UNITED STATES
NUCLEAR REGULATORY COMMISSION
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March 02, 2022

MEMORANDUM TO: Michael I. Dudek, Chief
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Division of New Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Rebecca L. Patton, Chief ***/RA/***
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SUBJECT: REGULATORY AUDIT REPORT OF THE GE-HITACHI NUCLEAR ENERGY AMERICAS, LLC TOPICAL REPORT NEDC-33922, "BWRX-300 CONTAINMENT EVALUATION METHOD"

Enclosed is the U.S. Nuclear Regulatory Commission (NRC) staff's audit report regarding the GE-Hitachi Nuclear Energy Americas, LLC (GEH) Licensing Topical Report (LTR) NEDC-33922P, "BWRX-300 Containment Evaluation Method," Revision 2 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21351A173). The staff performed an off-site-audit of the LTR describing the GEH BWRX-300 design containment analysis method for licensing design-basis and special events that are evaluated to establish the suitability of the containment performance acceptance criteria for the BWRX-300.

The audit was conducted over approximately 11 months, starting on January 5, 2021 (ADAMS Accession No. ML20363A025), and concluding with an exit meeting on December 8, 2021. The regulatory audit was completed remotely using the GEH Electronic Reading Room (eRR). The staff reviewed the applicants containment evaluation methods calculation reports that employed the Transient Reactor Analysis Code General Electric (TRACG) the thermal hydraulics method analysis code for the mass and energy release from the reactor pressure vessel combined with the Generation of Thermal-Hydraulic Information for Containments (GOTHIC) containment evaluation method analysis code. The staff also conducted weekly regulatory audit discussions and the staff performed independent confirmatory analyses using the TRAC/RELAP Advanced

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Computational Engine (TRACE) best-estimate reactor systems code developed by the NRC for analyzing transient and steady-state thermal-hydraulic behavior in light-water reactors and MELCOR to confirm the GEH containment thermal hydraulic analysis in support of the findings in the staff safety evaluation (ADAMS Accession No. ML22040A004). As the audit proceeded, the staff requested additional documents to review in the eRR which were provided by GEH.

Docket No. 99900003

Enclosure:
Audit Report

cc w/encl: Listserv

SUBJECT: REGULATORY AUDIT REPORT OF THE GE-HITACHI NUCLEAR ENERGY AMERICAS, LLC TOPICAL REPORT NEDC-33922, “BWRX-300 CONTAINMENT EVALUATION METHOD” DATED: MARCH 02, 2022

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REGULATORY AUDIT OF
GE-HITACHI NUCLEAR ENERGY TOPICAL REPORT
NEDC-33922, "BWRX-300 CONTAINMENT EVALUATION METHOD"

Dates of Audit: January 05 – December 08, 2021

Audit Location: U.S. NRC Headquarters
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Audit Scope

The specific scope of this audit included a review of the detailed calculations, analyses, and bases used by GE-Hitachi Nuclear Energy Americas, LLC (GEH) in development of its mass and energy (M&E) Licensing Topical Report (LTR) for the BWRX-300 reactor design.

The purpose of this audit was for the staff to: (1) gain a better understanding of the detailed calculations, analyses, and bases used for the BWRX-300 to evaluate the containment performance acceptance criteria; (2) gain a better understanding of the code, scaling, applicability and uncertainty relevant to the GEH Phenomena Identification and Ranking Table (PIRT) as documented in the LTR; and (3) confirm that the methodology LTR conforms to the NRC regulations and meets the acceptance criteria documented in the approved LTR NEDC-33911P-A, Revision 3, "BWRX 300 Containment Performance," dated January 7, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No.ML22007A021).

A list of GEH calculation reports and documents available for this audit is included in Table 1, "List of Calculation Reports and Documents for the BWRX-300 Containment Evaluation Method Audit," which was provided by the applicant during the audit. The summary and list of staff audit issues raised as well as their resolution in the course of the audit are listed in Table 2, "List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit." Finally, a list of the GEH Participants are shown in Table 3 of this audit report.

Audit Summary

During the audit entrance on January 5, 2021, the NRC staff made introductory remarks regarding the regulatory audit scope, background, objectives, and agenda. This included the regulatory basis for the staffs' audit and the office instruction for conducting a regulatory audit.

In order to support an efficient and effective staff review, to develop the limitations and conditions (L&Cs) and the conclusions documented in the staff safety evaluation (SE) (ADAMS Accession No. ML22040A004), the NRC staff determined that an audit was needed to ensure that the applicant had established an acceptable BWRX-300 CEM that could be referenced by a future applicant in accordance with Title 10 of *Code Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," or 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," as applicable.

Following these audit opening remarks, GEH presented an overview of its Electric Reading Room (eRR) and the process for accessing the files (audit report Table 1) and information on the eRR. The staff, with support from GEH, established weekly regulatory audit discussions that were used as a forum to provide questions and develop issues that needed to be resolved before the staff could make its final SE conclusions. During the course of the audit the staff developed specific issues that were tracked as part of an issue resolution tracking list as shown in audit report Table 2, "List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit." In the course of the audit the staff as a subset of its issue resolution provided requests for additional information (RAIs) to GEH on April 20, 2021 (ADAMS Accession No. ML21110A127) and August 5, 2021 (ADAMS Accession No. ML21216A356). GEH responded to the staff RAIs on May 19, 2021 (ADAMS Accession No. ML21139A113), September 17, 2021 (ADAMS Accession No. ML21260A011), October 8, 2021 (ADAMS Accession No. ML21281A084), October 29, 2021 (ADAMS Accession No. ML21302A083) and finally on December 17, 2021 (ADAMS Accession No. ML21351A168), GEH submitted a revised response to RAI 06.02.01-01. In addition, on November 19, 2021, GEH submitted LTR Revision 1, and on December 17, 2021, GEH submitted the final LTR Revision 2 reflecting the RAI responses along with the many issue Items discussed and addressed during the regulatory audit.

The audit concluded with an exit meeting on December 8, 2021, where the staff conveyed to GEH that the NRC had completed its detailed LTR audit, and the confirmatory evaluations needed for the staff to complete its safety evaluation report.

Detailed Review and Discussions

The staff audited information related to multiple aspects of the BWRX-300 design related to the BWRX-300 CEM. The eRR contained information previously developed for the CEM prior to the start of the audit, information to support discussion on staff questions raised during the audit, and in limited cases, as allowed, some preview of GEH proposed information as pre-draft RAI responses and LTR updates.

The BWRX-300 is a 300 MWe (870 MWth) water-cooled, natural circulation Small Modular Reactor (SMR) utilizing simple, natural phenomena driven safety systems. The BWRX-300 is an evolution of the U.S. NRC-licensed, 1,520 MWe GEH Economic Simplified Boiling Water Reactor (ESBWR). The BWRX-300 core design uses a 240-bundle core configuration. The BWRX-300 utilizes passive safety-related systems as part of its design approach to licensing and safety.

TRACG Method for Mass and Energy Release

To enable the staff's confirmatory analysis effort, GEH provided proprietary TRACG (and GOTHIC) media files on December 17, 2020 (ADAMS Accession No. ML21028A472), March 23, 2021 (ADAMS Accession No. ML21082A501) and on December 14, 2021 (ADAMS Accession No. ML21348A074).

