RAIO-0319-64797

March 08, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 465 (eRAI No. 9494) on the NuScale Design Certification Application

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 465 (eRAI No. 9494)," dated May 04, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 465 (eRAI No.9494)," dated January 9, 2019

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) response to the referenced NRC Request for Additional Information (RAI).

The Enclosures to this letter contain NuScale's response to the following RAI Question from NRC eRAI No. 9494:

- 06.02.01.01.A-16

The response to RAI Questions 06.02.01.01.A-17 was previously provided in Reference 2. This completes all responses to eRAI 9494.

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 465 (eRAI No. 9494). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The proprietary enclosures have been deemed to contain Export Controlled Information. This information must be protected from disclosure per the requirements of 10 CFR § 810. The enclosed affidavit (Enclosure 3) supports this request. Enclosure 2 is the nonproprietary version of the NuScale response.

This letter and the enclosed responses make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Paul Infanger at 541-452-7351 or at pinfanger@nuscalepower.com.

Sincerely,

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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9494, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9494, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0319-64798

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9494, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9494, nonproprietary

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9494
Date of RAI Issue: 05/04/2018

NRC Question No.: 06.02.01.01.A-16

NIST-1 Test Data Scaling Distortions Relevant to Containment Design & Applicability of the NIST-1 Validation to the Containment Response Analysis Methodology

Title 10, Part 52, of the Code of Federal Regulations (10 CFR Part 52), "Licenses, Certifications, and Approvals for Nuclear Power Plants," Section 52.47, "Contents of Applications; Technical Information" (10 CFR 52.47), specifies that an application for certification of a nuclear power reactor design that uses simplified, inherent, passive, or other innovative means to accomplish its safety functions must meet the requirements of 10 CFR Part 50.43(e) and 10 CFR Part 52.47(c)(2). 10 CFR 50.43(e) requires, in part, assessment of the analytical tools used for safety analyses over a sufficient range of normal operating conditions, transient conditions, and specified accident sequences. Regulatory Guide 1.203 describes a process that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in developing and assessing evaluation models (EMs) that may be used to analyze transient and accident behavior that is within the design basis of a nuclear power plant.

To make its safety findings, the staff must understand and assess the ability of the applicant's analytical tools used in the safety analyses to meet the aspects of the General Design Criteria (GDCs) 16, 38, and 50; and 10 CFR Part 52.47 and Part 50.43(e) relevant to the containment design basis. Specifically, the staff must assess the ability of the applicant's NRELAP5 models to predict the safety-significant phenomena in order to conclude that the evaluation model results are valid over the applicable range of design basis event (DBE) conditions. The thermal-hydraulic phenomena pertinent to NuScale FSAR Section 6.2 containment DBE analyses are the heat transfer from the containment vessel (CNV) to reactor pool (including condensation on the inner surface of the CNV), conduction through the CNV wall (represented by the heat transfer plate in the NIST-1 testing), and the convection to the reactor cooling pool. The staff needs to understand and assess the conservatism in the applicant's NPM DBE safety analyses, as well as the NIST-1 test data used to validate the DBE phenomenology.

The purpose of NIST-1 facility is to provide realistic test data for the NRELAP5 evaluation model validation. As there are no other counterpart tests, the NIST-1 testing is critical for NRELAP5 code validation. Validation of NRELAP5 with the set of NIST-1 DBE tests will bring confidence in the code's ability to predict the containment response to the mass and energy release events.

However, this requires an additional step of scaling distortions evaluation of the NIST-1 test data that are presented by the applicant to support the LOCA evaluation models and containment response analysis methodology. Significant distortions in initial/boundary conditions and important scaling similarity groups (Pi group) need to be assessed before the code is qualified to predict the containment peak pressure and temperature. For regulatory purposes, the containment peak pressure prediction has to be realistic and should either show conservatism or should have a statement of uncertainty.

In the scaling distortion report (Calculations to Support NIST-1 Distortion Analysis and Modeling of Containment and Pool heat Transfer, {{ }}$^{2(a),(c)}$), the applicant quantifies the effect of the scaling distortions by performing sensitivity calculations for NPM and NIST-1 configuration. Section 4.1 of the "Containment Response Analysis Methodology" Technical Report (CRAM TeR) (TR-0516-49084-P Rev. 0) addresses some scaling distortions for the primary and secondary system releases. In the course of review, the staff identified several additional distortions and discrepancies that affect peak containment pressure, and some of them were not adequately addressed in audit discussions with the applicant. The staff needs to assess how these outstanding distortions and discrepancies contribute to the peak containment pressure. Assessment of test data scaling distortions is essential to the peak containment pressure prediction due to the small margin available in the NuScale design. The staff needs to ensure consistency of sensitivity calculations with the predicted containment pressure in response to scaling distortions. The staff has also issued RAI 9208 under LOCA EM topical report (TR-0516-49422-P) that involves additional containment aspects of the scaling analysis report relevant to CRAM (especially RAI 9208, Question 30890, Parts c and d) that need further clarification. The current RAI is closely related to RAI 9208 in terms of the phenomena in the LOCA transient. Therefore, the applicant is requested to provide an integral estimate of the uncertainty of peak containment pressure in the NuScale design, and address the concerns identified in the following seven questions in addition to RAI 9208. The regulatory bases and the SRP acceptance criteria identified above are applicable to all questions in this RAI.

