February 14, 2017

Ms. Lesa Hill, Chairman
Boiling Water Reactor Owner's Group
Southern Nuclear Operating Company
c/o GE Hitachi
BWROG
3901 Castle Hayne Road
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Wilmington, NC 28401

SUBJECT: BOILING WATER REACTOR OWNERS' GROUP EMERGENCY CORE COOLING SYSTEM SUCTION STRAINER PROJECT - U.S. NUCLEAR REGULATORY COMMISSION STAFF AUDIT SUMMARY OF A RISK-INFORMED APPROACH TO POTENTIAL ISSUE(S) RESOLUTION

Dear Ms. Hill:

On February 23 and 24, 2016, the U.S. Nuclear Regulatory Commission (NRC) staff conducted a regulatory audit at the Albuquerque Nuclear Safety Divisions (NSD) branch of Alion Science and Technology in Albuquerque, New Mexico. The objective of the audit was to gain a better understanding of the Boiling Water Reactor Owners' Group (BWROG) approach to implementing a risk-informed evaluation of the technical issues identified in the John A. Grobe (NRC) to Richard Anderson (BWROG) letter dated April 10, 2008, "Potential Issues Related to Emergency Core Cooling Systems (ECCS) Strainer Performance at Boiling water Reactors" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML080500540). The BWROG first introduced its risk-informed approach in December of 2014 during a public meeting with NRC staff (ADAMS Accession No. ML14357A048).

The NRC regulatory audit is the second in a planned series of three with the BWROG, which aligns with the BWROG's development of the Phase II, III, and final Phase IV reports respectively. A public meeting was held on December 2, 2015, with representatives of the BWROG ECCS Suction Strainer Risk-Informed Project Committee (ADAMS Accession No. ML16181A264) where an agreement was reached between the NRC staff and BWROG representatives to hold the audit at the Alion Science and Technology offices. A specific goal of the NRC staff was to evaluate the BWROG's technical approaches implemented in support of the methodology for its risk-informed approach and to identify related verification and validation activities.

The enclosure to this letter describes the results of the NRC staff's audit and some of the key technical issues highlighted by the staff during the audit. The NRC staff and the BWROG will continue discussions for resolution of the technical issues during the future interactions.

If you have any questions or require additional information, please contact me at 301-415-8378 or via electronic mail at Jason.Drake@nrc.gov.

Sincerely,

/RA/

Jason J. Drake, Project Manager
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Office of Nuclear Reactor Regulation

Project No. 691

Enclosure:
As stated

cc w/enclosure: See next page

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NRC STAFF AUDIT SUMMARY

BOILING WATER REACTOR OWNERS' GROUP

RISK-INFORMED EMERGENCY CORE COOLING SYSTEM

SUCTION STRAINER PROJECT

1.0 Background

The objective of this audit was to gain an overall understanding of the Boiling Water Reactor Owners' Group (BWROG) proposed methodology that would address the technical issues identified in the John A. Grobe (NRC) to Richard Anderson (BWROG) letter dated April 10, 2008, "Potential Issues Related to Emergency Core Cooling Systems (ECCS) Strainer Performance at Boiling Water Reactors" (Agencywide Documents Access and Management System (ADAMS) at Accession No. ML080500540). A description of these issues and the proposed BWROG risk-informed approach is available at ADAMS Accession No. ML14337A227. The audit was conducted at the Alion Science and Technology (BWROG contractor) offices in Albuquerque, New Mexico on February 23 and 24, 2016. The audit was conducted in accordance with Office of Nuclear Reactor Regulation Office Instruction LIC-111 (ADAMS Accession No. ML082900195).

