February 2, 2010

Ms. Sandra Sloan
AREVA NP, Inc.
3315 Old Forest Road
P.O. Box 10935
Lynchburg, VA 24506-0935

SUBJECT: AUDIT REPORT FOR JUNE 25, 2009, AUDIT TO REVIEW SELECTED AREAS RELATED TO THE U.S. EPR FSAR CHAPTER 19

Dear Ms. Sloan:

On June 25, 2009, the Nuclear Regulatory Commission (NRC) staff conducted an audit at the AREVA office in Rockville, MD, to review selected information related to Chapter 19 of the U.S. EPR design certification (DC) application Final Safety Analysis Report (FSAR). The purpose of this audit was to compare results of calculations obtained by AREVA NP using modular accident analysis program (MAAP) with those obtained by the NRC Office of Research (RES) using the MELCOR code, of representative severe accident scenarios for the U.S. EPR.

The NRC Probabilistic Risk Assessment (PRA) staff audited dozens of documents that describe U.S. EPR probabilistic risk assessment and severe accident analysis. These documents are first-tier references in Chapter 19 of the docketed U.S. EPR Final Safety Analysis Report (FSAR) and include a level of detail higher than is required in the FSAR. However, auditing such information allows the staff to conduct its review more efficiently. Specifically, the staff gains a better understanding of the basis underlying the formal application and identifies areas where additional information should be submitted to allow a licensing decision on the application.

The review of additional technical documents was facilitated by the presence of AREVA personnel at the audit. The enclosed report presents the details of the audit activity.

The staff concludes that the enclosed report does not contain any information for which exemption from public disclosure has been sought or approved. However, the NRC will withhold the enclosed report from public disclosure for ten calendar days from the date of this letter to allow you the opportunity to verify the staff's conclusion that the report contains no such exempt information. If within that time, you do not request that all or portions of the report be withheld from public disclosure in accordance with 10 CFR 2.390, "Public Inspections, Exemptions, Requests for Withholding," the enclosure will be made available for public inspection through the NRC's Public Document Room and the Publicly Available Records component of the NRC's ADAMS. ADAMS is accessible from the Public Electronic Reading Room section of the NRC Web site at http://www.nrc.gov/reading-rm/adams.html.

If you have any questions regarding this matter, please contact me at 301-415-3361.

Sincerely,

/RA/

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

Docket No.: 52-020

Enclosure:
As stated

cc: DC AREVA - EPR Mailing List

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/RA/

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APPLICANT: AREVA NP, Inc.

PROJECT: U.S. EPR DESIGN CERTIFICATION

SUBJECT: AUDIT REPORT FOR JUNE 25, 2009, AUDIT TO REVIEW SELECTED AREAS RELATED TO THE U.S. EPR FSAR CHAPTER 19

1.0 INTRODUCTION

The Nuclear Regulatory Commission (NRC) staff conducted a confirmatory assessment of several severe accident scenarios in the U.S. EPR, using the MELCOR 1.8.6 code. As a consequence, some significant differences from the AREVA MAAP 4.0.7 results were obtained.

In order to cover important review areas handled by the Office of New Reactors (NRO) Probabilistic Risk Assessment (PRA) and Severe Accidents Branch staff carried out an audit at the AREVA office in Rockville, MD on June 25, 2009, to help resolve existing questions in accomplishing the U.S. EPR review schedule in an efficient manner. The purpose of this audit was to compare results of calculations obtained by AREVA NP using modular accident analysis program (MAAP) with those obtained by the NRC Office of Research (RES) using the MELCOR code, of representative severe accident scenarios for the U.S. EPR. The scenarios include depressurized station blackout (SBO) with and without containment isolation failure, high pressure SBO with molten core-concrete interaction (MCCI), and main steam line break (MSLB) inside containment. Attachment A of this report contains an agenda of the audit activities.