a. The distortion report ({{ }}$^{2(a),(c)}$) shows NIST-1 predictions and NPM base calculation, and lists the differences between the NIST-1 and NPM initial and boundary conditions and procedures. There are differences in the timing of ECCS actuation as the conditions in the NPM calculations are changed. The timings of ECCS in NPM base calculation and NIST-1 are close as shown in Figure 5-10. Figure 5-17 (page 57) shows CNV pressures for NIST-1 and NPM, after corrections were made in the NPM reactor power and pool temperature to match with NIST-1 testing. If NIST-1 scales the NPM initial conditions correctly, the CNV pressure curves should be closer after correction. However, the ECCS actuation timing got worse. Figure 5-29 (Pg. 67) presents the results of another calculation in which conditions in NPM are made even closer to NIST-1. There is improvement seen in the prediction of ECCS actuation timing, which depends on conditions in the CNV and RPV, and will affect the DBE response afterwards. There was no NPM calculation to match initial pressure conditions in NIST-1 and it may have additional effect on ECCS actuation timing. It seems different distortions produce compensating effects. NuScale is requested to explain and quantify the consequences of different distortions on the timing of ECCS actuation.

b. In the distortion report ({{ }}$^{2(a),(c)}$), Figures 5-10, 5-17 and 5-29 show CNV pressure history. The NPM calculation results in Figure 5-29 are the closest to NIST-1 conditions. However, the figure shows {{ }}$^{2(a),(c)}$ for CNV before ECCS actuation compared to NIST-1. No clear explanation of the impact of different distortions on the initial CNV pressurization rate is provided in the report. As the purpose of the NIST-1 facility is to provide integral data to validate the NRELAP5 code to model the phenomena involved in the range of NIST-1 operation, NuScale is requested to provide explanation for this discrepancy in early CNV pressurization in terms of distortions in the NIST-1 design or code's scaling-up toward NPM.

c. The NIST-1 tests were not initiated from the steady conditions expected in NPM. The NIST-1 initial pressure conditions were obtained from NPM blowdown calculation. At the time when NPM RPV is depressurized to {{ }}$^{2(a),(c)}$, the CNV pressure is increased to {{ }}$^{2(a),(c)}$. These pressure conditions were used to initialize RPV and CNV in NIST- 1 testing due to the limitation of the NIST-1 facility upper bound operating pressure. The distortion report does not address this distortion and other initial condition distortions for the NIST-1 testing. Therefore, NuScale is requested to provide an evaluation to quantify the impact on CNV peak pressure, should the corresponding scaled NPM initial conditions had been used for all NIST-1 test cases.

d. The distortion report ({{ }}$^{2(a),(c)}$) Section 5.1.3 shows analyses of another distortion case. NPM is modeled in the same way as NIST-1 was operated except for initial CNV and RPV pressures. From Figures 5-28 (Pg. 67) and 5-29 (Pg. 67), the CNV pressure of {{ }}$^{2(a),(c)}$ and RPV pressure of {{ }}$^{2(a),(c)}$ occur at similar times in the modified NPM calculation and at NIST-1. With the time history matching, the peak CNV pressure is still higher in NPM than at NIST-1 by {{ }}$^{2(a),(c),ECI}$. The cause of this over prediction of CNV peak pressure is not discussed adequately in the report. NuScale is requested to provide explanation for this over prediction.