The following NRC staff members participated in the audit:

- Victor Cusumano, Chief, Safety Issues Resolution Branch (overall NRC lead)
- CJ Fong, Technical Reviewer, Probabilistic Risk Assessment (audit team leader)
- Stephen Smith, Technical Reviewer, Debris Generation & Transport
- Shilp Vasavada, Technical Reviewer, Probabilistic Risk Assessment
- Osvaldo Pensado, NRC Contractor/SwRI
- John Bickel, Consultant to NRC Contractor/SwRI

The BWROG was represented by the following personnel:

- Larry Naron, BWROG/Exelon
- Phil Grissom, BWROG/Southern Nuclear
- Larry Lee, Jensen Hughes
- Bruce Letellier, Alion Science & Technology
- Benjamin Bridges, Alion Science & Technology
- Dominic Muñoz, Alion Science & Technology
- William Cook, Alion Science & Technology
- Jeremy Tejada, SIMCON
- Kent Sutton, iNgrid Consulting
- Michael Iannantuono, BWROG/GEH

Enclosure

2.0 Technical Areas Discussed During the Audit

Several technical discussions were conducted during the audit on the following items:

- BWROG responses to several questions and comments that the NRC staff had raised during the December 2nd public meeting (ADAMS Accession No. ML16181A264) on the BWROG 1st Pilot Plant Evaluation (designated as "Phase II").

- BWROG methodology and results for the 2nd Pilot Plant Evaluation (designated as "Phase III").

- BWROG plan for the fleet-wide evaluation ("Phase IV") including an outline of the proposed approach for the performance and documentation of Phase IV results. The proposed approach included using the information obtained from the Phases II and III analysis to develop a matrix of key parameters ("salient features") to compare individual plant features and capabilities. BWROG proposed a tiered approach wherein some plants would not be considered further due to limited availability of fibrous debris, others would be treated using the approach presented in Phase II and the remainder would be subject to individual (case-by-case) analyses.

The audit team met the objectives defined in the audit plan, which included:

2.1 Probabilistic Risk Assessment (PRA)

- The audit team confirmed that the scope and level of detail of the PRA used in the Phase III analysis was similar to the Phase II PRA. The audit team stated that using a PRA of sufficient quality that is subjected to a peer-review in accordance with the guidance in RG 1.200 would facilitate the review process. The audit team suggested that PRA quality be one of the "salient features" in the Phase IV evaluation.

- The audit team stated the staff's position that all events that can be credibly shown to generate and transport debris should be should be evaluated or screened. The analysis should be expanded to consider all internal and external hazards per the Regulatory Guide (RG) 1.174 and not solely the design basis events (e.g., loss-of-coolant accidents (LOCAs)) as currently proposed. Initiating events that can be demonstrated to generate and/or transport insufficient debris amounts or to not result in the activation of the recirculation function of the ECCS may be excluded from further consideration. The audit team clarified that qualitative arguments may be used for such exclusions, as long as such arguments are technically consistent and justified.

- BWROG discussed a sensitivity performed and documented in the Phase II report in response to an open item from the August 2015 audit (ADAMS Accession No. ML15238B610). The open issue was addressed with a sensitivity case considering plant response to debris with one train unavailable (planned or unplanned). The audit team stated that consideration of plant configurations and

equipment unavailability (as shown in a BWROG sensitivity) in future analyses would facilitate the staff's review.

- The BWROG addressed an open item from the August 2015 audit (ADAMS Accession No. ML15238B610) related to the lack of details about the ΔLERF metric in accordance with RG 1.174. The BWROG offered an approach and additional information to support the conclusion that ΔLERF is small. The audit team informed BWROG that continued calculation and documentation of ΔLERF, or providing semi-quantitative rationale to conclude that ΔLERF is small, with respect to RG 1.174 acceptance guidelines, would facilitate the staff's review.

- The BWROG approach to determining the time available for operator actions based on deterministic results and operator interviews was discussed. BWROG provided information regarding development of Human Error Probabilities (HEPs) used in the PRA analysis for operator actions.

- The audit team reviewed the proposed BWROG approach for Phase IV that would identify key parameters (termed "salient features") for sump blockage from Phase II and Phase III. The audit team stressed the importance of a relatively comprehensive list of key parameters influencing the ΔCDF and ΔLERF based on agreement between the NRC staff and BWROG. The audit team stated that appropriate quantification of each "salient feature" was essential to facilitate the staff's review.