In LTR Section 5.2.4, the radiolytic gas source term is given as an empirical correlation from (NEDC-33004P-A, Revision 3, "Constant Pressure Power Uprate," dated March 2003 ADAMS Accession No. ML031190318). The staff began looking at how noncondensable gases (NCGs) are modeled. [[redacted]]] The staff determined that the GEH method of using this correlation for the isolation condensers may provide non-conservative results."

The staff used the supplied GEH TRACG input models to develop NRC TRACE models for confirmatory analysis to support the review. The TRACE models included mechanistic transport of the NCGs in steam and calculational results. In using these models the staff confirmatory results indicated that there can be significant buildup of NCGs in the IC which could significantly degrade the heat transfer capability of the ICs, particularly for the un-isolated small break cases. The staff asked for clarification on this issue in RAI Question 06.02.01-01 on April 20, 2021.

The staff also found that the volumes in the TRACG input for the ICs were not modeled correctly and the applicant agreed to correct the IC volume inputs.

The staff noted Section 5.3.1 of the TR indicates that the reactor power [ ]] The TR also indicates that the turbine stop valve is closed instantaneously, concurrent with the break initiation. For large, and particularly smaller break sizes, staff asked the applicant if there is a potential that reactor power will increase at break initiation due to the assumption of a concurrent turbine trip. GEH indicated that the power was conservatively modeled, in part, to account for the potential increase in power, since [[ ]] is built into the decay heat curves.

The staff reviewed the GEH responses to RAI Question 06.02.01-01 dated May 19, 2021, and noted that the TRACG sensitivity calculation provided did not meet the staff expectation for the range of parameters used to ensure that the ICs could perform their safety function, therefore GEH provided a revised response to RAI Question 06.02.01-01 dated September 17, 2021.

The staff used the updated GEH small steam line break input model to create a liquid line break case for its confirmatory analysis. The results were reasonably consistent with GEH results shown in LTR Figures 5-25 and 5-26. The staff performed additional sensitivity analyses using the GEH model and observed the possibility that the reactor coolant system inventory loss during small breaks could potentially result in reactor core downcomer water levels that drop below the top of active fuel (TAF), creating the potential for fuel cladding heat up under certain conditions, [ ]]. The staff asked GEH to explain the flow phenomenon within the core region and why the current methodology can conservatively bound the post critical heat flux heat up within 72 hours. GEH indicated that models for the boiling-water reactor (BWR) fleet have been qualified for these phenomena, where similar or more harsh cladding heat up occurs. The staff noted, as observed in the staff sensitivity calculations, that for a small liquid break, depressed core levels [[ ]]. At the end of 72 hours, the calculational results suggest that uncontrolled heat up potentially could occur if there is no core makeup near the end of the transient. The staff also questioned if the current acceptance criteria, i.e. cladding temperatures remaining below normal operating temperature, is adequate to prevent uncontrolled heat up. GEH indicated that the TRACG core modeling capability to compute clad temperature heat up in this scenario is supported by NRC approved BWR 2/6 topical report NEDE-33005P (ADAMA Accession No. ML18143A221).

The staff issued RAI Question 06.02.01-09 dated August 5, 2021, to request GEH provide information on heat dissipation and any effect on ICS performance. In addition, the staff's confirmatory calculations agreed with the GEH response dated September 17, 2021, [[ ]].

The staff requested to see changes made to the TRACG model to generate the M&E release for the GOTHIC containment analysis of the liquid small break loss-of-coolant accident (SBLOCA), since inputs for this case were not provided in the initial deck transmittals dated December 17, 2020. The staff reviewed the overlays for the liquid SBLOCA TRACG model that GEH made available for the audit. The staff compared the information provided by GEH with the staff generated input model and noted the changes were consistent. As previously indicated, GEH sent two sets of analysis input in their submittals dated March 23, 2021 and December 14, 2021, with the UPDATE modeling being most current based on minor corrections, changes, and consolidation of overlays to execute cases. The staff used an electronic difference routine to review the large break steam case changes and found the major changes were as follows:

1. [[

4.]]

The staff reviewed the audit material for the major changes made to the TRACG code since the time of the reviews performed for ESBWR in 2009. The staff reviewed the code change list and applicable regression test report. The staff noted the changes were minor and that no major changes had been made. The staff confirmed with GEH that the current TRACG version is Version 76.01, which is used for UPDATE model case analyses.

The staff completed TRACG runs for the SBLOCA case with no break opening (Station Blackout) and noted that [[ ]].

The staff also completed confirmatory analysis runs with the NRC TRACE code in coupled mode to review effects of [[

[redacted]]] This indicated to staff

that the PCCS is very important in maintaining low containment pressures early and throughout the evaluated event.

GOTHIC input audit clarification

The staff clarified some data inconsistencies and gaps with GEH during the audit. The staff identified inconsistencies in the calculation of various dimensions and GOTHIC input data including the local friction loss coefficients for the PCCS when comparing data from the GOTHIC file against independently derived values based on information from the LTR. The staff determined that the loss coefficients in the GOTHIC decks for the manholes and PCCS were inconsistent with other available information and the LTR. Since the BWRX-300 design was not yet finalized and the loss coefficients in the GOTHIC decks are reasonable, the staff used the vales in the GOTHIC decks for their confirmatory analyses. GEH provided additional detailed information in audit meetings to confirm the geometry used in its GOTHIC models and provided the corrected input information including updated analysis as part of its LTR Revision 2, on December 17, 2021, and its updated GOTHIC files submitted on December 14, 2021.

Mass and Energy release input to GOTHIC

In the course of the regulatory audit, the staff asked how the TRACG break flow model results were biased to maximize the mass and energy release into the containment, and if GOTHIC predictions were conservative. The following issues were discussed with GEH:

- The GEH TRACG M&E release enthalpy calculation is not discussed in the LTR. GEH confirmed that the specific enthalpy released from the break as shown in the LTR, is from the upstream TRACG donor cell. GEH indicated that this is the same method used for the ESBWR M&E releases.

- TRACG has the ability to apply a multiplier to selected internally calculated nominal values over a specified range of the solution domain. The multipliers used in the approved ESBWR TRACG application for conservative cases are used for the BWRX-300 calculations. LTR Table 5-1 identifies the multipliers used in the M&E release calculations. The staff asked GEH to confirm the multipliers for the BWRX-300 TRACG model, specifically the critical flow multiplier. GEH confirmed the multiplier and how it was applied, and that this is considered to be a part of the CEM that would not change without prior NRC approval.

- The staff asked if a discharge coefficient was used in the methodology. The staff understood that TRACG uses a thermal equilibrium model for the two-phase break flow. The staff requested GEH to elaborate on the break flow model used. GEH referenced in part information from the NRC approved LTR NEDE 32176PA, Revision 4, "TRACG Model Description," January 2008 (ADAMS Accession No. ML080370261).

- GEH indicated that the originally submitted GOTHIC results presented in the LTR pertain to the TRACG and GOTHIC input files provided December 17, 2020 and NOT the ones provided under the UPDATE folder. The staff noted differences between NRC calculated TRACG M&E (using the UPDATE models) versus the M&E noted in the LTR for steam large break loss-of-coolant accidents (LBLOCAs) results, so the staff requested that GEH explain the differences in these M&E results documented in its LTR.

