August 17, 2010

Ms. Sandra Sloan
AREVA NP Inc.
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SUBJECT: AUDIT REPORT FOR SEPTEMBER 15, 2009, AUDIT TO REVIEW SELECTED AREAS RELATED TO U.S. EPR FINAL SAFETY ANALYSIS REPORT CHAPTER 15 SAFETY EVALUATION

Dear Ms. Sloan:

AREVA NP Inc., (AREVA) has submitted by a letter dated December 11, 2007, to the U.S. Nuclear Regulatory Commission a Final Safety Analysis Report for its application of the U.S. EPR design, accessible by Agencywide Documents Access and Management System (ADAMS) Accession No. ML073520305. In a letter dated March 31, 2007, AREVA submitted ANP-10278P, "U.S. EPR Realistic Large Break Loss of Coolant Accident Methodology Topical Report," Revision 0 (ADAMS Accession No. ML070880737). Audits on information supporting the development of ANP-10278P were held on December 3–4, 2008, and April 22–23, 2009.

The audits performed on ANP-10278P identified the need for additional information to cover important review areas handled by the Office of New Reactors, Reactor Systems, Nuclear Performance, and Code Review Branch. In order to address these concerns, the staff held an audit at the AREVA Rockville office on September 15, 2009. The review of additional technical documents was facilitated by the presence of AREVA personnel at the audit. The audit report is contained in the enclosure to this letter. If you have any questions regarding this matter, I may be reached at 301-415-3361or at Getachew.Tesfaye@nrc..gov.

Sincerely,

/RA/

Getachew Tesfaye, Senior Project Manager
EPR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-020

Enclosure:
Audit Report
cc: DC AREVA – EPR Mailing List

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ADAMS Accession Number: ML101290002 **NRO-002**

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APPLICANT: AREVA NP, INC.

PROJECT: U.S. EPR DESIGN CERTIFICATION

SUBJECT: AUDIT REPORT FOR SEPTEMBER 15, 2009, AUDIT TO REVIEW SELECTED AREAS RELATED TO U.S. EPR FINAL SAFETY ANALYSIS REPORT CHAPTER 15 AND SUPPORTING TECHNICAL/TOPICAL REPORTS SAFETY EVALUATION

BACKGROUND

AREVA NP, Inc. (AREVA) has submitted to the U.S. Nuclear Regulatory Commission (NRC) a Final Safety Analysis Report (FSAR) for its application of the U.S. EPR in December 2007. The staff initiated the design certification review on March 19, 2008. In addition, topical reports related to FSAR Chapter 4 (ANP-10285P) and Chapter 15 (ANP-10278 and EMF-2013) and supporting technical reports have been submitted for review. In order to cover important review areas handled by the Office of New Reactors, Reactor Systems, Nuclear Performance, and Code Review Branch, the staff proposed an audit that was carried out at the AREVA office in Rockville, MD on September 15, 2009. The review areas were previously discussed with AREVA. The review of the additional technical documents, made available by AREVA at its Rockville office, was facilitated by the presence of AREVA personnel at the audit. The audit was performed to resolve open questions in accomplishing the U.S. EPR FSAR review schedule in an efficient manner.

AUDIT APPROACH

The purpose of this audit was to review additional documents provided by AREVA that pertain to the FSAR safety evaluation related to determination of the initial stored energy in the reactor core for peak clad temperature predictions following loss of coolant accidents (LOCAs). The specific issues of concern were that initial stored energy and gap conductance may be under-predicted, that may result in under-prediction of peak cladding temperatures and oxidation. The staff audited documents related to the Accumulator Nitrogen Injection, Accumulator Minimum Temperature, RODEX4 database, and FUELK applications related to U.S. EPR FSAR Chapters 4 and 15. The audit agenda as practiced is given in Attachment A.

To achieve the review goals in an efficient manner, the staff assembled an interdisciplinary audit team consisting of professionals with expertise in the thermal-hydraulic, reactor physics, and reactor fuel areas. The audit team included experts from the staff and consulting organizations. To facilitate and expedite the work, the audit was supported by representatives from AREVA who introduced the audit topics along with the supporting documents and technical evidence to the reviewers. The attendance list is provided in Attachment B.

SUMMARY OF TOPICS DISCUSSED

Presentations on topics discussed previously at the public meeting with the applicant on August 6, 2009, were given by AREVA representatives addressing the five topics identified below.