- BWROG also indicated its preference to use a threshold value of fibrous bed thickness of 1/8 inch to indicate strainer failure probability to support ΔCDF and ΔLERF computations. The audit team stated that the use of such a threshold value is promising as it would address the staff's concerns regarding the use of empirical correlations estimate head loss across debris-loaded strainers. However it was noted that the 1/8 inch criterion may not be justified as a threshold when problematic materials are present in the containment. BWROG indicated that an appropriate justification for the use of the threshold or thresholds will be provided.

- BWROG used NUREG-1829 to derive the LOCA initiating event frequencies for their analysis and indicated that Phase IV implementation will also use that source material. BWROG used the NUREG-1829 frequencies as a function of the break size. The audit team noted that the NUREG-1829 frequencies were categorized based on the flowrate from the break which was then converted to an effective break size. The audit team requested BWROG to examine NUREG-1829 frequencies, break locations, and flowrate categorizations to ensure the information is consistently used, or justify alternative approaches.

- The audit team stated that assurance and discussion of performance monitoring in accordance with RG 1.174, Principle 5, will be important in facilitating the staff's review. The staff stated that the process to monitor and track the important factors contributing to the debris generation and sump strainer

blockage should be documented and included in the Phase IV report. The audit team noted that proposed processes can include current plant programs.

- The BWROG discussed the format and content of the Phase III final report and subsequent documentation with the audit team. The audit team noted that some discussion points from the audit (e.g., calculation of ΔLERF, inclusion of all credible scenarios) should be included in the Phase III report.

2.2 Deterministic Methodologies

- The audit team reviewed the BWROG responses to the comments and questions raised in the December 2nd public meeting (ADAMS Accession No. ML16181A264) regarding the deterministic analyses performed in Phase II.

- The audit team stated that a sensitivity for the timing of debris introduction to the SP might provide justification that the timing chosen by the BWROG is reasonable. The staff stated that realistic timing would include the immediate introduction of most of the fine and small debris generated by the break, followed by the introduction of debris from erosion and washdown over a longer period of time. However, the current analyses assume that debris is trapped permanently in the strainers after the associated pumps are shut off. BWROG and the audit team discussed the behavior of the debris accumulated on the screen after the pump(s) drawing from that screen are secured. Based on the discussion BWROG stated that alternative assumptions will be explored to deal with "sequestered" debris, including complete re-mixing (with the SP water) of the debris that is trapped in the strainers with shut-off pumps.

- BWROG presented a methodology, termed Probability of Exceeding a Tested Threshold (PETT), for consideration of debris and resulting blockage for the Phase III plant that was different from that used for the Phase II plant. BWROG stated that the reason for departure from the Phase II methodology was due to different plant design and debris types. The audit team preliminarily reviewed and discussed the methodology and its implementation. BWROG also presented several sensitivities to capture a number of Grobe letter issues using the PETT approach.

- The audit team reserved judgement and feedback on the PETT method. The team stated that it required more time to understand the basis and application of the method to determine its appropriateness.

- The audit team raised an issue about the consistency of the suppression pool (SP) cooling assumption across the analysis methods (e.g., CASA Grande code and the PRA model) used in Phase II and Phase III. BWROG agreed to perform a sensitivity study to capture the issue raised by the team.

- The audit team questioned BWROG's definition of core damage applied for the MAAP simulations where exceeding 1800 °F for 10 minutes was considered as a surrogate to core damage. BWROG stated that the definition is from the plant-

specific PRA model but agreed to provide assurance that the success criteria was being applied in a technically justifiable manner. The audit team requested investigating whether temperature spikes would exceed the temperature threshold of 1,800 °F.

- The audit team raised the issue of uncertainty considerations in decay heat input (the General Electric Service Information Letter (SIL)-636 issue) in the MAAP simulations used to compute the time to core damage. BWROG stated that the cited uncertainty/correction was not currently accounted for and agreed to include it in future analysis.