e. The distortion report ({{ }}$^{2(a),(c)}$) shows the sensitivity study of reducing condensation heat transfer (Figure 5-145, Pg. 164). The figure shows that it has significant effect on {{ }}$^{2(a),(c), ECI}$ for steam space LOCA (HP-09). Same effect could occur in a liquid space LOCA, e.g. HP-06b. However, this observation appears inconsistent with the conclusion drawn in Section 5.6.1.1 of the distortion report based on Figure 5-139 that the condensation heat transfer coefficient does not affect the overall heat transfer coefficient much, it only affects by {{ }}$^{2(a),(c), ECI}$. The staff also noticed that Figure 5-139 is based on Butterworth correlation for condensation, and not the extended Shah correlation. Therefore, the following information is needed for the staff to evaluate the detailed phenomena: (1) An expanded figure of CNV pressure for first 500 seconds to see the effect of condensation heat transfer on early blowdown and ECCS phase in a liquid space LOCA such as HP-06b, (2) Verify the conclusion drawn in Section 5.6.1.1 by providing a similar plot of Figure 5.139 based on the extended Shah correlation as implemented in NRELAP5 code, (3) Similar sensitivity study of condensation heat transfer for NIST-1 calculation, and (4) Non-condensibles effects on condensation based on NIST-1 test results. NuScale is requested to provide the abovementioned information and explain why the NIST-1 containment layout did not adversely affect its capability to produce quality data for containment peak pressure estimation for NPM.

f. In the distortion report ({{ }}$^{2(a),(c)}$), Figure 5-29 (Pg. 67, HP-06 test) and Figure 5-50 (Pg. 84, HP-06b test) compare CNV pressures from data and calculations for NIST-1. The predicted NIST-1 CNV pressure shows good match with data in Figure 5-29 for HP-06 test but not as good in Figure 5-50 for HP-06b test, for pressurization phase prior to ECCS initiation. While differences are small, the increase in under prediction of CNV pressure is of concern. NuScale is requested to explain the difference with respect to code validation for peak containment pressure evaluation.

g. In the distortion report ({{ }}$^{2(a),(c)}$), Figure 5-44 shows the effect of {{ }}$^{2(a),(c)}$ on predicted NPM CNV pressure, for the HP-06 test scenario. It shows there is only a small effect on CNV peak pressure. However, Figure 5-95 (Page 122) shows the effect of {{ }}$^{2(a),(c)}$ on predicted NPM CNV pressure for HP-07 scenario (pressurizer spray line break). The figure indicates that for slower transient like HP-07 scenario, the wall conditions and heat transfer effect on CNV peak pressure are significant. It implies that conclusions from the scaling study for HP-06 test, a fast transient, are not valid for HP- 07 test which is a slower transient. There is a need for a scaling study for slow transient like HP-07 test. The discrepancy indicates that distortions exist in the scaling of {{ }}$^{2(a),(c)}$. In the scaling report ({{ }}$^{2(a),(c)}$) only one LOCA event – the CVCS discharge line break is analyzed. There are other locations of coolant discharge for design basis event. Some of these design basis events may reveal other distortions such in HP-7 that becomes limiting for safety. An evaluation of non-dimensional similarity groups (PI groups) for slower LOCA transients is requested for NuScale to justify the CVCS line LOCA distortion bounds all other coolant discharge points.

NuScale Response:

The NuScale document entitled "Calculations to Support NIST-1 Distortion Analysis and Modeling of Containment and Pool Heat Transfer" (i.e., Distortion Report) has been revised (Revision 2) to address the scope of this eRAI question and has been made available for NRC audit. The following responses to eRAI 9494, Question 06.02.01.01.A-16 are based on the revised Distortion Report. Conservatism in the containment peak pressure prediction is discussed as part of response to part (e).

RAI 9494, Question 06.02.01.01.A-16, Part (a)

Distortion Report Revision Summary:

The primary objective of the Distortion Report Revision 1 analysis was to identify and quantify the biases and scaling distortions in the as-performed NIST-1 integral effect tests (IET). The analysis was performed for NIST-1 tests HP-05, HP-06, HP-06b, HP-07, and HP-09. The NuScale Power Module (NPM) NRELAP5 model was systematically updated to account for selected biases and scaling distortions. By comparing the NPM NRELAP5 predictions and the NIST-1 IET data, it was demonstrated that the differences are reduced when the biases and distortions are taken into account. The Distortion Report has been updated to provide the following:

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}}2(a),(c)

{{

}}2(a),(c)

ECCS Actuation Timing in HP-06 Test Analysis

The Distortion Report, Revision 1, Figures 5-10, 5-17, and 5-29, depicting HP-06 CNV pressure, were replaced by a single figure. Figure 1 below shows the comparison of CNV pressure in the NPM and NIST-1 for the HP-06 test analysis. Additionally, Figures 2, 3, and 4 show similar comparisons for pressurizer, RPV, and CNV collapsed liquid levels. The NPM break initiation time corresponds with time zero in these figures. {{ }}2(a),(c). Accordingly, the {{ }}2(a),(c) Table 1 shows the comparison of initial conditions between the NPM {{ }}2(a),(c) and NIST-1 at the start of the test. Table 2 shows the comparison of event sequence timing between NPM and NIST-1, for the HP-06 test analysis. As shown in Table 2, {{ }}2(a),(c)

The ECCS is actuated on the RPV collapsed water level setpoint, at approximately {{ }}2(a),(c) after the initiation of the NIST-1, HP-06 test (see Table 2). Considering the {{ }}2(a),(c) In the NPM Base Case, the ECCS activates at approximately {{ }}2(a),(c) based on the high CNV level set-point. It is observed from Figure 1 that the {{ }}2(a),(c) The ECCS actuates at {{ }}2(a),(c) It is also observed that the final RPV and CNV levels in the long-term are similar for all the NPM cases, since all the NPM cases are initiated at the same initial RPV inventory.