ENCLOSURE

1. Accumulator nitrogen injection
2. Accumulator minimum temperature
3. RODEX3 topics
4. Lower plenum refill
5. Decay heat

A set of slides covering the above identified areas was presented by the applicant and made available to the participants (Reference 1). Discussions took place during each presentation followed by separate closed discussions among the staff and consultants on one side, and the applicant representatives on the other. Due to time constraints, no additional technical materials were reviewed by the staff.

AUDIT TOPICS COVERED

The main presentation points for each individual technical area identified in the above introduction to this audit report are documented in the following sections following Reference 1.

Accumulator Nitrogen Injection

Under this topic, the applicant addressed two technical issues: (1) Status of critical flow evaluation and (2) sensitivity study on blocking nitrogen.

Regarding the Realistic Large Break Loss of Coolant Accident (RLBLOCA) Topical Report issue related to S-RELAP5 critical flow capabilities with the presence of nitrogen, AREVA initiated a Condition Report Review, which has been completed and closed. It was determined that the S-RELAP5 critical flow adequately modeled non-condensable and mixed gases. Additional details in this regard will be presented by the applicant at a subsequent meeting.

Regarding the issue related to nitrogen injection, AREVA performed analyses to address the associated effects on the system pressure results. The cases previously submitted as part of the sample problem in ANP-10278P were rerun with no nitrogen injection by isolating the accumulators when close to empty with the approach similar to a study conducted in response to RAI-28 on ANP-10278P. Graphical results were presented to illustrate the magnitude of the reactor coolant system (RCS) pressure spike as predicted. In addition, the effect of the axial power shape skew on the predicted upper plenum pressure was presented for bottom-peaked, mid-peaked, and top-peaked axial power profiles. The applicant also presented a comparison of peak cladding temperature (PCT) predictions for the base case and the sensitivity case. A summary plot showing the effect of accumulator nitrogen isolation on the predicted PCT for all cases was also provided.

At the end of the topic's presentation, the applicant proposed conclusions as listed in Reference 1.

Accumulator Minimum Temperature

The applicant stated that the RLBLOCA model applies the sampled value of the containment temperature to the accumulators and the containment vapor and liquid. RAI-24 on ANP-10278P questioned the containment temperature sampling range used. It was pointed out that the initial lower bound of the containment temperature sampling range was related to the Technical Specification minimum temperature for the in-containment refueling water storage tank (IRWST)

(Technical Specification Surveillance Requirements (SR) 3.5.4.1), recognizing that the staff considered this lower limit too low for a best-estimate plus uncertainties. To address this issue, the applicant presented operating plant results and values from ANP-10299P and containment analysis in order to justify a more realistic minimum temperature for the sampling range.

A basis for the new lower bound of the sampling range was presented, taking into account the expected operating range of the U.S. EPR IRWST temperature and experience from currently operating plants. Using this information, the applicant proposed a new value for the accumulator minimum temperature.

At the end of the presentation, AREVA presented conclusions as shown on slide 18 of Reference 1.

RODEX3 Topics

The presentation on RODEX3 included four different sub-topics formulated as follows: (1) RODEX3 data base; (2) sensitivity study on centerline fuel temperature; (3) maintaining FUELK in transient; and (4) review of average core treatment plans. Each sub-topic is addressed below.

1. RODEX3 Data Base: For the discussion of the RODEX3 data base, the applicant presented several plots comparing RODEX3A predictions to data. The applicant presented a potential further adjustment in order to compensate for discrepancies between the code and data.

2. Centerline fuel temperature: To demonstrate the associated impact of increases in the fuel centerline temperature, the applicant presented several plots on a sensitivity study to determine the effects of an increase in fuel centerline temperature on PCT.

3. FUELK in transient: Under this sub-topic, the applicant addressed the observation that the value of FUELK is set to unity for transient analyses even though it may have been less than unity for initialization of the steady-state calculation. The applicant was asked to justify the values used for FUELK. A presentation was given that attempted to justify the maintenance of FUELK during the transient by claiming that using a value less than unity would be less conservative. Temperature history results were shown for specific cases during the transient, and overall effects were provided for all cases run in a summary plot. The applicant concluded that the maintenance of FUELK at unity was sufficient, but requested staff feedback in a future public meeting.

4. Average Core: The applicant discussed a potential modification to a certain portion of the calculation, and recommended no change in the methodology as shown on slide 31 of Reference 1. The average core topic will be discussed in more detail in subsequent meetings in October 2009.