An RAI Question 06.02.01-07 dated August 5, 2021, was issued requesting clarification on this subject. GEH stated in its response dated October 8, 2021, that there were minor unintentional differences between the model described in the LTR and the model that produced the figures in the LTR. The effect of these differences was not noticeable in most cases. The final appropriate LTR Revision 2 figures will be produced using the corrected model provided in the UPDATE folder after making the additional changes resulting from the all RAI responses.

Biases of convection and condensation heat transfer correlations

The staff was concerned with the biases used for convection and condensation heat transfer correlations implemented in the heat transfer methodology. Several aspects related to this concern were raised with GEH during the audit to get a better understanding of the following issues:

- The staff requested GEH to clarify the purpose of the GOTHIC forcing functions parameters. The staff wanted to understand how they were being used in the GOTHIC model. GEH explained that these multipliers were used to reduce heat transfer coefficients for (1) containment shell condensation, (2) inner surface of the PCCS, and (3) lower surface of the containment dome.

- The LTR states that the BWRX-300 containment model uses the Diffusion Layer Model (DLM) condensation model. The staff requested clarification on whether "DLM" as it appeared refers to one of the eight options available in GOTHIC.

- LTR Figure 6-23 shows the results of GOTHIC containment pressure benchmarking to the Carolina Virginia Tube Reactor (CVTR) integral tests data. GEH was asked to explain differences in comparison to the results on the information related to LTR Figures 6-24 and 6-25.

- GEH was asked to describe the test geometry that was used to collect the COPAIN data that are discussed in LTR Section 6.8.2 and to explain the applicability of the test data convection and condensation to the BWRX-300 containment design.

- The staff noted that the convection correlation biases were determined from the COPAIN test data as presented in LTR Figure 6-18 but needed clarification on the corresponding condensation correlation biases, as documented in LTR Section 6.8.2.

- The staff also needed clarification on any assumptions made that would impact the convection or condensation correlations biases based on the orientation of the reactor coolant flow as it exits the break.

- GEH was asked to justify the heat transfer modeling used for the PCCS tube-inside heat transfer coefficient noted by the three equations in LTR Section 6.8.2, that use a natural convection part and a forced convection part to calculate the overall single-phase heat transfer coefficient.

These staff raised issues during the regulatory audit lead to RAI Question 06.02.01-08 dated August 5, 2021.

The staff needed additional clarification on the RAI Question 06.02.01-08 response submitted on October 8, 2021, since there were some important assumptions described in the response that were not included in the LTR. The staff tracked this RAI and the subsequent clarification issues in Item #43 of the staff's, "List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit," Table 2 of this audit report.

The LTR Revision 0, provided little information on how the density-driven single-phase flow recirculation is calculated. The staff obtained clarification on how the three-equation model (from Section 6.5 of the LTR) is used to determine the heat transfer coefficients. The staff noted that some of GEH's assumptions could be nonconservative, namely use of the higher of two values associated with laminar vs. turbulent flow or natural circulation vs. forced circulation.

GEH clarified these questions and issues during the audit meetings verbally and updated the LTR in Revision 1 to incorporate this information specifically in revised LTR Sections 6.5 and 6.8.2.

Radiolytic gas and mole (volume) fraction versus mass fraction

In LTR Section 6.10.3 the staff needed to understand how radiolytic gas volume fractions are specified in the break flow boundary condition. The staff reviewed documents in the eRR that, provided a description of the radiolytic gas data transfer from TRACG to GOTHIC. The staff tried to reconcile the details provided with the GOTHIC decks received. During the audit GEH provided clarifications related to the base case and conservative case input media decks that the NRC received on December 14, 2021. The staff was unable to locate information in the GOTHIC decks representing the radiolytic gas transfer. GEH clarified that this was not included in the GOTHIC decks provided to the NRC

GEH stated during the audit meetings that, since steam and radiolytic gases are at the same pressure and temperature in the break flow; the density of the gas and steam is exactly the same as in the break flow, if steam behaves as an ideal gas. In summary, after review and discussions during the audit the staff agreed with GEH that the difference was not significant since these noncondensable concentrations coming into the containment were small and inconsequential compared to inerted nitrogen.

GOTHIC nodalization study

During the audit the staff requested that GEH add the GOTHIC assessment of the CVTR experiment contained in LTR Reference 7.17, "GOTHIC Thermal Analysis Package Qualification Report, Version 8.3(QA)," dated November 2018, to the eRR. GEH responded that the Code manual of GOTHIC 8.3 qualification report has the same information requested by the staff.

The staff noted that the height, shape, and free volume of the CVTR containment are very close to the BWRX-300 containment. In the CVTR benchmark, similar nodalization study like the one in the LTR is desired to prove the convergence of the GOTHIC model for this facility. GEH indicated that the Code manual does show a CVTR nodalization study which should be sufficient to address the staff concerns. The staff revisited the CVTR documentation in the code manual and found the necessary information as described by GEH.

In the CVTR assessment, a condensation heat transfer sensitivity study was performed to show the pressurization effect in LTR Figure 6-23. It indicates that the condensation heat transfer model affects the pressure prediction significantly. GEH indicated that Section 6.8.2 of the LTR described the heat transfer with the effect of noncondensable gases. The staff conducted a sensitivity study on the noncondensable gas effect on condensation heat transfer using the TRACE and MELCOR codes and found that the nodalization can influences the steam concentration near the heat conductors, which will affect the condensation heat transfer. Therefore, the staff issued RAI 06.02.01-01 on April 20, 2021, for additional clarification.

In the LTR, a containment nodalization study is presented for the LBLOCA event but none were similarly conducted for the SBLOCA. The staff considered that in the SBLOCA, the break flow is not isolated as in the LBLOCA and the movement of steam/air mass inside the containment is expected to be very different. Also, the SBLOCA pressure response, presented in LTR Figure 6-31, shows that the containment pressure plateaus after reaching the peak pressure, indicating that the energy removal and energy addition balance each other. Additionally, eRR document # 426 listed in Table 1, "DBR-0056194 Conservative_SBSTM-A.xlsm," and LTR Revision 0, Figure 6-37 show that the break flow in SBLOCA starts increasing after the second day, which is consistent with the containment pressure increasing again as shown in LTR Revision 0, Figure 6-31. Since the SBLOCA phenomenology involves a new PCCS design and reactor cavity pool, staff was concerned that the nodalization effect could influence the containment pressure trends. GEH was requested to provide additional justifications to confirm that later SBLOCA results and trends approach steady-state behavior such that there is no need for a nodalization study. After some discussion, GEH agreed to provide results for a conservative SBLOCA nodalization study. The staff decided to issue RAI 06.02.01-01 on April 20, 2021, to clarify the information needed.

The staff noted that LTR Revision 0, Figures 6-15, 6-16 and 6-17 summarized sensitivity studies of friction and turbulence for LBLOCA, and likewise, LTR Revision 0, Figures 6-28, 6-29, and 6-30 presented the sensitivity studies for the selection of condensation heat transfer correlation. However, there were no such sensitivity studies presented for SBLOCA.

Therefore, the staff asked GEH to provide justification for not performing similar sensitivity studies for SBLOCA, where results could be equally safety-significant, especially considering the rise in containment pressure near the end of the transient. In response to staff RAI Question 06.02.01-01 dated September 17, 2021, and revised dated October 29, 2021. The applicant provided a similar nodalization study for limiting SBLOCA including additional information in its RAI responses and revised response to Question 06.02.01-01, dated December 17, 2021, which confirm that the relevant thermal-hydraulic phenomena were adequately captured up to 72 hours in the SBLOCA analysis as evaluated by the staff in Section 6.7.1 and Section 6.10.2 of the staff SE.

