ENCLOSURE 2

M180090

Comment Summary Table and Draft SE Markup

Non-Proprietary Information – Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

Comment Summary Table for Draft Safety Evaluation for

Licensing Topical Report NEDE-33005P-A / NEDO-33005-A, TRACG Application for Emergency Core Cooling Systems / Loss-Of-Coolant Accident Analysis for BWR/2-6 Satisfaction of Limitation 10.7

Note: Page numbers shown in this table reflect the page numbers in this enclosure. Due to suggested changes in the Safety Evaluation (SE) and the addition of proprietary marking, these page numbers differ from the page numbers in the draft SE sent to GEH for review.

Location	Comment
Section 3.1.3.3 CHAN Nodalization Adequacy	Page 8: The text implies that for [[ ]] GEH suggests the following change: “[[ ]]” *Suggested changes shown in the markup.*

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO LICENSING TOPICAL REPORT NEDE-33005P-A / NEDO-33005-A

TRACG APPLICATION FOR EMERGENCY CORE COOLING SYSTEMS /

LOSS-OF-COOLANT ACCIDENT ANALYSES FOR BWR/2-6

SATISFACTION OF LIMITATION 10.7

GENERAL ELECTRIC HITACHI NUCLEAR ENERGY

1.0 INTRODUCTION

By letter dated February 14, 2017, the NRC staff issued a safety evaluation (SE) approving General Electric – Hitachi Nuclear Energy (GEH, the vendor) licensing topical report (LTR) NEDE-33005P, "TRACG Application for Emergency Core Cooling Systems / Loss-of-Coolant Accident Analyses for BWR [boiling water reactor]/2-6," for use (Approved Copy, NEDE-33005P-A, Rev. 1, Reference 1). Chapter 10 of the NRC staff SE contained limitations on the NRC staff approval. Limitation 10.7, "BWR/3-6 First-of-a-Kind Application," required the re-execution of several analyses and sensitivity studies contained in NEDE-33005P prior to its unrestricted implementation in BWR/3-6 plants.

GEH provided two letters containing information necessary to satisfy Limitation 10.7. The first was dated July 7, 2017, and provided the results of the required analyses and sensitivity studies for NRC staff review (M170165, Reference 2). The second, dated February 13, 2018, provided additional information and made a minor revision to the TRACG-LOCA analytic methodology based on the NRC staff review (M180029, Reference 3).

This evaluation reviews the letters submitted by GEH, and provides a basis for the NRC staff conclusion that Limitation 10.7 is satisfied as written, and requires revision to reflect newly revised modeling requirements.

2.0 BACKGROUND

The TRACG reactor analysis code solves thermal-hydraulic transient behavior in off-normal conditions in a reactor system. In order to provide such solutions, the computer code relies on a model of the reactor system that is represented by a series of one-dimensional volumes joined together at various junctions. The code also provides a three-dimensional vessel (VSSL) component that serves as a volume to contain all the various internal flow paths and associated interconnections within the reactor vessel. As originally proposed in NEDE-33005P, Rev. 0, the modeling in the core region of the VSSL component, specifically the number of CHAN components that represent fuel channels, was not sufficient to provide an acceptably accurate representation of the complex thermal-hydraulic interactions that could be experienced during a hypothetical loss-of-coolant accident (LOCA). Through the course of responding to NRC staff requests for additional information (RAIs) associated with the NEDE-33005P review, the vendor proposed to increase the detail of the TRACG model, in order to provide a more accurate representation.

Sections 4.3.1 and 5.3 of the NRC staff SE approving TRACG-LOCA (Reference 4) discuss this review evolution in detail, identifying the review challenge that brought about Limitation 10.7. Specifically, the NRC staff evaluated the TRACG nodalization using Regulatory Position 2.1 of Regulatory Guide (RG) 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance." However, the information provided in NEDE-33005P, Rev. 0, was based on the less-detailed model, and in some cases, because of the less detailed model, it was difficult to discern whether changes from case to case were a result of insufficient modeling detail, or due to nonphenomenological uncertainties or excessive numerical diffusion.

