NRC). AREVA stated that in order to get similar results with SQUIRT, they use a penalty factor of 26 for KRACKFLO and an improved crack morphology option for SQUIRT. A follow-up RAI will be submitted concerning this issue.
In addition, AREVA stated that the material properties of ASME SA-106 were being used for the analysis. However, ASME SA-508 material is to be used in the design. AREVA agreed to perform a confirmatory analysis on ASME SA-508. In addition, AREVA agreed to perform a finite element analysis (FEA) much like EMC2 performed in their presentation. EMC2 will provide the stress/strain curve for SA-508.
In addition, a discussion on DSA was held. DSA is caused by free carbon or nitrogen atoms pinning dislocations during plastic flow of the material. The pinning of the dislocation motion increases the ultimate strength and reduces the percent elongation in tensile tests. In fracture toughness testing, DSA can cause a drop in toughness as the temperature increases. Additionally, DSA can affect the crack growth resistance by having unstable crack jumps at LWR temperatures. AREVA stated that in an effort to minimize DSA, they will be working with material suppliers to modify chemistry and cooling rates on specific heats of materials.

Discussions on open RAI's regarding Section 3.6.3 were held (refer to Item 4 in Attachment 1), and as a result, follow-up RAI's were issued. The following RAI's were generated based on the audit:

RAI 3358, Question 03.06.03-20:
Follow-up to RAI Question 03.06.03-3

During the June 9, 2009, audit, the staff reviewed information related to 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.

RAI 3358, Question 03.06.03-21:
Follow-up to RAI Question 03.06.03-6

RAI Question 03.06.03-6 requested AREVA to provide the material toughness (J-R curves) values for each of the materials used in the analyses as well as material constants. AREVA responded that the J-R curves for the MSL were reviewed by the staff during the June 26, 2008 audit. It was also stated that for stainless steel material, the material constant was reduced by 30% to account for heat to heat variations and thermal aging. Please provide the J-R curves and the basis for the 30% reduction of J-R toughness curves.

RAI 3358, Question 03.06.03-22:
Follow-up to RAI Question 03.06.03-10

In RAI 03.06.03-10 AREVA was requested to justify the use of the crack morphology parameters used in the leakage calculations. During the 06/09/2009 audit, AREVA provided a comparison of the data between KRACKFLO (AREVA) and SQUIRT (NRC) software. AREVA stated in order to get similar results with SQUIRT, they used a penalty factor of 26 in KRACKFLO (and an improved crack morphology option with SQUIRT). Please provide the basis for using these criteria. Additionally, the following factors need to be accounted for by AREVA that could affect the ALL diagram:

a. Compare crack length for the leakage limits between KRACKFLO and SQUIRT with and without the improved COD-dependant crack morphology.

b. Examine and validate the effect of tensile stress-strain curve on crack-driving force J-applied to assess, leak versus moment curves as well as J applied for flaw stability analysis.

c. Effect of J-R material property data being too low. While using a low J-R curve is conservative, the values to fit the J-R curve seemed to result in an unusually low curve and may need to be confirmed.

d. As was discussed in the audit of June 9, 2009, air fatigue morphology is the least conservative assumption for leak-rate calculations. If an SCC or corrosion morphology is assumed in the calculations (as a lower bound conservative case), each of the ALL diagrams will change. AREVA is requested to provide justification for using air fatigue or provide an analysis using a corrosion fatigue and SCC for comparison.

RAI 3358, Question 03.06.03-23:
Follow-up to RAI Question 03.06.03-13

In response to RAI 03.06.03-13, AREVA referenced EPRI Report 1009801, "Materials Reliability Program (MRP), Resistance to Primary Water Stress Corrosion Cracking of Alloys 690, 152, 52 in Pressurized Water Reactors (MRP-111), Electric Power Research Institute, March 2004, which contained controls for welding dilution effects and chromium content. Please provide the data contained in the EPRI Report for review and clarification of dilution effects and chromium content in nickel based welds.

RAI 3358, Question 03.06.03-24:
Follow-up to RAI Question 03.06.03-14

In response to RAI 03.06.03-14, AREVA stated that a safety factor of 1.7 is the highest attainable safety factor that can be used to qualify the MSL piping for LBB for the U.S. EPR design. AREVA is requested to check the Ramberg-Osgood fit of the stress-strain data for the MSL to verify that the J driving force is modeled correctly, and then again address the safety factor of 1.7.

RAI 3358, Question 03.06.03-25:

During the NRC/AREVA audit on June 9, 2009, there was much discussion between AREVA and the NRC staff concerning the comparison data between KRACKFLO (AREVA) and SQUIRT (NRC). AREVA stated that in order to get similar results with SQUIRT, it uses a "penalty factor" of 26 for KRACKFLO and an improved crack morphology option for SQUIRT. AREVA is requested to provide the basis for their penalty factor of 26 in KRACKFLO to compare their results to SQUIRT results using the improved crack morphology option. Please identify what variable/variables are modified by the penalty factor in their leak rate analysis.