GOTHIC Numerics

The staff noted time step sensitivity and mass/energy error sensitivity were not addressed in the LTR or the eRR audit files. The staff performed a preliminary sensitivity study of the maximum time step and numeric methods and observed that some combinations of numeric method option and maximum time step resulted in a significant mass error upon reaching convergence. GEH was requested to describe how the Courant limit and mass/energy errors are controlled in the GOTHIC model through the GEH selected settings of numeric scheme, maximum time step, and nodalization. GEH responded that a successful run to the end guaranteed convergence of the numerical method with a mass error within the tolerance set by the user. GEH also mentioned the automatic time step calculational feature in GOTHIC to speed up calculation if the mass error was preserved. No changes to the LTR were required based on these audit discussions.

The staff noted issues with early termination of calculations using the GOTHIC input from the December 17, 2020, media files. The case did not run completely up to the expected 72 hours (259200 sec). GEH was able to get the GOTHIC model calculations to converge that were updated for LTR Revision 2 and successfully ran the case to 72 hours for the SBLOCA.

Containment Dome heat transfer

In LTR Section 6.11, GEH states that for the BWRX-300 conservative GOTHIC CEM no credit is taken for heat transfer from the outer surface of the metal containment shell to the concrete or surroundings, except for heat transfer from the submerged section of the containment dome to the reactor cavity pool above the dome. The staff compared containment dome heat transfer for the LBLOCA and SBLOCA cases. In LTR Figure 6-7, the maximum heat transfer is shown and the staff noted that heat transfer is mainly by steam condensation in the dome as steam enters through the manholes. However, as NCGs build up in the course of an event, they could inhibit the condensation heat transfer. Therefore, the staff asked if the break orientation and location were also impacting the magnitude of containment dome heat transfer. GEH subsequently agreed to perform a nodalization study along with break orientation study to cover any uncertainty of the containment dome heat transfer if they exists.

GEH made plots available of the dome heat transfer and steam fraction inside the containment dome and the staff observed that the behavior was as expected and did not need further review.

The staff asked about the condensation and convection modeling on the internal dome surface potentially contributing to the issue. GEH explained that the heat transfer coefficients (HTCs) were modeled conservatively. [[

[redacted]]] The staff noted that the dome heat transfer modeling was not fully consistent with the information in the LTR Revision 0. GEH subsequently added this clarification to the revised LTR Revision 2.

LOCA break locations and orientation

The staff noticed that the break location and orientation, as shown in LTR Figure 6-11, could increase the condensation heat transfer coefficient and enhance the heat removal to the containment shell. While this has the desired effect of maximizing the shell temperature, it would also have an adverse impact on the peak containment pressure. The staff therefore considered the current break location to be nonconservative with respect to containment pressure and requested GEH to provide justification that the chosen break location is bounding for all acceptance criteria.

GEH provided a sensitivity analysis of the break location's impact on peak containment pressure and temperature for both LBLOCA and SBLOCA, including a sensitivity study in both radial and axial direction for the lowest location inside the containment for the SBLOCA. The staff determined that due to its safety significance, the information should be available on the docket, and issued RAI Question 06.02.01-03 dated August 5, 2021. In response to Question 06.02.02-3 dated September 17, 2021, GEH provided results of its sensitivity study and made changes to its results for the pressures in its conservative case shown in

Figures 6-26, and all cases in Figures 6-28 and 6-31 that will be based on the break location near the RPV as described in the LTR Revision 2. In addition, GEH revised LTR Sections 6.10.1 and 6.10.2 to explain that break location near the RPV is used to maximize the containment pressure, and break location near the shell is used to maximize the shell temperature.

The staff noted that LTR Revision 0, did not present any results on the liquid-space SBLOCA and asked for a justification for not including a containment response, since RPV TRACG M&E results were presented in the LTR, Revision 0, Section 5.5. GEH committed to evaluation of both cases in the future applications of the methodology, and GEH updated the LTR Revision 2 with these results.

In Part 3 of the staff RAI Question 06.02.01-03, dated August 5, 2021, GEH was asked to provide justification of GOTHIC's flow direction/convection-mode dependent conservatisms in the BWRX-300 CE methodology. However, in the RAI response, the GOTHIC qualification information provided did not adequately address conservatism of flow direction modeling. The staff had some questions about how robust the justification provided in the RAI 06.02.03 supplemental response dated October 29, 2021, was. GEH made some studies available for staff during the audit (Table 1, item #642 of this Audit Summary) based on an expanded range of Richardson (Ri) numbers [ ]].

LTR documentation and RAI response clarifications

In LTR Section 6.10.2, GEH states the calculations conservatively assume no heat loss from the reactor cavity pool to the surroundings. The staff understood the statement to apply to the reactor cavity pool walls and roof, assuming them to be adiabatic, as there is heat transfer from the containment to the reactor cavity pool through the dome. However, based on staff review of the GOTHIC model, the reactor cavity pool is exposed to the atmospheric boundary condition that allows heat and mass exchange at reactor cavity pool surface through air and moisture exchange. The staff requested a clarification via RAI Question 06.02.01-05, dated August 5, 2021.

In the response, GEH clarified that there was a flow path to atmosphere in the model, and also indicated that the heat transfer is minimal.

The staff performed GOTHIC calculations using the submitted conservative GOTHIC deck for a LBLOCA. Using the output, the staff generated PCCS exit temperatures and pool temperature plots to compare against the SBLOCA results in LTR Figure 6-32. The [[ ]] behavior was not what the staff expected, however, GEH was able to explain the differences in terms of relevant phenomena during the audit discussions.

In addressing the staff's questions and comments, GEH identified a model error, i.e., missing the heat transfer area input for PCCS heat structures. GEH also indicated that the RAI Question 06.02.01-01 response needed to be revised along with all related plots in the LTR. These actions and changes resulted in an extension of the audit as well as the schedule for the staff review of the LTR. Both the revised RAI Question 06.02.01-1 and the LTR Revision 2 were submitted on December 17, 2021.

The staff clarified with GEH during the audit that the scope of this LTR does not include potential accidents where release could occur outside containment, such as an ICS loss-of-coolant accident (LOCA) outside containment.

The staff also clarified assumptions related to the amount of oxygen initially present in the containment and how GEH adds the radiolytic oxygen to determine that the deflagration limit is satisfied. The staff reviewed the issues of containment mixing for combustible gases in Section 6.10.3 of the SE.

Summary of Information Reviewed

Table 1 provides a list of the documents that were provided by GEH in the eRR for review and Table 2 documents the 45 specific issues or items raised and resolved with GEH in the course of this audit. Specific findings relative to the topics described in this audit summary are detailed in the staff's SER.