2.0 PARTICIPANTS

The following NRC staff members from the NRO, Division of Safety Systems and Risk Assessment (DSRA) and Division of New Reactor Licensing (DNRL) participated in the audit:

- E. Fuller (Audit Team Leader)
- L. Mrowca (Chief of PRA Licensing, Operational Support, and Maintenance Branch 1)
- H. Phan (Senior Risk & Reliability Analyst)
- S. Schroer (NSPDP General Engineer))
- I. Madni (Office of Research)
- H. Esmaili (Office of Research)
- M. Salay (Office of Research)
- P. Chowdhury (Project Manager)

The following NRC contractors from Energy Research Incorporated (ERI) participated in the audit:

- M. Khatib-Rahbar
- M. Zavisca
- P. J. Fulford

The following key individuals from the applicant's organization participated in the audit on a regular basis:

- R. Martin
- R. Sanders

- W. Szymczak
- S. Sloan
- D. Noxon

There were a number of other participants from AREVA via teleconference.

3.0 AUDIT ACTIVITIES

The audit was conducted by a team of NRC staff and contractor personnel knowledgeable in the U.S. EPR PRA and severe accident evaluations. The audit covered the comparisons of the simulations of the representative severe accident scenarios performed by the applicant and the NRC contractor (ERI).

3.1 Synopsis

The NRC Project Manager, Prosanta Chowdhury, opened the meeting and stated that the purpose of this audit is to compare MELCOR 1.8.6 code severe accident scenario results obtained by the NRC Office of Research against MAAP 4.0.7 results for similar scenarios as reported in the AREVA NP Response to RAI 22, Question 19-161 and supporting Design Certification Documentation for the U.S. EPR. The scenarios selected for discussion include depressurized SBO with and without containment isolation failure, high pressure SBO with MCCI, and main steam line break (MSLB) inside containment. The Document Audit plan is to be available as ADAMS document accession number ML091750957.

The meeting detailed technical discussions were based on the scenario analysis methodology and results presented in an interim report[1] prepared by ERI/NRC. These were led by Dr. Edward Fuller, the Audit Team Leader and the lead NRO Level 2 PRA and Severe Accident Evaluation reviewer, Dr. Robert Martin, the AREVA MAAP analyst, and Dr. Mohsen Khatib-Rahbar, the ERI project manager for the Level-2/-3 PRA and Severe Accident review and the MELCOR confirmatory analyses. These discussions centered on the areas of agreement, possibly significant differences, and the factors that could be contributing to these differences. In general, the results were found to be in fairly good agreement with no major points of divergence. Some discrepancies were identified that will require follow-up information exchanges, requests for additional information (RAIs) and clarifications) for resolution. At the conclusion of the meeting, Edward Fuller laid out the path and timing for achieving closure on the audit results.

3.2 Technical Discussions

3.2.1 Methods and Models

The MELCOR 1.8.6 input model for U.S. EPR is one of the most detailed and complex one that ERI has developed over the last twenty years. The modeling for the effects on core melt progression of the heavy reflector around the core, the reactor pit with its melt plug, and provision for hot leg/steam generator counter-current natural circulation needed special attention. Some of the specific design features are not available as modeling options in MELCOR and work-arounds were required.

[1] Z. Yuan, et al., "Comparison of MELCOR and MAAP Results for Selected U.S. EPR Severe Accident Scenarios," June 25, 2009 (Contains AREVA Proprietary Data - limited distribution).

The set of accident scenarios were selected to retain conditions that are as close as possible to the AREVA/MAAP cases.

Some MELCOR deck liquid/gas flow paths modeled between lower level containment volumes may need further definition of the opening pressures. There also may be some drain paths that have not been modeled (or accounted for) that will require further design information from AREVA.

3.2.2 MELCOR Scenario S1 - Equivalent to MAAP Scenario st_1_5bar

This scenario is an SBO-induced reactor coolant pump (RCP) seal loss of coolant accident (LOCA) with severe accident heat removal system (SAHRS) passive flooding, containment sprays and passive autocatalytic recombiners (PARs) available, but no safety injection (SI) or feedwater (FW). The containment is intact. The two codes produced similar in-vessel melt progression temperature, pressure, and water level traces, with the MAAP traces leading the MELCOR results by about 1/2 hour. Local reactor pressure vessel (RPV) failures occurred at about the same time, and the corium melt temperature at the time of melt relocation to the reactor pit was about 200K lower in the MELCOR calculation as compared to MAAP predictions.