In the course of the review, the vendor updated nodalization sensitivity studies, using the more detailed modeling approaches, but only for the BWR/2 analyses. Therefore, the NRC staff limited its initial approval only to BWR/2 plants, and required that GEH update the sensitivity studies prior to allowing unrestricted use at later-vintage BWRs. M170165 provided the updated sensitivity studies.

3.0 EVALUATION

3.1 Nodalization

3.1.1 Summary of Original Studies

Regarding the appropriate level of detail to include in the system nodalization, RG 1.157 contains little guidance, as do other available guidance documents on the subject. Regulatory Position 2.1.1, "Numerical Methods," states, "Sensitivity studies and evaluations of the uncertainty introduced by noding should be performed." Similarly, RG 1.203, "Transient and Accident Analysis Methods," also characterizes the need to demonstrate adequate nodalization detail, indicating that nodalization convergence studies should be performed. On a more fundamental level, introductory discussion in NUREG/CR-5249, "Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation to a Large-Break, Loss-of-Coolant Accident" (colloquially known as "CSAU") suggests that nuclear power plant nodalization should be adopted that is consistent with that used to model the supporting experimental studies (CSAU, Page 8).

The effects of nodalization are discussed in Section 5.2 of NEDE-33005P-A, Rev. 1. For the BWR/4 model, nodalization is investigated by comparing results obtained from analyses performed using the default nodalization to those obtained from analyses that are performed with increased noding detail in various TRACG model components. These comparisons produce an estimated net change in predicted peak cladding temperature (PCT), as well as comparative trends of PCT vs. time. Because it is understood that some of the variation in PCT is attributable to other sources of numerical or model variability, a baseline amount of variability is established to compare the differences in PCT and ascertain whether the differences are sufficiently minimal as to conclude that the default model nodalization is adequate.

The BWR/4 studies in the LTR, however, were based on a less detailed core model that was prone to excessive variability in the results. This variability made it difficult to discern whether specific nodalization sensitivity study results truly provided an indication of adequate spatial resolution. In particular, large PCT differences were observed for VSSL axial nodalization and for CHAN axial nodalization.

3.1.2 Updated Studies

The updated sensitivity studies were provided in M170165. The study was performed as described in Section 2 of the Enclosure to M170165; detailed results were provided in Table B5.2-1 and Figures B5.2-1 through B5.2-9.

The study was accomplished by comparing baseline TRACG analyses of a large-, intermediate-, and small-break LOCA, to successive analyses, in which more detailed nodalization was applied to various components in the model geometry. The baseline analyses were executed using the more detailed core model that was developed during the model review process. These analyses were executed in the de-biased mode, meaning that all uncertainty parameters were set to their most probable values. Entries in Table B5.2-1 explain how the model detail was increased for each analysis. For example, channel nodalization was studied [[ ]]

To provide a basis to evaluate the magnitude of the sensitivity study results, GEH depicted error bars, in Figures B5.2-1 through B5.2-9, [[ ]] The analytic resolution is discussed in detail in Section 6.4 of NEDE-33005P-A, Revision 1, and the small perturbation study itself is described on Page 6-26 of NEDE-33005P-A, Revision 1.

A detailed review of the results contained in Table B5.2-1 reveals that the apparent sensitivity of predicted PCT to nodalization detail is significantly reduced relative to some of the results provided in Table 5.2-1 of NEDE-33005P-A, Revision 1. Consider the following examples:[1]

- [[ ]]

Detailed results are summarized in Table 1.

As discussed in Section 3.1.1, given the combination of (1) heightened PCT sensitivities observed in the less-detailed core model, and (2) the large amount of non-phenomenological uncertainty, the nodalization adequacy was difficult to discern. In the original review, GEH justified results like those above, in part, by stating that the PCT sensitivities were commensurate with the analytic resolution of the model. Stated differently, it would be difficult to discern whether significant changes in PCT associated with the nodalization sensitivity studies were truly attributable to the model nodalization, or rather, random variability; hence, there was not conclusive evidence that use of the standard nodalization biased the results.