TABLE 1:

List of Documents Reviewed During the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

eRR ID (Document ID Number in the eRR)	Title in CERTREC Electronic Reading Room (eRR)	Filename in CERTREC Electronic Reading Room (eRR)	Area in CERTREC Electronic Reading Room (eRR)
14	Status of Audit Items as of 01082021 GEH	Status of Audit Items as of 01082021.pdf	
266	0-DBR-0051860 Revision 0	0-DBR-0051860 Revision 0.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
270	0-DBR-0055891 Revision 0	0-DBR-0055891 Revision 0.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
274	DBR-0051860 BWRX TRACG input basedeck for 240 core	DBR-0051860 BWRX TRACG input basedeck for 240 core.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
278	DBR-0051860 Case6a TRACG and Excel Files	DBR-0051860 Case6a TRACG and Excel Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
282	DBR-0051860 LOCA Power Shape Files	DBR-0051860 LOCA Power Shape Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
286	DBR-0051860 nc0.000 - Attachment 2 Files	DBR-0051860 nc0.000 - Attachment 2 Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
290	DBR-0051860 ncR2 - Attachment 3 Files	DBR-0051860 ncR2 - Attachment 3 Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
294	DBR-0051860 reduced channels	DBR-0051860 reduced channels.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
298	DBR-0051860 TRACG basedeck	DBR-0051860 TRACG basedeck.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
302	DBR-0051860 verification comment response for BREK VOLIN	DBR-0051860 verification comment response for BREK VOLIN.pdf	NEDC-33922P Associated TRACG Calculation Notebooks

TABLE 1:

List of Documents Reviewed During the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

306	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 1	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 1.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
310	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 2	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 2.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
314	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 3	DBR-0051860 WI-03-100-30-F301 - CA-00022454 Scope 3.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
318	DBR-0055891 Base_LBLIQ.xlsm	DBR-0055891 Base_LBLIQ.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
322	DBR-0055891 Base_LBSTM.xlsm	DBR-0055891 Base_LBSTM.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
326	DBR-0055891 Base_SBSTM.xlsm	DBR-0055891 Base_SBSTM.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
330	DBR-0055891 Conservative_LBLIQ.xlsm	DBR-0055891 Conservative_LBLIQ.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
334	DBR-0055891 Conservative_LBSTM.xlsm	DBR-0055891 Conservative_LBSTM.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
338	DBR-0055891 Conservative_SBLIQ.xlsm	DBR-0055891 Conservative_SBLIQ.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
342	DBR-0055891 Conservative_SBSTM.xlsm	DBR-0055891 Conservative_SBSTM.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
346	DBR-0055891 Conservative_SBSTM-A.xlsm	DBR-0055891 Conservative_SBSTM-A.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
350	DBR-0055891 Large FWLB Case Files	DBR-0055891 Large FWLB Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
354	DBR-0055891 Large MSLB Case Files	DBR-0055891 Large MSLB Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks

358	DBR-0055891 LBSTM PIRT ECP Files	DBR-0055891 LBSTM_PIRT.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
362	DBR-0055891 LBSTM_PIRT.xlsm	DBR-0055891 LBSTM_PIRT.xlsm(1).pdf	NEDC-33922P Associated TRACG Calculation Notebooks
366	DBR-0055891 SBSTM PIRT ECP Files	DBR-0055891 SBSTM PIRT ECP Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
370	DBR-0055891 SBSTM_PIRT.xlsm	DBR-0055891 SBSTM_PIRT.xlsm.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
374	DBR-0055891 Small Liquid Pipe Break Conservative Case Files	DBR-0055891 Small Liquid Pipe Break Conservative Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
378	DBR-0055891 Small Steam Pipe Break Base Case Files	DBR-0055891 Small Steam Pipe Break Base Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
382	DBR-0055891 Small Steam Pipe Break Conservative Case Files	DBR-0055891 Small Steam Pipe Break Conservative Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
386	DBR-0055891 Small Steam Pipe Break Sensitivity Case Files	DBR-0055891 Small Steam Pipe Break Sensitivity Case Files.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
390	DBR-0055891 WI-03-100-30-F301 CA-00024508	DBR-0055891 WI-03-100-30-F301 CA-00024508.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
394	0 - DBR-0056194 Revision 0	0 - DBR-0056194 Revision 0.pdf	NEDC-33922P GOTHIC Documentation
398	DBR-0056194 Base_LBLIQ.xlsm	DBR-0056194 Base_LBLIQ.xlsm.pdf	NEDC-33922P GOTHIC Documentation
402	DBR-0056194 Base_LBSTM.xlsm	DBR-0056194 Base_LBSTM.xlsm.pdf	NEDC-33922P GOTHIC Documentation
406	DBR-0056194 Base_LBSTM_Turbulence.xlsm	DBR-0056194 Base_LBSTM_Turbulence.xlsm.pdf	NEDC-33922P GOTHIC Documentation
410	DBR-0056194 BWRX FCS RB GA 20200601	DBR-0056194 BWRX FCS RB GA 20200601.pdf	NEDC-33922P GOTHIC Documentation

TABLE 1:

List of Documents Reviewed During the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

414	DBR-0056194 BWRX-PCV 20190718	DBR-0056194 BWRX-PCV 20190718.pdf	NEDC-33922P GOTHIC Documentation
418	DBR-0056194 Conservative_LBSTM.xlsm	DBR-0056194 Conservative_LBSTM.xlsm.pdf	NEDC-33922P GOTHIC Documentation
422	DBR-0056194 Conservative_SBSTM.xlsm	DBR-0056194 Conservative_SBSTM.xlsm.pdf	NEDC-33922P GOTHIC Documentation
426	DBR-0056194 Conservative_SBSTM-A.xlsm	DBR-0056194 Conservative_SBSTM-A.xlsm.pdf	NEDC-33922P GOTHIC Documentation
430	DBR-0056194 Conservative_SBSTM-H2.xlsm	DBR-0056194 Conservative_SBSTM-H2.xlsm.pdf	NEDC-33922P GOTHIC Documentation
434	DBR-0056194 GOTHIC_base_cases	DBR-0056194 GOTHIC_base_cases.pdf	NEDC-33922P GOTHIC Documentation
438	DBR-0056194 GOTHIC_conservative_cases	DBR-0056194 GOTHIC_conservative_cases.pdf	NEDC-33922P GOTHIC Documentation
442	DBR-0056194 GOTHIC_nodalization_cases	DBR-0056194 GOTHIC_nodalization_cases.pdf	NEDC-33922P GOTHIC Documentation
446	DBR-0056194 GOTHIC_sensitivity_cases	DBR-0056194 GOTHIC_sensitivity_cases.pdf	NEDC-33922P GOTHIC Documentation
450	DBR-0056194 Nodalization Study.xlsm	DBR-0056194 Nodalization Study.xlsm.pdf	NEDC-33922P GOTHIC Documentation
454	DBR-0056194 WI-03-100-30-F301 - CA-00024878	DBR-0056194 WI-03-100-30-F301 - CA-00024878.pdf	NEDC-33922P GOTHIC Documentation
462	DBR-0055078 boiling	DBR-0055078 boiling.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
466	0 DBR-0055078 Revision 0	0 DBR-0055078 Revision 0.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
470	DBR-0055078 P1_Crud	DBR-0055078 P1_Crud.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
474	DBR-0055078 P1_Inner_Heat	DBR-0055078 P1_Inner_Heat.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
478	DBR-0055078 P1_loss	DBR-0055078 P1_loss.pdf	NEDC-33922P PCCS and Heat Transfer Documentation

TABLE 1:

List of Documents Reviewed During the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