The RPV level comparison in Figure 2, {{ }}2(a),(c)

{{

}}$^{2(a),(c)}$

Impact of Distortions in Initial Conditions on ECCS Actuation

The NIST-1 tests start from steady-state natural circulation conditions {{

}}$^{2(a),(c)}$

{{

}}$^{2(a),(c)}$

{{

}}$^{2(a),(c)}$

As noted earlier, the ECCS in the NPM is actuated based on the CNV level setpoint. In general, the CNV level is relatively less affected by the distortions in initial conditions. Furthermore, the LOCA EM break spectrum calculations cover large range of ECCS actuation timings. Similarly, a large range of ECCS actuation conditions are also considered in the Containment Response Analysis Methodology.

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}}$^{2(a),(b),(c),ECI}$

Figure 1 HP06 CNV Pressure Comparison

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}}2(a),(b),(c),ECI

Figure 2 HP06 Primary Liquid Level Comparison

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}}$^{2(a),(b),(c),ECI}$

Figure 3 HP06 PZR Liquid Level Comparison

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}}$^{2(a),(b),(c),ECI}$

Figure 4 HP06 CNV Liquid Level Comparison

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}}$^{2(a),(c)}$

Figure 5 RPV and CNV liquid inventory comparison between NPM Distortions Case and NIST-HP-06 assessment

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}}$^{2(a),(c)}$

Figure 6 Comparison of total RCS and CNV internal energy between NPM and NIST-1 for HP-06 distortion case

Table 1. Comparison of NPM CVCS discharge line break LOCA IC/BC and procedure case conditions at 1650 psia RCS pressure and initial conditions in NIST-1 HP-06 and HP-06b tests

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}}$^{2(a),(b),(c),ECI}$

Table 2. Sequence of Events for NPM HP-06 Scenarios and NIST-1 HP-06 test

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}}2(a),(b),(c),ECI

RAI 9494, Question 06.02.01.01.A-16, Part (b)

As previously discussed, the Distortion Report analysis has been updated to Revision 2. Figures 5-10, 5-17, and 5-29 of Distortion Report, Revision 1 have been replaced by Figure 1 above, that shows the comparison of CNV pressure in the NPM Base, IC/BC, and Distortion Cases against the NIST-1 HP-06 data and NRELAP5 assessment.

Furthermore, as summarized in response to Part (a) of this eRAI, the scope of the analysis has been expanded by providing quantification of biases and distortions through comparison of scaling non-dimensional numbers or π groups between NPM and NIST-1. The response to eRAI-9390, provided by NuScale letter RAIO-0219-64680, dated February 27, 2019, provides further information on the methodology developed for the calculation of mass and energy balance π groups in the NPM and NIST-1 RPV and CNV. Figure 7 below shows the comparison of RPV and CNV energy balance π groups calculated continuously as a function of time, for the NPM Base Case and the NIST-1 NRELAP5 assessment of HP-06 test. Figure 7, time zero, represents {{ }}$^{2(a),(c)}$ The CNV energy balance π groups are used to describe the difference in CNV pressurization rate observed between the NPM Base Case calculation and the NIST-1 data.

As shown Table 1 above, the initial CNV pressure is scaled well in the NIST-1 HP-06 test {{ }}$^{2(a),(c)}$ As observed from Figure 1 above, {{

}}$^{2(a),(c)}$

In the later part of Phase 1a, before the ECCS actuation, {{

}}$^{2(a),(c)}$

{{

}}$^{2(a),(c)}$

{{

}}$^{2(a),(c)}$

Figure 7 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM and NIST-1 for HP-06 test for the Base Case

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}}2(a),(c)

Figure 8 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM and NIST-1 for HP-06 test for the IC/BC Case

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}}$^{2(a),(c)}$

Figure 9 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM and NIST-1 for HP-06 test for the Distortion Case

RAI 9494, Question 06.02.01.01.A-16, Part (c)