Furthermore, the MAAP maximum corium mass in the pit was higher by some 60 tons. The MELCOR-calculated time for corium relocation (melt plug failure) to the spreading area was about 1/2 hour after the RPV failure while the MAAP-calculated time was 3 hours after RPV failure. The bulk temperature at melt plug failure was about 600 K higher in the MAAP case. Differing timing of SAHRS water transfers raised some questions regarding external rapid steam pressurization in the escape channel and the spreading room. The subsequent start of the SAHRS containment spray occurred 12 hours earlier in MAAP compared to MELCOR, due to an approximately 2 times faster containment pressurization rate. The rapid pressurization rate inside containment as predicted by MAAP was noted to have been observed in other plant calculations by ERI, and the reasons for these differences cannot be reconciled at this time.

Some possible contributing factors to the above inconsistencies discussed were: The choice of phenomenological models such as for MCCI, utilization of a forcing function algorithm for the MAAP steaming rate in the core spreading area, treatment of radiation heat transfer from the corium in the pit upwards into the reactor pressure vessel structures, differences in the reference levels, model flow junction levels and opening pressures, and different treatment of the fraction of the RPV lower head mass added to the corium in the pit. AREVA noted that, depending on pour rates and residual core delayed releases from the vessel, the pit gate failure time could vary by several hours. The plant is designed to accommodate such uncertainties. It was also noted that MAAP input parameter values were chosen such as to bias the results towards higher temperatures.

It was noted that the current MELCOR design basis leakage calculations need to be changed to reduce the frictional pressure drop through the leakage path (i.e., reduce the long flow path length for very small diameter leakage path). This change is expected to result in design basis leakage environmental radioactivity releases for the intact containment cases that are closer to those of the MAAP EPR calculations.

3.2.3 MELCOR Scenario S2 - Equivalent to MAAP Scenario St1.5

This scenario is similar to Scenario S1 except that containment sprays are unavailable and the containment has a one inch diameter isolation failure. The results and observations for this comparison set are not considered to be significantly different from the preceding set and no discussion occurred in the meeting regarding the information presented in the handout report. However, in this case, the calculated fission product releases (as exemplified by Xe group) are in reasonable agreement (i.e., containment isolation failure).

3.2.4 MELCOR Scenario S4 – Equivalent to MAAP Scenario st1-10a (approximately)

This scenario is an SBO-induced hot leg rupture with PARs available, the SG valves are not assumed to stick open at core uncovery, but it is assumed that there is no primary system depressurization, SI, feedwater flow, SAHRS containment spray, and SAHRS passive flooding. The containment is intact. The MAAP event progression leads MELCOR by about one hour. (AREVA noted a transcription error in the reported MAAP event times which will be corrected in an RAI supplemental update.)

Cumulative hydrogen generation during the ex-vessel phase was notably higher and continuing (for 40 hours) in the MELCOR results. The MAAP results showed little production after 20 hours. Since the total amount of hydrogen is limited by the amount of unoxidized metal, this anomaly is presumably traceable in large part to differing in-vessel/ex-vessel splits of oxidation. Differences in concrete erosion were found with the MAAP rates being greater than the MELCOR ones.

3.2.5 MELCOR Scenario S5 - Equivalent to RELAP5/MAAP Scenario

This scenario is a main steam line break inside containment with feedwater, PARs, and SAHRS passive flooding available, but no SI, primary- or secondary-side depressurization, and no SAHRS containment sprays.

A point kinetics model was developed by ERI and introduced via the Control Function features into MELCOR 1.8.6 to allow comparison with the TRACE 3D three-group diffusion theory model results for exactly the same EPR scenario (using the MELCOR calculated inlet temperature into the reactor pressure vessel as forcing function). The reactivity feedback coefficients were based on the values provided by AREVA in response to an NRC RAI. The reactor was found to remain subcritical for the duration of the accident, and core damage did not occur within 48 hours. Therefore, recriticality is not an issue of concern for the EPR, due to the very large shutdown margin that appears to be available.