For all the RODEX3 topics, the applicant requested staff feedback in a subsequent meeting. The staff committed to provide feedback in a meeting in October 2009, after reviewing the material presented and holding internal discussions.

Lower Plenum Refill

The lower plenum (LP) filling issue was related to the staff observation that the predicted start of reflood occurred before the LP was full of liquid. For the U.S. EPR RLBLOCA limiting case, predictions exhibited significant flow into the core before the LP was liquid full, as evidenced by the computed void fraction distribution for this region.

In addressing the issue, AREVA presented an extensive assessment aimed at demonstrating that in spite of LP not being full at the start of reflood, the calculations showed that the start time of reflood was modeled correctly-to-conservatively, based on detailed evaluation of the liquid distribution in the primary system. The timing of the start of reflood as calculated for the U.S. EPR RLBLOCA methodology was further justified with additional considerations of experimental data, system code limitations, relevant correlations and evaluations, and benchmarks.

Providing relevant experimental observations, the applicant referred to several separate and integral tests conducted in the Upper Plenum Test Facility to investigate emergency closed cooling (ECC) penetration and counter-current flow phenomena in the downcomer of a pressurized water reactor (PWR) during the end-of-blowdown and refill portions of an LBLOCA. The conclusions drawn by the applicant from the experimental evidence are shown on slide 45 of Reference 1.

The applicant provided a presentation on system code limitations in predicting LP refill. With regard to S-RELAP5 benchmarking, the applicant referred to a correlation that was based on experimental test data to calculate liquid downflow in the downcomer during the refill phase. AREVA used this correlation in a deterministic approach to calculate complete end-of-bypass. The applicant concluded that predicted beginning times of LP fill were delayed while the LP fill rates were under-predicted, and that the results were consistent with code limitations in predicting separated flow distributions in the downcomer as identified in Reference 1.

In conclusion, the applicant stated that S-RELAP5 conservatively calculated the timing of start of reflood in the U.S. EPR RLBLOCA cases, justifying it with the arguments listed on slide 66 of Reference 1.

Decay Heat

The presentation by the applicant on this topic addressed the following four main areas: (1) Staff approval in Regulatory Guide (RG) 1.157; (2) The 1979 American National Standards Institute (ANSI) and American Nuclear Society (ANS) Standard and Uncertainty; (3) energy per fission; and (4) sensitivity studies.

1. RG 1.157: The applicant pointed to Section B in RG 1.157, which states that “the current revision of Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46 permits ECCS evaluation models to be fully ‘best-estimate’ and removes the arbitrary conservatisms.…” Furthermore, the applicant referred to Item 3.2.4, “Fission Product Decay Heat,” of Section C, “Regulatory Position,” in RG 1.157 Section B, citing that, “the heat generation rates from radioactive decay of fission products, including the effects of neutron capture, should be included in the calculation and should be calculated in a best-estimate manner ….” The model in Reference 10 is considered acceptable for calculating fission product decay heat.” Reference 10 in RG 1.157 is the ANSI/ANS-5.1-1979 Standard, “Decay Heat Power in Light Water Reactors.”

2. Addressing the ANSI/ANS-5.1-1979 Standard, "Decay Heat Power in Light Water Reactors," the applicant reproduced the first 18 tabulated entries in Table 4, "Tabular Data for Standard Decay Heat for Thermal Fission of ^{235}U and for Irradiation of 10^{13} Seconds," of the Standard representing the initial 80 seconds (s) after shutdown. In addition, the behavior of the one-sigma uncertainty interval for ^{235}U decay heat documented in Table 4 was presented graphically for the time interval from 0 s to 200 s, pointing out the change of this parameter in time.

3. Discussing the energy per fission quantity, the applicant stressed the fact that the value assumed in the RLBLOCA decay heat application amounts to 200 mega electron volts (MeV). In this regard, it was stated that the values appropriate for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu are approximately 202 MeV, 205 MeV, 211 MeV, and 214 MeV, respectively. With the fresh fuel containing only ^{235}U and ^{238}U and no radiation exposure, the applicant cited a minimum margin value greater than one percent with the margin amount building up to several percent as the exposure increases.

4. A summary plot presenting the sensitivity effect of fixing the decay heat multiplier at 1.06 on the predicted PCT results for all cases was provided. The effect of fixing the decay heat multiplier on the maximum PCT temperature was noted by the staff.

The applicant presented the following conclusions as listed on slide 73 of Reference 1.