The Distortion Report, Revision 1 has been updated to include detailed comparisons of initial conditions and the event sequence timings for the NIST-1 IETs considered in the LOCA Evaluation Model (TR-0516-49422, Revision 0). For example, Table 1 and Table 3 of the response to eRAI-9390 Question 15.06.05-19 Part 1, provided by NuScale letter RAIO-0219-64680, dated February 27, 2019, provide detailed comparison of the conditions in the NPM at {{ }}$^{2(a),(c)}$ and the initial conditions in the NIST-1 tests HP-06 and HP-06b. Furthermore, Table 2 and Table 4 of the response to eRAI-9390 Question 15.06.05-19 Part 1, provided by NuScale letter RAIO-0219-64680, dated February 27, 2019, provide comparison event sequence timings between NPM and the NIST-1 tests HP-06 and HP-06b. The updated distortion analysis also documents the quantification of initial condition biases and scaling distortions performed through calculation and comparison of the important RCS and CNV, mass and energy balance π groups. The impact of initial and boundary condition biases/differences and the scaling distortions on the RPV and CNV pressures and levels is analyzed through the comparison of π groups.

The NIST-1 tests start from steady-state natural circulation conditions. Due to design pressure limitation, {{

}}$^{2(a),(c)}$

Figures 10 through 13 show the comparison of NPM and NIST-1 RCS and CNV internal energies and liquid inventories for the HP-06 and HP-06b NIST-1 tests. Similar comparisons of the RCS and CNV internal energies for the NIST-1 tests HP-07 and HP-09 are shown in Figure 14 and Figure 15.

The impact of biases in some of the selected initial conditions is summarized below:

Initial core power: {{

}}$^{2(a),(c)}$

Initial RCS temperature/subcooling distribution: The initial temperature distribution in the RCS loop is important as it directly affects the conditions upstream of the break. The difference in subcooling upstream of the liquid space break has direct impact on the RCS depressurization rate. For the gas space breaks, the difference in RCS temperature/subcooling can affect how fast the RCS approaches saturated conditions.

For the NIST-1 tests considered in the distortion analysis, {{

}}$^{2(a),(c)}$

{{

}}$^{2(a),(c)}$

Initial reactor pool temperature: Since the conduction time constant corresponding to the thick CNV wall is in the order of hundreds of seconds, it takes a considerable amount of time for the pool heat transfer to establish and impact the CNV pressure trends. Consequently, {{

}}$^{2(a),(c)}$

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}}$^{2(a),(c)}$

Figure 10 Comparison of total RCS and CNV internal energy between NPM and NIST-1 for HP-06 distortion case

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}}$^{2(a),(c)}$

Figure 11. Comparison of total RCS and CNV liquid inventory between NPM and NIST-1 for HP-06 distortion case

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}}2(a),(c)

Figure 12. Comparison of total RCS and CNV internal energy between NPM and NIST-1 for HP-06b distortion case

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}}2(a),(c)

Figure 13. Comparison of total RCS and CNV liquid inventory between NPM and NIST-1 for HP-06b distortion case

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}}$^{2(a),(c)}$

Figure 14 Comparison of total RCS and CNV internal energy between NPM and NIST-1 for HP-07 distortion case

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}}$^{2(a),(c)}$

Figure 15 Comparison of total RCS and CNV internal energy between NPM and NIST-1 for HP-09 distortion case

RAI 9494, Question 06.02.01.01.A-16, Part (d)

Figure 1 in the response to Part (a) of this RAI, shows the comparison of CNV pressure calculated for the NPM in the Base Case, IC/BC Case, and Distortion Case to the measured CNV pressure in the NIST-1 HP-06 test. It is observed from the figure that the CNV pressure before the actuation of ECCS, as well as the peak CNV pressure in the NPM, is higher than the CNV pressure measured in the NIST-1 test. This observation is also applicable for the NPM distortion case that accounts for some of the biases and distortions in the NIST-1 test.

Figure 9 in response to Part (b) of this RAI shows the comparison of RPV and CNV energy balance π groups calculated continuously as a function of time for the NPM Distortion Case and the NIST-1 NRELAP5 assessment of HP-06 test. As discussed in the response to Part (b) of this RAI, and observed from the comparison of CNV energy balance π groups, {{

}}[2(a),(c)] In summary, the peak CNV pressure measured in NIST-1 is impacted by the bias and distortions in RCS temperature distribution and break enthalpy flow as well as the distortion due to condensation on the NIST-1 CNV shell.