2.3 Integrated (PRA and Deterministic)

- The audit team stated that the staff will require reasonable assurance about the effectiveness of the walkdown and surveys performed for plant-specific debris sources as a condition of issue closure. BWROG informed the staff of the planned process of performing the surveys and walkdowns.

- The audit team reviewed additional information provided by the BWROG related to defense-in-depth measures that could be implemented if strainer clogging were to occur including timing considerations and pilot plant-specific details. BWROG stated that if a particular defense-in-depth action (e.g., backflush) is present in the procedures of only a few plants, such actions will not be credited in Phase IV.

- The audit team provided additional information about the NRC staff's position on defense-in-depth.

3.0 Exit Meeting

The audit team presented the following comments to the BWROG representatives and contract staff at the conclusion of the audit:

- The audit team agreed with tentatively scheduling a public meeting in June 2016 to discuss the Phase III results.

- The audit team recognized the potential merits of the BWROG's decision to use a 1/8 inch fibrous debris bed thickness as a threshold for sump strainer failure in Phase IV but noted that further evidence demonstrating the adequacy of the threshold or thresholds would be necessary, especially when problematic debris sources are present in the containment.

- BWROG was advised by the audit team that completion of the Phase IV analysis and documentation for all affected plants prior to any formal submission to the NRC requesting closure of the issues raised in the Grobe letter would facilitate the staff's review.

4.0 Open Items

- The issue of whether parametric uncertainties in the PRA (e.g., LOCA frequency epistemic uncertainty) were properly propagated to the CASA Grande computations was not addressed by the BWROG. This issue was an open item from the August 2015 audit (ADAMS Accession No. ML15238B610) and continues to be open.

- The BWROG agreed to analyze the LOCA frequencies and the approach to group equivalent break sizes as a function of flowrates in NUREG-1829 and adjust their analyses for consistency, if needed.

- The BWROG agreed to perform sensitivity studies to address the following comments from the audit team:

  - Ensure correct RHR pump configurations to maintain consistency of the SP cooling assumption.

  - Capture the correction in decay heat input (the GE SIL-636 issue) in the MAAP thermal-hydraulic simulations used to compute the time to core damage as well as success criteria.

  - Understand the potential impact of debris being removed from a strainer after the corresponding pump(s) are secured (or the strainer is back-flushed) by assuming complete re-mixing of the debris collected on the subject strainer(s).

- BWROG agreed to incorporate the staff's position that all events that can be credibly shown to generate and transport debris should be evaluated or screened. The analysis should be expanded to consider all internal and external hazards per the RG 1.174. Initiating events that can be demonstrated to generate and/or transport insufficient debris amounts or to not result in the activation of the recirculation function of the ECCS may be excluded from further consideration. Technically consistent and justifiable qualitative arguments may be used to support such exclusions.

5.0 References

- April 10, 2008, NRC Letter, "Potential Issues Related to Emergency Core Cooling Systems (ECCS) Strainer Performance at Boiling water Reactors," ADAMS Accession No. ML080500540.

- December 4, 2014, Summary of Public Meeting with the Boiling Water Reactor Owners' Group (BWROG), ADAMS Accession No. ML14356A148.

- June 10, 2015, Summary of Public Meeting with the Boiling Water Reactor Owners' Group (BWROG), Emergency Core Cooling System, Suction Strainer Risk-Informed Project Committee, ADAMS Accession No. ML15210A153.

- Boiling Water Reactor Owner's Group Emergency Core Cooling System Suction Strainer Project - U.S. Nuclear Regulatory Commission Staff Audit Summary of a Risk-Informed Approach to Potential Issue(s) Resolution, Summary of Audit on August 11-12, 2015, ADAMS Accession No. ML15238B610.

- December 2, 2015, Summary of Public Meeting with the Boiling Water Reactor Owners' Group Emergency Core Cooling System Suction Strainer Committee and the Emergency Core Cooling System Suction Strainer Risk-Informed Solutions Committee, ADAMS Accession No. ML16181A264.

- General Electric, Service Information Letter 636: Additional Terms Included in Reactor Decay Heat Calculations, Revision 1, June 6, 2001.