February 10, 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. NRC STAFF AUDIT SUMMARY OF LICENSING TOPICAL REPORT: BOILING WATER REACTOR EMERGENCY CORE COOLING SUCTION STRAINER IN-VESSEL DOWNSTREAM EFFECTS, NEDC-33608P

Dear Ms. Hill:

On February 9 through 11, 2016, the U.S. Nuclear Regulatory Commission (NRC) staff conducted a regulatory audit at the Structural Integrity Associates (SIA) offices in San Jose, California. 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) at Accession No. ML080500540).

The NRC regulatory audit followed a public meeting on December 2, 2015, with representatives of the BWROG ECCS Suction Strainer Project Committee (ADAMS Accession No. ML16181A264), where an agreement was reached between the NRC staff and BWROG representatives to hold the audit at the SIA offices in San Jose, California. A specific goal of the NRC staff was to evaluate the BWROG's technical approaches implemented in support of the methodology for its deterministic 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
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 691

Enclosure:
As stated

cc w/encl: See next page

SUBJECT: BOILING WATER REACTOR OWNERS' GROUP EMERGENCY CORE COOLING SYSTEM SUCTION STRAINER PROJECT - U.S. NRC STAFF AUDIT SUMMARY OF LICENSING TOPICAL REPORT: BOILING WATER REACTOR EMERGENCY CORE COOLING SUCTION STRAINER IN-VESSEL DOWNSTREAM EFFECTS, NEDC-33608P DATED _____

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NRC STAFF AUDIT SUMMARY

BOILING-WATER REACTOR OWNERS' GROUP
LICENSING TOPICAL REPORT: BOILING WATER REACTOR EMERGENCY CORE COOLING SUCTION STRAINER IN-VESSEL DOWNSTREAM EFFECTS, NEDC-33608P

February 9-11, 2016

1.0 Background

The objective of this audit was to review and discuss the Boiling-Water Reactor Owners' Group (BWROG) Licensing Topical Report, "Boiling Water Reactor Emergency Core Cooling Suction Strainer In-Vessel Downstream Effects, NEDC-33608P" (Agencywide Documents Access and Management System Accession No. ML110140482). The audit was conducted in accordance with Office of Nuclear Reactor Regulation Office Instruction LIC-111 (ADAMS Accession No. ML082900195).

General Audit goals:

- Gain better perspective regarding SAFER analyses
- Improve understanding of the testing plan, and its nexus to the SAFER analyses
- Develop an understanding of what additional methods could be used to buttress the SAFER analyses

The following NRC staff members participated in the audit:

- Vic Cusumano, Branch Chief, Safety Issue Resolution
- Benjamin Parks, Technical Reviewer, Nuclear Performance and Code Review
- Josh Whitman, Technical Reviewer, Nuclear Performance and Code Review
- Jason Drake, Project Manager, Licensing Processes

The BWROG was represented by the following personnel:

- Greg Broadbent, BWROG/Entergy
- Rob Choromokos, BWROG/SIA
- Dan Fouts, BWROG/SIA
- Michael Kennard, BWROG/SIA
- Michael Iannantuono, BWROG/GEH
- Phil Sharpe, BWROG/GEH
- José Luis Casillas, BWROG/GEH
- Baris Sarikaya, BWROG/GEH
- Ludwig Haber, Alden Lab

Audit Location:

Structural Integrity Associates (SIA) Office
5215 Hellyer Ave #210
San Jose, CA 95138

Enclosure

2.0 Technical Areas Discussed During Audit

2.1 SAFER Analyses

The analytic portion of NEDC-33608P is based on a body of four BWR/3 SAFER analyses, and is supported by five follow-on sensitivity studies. The BWROG and NRC staff discussed these analyses. Several specific discussion topics are reviewed below, including: (1) Lower Tie Plate (LTP) Assembly Blockage Assumptions, (2) Upper Tie Plate (UTP) Assembly Blockage Assumptions, and (3) General SAFER Limitations.

2.1.1 Lower Tie Plate Assembly Blockage Assumptions

The analyses investigating lower tie plate blockage consequences assume varying combinations of blockage (i.e., open, 50% blockage, full blockage) in either the side entry orifice or the bypass leakage paths, or both. The timing of the blockage is typically about 200 seconds after the initiation of the loss-of-coolant accident (LOCA), and the blockage is applied abruptly.

In actuality, the blockage is more likely to occur at the debris filter and the amount of blockage is expected to be time-dependent. The BWROG expects the assembly testing results, specifically, those from Tests 1, 2, and 3, to confirm the bounding nature of the SAFER analyses and the adequacy of the input assumptions.