482	DBR-0055078 P1_node	DBR-0055078 P1_node.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
486	DBR-0055078 P1_PCCS	DBR-0055078 P1_PCCS.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
490	DBR-0055078 P2_Crud	DBR-0055078 P2_Crud.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
494	DBR-0055078 P2_Inner_Heat	DBR-0055078 P2_Inner_Heat.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
498	DBR-0055078 P2_loss	DBR-0055078 P2_loss.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
502	DBR-0055078 P2_node	DBR-0055078 P2_node.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
506	DBR-0055078 P2_PCCS	DBR-0055078 P2_PCCS.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
510	DBR-0055078 WI-03-100-30-F301	DBR-0055078 WI-03-100-30-F301.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
513	GEH Follow-Up Items from 1/14/2021 Audit Meeting	Audit Follow-Up Items 1-14-2021.pdf	
517	Status of Audit Items as of 01152021 GEH	Status of Audit Items as of 01152021 GEH.pdf	
521	TRACG Basedeck	TRACG basedeck.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
525	Status of Audit Items as of 02042021 GEH	Status of Audit Items as of 02042021 GEH.pdf	
529	005N0092-rB_BWRX-300_RPV_and_Core_Analyses	005N0092_BWRX_RPV_and_Core_Modeling_Spec_RevC.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
533	240_LOCA.chan	240_LOCA.pdf	NEDC-33922P Associated TRACG Calculation Notebooks

TABLE 1:

List of Documents Reviewed During the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

537	240_reduced.chan	240_reduced.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
541	BWRX_240-R9A-LOCA.bdk	BWRX_240-R9A-LOCA.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
545	CNTRL-R9A-LOCA.ovl	CNTRL-R9A-LOCA.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
549	CNTRL-R9B-LOCA.ovl	CNTRL-R9B-LOCA.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
553	eor_reduced.TDT	eor_reduced.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
557	TRIPs-LOCA.ovl	TRIPs-LOCA.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
561	Audit Follow-Up Items 1-25-2021 Items 11,12 02082021 GEH	Audit Follow-Up Items 1-25-2021 Items 11,12 02082021 GEH.pdf	
565	differences between GOTHIC base and conservative LB-STM inputs	differences between GOTHIC base and conservative LB-STM inputs.pdf	NEDC-33922P GOTHIC Documentation
569	DBR-0055078 alternate calculations	DBR-0055078 alternate calculations.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
573	DBR-0055078 alternate calculations.xlsm	DBR-0055078 alternate calculations.xlsm.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
577	DBR-0055078 formulas	DBR-0055078 formulas.pdf	NEDC-33922P PCCS and Heat Transfer Documentation
591	Audit Follow-Up Items 3-1-2021	Audit Follow-Up Items 3-1-2021.pdf	
592	Audit Follow-Up Items 4-1-2021	Audit Follow-Up Items 4-1-2021.pdf	
596	2021 June 18 Summary Audit Open Items	2021 June 18 Summary Audit Open Items (NEDC-33922P)+Audit+Questions+Action items.pdf	
600	Audit Follow-Up Items 5-13-2021 Update 6-18-2021	Audit Follow-Up Items 5-13-2021 Update 6-18-2021.pdf	

604	2021 June 24 Summary Audit Open Items	2021 June 24 Summary Audit Open Items (NEDC-33922P) Open Questions+Action items.pdf	
608	2021 July 8 Summary Audit Open Items (NEDC-33922P) Open Questions+Action items 7-1-21	2021 July 8 Summary Audit Open Items (NEDC-33922P) Open Questions+Action items 7-1-21.pdf	
612	ICS Performance with Radiolytic Gas Control	ICS performance with radiolytic gas control.pdf	
614	Audit Follow-Up Item 4.d 6-10-2021	Audit Follow Up Item - 6102021 Question 4.d.pdf	
618	Audit Follow Up Items 7-15-2021	Audit Follow Up Items - 07-15-2021.pdf	
622	TRACG Code Changes	TRACG04P_ CodeChanges.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
626	TRACG Version 75.0 Test Report	RTR_TRAC04P_R2.pdf	NEDC-33922P Associated TRACG Calculation Notebooks
636	Audit Follow-Up Items 10-28-2021	Audit Follow-Up Items 10-28-2021.pdf	
640	GEH Comments on Question 4 of the October 28 2021 Audit Discussion Questions	GEH Comments on Question 4 of the Oct 28 2021 Audit Discussion Questions.pdf	
642	Audit Follow-Up Items from 11-04-2021 Audit Meeting	Audit Follow-Up Items 11-04-2021.pdf	
646	Revised eRAI 9862 Question 06.02.01-01 Response - Draft Unverified	eRAI 9862 Q 06.02.01-01 Revised Response - DRAFT UNVERIFIED.pdf	NEDC-33922P Revised eRAI 9862 Question 06.02.01-01 Response and Updated Chapter 6 Figures
650	Revised Chapter 6 Small Break Figures - Draft Unverified	NEDC-33922P Chapter 6 SB Revised Figures - Draft Unverified.pdf	NEDC-33922P Revised eRAI 9862 Question 06.02.01-01 Response and Updated Chapter 6 Figures
654	NEDC-33922P Revised Chapter 6 Figures - Draft Unverified	NEDC-33922P Revised Chapter 6 Figures.pdf	NEDC-33922P Revised eRAI 9862 Question 06.02.01-01 Response and Updated Chapter 6 Figures

List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit				
		Audit Issue	**Audit Discussion**	**Status**
		GOTHIC Model, Containment, and PCCS Related Questions		
1	nodalization	In the GEH LTR NEDC-33922P on BWRX-300 Containment Evaluation Method, a containment nodalization study is presented for the large break LOCA event, while the staff did not find any containment nodalization studies conducted for the small break LOCA.	The staff is concerned about the possibility and implications of a backflow from the Cont. to the RPV during course of a SBLOCA. Staff considering Limitation and Condition in its SER	**Closed** RAI 06.02.01-01 eRAI 9862 GEH will provide Revised RAI on Dec 17, 2021
2	nodalization	Figures 6-12 and 6-13 show sensitivity to nodalization for LBLOCA	Add info as necessary to Figures 6-31 thru 6-37 of LTR to show SBLOCA liquid break containment and PCCS response, containment response to small liquid pipe breaks **Audit Qs 10/21/21** GEH commitment to providing overlays for their liquid SBLOCA TRACG model.	**Closed** RAI 06.02.01-02 eRAI 9862 revised Section 6.11 revised Section 6.10.2 and added Figures 6-39 to 6-41 Audit Issue 2 revised Figures 6-31 through 6-34
3	nodalization	5/06/2021 audit question Figures 6-15, 6-16 and 6-17 summarize sensitivity studies of friction and turbulence for LBLOCA. Likewise, Figures 6-28, 6-29, and 6-30 present the sensitivity studies for the selection of condensation heat transfer correlation. However, no such sensitivity studies are presented for SBLOCA. Please justify not performing these sensitivity studies for SBLOCA.	Discussed at June 16, 2020 audit call.	**Closed**

4	model	**May 6 Q 3.c** The staff was not able to locate any time step sensitivity study and the mass/energy error sensitivity study for the non-condensable and steam/water parts, either in the LTR or in the eRR audit files.	GEH responded with information to the eRR – July 21	**Closed**
5	nodalization Break location and orientation	Provide justification that the chosen break location is bounding for all break locations.	Update RAI response with correct wording in paragraph below table. (final response pkg 10/29) below table 9862-1	**Closed** RAI 06.02.01-03 eRAI 9862 GEH to updated LTR nomenclature GEH to updated figure 6-7 NRC eRAI 9862 Question 06.02.01-03 revised Sections 6.5, 6.6.1, 6.6.2, 6.10, 6.10.2 and 6.11 and revised Figures 6-26, 6-28, and 6-31.
6	Running and plotting GOTHIC	the staff needs the nodal information about the plotted variables for all LTR graphs. The staff is unable to trace the nodal information from the legends that appear on those graphs, in general. The staff does need the Graphs/variable descriptions for the submitted SBLOCA and LBLOCA GOTHIC models, in general.	Response to Q5 and Q6.e discussed response June 16, 2021.	**Closed**
7	Break flow uncertainty	TRACG break flow model		**Closed** **See Issues 8-13**