RAI 9494, Question 06.02.01.01.A-16, Part (e)

1. *An expanded figure of CNV pressure for first 500 seconds to see the effect of condensation heat transfer on early blowdown and ECCS phase in a liquid space LOCA such as HP-06b*

The Base Case NPM NRELAP5 calculation results for the inadvertent RVV opening transient (HP-09 case) and discharge line break LOCA (HP-06) cases are analyzed using sensitivity studies to investigate the importance of various CNV heat transfer mechanisms and their impact on the CNV pressure. Two sensitivity calculations are performed with different levels of degradation applied to the NRELAP5 calculated condensation heat transfer coefficient at the CNV inside surface. {{

}}$^{2(a),(c)}$

Figure 16 below shows the impact of reduced condensation heat transfer coefficient on the CNV pressure for the inadvertent RVV opening case (HP-09). Table 3 below summarizes the impact on calculated peak CNV pressure. The degradation of condensation heat transfer results in increase of CNV pressure. The peak CNV pressure increases by approximately {{

}}$^{2(a),(c)}$

Figure 17 shows the temperature drop between the CNV fluid and CNV inside wall surface, across the CNV wall, and between the CNV outside surface and pool at the 50 ft elevation (upper CNV); similar results are obtained at a lower 16 ft elevation. These temperature drops correspond to each of the different CNV heat transfer mechanisms. The temperature difference between the CNV fluid and the CNV inner wall is indicative of the thermal resistance due to condensation or convection at the CNV inside surface. The temperature drop across the CNV wall is due to conduction heat transfer and the temperature drop between the CNV outside surface and the pool is due to pool convection.

The transient temperature difference plots indicate that {{

}}$^{2(a),(c)}$

{{

}}2(a),(c)

Figure 18 shows the average heat transfer coefficient plotted for the CNV inside and outside surfaces calculated in the NPM NRELAP5 calculation for HP-09. The condensation heat transfer coefficient is approximately four times higher than the pool convection heat transfer coefficient in the long-term after opening of ECCS. Figure 19 shows the percentage contribution from various CNV heat transfer mechanisms to the total heat transfer resistance in the Base Case NPM NRELAP5 calculation for HP-09. {{

}}2(a),(c)

A similar analysis for the discharge line break LOCA (HP-06) is presented in Figures 20 through 22. Figure 20 shows that the CNV pressure is higher for the degraded condensation heat transfer cases. The CNV pressure before the ECCS actuation, as well as the peak CNV pressure, increases with the decrease in condensation heat transfer coefficient. Table 3 shows that the peak CNV pressure increases by approximately {{

}}2(a),(c)

{{ }}2(a),(c) These results are also confirmed by the resistance contribution plot shown in Figure 22.

Table 3 Peak CNV Pressure in NPM NRELAP5 Condensation Sensitivity Calculations for HP-09 and HP-06 Cases

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}}2(a),(c)

{{

}}2(a),(c)

Figure 16 Impact of reduced CNV inside surface heat transfer coefficient on CNV pressure in NPM NRELAP5 calculation for HP-09

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}}$^{2(a),(c)}$

Figure 17 Temperature difference at upper CNV between CNV fluid and CNV inner wall, CNV inner and outer walls, and CNV outer wall and reactor pool fluid for HP-09 base case

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}}$^{2(a),(c)}$

Figure 18 CNV inside and outside heat transfer coefficients in NPM NRELAP5 calculation for HP-09

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}}$^{2(a),(c)}$

Figure 19 CNV heat transfer resistance contribution in NPM NRELAP5 Base Case calculation for HP-09

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}}2(a),(c)

Figure 20 Impact of reduced CNV inside surface heat transfer coefficient on CNV pressure in NPM NRELAP5 calculation for HP-06

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}}$^{2(a),(c)}$

Figure 21 Temperature difference at upper CNV between CNV fluid and CNV inner wall, CNV inner and outer walls, and CNV outer wall and reactor pool fluid for HP-06 base case

{{

}}$^{2(a),(c)}$

Figure 22 CNV heat transfer resistance contribution in NPM NRELAP5 calculation for HP-06

2. *Verify the conclusion drawn in Section 5.6.1.1 by providing a similar plot of Figure 5.139 based on the extended Shah correlation as implemented in NRELAP5 code*

It is highlighted that the analytical calculations presented in the Distortion Report, Section 5.6.1.1 are based on the assumption of steady state heat transfer from the CNV gas space to the reactor pool. As described in the response to Item 1 of this RAI, {{

}}$^{2(a),(c)}$ Refer to updated Distortion Report, Section 5.6.1.1 for the following discussion.

Three equations representing the three CNV heat transfer mechanisms (condensation, conduction, and pool convection) were solved simultaneously for a given CNV pressure and pool temperature boundary conditions using the non-linear equation solver for three unknowns: total heat transfer rate, CNV outside wall temperature, and CNV inside wall temperature. The condensation heat transfer coefficient was calculated {{

}}$^{2(a),(c)}$

{{

}}2(a),(c) Finally, the overall heat transfer coefficient was calculated.