The audit team discussed the following topics with the BWROG:

- The possibility that lower assembly blockage could provide an analytic benefit by allowing fuller refill of the hot channel
- Whether some intermediate blockage (probably slightly less than 100%) could result in a more limiting peak cladding temperature (PCT)
- Whether the SAFER analysis is appropriately bounding with respect to scenarios with gradual, earlier buildup of debris
- Whether the correspondence between testing acceptance criteria, or information to be gathered and the SAFER analysis confirms the underlying assumptions used in the analyses

2.1.2 Upper Tie Plate Assembly Blockage Assumptions

The SAFER analyses assume that a limiting blockage at the UTP is 50 percent, and the blockage is applied in a very late stage of the transient, on the order of 2500 seconds following the LOCA. Like the blockage at the LTP, this blockage is expected to begin to accumulate earlier in the event and to build up gradually over time. In addition, the blockage is expected to wash down the bundle to some extent. Again, BWROG expects that testing will confirm that the analysis captures an appropriate debris blockage timing that is representative of realistic scenarios. Test 4 is intended to provide information regarding debris transport from core spray to the UTP and below.

The audit team discussed the following specific topics with the BWROG:

- Whether upper channel blockage is appropriately modeled by assuming it occurs at the upper tie plate, rather than in lower spacer grids
- Whether less-complete blockage at multiple locations (likely spacer grids) could be more challenging than more-complete blockage at the UTP
- Whether flow area blockage with no change in hydraulic diameter (or CCFL coefficients) is appropriate.

The first two bullets may be able to be addressed through the use of TRACG, while the last bullet may need to wait for testing results to see if the assumptions made are appropriate.

2.1.3 General SAFER Analyses and Limitations

In addition to the above blockage analysis assumptions, the audit team also discussed, more generally, the SAFER analyses and several limitations associated with the evaluation model.

2.1.4 Discussion and Observations

Throughout the discussion, the BWROG reviewed information related to the above items, which has already been docketed in the form of request for additional information (RAI) responses. The BWROG also discussed testing and additional analytic capabilities that could help to address issues that have been identified by the staff, but that have not been sufficiently addressed in RAI responses. These discussions helped the audit team gain a better understanding what additional information could be requested that might address the discussion items identified above most efficiently.

The audit team also shared some specific observations, relative to the SAFER analyses:

- The assembly testing plans test scenarios that have no direct analog in the analysis. For example, Tests 1 and 2 consider the effects of early blockage but no explicit analysis considers these scenarios. A better tie between analysis and testing could be made if SAFER analyses that reflect the expected test conditions as closely as practical were performed.
- While the testing appears intent on verifying assumptions made in the SAFER analysis, it should also provide evidence regarding SAFER modeling capabilities relative to debris blockage, especially in amounts less than 100 percent. To this end, the testing should aim to measure data that maps directly to code output.

The audit team will address these observations with the BWROG in future RAI correspondence and testing plan feedback, as appropriate.

2.2 Testing Plans

The BWROG provided an overview of both the assembly testing (AT) plans and the bench top (BT) testing plans. The relationship between the SAFER analysis and the AT plans was discussed and the BT test series was reviewed in detail.

Although BWROG provided an overview of the AT plans, the discussion was generally limited to information that has already been docketed, or that pertained to the relationship between SAFER analysis and AT plans, which is covered in the SAFER section, above.

The audit team reviewed BT1 and BT3 with the BWROG. These bench tests are intended to obtain information related to in-channel effects related to boiling concentration and transport of debris. The BWROG reviewed the BT plans with the audit team, and discussed the existing RAIs that they are intended to address. More specifically, BT1 is intended to address the in-channel effects of transport of concentrated debris, while BT3 is intended to investigate the deposition behavior of fibrous debris on a heated rodlet. The discussion indicated that the audit team was not in alignment with the BWROG regarding the degree to which these tests would resolve specific issues identified in the associated RAIs.

The BWROG discussed BT2 with the audit team. This test is intended to examine the effect of fuel rod roughness on in-channel debris transport. Since this test depends not only on a well-characterized debris source term, but also on an understanding of how debris transports past the UTP or LTP and into the assembly, it was agreed that further feedback on this test would be more appropriate once further information is gathered.