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[1] [[ ]]

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Table 1. Summary of nodalization sensitivity study results contained in Table B5.2-1 of M170165. PCT and ΔPCT values have been converted to °F. Absolute values of ΔPCT greater than 20 °F appear in italicized text, while absolute values of ΔPCT greater than 30 °F also appear in bold-face text. Refer to Table B5.2-1 of M170165 for a more detailed description of each component, as well as additional detail explaining how the nodalization for each component was studied.

3.1.3 Evaluation of Nodalization Adequacy

When the model susceptibility to non-phenomenological uncertainty was reduced via more modeling detail, it was expected that the significant reductions identified above would be observed. However, a more detailed comparison between Table 5.2-1 of NEDE-33005P-A, Revision 1, and Table B5.2-1 of Enclosure 1 to M170165, reveals that, [[

]] Since the uncertainty analysis does not perturb nodalization detail, the NRC staff was concerned that a potential bias in the nodalization could result in an underestimation of the predicted PCT, or other figures of merit.

The evaluation below is comprised of several parts. The first considers an evaluation of potential nodalization biases relative to the TRACG qualification, which was provided in Section 5.0 of M180029. [[

]] The third addresses a revised modeling approach intended to address, specifically, sensitivity to the CHAN axial nodalization, and an overall conclusion.

3.1.3.1 Standard Nodalization Justification

Section 5.0 of M180029 provides a justification for the TRACG-LOCA standard nodalization (i.e., that described in Chapter 5 of NEDE-33005P-A, Rev. 1) relative to the evaluation model's qualification basis. GEH justified the standard nodalization based on its consistency with the qualification basis. To provide further support for, in particular, the VSSL radial and CHAN axial nodalization, the vendor highlighted the results of several tests (M180029, Page 29 of 47). For the tests relevant to CHAN axial nodalization, GEH performed sensitivity studies using the standard, and the more detailed, nodalizations to show that differences were minimal between the two. For the test relevant to the VSSL radial nodalization, GEH provided a combination of existing sensitivity studies and updated studies using the as-approved version of TRACG to show a reasonable insensitivity to increased VSSL radial detail relative to TRACG's capability to predict the significant results.

Considering the above information, the NRC staff determined that GEH has justified the TRACG nodalization adequacy in a manner that is, to an extent, consistent with suggestions contained in CSAU. In particular, the standard nodalization is largely consistent with the appropriate experimental studies (CSAU, Page 8). The NRC staff acknowledges that, while the sensitivity studies include the grid convergence studies suggested by CSAU and RGs 1.157 and 1.203, neither the standard, nor the refined, nodalizations used are expected to be grid-asymptotic. Therefore, the NRC staff concedes that reasonable agreement to test data for simulations performed consistently with the standard nodalization provide evidence that the standard nodalization should be considered adequate, despite sensitivities indicated in the nodalization studies.

However, the NRC staff also noted that the nodalization sensitivity for the VSSL radial and CHAN axial detail was not evident in the test comparisons, as it was for the demonstration sensitivity studies. This fact suggested that the full model was susceptible to a sensitivity not accounted for in the qualification, and that further investigation was warranted.

3.1.3.2 VSSL Nodalization Adequacy

To provide further support for the adequacy of the VSSL radial nodalization, GEH performed a full-scope uncertainty analysis using both the standard and the finer VSSL radial model, in concert with the revised axial power shape that is discussed below (M180029, Page 26 of 47). While the mean PCT sensitivity using a 59-case small perturbation analysis was somewhat reduced, it was not entirely eliminated. The mean PCT sensitivity was of similar magnitude when GEH compared a set of two, 124-case, full parametric uncertainty analyses. However, the upper tolerance limits of the full uncertainty analyses differed [[ ]] from the less- to more-detailed VSSL radial model. This small difference in upper tolerance limit values suggested that the existing VSSL radial nodalization was adequate. The NRC staff conclusions in this regard are provided in Section 3.1.3.4.