{{

}}2(a),(c) This shows that a significant change in condensation heat transfer coefficient results in a relatively small change in the overall heat transfer coefficient as condensation heat transfer offers the least resistance as compared to conduction through the CNV wall or convection to pool.

Table 4 Variation of overall heat transfer coefficient

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}}2(a),(c)

Figure 25 shows the percentage contribution of different heat transfer mechanisms to the total heat transfer resistance between the CNV and pool under steady state conditions. The dotted lines with unfilled symbols show the heat transfer resistances calculated {{ }}2(a),(c) for condensation heat transfer. The solid lines with filled symbols show {{ }}2(a),(c) Irrespective of the condensation correlation used, the contribution from the condensation heat transfer to the overall heat transfer resistance {{ }}2(a),(c) is more representative of the heat transfer in the NPM CNV during Phase 1a and 1b of LOCA.

In summary, under steady state conditions, the dominant CNV heat transfer mechanisms are conduction and pool convection. {{ }}2(a),(c)

Figures 23 and 24 show that the overall heat transfer coefficient is not strong function of pressure. Furthermore, the overall heat transfer coefficient calculated {{ }}2(a),(c)

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}}$^{2(a),(c)}$

Figure 23 Containment Overall Heat Transfer Coefficient for Steady-State Conditions as a function of Containment Pressure at pool temperature of 70 degree F

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}}$^{2(a),(c)}$

Figure 24 Containment Overall Heat Transfer Coefficient for Steady-State Conditions as a function of Containment Pressure at pool temperature of 140 degree F

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}}2(a),(c)

Figure 25 CNV to Pool Heat Transfer Resistance Contribution for Steady-State Conditions as a function of Containment Pressure at pool temperature of 70 degree F

{{

}}$^{2(a),(c)}$

Figure 26. Liquid Film Reynolds Number for Steady-State Conditions as a function of Containment Pressure at pool temperature of 70 degree F

3. Sensitivity study for NIST-1 calculation

The condensation heat transfer coefficient sensitivity calculations are performed for the NIST-1 NRELAP5 assessment of the RVV opening test (HP-09) and a discharge line break LOCA test (HP-06). Similar to the NPM sensitivity calculations presented earlier in response to Item 1, {{

}}2(a),(c) The impact on peak CNV pressure is summarized in Table 5. Figures 27 and 28 show the impact on CNV pressure. Overall, the NIST-1 peak CNV pressure shows similar sensitivity to the condensation heat transfer coefficient as observed in the NPM sensitivity calculations. Similar to NPM sensitivities, {{

}}2(a),(c)

Table 5 Peak CNV Pressure in NIST-1 NRELAP5 Condensation Sensitivity Calculations for HP-09 and HP-06 tests

{{

}}2(a),(c)

{{

}}$^{2(a),(b),(c),ECI}$

Figure 27 Impact of reduced HTP inside surface heat transfer coefficient on CNV pressure in NIST-1 NRELAP5 calculation for HP-06 test

{{

}}$^{2(a),(b),(c),ECI}$

Figure 28 Impact of reduced HTP inside surface heat transfer coefficient on CNV pressure in NIST-1 NRELAP5 calculation for HP-09 test

4. Noncondensibles effects on condensation based on NIST-1 test results

The effect of non-condensable gas on condensation inside the NPM CNV and its impact on the peak CNV pressure were discussed in the response to eRAI-8776, Question 15.06.05-6, provided by NuScale letter RAIO-1017-56660, dated October 18, 2017. It is well known that the presence of non-condensable gas has a degrading effect on condensation rate of steam. As the condensation progresses, non-condensable gases from the gas mixture tend to concentrate near the condensate film surface. This results in reduction of the partial pressure of steam near the film surface and a lower condensation rate. The non-condensable gas effect in the NPM containment is expected to be negligible. The NPM containment implements a vacuum during normal operation and the total mass of non-condensable gas in the NPM containment is very small. Therefore, the mass fraction of non-condensable gas, immediately after the onset of a LOCA, is expected to remain low and decrease continuously relative to the mass fraction of steam as containment pressure increases to the peak value.

In addition to non-condensable gas that may be initially present in the evacuated CNV vessel during normal operation, non-condensable gas that is initially present in the RCS may be transported to the CNV during a LOCA and following ECCS actuation. Analytical calculations to estimate the total amount of non-condensable gas that can be present in the NPM RCS and CNV, and the maximum concentration of non-condensable gas possible in the CNV were performed. The sources of non-condensable gas in the RCS included {{

}}2(a),(c)

Table 6 shows the estimated mass of non-condensable gas in the CNV and RCS. {{

}}2(a),(c)

Table 6 Inputs for NPM CNV heat transfer analytical calculations

{{

}}2(a),(c)

{{

}}$^{2(a),(c)}$ The small mass fractions of non-condensable gases in the NuScale containment are not expected to significantly reduce the condensation heat transfer rates.