Finally, the plans for BT4 were reviewed. This BT is set up to include a scaled core spray header, which sprays into a hopper that includes a 6-foot fuel assembly mockup, which includes characteristic upper geometry, including the UTP, a partially rodded spacer grid, and a fully rodded spacer grid. The test is intended to gather information regarding the effect of core spray nozzle inclination and debris wash-down past the UTP. This test would then be useful in confirming or revising plans for AT4, which is intended to simulate the effects of core spray entering the bundle at the UTP. The BWROG provided an overview of the test plan and discussed which RAIs would be resolved by the testing. While the audit team agreed that data obtained from this test would be useful in finalizing plans for AT4, the audit team did not agree with the BWROG regarding the extent to which BT4 would resolve specific RAIs.

2.2.1 Discussion and Observations

Based on the discussions outlined above, the audit team and the BWROG agreed that a roadmap document for each BT would be useful in ensuring common understanding regarding the specific goals for each BT and in helping the NRC reviewers provide meaningful evaluations and feedback. The BWROG agreed to develop and submit to the NRC, BT roadmaps (beginning with BT4), containing the following information:

- The RAI responses that are relevant to/affected by each bench test

- The specific portion of the RAI response that is expected to be resolved or justified based on testing or test results
- How the testing or test results are intended to resolve, or help to resolve, the specific RAI
- Whether after developing more specific and updated bench testing plans, RAI responses require clarification or revision

Specifically regarding BT1 and BT3, the audit team observed the following:

- BT1 and BT3 as currently planned may not address all of staff's concerns and may focus too much on phenomena that evidence already suggests are insignificant
- Testing, on at least a sub-bundle scale (i.e., larger than a single heated rodlet), with heat transfer could prove hugely informative relative to issues that appear to lack an adequate disposition
- A more robust alternative to the present testing and analysis plan would be required to address boiling heat transfer and debris/object interaction concerns
- Inputs from the debris source term subcommittee would reduce significant uncertainties associated with the phenomena that these tests investigate
- Results of benchtop testing could similarly reduce uncertainties. For example, the only debris expected to come into contact with the fuel is debris that is caught in neither the fuel filter nor the upper tie plate. This, coupled with the source term subcommittee's findings, form the "source term" for the heated section of the bundle.

At the conclusion of the audit, it was agreed that the BWROG's development and submittal of roadmap documents will enable the NRC review team to provide feedback regarding these tests. This effort will be initiated once the NRC and the BWROG achieve better alignment regarding BT4.

Specifically regarding BT4, the audit team observed the following:

- The BWROG desires some level of feedback prior to initiating BT4
- In considering feedback, the NRC review team may focus first on "bigger picture" or "higher-level" considerations, and second on whether or not the staff agrees the test will conclusively address specific aspects of RAIs
- Important information relative to conducting larger tests, even with RAIs aside, can be obtained from BT4

- NRC review team and the BWROG may not achieve total agreement regarding BT4's role in addressing certain RAIs
- If agreement isn't achieved, concerns will be noted in feedback to the BWROG
- Objective is to allow the BWROG to proceed with testing and gather necessary information

At the conclusion of the audit, it was agreed that the staff would prioritize providing feedback on BT4 over other testing-related aspects of the NEDC-33608P review effort, given the potential that this test has to inform other, planned bench tests.

2.3 TRACG Capabilities

The BWROG reviewed several presentations discussing TRACG capabilities to analyze the phenomena associated with in-vessel downstream effects. These presentations relied heavily on content from two previous public meetings, which were held prior to the submittal of NEDC-33608P. The presentations had been intended to demonstrate TRACG's analytic capabilities with regard to in-vessel debris transport.[1]

The audit team communicated to the BWROG its view that, despite that SAFER analyses were required to form the basis for the LTR, since SAFER had been approved, the staff state of knowledge relative to TRACG, especially with regard to its LOCA modeling capabilities, has evolved since the original revision of the LTR was submitted. This is because the NRC staff has been concurrently reviewing NEDE-33008P, "TRACG Application for Emergency Core Cooling Systems/Loss-of-Coolant Accident Analyses for BWR/2-6."

2.3.1 Discussion and Observations

Based on the discussions related to TRACG, the audit team understood that TRACG could be used to simulate more realistic scenarios than SAFER. For example, whereas SAFER can most practically model upper blockage at the UTP, TRACG can simulate partial blockage at the UTP and at several spacer grids below. Also, TRACG appears to be readily capable of analyzing and succinctly displaying results of parametric sensitivity studies.