TABLE 2:

List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

8	TRACG break enthalpy	The LTR documents that the break mass flow rate and enthalpy are specified as a function of time as obtained from the TRACG mass and energy release calculation. However, the LTR does not specify where the enthalpy is calculated.	GEH provided information - Closed	**Closed**
9	TRACG break enthalpy	The staff needs to understand the assumptions used in the TRACG model	GEH provided information - Closed	**Closed**
10	TRACG break enthalpy	Please explain the legend used in Figure 6-5, and the relevance of a reference to isenthalpic expansion of steam from the RPV to the containment as mentioned in the description of Figure 6-5.	GEH provided information - Closed	**Closed**
11	TRACG Break flow RAI 9826 revision	**Q2. June 10**. In the RAI 9826 response, item 6, GEH stated references to summaries of comparisons to tests without showing any actual comparisons to data. therefore staff evaluations for ESBWR are not directly applicable to BWRX-300, particularly regarding critical flow per NEDC-33922P Table 5-1.	GEH provided information - Closed	**Closed** 06.02.01-01 (eRAI 9817) supplemental response
12	Break flow uncertainty	**5/6/2021** LTR Table 5-1	Addressed in 6.b. 6/17/2021 GEH provided information - Closed	**Closed**
13	Break flow uncertainty	May 6 2021 audit question The staff did not find any discharge coefficient information documented in the LTR and would request clarification.	Addressed in 6.b and 6.c. Discharge coefficient. 6/17/2021	**Closed**
14	Combustible gas control (H_2 / O2 limits)	Section 6.10.3 of the LTR states that the calculated hydrogen and oxygen volume fractions are far below the “deflagration limits.” GEH had some discussion on this concern in an audit meeting, dated April 1, 2021.	Question 8.f – Amount of Oxygen Initially Contained in Containment April 1 eRR Response.	**Closed** RAI 06.02.05-01 eRAI 9854 RAI Response 9/17/21-
		Audit Questions Provided June 2, 2021		

15	ICS NCG control	TRACG Model, RPV, and ICS Related Questions	Calculation from GEH Closed based on 06.02.01-01 (eRAI 9817) supplemental response	**Closed**
16	ICS NCG control	1. Venting and/or Passive Autocatalytic Converters The staff needs to understand how the M&E release would be conservative with any potential design change features. Alternately, the methodology could be limited to be applicable for demonstrated performance of these conceptual designs.	GEH imposed requirement on the Design (see Issue 15) Closed based on 06.02.01-01 (eRAI 9817) supplemental response	**Closed**
		2. TRACG Modeling and Qualifications		
17	ICS NCG control	A TRACG sensitivity calculation was performed for non-condensable gas accumulation in the IC tube bundle?	Non-Condensable gases are tracked by TRACG for IC performance evaluation. Closed based on 06.02.01-01 (eRAI 9817) supplemental response.	**Closed**
18	ICS NCG control	For non-condensable gas volume fraction does the original PANTHER test data cover the range of non-condensable gas volume fraction? Has the original PANTHER separate effect benchmark model been rerun with the latest version of TRACG? Figure 5-1 of LTR showed the volume fraction of radiolytic gases during a 1-in liquid break.	Expected draft results for July 1 audit call. Closed based on 06.02.01-01 (eRAI 9817) supplemental response.	**Closed**
19	ICS NCG control	**6/2/2021** audit question TRACG mass and energy release model	eRR June response. Provided graphical (and color) plots of NCG and temperature distribution in the axial and radial directions for the conservative SBLOCA inside containment. PCCS heat transfer will be included since this is ultimately what	**Closed**

			impacts the containment response.	
20	ICS NCG control	The TRACG model conservatism.	Staff wants to put a limit on use of TRACG NCG model for BWRX-300. (see issue 21)	**Closed**
21	ICS NCG	**June 10** Audit Question Staff RAI response, that an analysis is provided for NCG without mechanistic modeling gas accumulation in TRACG.	RAI 06.02.01-9 eRAI 9856 RAI Response 09/17/21 Supplement response to RAI 06.02.01-01 (eRAI 9817) RAI Letter 14, response dated May 19, 2021 (ML21139A110)	**Closed** Staff considering Limitation and Condition in its SER
22	ICS NCG	would like to see results of this analysis in the RAI response. It should be noted that staff anticipates need for a limitation in the SER to limit per the passive system objective listed in the RAI response.	Provide NRC analysis results and resolve need for a limit.	**Closed**
23	TRACG changes	Staff request was made for a list of code changes made to the TRACG code since staff reviewed the application for ESBWR (NEDC-33083PA, Revision 1).	GEH provided the list.	**Closed**
24	TRACG changes	The staff have not seen any documentation added to eRR for “List of code changes made to the TRACG code since the application to ESBWR” from the audit plan. Staff needs to understand changes and developments to the code since it was reviewed for ESBWR.	Maintenance updates only. Changes should not impact results.	**Closed**

TABLE 2:

List of Issues and Resolutions for the BWRX-300 Containment Evaluation Method Audit
OFFICE USE ONLY – POTENTIAL PROPRIETARY/ECI INFORMATION

25	TRACG	**January 25, 2021** Audit Question TRACG input for the IC. don't seem to be correct.	TRACG basedeck was corrected soon after the comment was made. All subsequent analyses were run with the corrected volumes. NRC wants to see comparison of old and new results used to support the conclusion that any effect is negligible.	**Closed**
26	NEDC- 33922	Correct NEDC-33922 Figure 5-3 (Feedwater and Steam) and node Figure 5-4 TRACG node diagram 5-4 of ICS.	GEH will correct figures in the LTR	**Closed** LTR Verification in revised submittal. Audit Issue 26 corrected Figures 5-3 and 5-4.
		Audit Questions Provided June 10, 2021		
27	Appendix K	Staff noted that in RAI 9826 response, item 2, GEH indicates that Appendix K is not applicable because containment back pressure is not credited in the model. Back pressure can be modeled conservatively as atmospheric pressure or as conservatively computed in a coupled code simulation. Appendix K D.2 additionally require inclusion of installed pressure reducing equipment so that a conservatively low-pressure boundary condition is selected for the analysis. In the staff's SER for NEDC-33911P, it is stated that "BWRX-300 containment analyses will be calculated accounting for all applicable sources of energy required for consideration in 10 CFR Part 50, Appendix K	Revise RAI 9826 to clarify and narrow the statement regarding Appendix K applicability. RAI-9826 clarify containment back pressure statement and why App K is not applicable to containment	**Closed**
28		in LTR NEDC-33083P-A, "TRACG Application for ESBWR", however, due to the differences in containment design and acceptance criteria used, several assumptions are not applicable to the BWRX-300 dry containment analysis.	Same as Item 27	**Closed**