3.1.3.3 CHAN Nodalization Adequacy

In the course of the generic review, GEH provided information to evaluate CHAN nodalization adequacy based on perturbations to each of hot, average, and core-wide CHAN nodalization detail. In the present effort, GEH ultimately narrowed its focus to changes to [[ ]] CHAN nodalization (M180029, Page 21 of 47). The NRC staff agrees that this is an acceptable approach, because it is prudent from a modeling perspective [[ ]]

In M180029, GEH provided an evaluation of various potential causes of the sensitivity to CHAN axial nodalization. Among the others, the vendor concluded that [[ ]]

The NRC staff reviewed the evaluation provided by GEH in M180029, which contended that the heat generation and transfer characteristics, along with break size, location, and system interactions, had greater importance on the overall event than the selected nodalization (M180029, Page 23 of 47). While the NRC staff agrees that the global thermal-hydraulic conditions and the bundle heat addition and removal characteristics are governing phenomena for the heat transfer behavior exhibited by the limiting channel, there was no conclusive evidence indicating that such physical phenomena are responsible for the nodalization sensitivity to the all CHAN axial nodalization.

Even so, GEH produced additional analyses using a less conservative axial power shape to illustrate the concept that reducing the severity of the power shape could help to eliminate some of the bias exhibited in the nodalization sensitivity studies. [[

]] The reduction in PCT sensitivity to CHAN axial nodalization was also exhibited in the large break studies.

The responses to NEDE-33005P-A, Revision 1, RAIs 72 and 73, dictate the assumptions required to assure an appropriately limiting set of hot channels are used in production safety analyses using TRACG-LOCA. Among other things, the response to RAI 73 included a revision to Table 6.2-2 of NEDE-33005, [[

]] (M180029, Page 25 of 27). Note that the NRC staff did not consider the language in the response to RAI 73 in the context provided by GEH's subsequent clarification. However, GEH points out that [[

]], and the NRC staff acknowledges that the [[ ]] is among several that are included to replicate hot channel behavior. Moreover, the governing limits that prescribe the LHGR are based on the fuel and cycle design, without regard to the specific power shape. These considerations suggest that GEH's use of a less severe axial power shape should be acceptable.

However, it is essential that [[

]] As such, the NRC staff has determined that a confirmation must be performed to assure that the analyzed axial power shape and peaking factor are bounding of potentially limiting bundles employed in cycle operation. In other words, GEH must confirm that the limiting bundles do not, at any point in the cycle design, exhibit a power shape/peaking factor combination that would produce a higher PCT than the [[

]] This item is included in the revision to Limitation 10.7, provided in Section 4.0 of this evaluation.

3.1.3.4 Revised Modeling Approach and Conclusion

In M180029, GEH proposed to update the TRACG-LOCA modeling to address the CHAN nodalization sensitivity as follows:

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This update eliminates one potential cause of the axial nodalization sensitivity, while preserving the more detailed nodalization. Subject to the revision to Limitation 10.7, discussed in Chapter 4.0 of this evaluation, the NRC staff determined that this approach is an acceptable way to address CHAN axial nodalization.

Regarding the VSSL radial nodalization, given that (1) the model was less sensitive, overall, to VSSL nodalization changes than to CHAN nodalization changes, (2) agreement between TRACG analysis and Steam Sector Test Facility results was acceptable with the selected nodalization, and (3) the additional evaluation provided by GEH indicated that refined VSSL nodalization would not significantly affect the estimated, upper tolerance limit PCT, the NRC staff determined that GEH has demonstrated that the VSSL nodalization documented in NEDE-33005P-A is adequate.

Based on these considerations, the NRC staff determined that GEH has addressed Limitation 10.7 satisfactorily with respect to the nodalization sensitivity studies.