Based on the discussions between the BWROG and the audit team, it was agreed that the review team may request, in future correspondence, that the BWROG validate SAFER assumptions regarding lower tie plate and upper tie plate blockage amount and timing using code-to-code comparison (i.e., TRACG).

- An example question could be: Show that 50 percent UTP blockage modeled in SAFER provides an adequate treatment of expected phenomena, such as potential blockage in upper grid spacers.

[1] Based on staff feedback at the time, the BWROG chose to pursue SAFER analyses over TRACG analyses, because TRACG had not been NRC-approved for ECCS evaluation for operating plants, but SAFER had.

- These analyses, or parametric studies, could help establish: (1) a better tie between the testing acceptance criteria and the SAFER analyses and (2) a broader range of acceptable testing outcomes.

While the SAFER analyses and the testing are focused on "bounding" or "worst-case" blockage phenomena, supplemental analysis could be informative regarding a more realistic blockage scenario (or set of scenarios). For example, the staff may be interested in an analysis that models lower tie plate/debris filter blockage while leaving the bypass flow paths open.

3.0 Exit Meeting and Key Takeaways

The NRC audit team discussed the following items with the BWROG representatives and contract staff at the conclusion of the audit:

1. NEDC-33608P Strategic Milestone Schedule – The audit team and BWROG representatives drafted the attached strategic milestone schedule for the remainder of 2016 for efforts associated with LTR NEDC-33608P. The BWROG has identified following the audit that they intend to submit a formal three year schedule on the basis of this draft document in the 2nd quarter of 2016.

2. Benchtop Testing Roadmap – The audit team requested the BWROG to develop a benchtop testing roadmap for each BT to ensure common understanding regarding the specific goals for each BT and to assist the NRC staff to provide meaningful evaluations and feedback.

3. NRC Review Prioritization – At the conclusion of the audit, it was agreed that the NRC staff would prioritize providing feedback on BT4 over other testing-related aspects of the NEDC-33608P review effort, given the potential that this test has to inform other planned bench tests.

4. SAFER Analysis Observations – Specific observations noted in Section 2.1.4. The audit team will address these observations with BWROG in future RAI correspondence and testing plan feedback, as appropriate.

5. TRACG Validation – Based on the discussions between BWROG and the audit team, it was agreed that the review team may request, in future correspondence, that BWROG validate SAFER assumptions regarding lower tie plate and upper tie plate blockage amount and timing using code-to-code comparison (i.e., TRACG). Specific observations noted in Section 2.3.1.

Attachment: 2016 NEDC-33608-P Strategic Schedule

2016 NEDC-33608-P Strategic Schedule

Enclosure 1: 2016 – 2018 NEDC-33608-P Strategic Schedule, (GEH Class I - Public) [2016]					
Item	**Approx. Span**	**Approx. Start**	**Approx. Finish**	**Expected Output**	**Output Owner**
Benchtop Testing (BT) Roadmap	3 Months	February 2016	April 2016	Informally provided from BWROG **[Completed]**	BWROG
NRC Provides NEDC-33608-P RAI Round 3 (Partial)	7 Months	February 2016	August 2016	Formal RAI Posting to ADAMS	NRC
BT4 NRC Staff Comments	3 Month	June 2016	August 2016	Preliminary Comments Emailed to BWROG; Final Version Posted to ADAMS	NRC
Test Debris Specification	N/A - In Progress	N/A - In Progress	September 2016	Formal BWROG Submittal	BWROG
Document Review & Project Update Public Meeting	1 Day	September 2016	September 2016	Late September Public Meeting	BWROG
BT4 Revised Test Plan	3 Month	August 2016	October 2016	Formal BWROG Submittal	BWROG
BWROG Response to RAI Round 3	3 Months	August 2016	October 2016	Formal BWROG Submittal	BWROG
Test Debris Specification NRC Staff Comments	2 Month	October 2016	November 2016	Preliminary Comments Emailed to BWROG; Final Version Posted to ADAMS	NRC
BWROG Response to RAI Round 3	2 Months	October 2016	November 2016	Formal BWROG Submittal	BWROG
BT2 Test Plan NRC Staff Comments	1 Month	December 2016	December 2016	Preliminary Comments Emailed to BWROG; Final Version Posted to ADAMS	NRC
2016 EOY Public NRC Meeting ▲	1 Day	December 7, 2016	December 7, 2016	Traditional EOY Update / 2017 Strategic Planning Meeting ▲	BWROG

▲ – 2017 "Item" & "Start / Finish" details expected to be proposed at the 2016 end-of-year (EOY) status & update meeting

Attachment