29	Uncertainties in conv/ Cond HTCs	BWRX-300 containment model condensation model. The staff needs clarification	Resolved	**Closed**
30	Uncertainties in conv/ cond HTCs	LTR Figure 6-23 shows the results of GOTHIC containment pressure benchmarking to the CVTR test data. Explain the terms on Figure 6-23, and Figures 6-24 and 6-25.	Clarify in the next revision of the LTR. Figure legends are confusing. They should be unified. Fix in the next LTR revision.	**Closed** LTR Verification in revised submittal. revised Section 6.9 and clarified the legends in Figures 6-23, 6-24, and 6-25.
31	Uncertainties in conv/ Cond HTCs	4c describe the test geometry that was used to collect the COPAIN data that are discussed in Section 6.8.2 and explain the applicability of the test data to the convection and condensation taking place inside the BWRX-300 containment design.	Resolved. Linked to RAI responses	**Closed**

32	Uncertainties in conv/ Cond HTCs	4d The staff has a better understanding of how the convection correlation biases were determined from the COPAIN test data as presented in Figure 6-18, but needs to understand how the corresponding condensation correlation biases, as documented on Page 92 of the LTR, were concluded.	Provide s some additional discussion similar to LTR description of figure 6-18 on page 91. Explain the biasing in Figure 6-20 for Sherwood number. Provide Staff with references to specific sections in Bucci's PhD thesis that address biasing of Sherwood No. GEH responded with information on -July 19 and Info loaded to eRR Linked to RAI responses	**Closed**
33	Uncertainties in conv./cond. HTCs	4e Are any assumptions made in the methodology that would impact the convection or condensation correlations biases when applied in the GOTHIC model, e.g., the orientation of the RC flow as it comes out of the break into the containment?	Specify that break flow sensitivity cases.	**Closed** See Issue 5 [[RAI 06.02.01-03 RAI Response 9/17/21-
34	Uncertainties in conv/ Cond HTCs	4f Please explain the term "biased DLM"? Does it mean the DLM option available in GOTHIC? How were the biases implemented within the GOTHIC model?	Figure legends are confusing, and legends should use consistent terminology.	**Closed** See issue 30
35	Uncertainties in conv/Cond HTCs	4g Can GEH elaborate on the following statement made on the LTR Page 92; "As will be shown in Section 0, the above biases bound the integral test data and also add conservatism to the BWRX-300 containment response results that is comparable to the conservatism that would be introduced by using the Uchida correlation."	GEH to identify the correct section references and provide to Staff Section where Section "0" appears. (e.g., Section 6.9)	**Closed** LTR Verification in revised submittal. corrected a broken link in Section 6.9.

		Audit Questions Provided July 1, 2021 **GOTHIC Model, Containment, and PCCS Related Questions**		
36		PCCS GOTHIC model	Staff will issue an RAI to document need to modify the LTR discussion. GEH to write up an explanation about why the PCCS geometry is not a significant methodology issue. **Audit Qs 9/30/21** delete all references in the LTR to the design option.	**Closed** RAI 06.02.01-04 eRAI 9862 RAI Response 9/17/21- Under Staff Review LTR Verification in revised submittal.
37		4. On Page 109, LTR states "the calculations conservatively assume no heat loss from the reactor cavity pool to the surroundings	GEH to discuss conservatism of PCCS pool model connected to a boundary condition at atmospheric pressure and 100% humidity. Staff will issue an RAI to document need to modify the LTR discussion.	**Closed** RAI 06.02.01-05 eRAI 9862 RAI Response 9/17/21-
38		Non-condensable gas concentration	RAI 06.02.01-6 eRAI 9857 RAI Response 10/08/21 However, GEH needs to update LTR to reflect the design decision "The loop seal will be retained in the final design."	**Closed** Staff considering Limitation and Condition in its SER

39	Gothic Model, Cont. & PCCS	Q1 from July 15 Audit Meeting NRC Staff Conf. Analysis GOTHIC PCCS exit temperatures and pool temperature in LBLOCA	No RAI needed GEH provide Qualification Basis of equation in eRR Linked to RAI responses	**Closed**
40		Q2 from July 15 Audit Meeting NRC Staff Conf. Analysis There exists significant difference between NRC calculated TRACG M&E (using the updated model received from GEH) versus the M&E in the LTR for LBLOCA. Please explain the M&E difference as shown below. Please also verify that GOTHIC M&E in the .SOT file is consistent with M&E output from TRACG output. Please confirm which M&E and associated GOTHIC calculations will be the final version for this application, in both LBLOCA and SBLOCA.	RAI Needed **10/20/21 Audit Qs** LTR figures will be updated as stated in the RAI response to Item 3	**Closed** RAI 06.02.01-07 eRAI 9862 RAI Response 10/08/21- revised several figures
41		Q3 from July 15 Audit Meeting NRC Staff Conf. Analysis GOTHIC containment bulk temperature (averaged) is shown in LTR Figure 6-27 and 6-34. Containment bulk temperature is based on the steam temperature. In order to resolve the discrepancy between the confirmatory calculations and GOTHIC predictions, and better understand the thermodynamic state and condensation heat transfer of steam during the transient, please provide steam saturation temperature plots for steam break LBLOCA and steam break SBLOCA.	No RAI Closed. NRC confirmatory calc. confirm the behavior.	**Closed**
42		Q4 from July 15 Audit Meeting NRC Staff Conf. Analysis In LTR Figure 6.38 (SBLOCA)	Closed. It's a code limitation to GEH and yet it proves to be a conservatism to confirm the current approach.	**Closed**
43		Q5 from July 15 Audit Meeting NRC Staff Conf. Analysis Please justify the heat transfer model for the PCCS tube-inside heat transfer coefficient as captured by the three equations on the LTR Page 65.	Audit Qs 11/12/21 Q3) GEH Confirmed Statements are correct on 11/12/21 Audit Discussion.	**Closed** RAI 06.02.01-08 eRAI 9862

			RAI Response 10/08/21- LTR Verification in revised submittal.	GEH provide Clarification in LTR Revision 1. revised Sections 6.5 and 6.8.2.
44	cavity pool	Q6 from July 15 Audit Meeting NRC Staff Conf. Analysis Why does the 2P boundary condition imposed on GOTHIC model temperature to the environment?	GEH provided response during meeting	**Closed**
45	containment dome heat transfer	**Audit Qs 09/30/21** break orientation and location impacting the magnitude of dome heat transfer? Staff noticed that GEH did not perform small break orientation sensitivity study in the RAI Response 06.02.01-03. Please explain and justify the difference. **Audit Qs 11/04/21 Q3)** GEH added the following file, “Audit Follow-Up Items 11-04-2021.pdf,” to the eRR for added clarification	**Audit Qs 10/28/21 #2a)** **Audit Qs 10/28/21 #2b)** GEH will describe the steam dome biases in more detail in updated LTR	**Closed** LTR Verification in revised submittal.

TABLE 3:
BWRX-300 Containment Evaluation Method Audit January 5 through December 8, 2021, GEH Participants

Last name	First Name	Organization
Wadkins	George	GEH
Schichlein	Lisa	GEH
Karkour	Suzanne	GEH
White	Frostie	GEH
Lanese	Lou	GEH
Heck	Charles	GNF
Pappone	Daniel	GEH
Hinds	David	GEH
Dahlgren	Christer	GEH
Kurul	Necdet	GEH
Harrington	Roseanne	GEH