3.1.3.5 Updated Break Spectrum Analyses

In addition to the updated nodalization sensitivity studies discussed above, Limitation 10.7 to NEDE-33005P-A, Revision 1, also required GEH to perform updated BWR/4 and BWR/6 break spectrum analyses using the TRACG-LOCA evaluation model that reflected the updates undertaken during the NRC staff review. GEH performed these studies and provided Figures B8.1-29 and B8.2-18 documenting the results (M170165, Pages B-14 and B-15). These analyses were performed to reflect a full-perturbation statistical analysis comprised of 124 cases, with sufficient resolution in the break spectrum to permit overlap when considering critical flow uncertainty (M170165, Page B-4). On Page B-5 of M170165, GEH explains the differences between the break spectra provided in Chapter 8 of NEDE-33005P-A, Revision 1, and those in the current submittal.

The NRC staff reviewed the updated break spectrum analyses. The PCTs shown are somewhat higher than in the prior studies, owing to a number of more conservative modeling approaches that were adopted during the NRC staff review. These results are as expected.

These studies are expected to provide a comparative basis for the NRC staff to consider when evaluating plant-specific licensing submittals that rely on TRACG-LOCA analyses. Since the new break spectra reflect the newer modeling approaches, excepting those proposed in M180029, the NRC staff determined that the portion of Limitation 10.7 requiring updated BWR/4 and BWR/6 break spectra has been satisfied.

4.0 <u>CONCLUSION</u>

Based on the review described above, the NRC staff has determined that GEH provided sufficient information to address Limitation 10.7 for NEDE-33005P-A, which required additional information to support nodalization adequacy and to update the demonstration analyses. During the review, GEH proposed to revise the analytic methodology, which is captured in a revision to the limitation. Limitation 10.7 for NEDE-33005P-A shall now be considered to read as follows:

Based on its review of M170165 and M180029, the NRC staff has determined that GEH has appropriately addressed the requirements of Limitation 10.7 for first-of-kind, jet pump BWR analyses. However, the information provided indicated that updates to the modeling approach were required, as follows:

1. When performing production analyses for jet pump BWRs in accordance with NEDE-33005P-A, GEH shall apply [[ ]]

2. In addition, GEH, or any other entity performing cycle-specific core design, shall confirm that the selected combination of axial power shape and peaking factor for the [[ ]] is reflective of a bounding power shape for the potentially limiting bundles in the as-designed and as-operated core.

The analytic methods described in NEDE-33005P-A, Revision 1, remain otherwise acceptable as described in the NRC staff approving SE.

5.0 References

1. General Electric – Hitachi Nuclear Energy Americas (GEH), "TRACG Application for Emergency Core Cooling Systems/Loss-of-Coolant Accident Analysis for BWR/2-6," Reports NEDE-33005P-A, Revision 1 (Proprietary) and NEDO-33005-A, Revision 1 (Non-Proprietary), and Transmittal Letter M170037, Project No. 710, February 24, 2017, Agencywide Document Access and Management System (ADAMS) Package No. ML17055A387.

2. GEH, "Satisfaction of Limitation 10.7 for NEDE-33005P, Revision 0, 'Licensing Topical Report TRACG Application for Emergency Core Cooling Systems / Loss-of-Coolant Accident Analyses for BWR/2-6,'" M170165, Project No. 710, July 7, 2017, ADAMS Package No. ML17188A083.

3. GEH, "Response to Request for Additional Information Regarding Review of Satisfaction of Limitation 10.7 for NEDE-33005P, Revision 0, 'Licensing Topical Report TRACG Application for Emergency Core Cooling Systems / Loss-of-Coolant Accident Analyses for BWR/2-6,'" M180029, Project No. 710, February 13, 2018, ADAMS Package No. ML18044A155.

4. Final Safety Evaluation for GE Hitachi Nuclear Energy – Americas, LLC Topical Report NEDE-33005P and NEDO-33005, Revision 0, "Licensing Topical Report TRACG Application for Emergency Core Cooling Systems / Loss-of-Coolant-Accident Analyses for BWR/2-6" (CAC No. ME5405), ADAMS Accession No. ML17032A280.

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