RAI 3358, Question 03.06.03-26:

During the audit on 06/09/2009 between the NRC and AREVA, AREVA stated that the material properties of ASME SA-106 was being used to obtain the moment vs. crack length curves for the surge line in the EPR design. However, the material that is to be used for construction is identified as ASME SA-508. In the staff's confirmatory analysis, the stress-strain curves for ASME SA-508 were higher, which would result in a greater amount of constraint of the plasticity. This was confirmed by the staff's Finite Element analysis. AREVA is requested to:

a. Verify that ASME SA-508 is the material to be used in construction for the nozzles and specify which grade or class of SA-508.

b. Provide a confirmatory analysis on ASME SA-508 and justify that ASME SA-106 is more conservative.

c. Perform a Finite Element analysis between the two materials much like what the staff has performed and discussed during the June 9, 2009 audit.

CONCLUSION:

The NRC staff successfully reviewed AREVA's input/results to the confirmatory LBB analyses using the PICEP and KRAKFLO codes. Discussions on open RAI's regarding Section 3.6.3 were held, and as a result, follow-up RAI's were issued to ensure that information needed for the staff's safety decision is properly included in the U.S. EPR docket file. These questions will be sent to AREVA as RAI 3358, Question's 03.06.03-20, 03.06.03-21, 03.06.03-22, 03.06.03-23, 03.06.03-24, 03.06.03-25 and 03.06.03-26. As a result of the audit, AREVA will re-run their LBB analyses using the parameters discussed during the audit, and future telecons/audits will be held as necessary to ensure agreement on the results of the updated confirmatory analysis

EXIT MEETING:

On June 09, 2009 the NRC and EMC2 presented the audit scope and findings during an exit meeting with Russ Wells and AREVA personnel.

ATTACHMENT 1

1. PERSONS CONTACTED

NAME	ORGANIZATION	E-MAIL
Jay Patel	NRC	Jay.Patel@nrc.gov
Eric Reichelt	NRC	Eric.Reichelt@nrc.gov
Do-Jun Shim	EMC^2	djshim@emc-sq.com
Prabhat Krishnaswamy	EMC^2	kswamy@emc-sq.com
Keith Wichman	EMC^2	keithwich@comcast.net
Elizabeth Kurth	EMC^2	ekurth@emc-sq.com
David C. Fischer	EMC^2	dfischer@numarkassoc.com
Heqin Xu	AREVA	Heqin.Xu@areva.com
Ashor Nana	AREVA	Ashok.Nana@areva.com
Tehemton Bhagwagar	AREVA	Tehemton.Bhagwagar@areva.com
Russ Wells	AREVA	Russell.Wells@areva.com
Ken Yoon	AREVA	Ken.Yoon@areva.com

2. DOCUMENTS REVIEWED

- U.S. EPR Leak-Before-Break (LBB) Update AREVA Slides (Propriety Info)
- Comparison of Specific Inputs AREVA Slides (Propriety Info)
- Confirmatory Analysis of US-EPR Surge Line – LBB Evaluation; EMC2 Presentation Slides (Propriety Info)
- AREVA's Sample Excel Spreadsheet calculation (Propriety Info)

3. STANDARD REVIEW PLAN AND GUIDANCE USED

U.S. EPR Design Certification Application Section 3.6.3, LBB Analysis

4. LIST OF RAI's DISCUSSSED

4.1 The issue of welding controls on dilution effects and chromium content (**RAI 3.6.3-13)**

4.2 The potential for thermal aging of the MSL carbon steel welds, A106CB base metal, SL stainless steel weld, and nozzle weld geometry for the pump housing **(RAI 3.6.3-6)**

4.3 The effects of dynamic strain aging for these carbon-steel materials at high loading rates (**RAI 3.6.3-7)**

4.4 The use of the appropriate crack morphology parameters in the leak rate calculations **(RAI 3.6.3-10)**

4.5 The use of the straight-pipe solution for bounding the elbow crack case in the flaw stability analyses (**RAI 3.6.3-18)**

4.6 The use of a Safety Factor of 1.7 in the flaw stability analyses for MSL (**RAI 3.6.3-14)**

4.7 The adequacy of the leakage detection system (**RAI 3.6.3-17)**

5. <u>LIST OF ACRONYMS USED</u>

NRC, Nuclear Regulatory Commission
RAI, Request for Additional Information
LBB, Leak-Before-Break
SL, Surge Line
DSA, Dynamic Strain Aging