The applicant requested feedback on the decay heat issue from the staff in a subsequent meeting. The staff took action to provide feedback at a public meeting in October 2009.

AUDIT FINDINGS

The September 15, 2009, RLBLOCA audit was performed successfully at the AREVA Twinbrook office in Rockville, MD. The information presented by the applicant provided the staff with a better understanding of the approach the applicant intended to use to address staff concerns and technical issues related to the safety evaluation of the FSAR and associated technical and topical reports.

During the exit meeting, the applicant committed to provide the staff with a revised topical report containing revised methodology based on the work currently underway. The applicant will meet with the staff regularly to present information that will be contained in the revised topical report, which will be submitted in January 2010. A subsequent public meeting will be scheduled to provide feedback to AREVA regarding several technical issues. A concluding summary discussion with all meeting participants took place at the end of the audit to determine follow-up action items.

ACTION ITEMS

At the conclusion of the September 15, 2009, audit on RLBLOCA methodology, AREVA reviewed the list of items for which staff feedback is requested to allow informed decisions to be made regarding the methodology for performing the revised U.S. EPR FSAR Chapter 15 RLBLOCA calculations. For the first six of the following seven items, staff feedback was described as necessary prior to initiation of the final set of U.S. EPR FSAR Chapter 15 RLBLOCA calculations.

1. Initial stored energy in hot rod and hot assembly: AREVA proposed an adjustment to RODEX as presented.

2. Initial stored energy in average and peripheral assemblies: AREVA proposed to use the approach presented. If this approach is accepted by the staff, there would be no penalty applied.

3. FUELK adjustment: AREVA proposed to implement the adjustment in the transient so that no direct PCT penalty is associated with this action.

4. Accumulator/containment temperature: AREVA proposed an adjusted temperature range to be more consistent with operating experience.

5. Accumulator nitrogen injection: AREVA requests staff feedback on whether or not to include accumulator nitrogen injection in the calculations. AREVA showed the effect of accumulators emptying when nitrogen injects and that S-RELAP5 appropriately predicts the effect. It would be reasonable to continue to allow nitrogen injection. An alternative is to isolate the accumulators when they are close to empty to prevent nitrogen injection. This analytical action has been shown to produce a conservative PCT.

6. Decay heat: AREVA proposes to use the approach as originally presented in ANP-10278, Revision 0.

7. LP refill and oscillations: AREVA showed that the figure of merit is conservatively calculated (specifically, at the start of reflood). AREVA proposes no change to methodology and no PCT penalty. Staff feedback on this item is not necessary to initiate Chapter 15 calculations.

The staff took action to deliberate on the information provided during this audit and schedule a subsequent public meeting to provide feedback on the issues listed in early October 2009.

AREVA took action to provide the audit slides, both non-proprietary and proprietary versions, to the staff for Agencywide Documents Access and Management System processing. This action resulted in the generation of Reference 1.

AREVA took action to provide the data used to generate slide 20 of Reference 1 for audit in the near future.

REFERENCES

1. AREVA NP, Inc., “U.S. EPR Design Certification Review RLBLOCA Methodology Audit,” Presentation at the AREVA-NRC Audit, Rockville, MD, September 15, 2009. ML092740593.

Table 1: Audit Agenda

Item No.	Time	Item	Responsible
		09/15/2009	
1	9:00 a.m. – 9:15 a.m.	Opening remarks, presentation of participants, organizational questions.	F. Forsaty (NRC)
2	9:15 a.m. – 12:00 p.m.	Presentation by AREVA on accumulator nitrogen injection, accumulator minimum temperature, and RODEX4 database.	AREVA
3	1:00 p.m. – 4:00 p.m.	Presentation by AREVA on remaining RODEX issues, FUELK applications, and other issues related to U.S. EPR FSAR Chapters 4 and 15.	AREVA
4	4:00 p.m. – 4:15 p.m.	Audit Summary / Exit	NRC and AREVA

Attendee List

AUDIT TO REVIEW SELECTED AREAS RELATED TO U.S. EPR FINAL SAFETY ANALYSIS REPORT CHAPTER 15 AND SUPPORTING TECHNICAL/TOPICAL REPORTS SAFETY EVALUATION

September 15, 2009, AREVA NP, Inc., Rockville, Maryland

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Shanlai Lu	NRC
Fred Forsaty	NRC
David Caraher	ISL, Inc.
Eugene Moore	AREVA
Liliane Schor	AREVA
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Attachment B

DC AREVA - EPR Mailing List (Revised 06/23/2010)

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