The containment pressurization (both in the early, post-steam line break phase, and over the long term) as predicted by RELAP5/MAAP is much higher than that calculated by MELCOR. Various sensitivity calculations, including a simple analytic solution, did not produce an explanation for the observed differences. AREVA will re-examine their calculations for this scenario, in particular the RELAP/MAAP interface. MAAP data for this comparison was derived from the response to RAI 22, Question 19-160.

3.2.6 Observations

The results from the AREVA and ERI/NRC calculations showed reasonable good agreement in various figures-of-merits. Differences that did occur have often been seen in similar comparisons for other plants. Some discrepancies were identified that will require follow-up information exchanges (RAIs and clarifications) for resolution. A list of such items is given in Section 4 (reproduced from page 57 of the ERI/NRC presentation).

4.0 SUMMARY OF AUDIT FINDINGS

The following are reproduced from the ERI/NRC presentation:

- Generally, MELCOR-predicted in-vessel hydrogen generation is lower than the MAAP predictions.
- The time duration from vessel breach to reactor pit melt plug failure is much shorter in MELCOR. The actual plug melt-through is dependent on the quantity, temperature, and (possibly) composition of core debris relocating from RPV into the reactor pit.
- The MAAP-predicted debris temperature in the reactor pit prior to the melt plug failure is 500~600 K higher than the MELCOR predictions
- MELCOR results show that the entire core debris content may not be in the reactor pit by the time the reactor plug melt-through occurs.
- Ex-vessel hydrogen production for S4 is higher in MELCOR even though the concrete erosion rate is lower than in MAAP.
- Predicted core debris cool-down rate is faster in MELCOR as compared with MAAP.
- MELCOR-predicted temperature in the spreading room is lower (due to lower initial temperature as compared with MAAP).
- The rate and magnitude of containment pressurization appear to be significantly higher in MAAP as compared to MELCOR.
- Containment pressurization is significantly greater in MAAP (even in comparison to a conservative calculation) than MELCOR for the MSLBI.
- Two pressure-dependent flow paths connecting the lower annular rooms to the IRSWT tank open in the MELCOR calculations for scenario S1. This does not appear to be the case for the MAAP simulation.

5.0 SUMMARY OF EXIT MEETING

The staff conducted an exit meeting with the applicant during the last hour of the day. The individuals listed in Section 2.0 above participated in the meeting. The staff summarized its activities during the audit and some additional information was identified as being required to complete the confirmatory assessment. The staff would prepare a new set of RAI questions.

6.0 RAIs ISSUED

The staff has issued RAI No. 262, Questions 19-319 through 19-326 based on the results of the audit.

Attachment A

AGENDA

NRC Chapter 19 U.S. EPR Design Certification Safety Evaluation
Confirmatory Assessment Comparison Audit

Thursday, June 25, 2009

AREVA NP, Inc., Twinbrook Office, Rockville, MD

AUDIT – proprietary

9:00 a.m. - 9:15 a.m.	Introduction	[NRC/AREVA NP]
9:15 a.m. - 10:00 a.m.	MELCOR Model and Nodalization	[NRC]
10:00 a.m. - 10:50 a.m.	MELCOR and MAAP Results for Selected Severe Accident Scenarios	[NRC/AREVA NP]
10:50 a.m. - 11:05 a.m.	Break	
11:05 a.m. - 12:05 p.m.	Discussion of Calculation Differences/ Documentation Review and Audit	[NRC/AREVA NP]
12:05 p.m. - 1:05 p.m.	Lunch	
1:05 p.m. - 2:40 p.m.	Discussion of Calculation Differences/ Documentation Review and Audit (cont.)	[NRC/AREVA NP]
2:40 p.m. - 2:55 p.m.	Break	
2:55 p.m. - 4:00 p.m.	Summary and Exit Meeting	[NRC/AREVA NP]
4:00 p.m.	Adjourn	