{{

}}$^{2(a),(c)}$

Figure 29 Mole fraction of non-condensable gas relative to steam as a function of NPM containment pressure

5. Why the NIST-1 containment layout did not adversely affect its capability to produce quality data for containment peak pressure estimation for NPM?

As described in response to eRAI-9208 15.06.05-15 Part c, provided by NuScale letter RAIO-0219-64682, dated February 27, 2019, the high-ranked phenomena governing the CNV pressure in NPM are the {{

}}$^{2(a),(c)}$ It is observed from these figures that the same high-ranked phenomena dominate the NIST-1 and NPM CNV pressure behavior. Furthermore, the comparison of magnitudes of π groups for {{

}}2(a),(c) indicates that the NIST-1 is capable of predicting the overall trends in CNV pressure.

As discussed in response to Parts (a) to (d) of this RAI, the NIST-1 data is affected by biases in initial and boundary conditions and scaling distortions. {{

}}2(a),(c) However, it is concluded from the comparison of π groups for the important high-ranked phenomena that the NIST-1 facility is applicable for generating the quality data over the required applicability range to validate NRELAP5 for prediction of RCS and CNV pressures and levels.

The objective of the NuScale containment pressure and temperature methodology is to show that the calculated peak CNV pressure is conservative. The methodology does not provide a direct estimate of the integral uncertainty in calculation of peak CNV pressure. The methodology objective is achieved by showing that each individual high-ranked phenomena/process that impacts the peak CNV pressure is modeled conservatively. As summarized earlier in the response to eRAI-9208 Part c, provided by NuScale letter RAIO-0219-64682, dated February 27, 2019, the phenomena governing peak CNV pressure are: {{

}}2(a),(c)

Therefore, it has been established that the peak CNV pressure is calculated conservatively by the NuScale CNV pressure and temperature methodology.

{{

}}$^{2(a),(c)}$

Figure 30 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM distortion case and NIST-1 assessment for HP-06b test

{{

}}$^{2(a),(c)}$

Figure 31 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM distortion case and NIST-1 for HP-07 test

{{

}}$^{2(a),(c)}$

Figure 32 π groups representing the components of RCS (Top) and CNV (Bottom) energy balance in NPM distortion case and NIST-1 for HP-09 test

RAI 9494, Question 06.02.01.01.A-16, Part (f)

The response to this part of the RAI focuses on the updated HP06 and HP06b assessment calculation results presented in the updated Distortion Report. Figure 33 and Figure 34 show the relevant plots of the containment pressure prediction from the revised distortion analysis. The results of the NRELAP5 test predictions are more similar in comparison to the results presented in Revision 1 of the Distortion Report.

The response to RAI 9390, Question 15.06.05-19, provided by NuScale letter RAIO-0219-64680, dated February 27, 2019, included summary tables of the HP-06 and HP-06b test initial conditions. These initial conditions are summarized in Table 7 for convenience; Figure 35 compares the measured core heater rod power in the two tests. Table 8 summarizes the measured and predicted maximum containment pressures for the updated assessment calculation results.

With respect to the containment pressurization, Table 34 and Figure 35 show that there are several differences in the test initial and boundary conditions {{

}}$^{2(a),(c)}$

As a result of the different initial and boundary conditions in the tests, {{

}}$^{2(a),(c)}$

{{

}}2(a),(c)

Overall, NRELAP5 simulates the key figures of merit of RCS and containment pressure and level with reasonable to excellent agreement for both the HP06 test and the HP06b test.

{{

}}$^{2(a),(b),(c),ECI}$

Figure 33 HP-06 Containment Pressure Comparison

{{

}}$^{2(a),(b),(c),ECI}$

Figure 34 HP-06b Containment Pressure Comparison

{{

}}$^{2(a),(b),(c),ECI}$

Figure 35 Comparison of Core Heater Rod Power for HP-06 and HP-06b Tests, Transient Short Term

{{

}}$^{2(a),(b),(c),ECI}$

Figure 36 HP06 Discharge Coefficient Sensitivity Cases, Break Upstream Temperature

{{

}}$^{2(a),(b),(c),ECI}$

Figure 37 HP06b Discharge Coefficient Sensitivity Cases, Break Upstream Temperature

{{

}}$^{2(a),(b),(c),ECI}$

Figure 38 HP06 Discharge Coefficient Sensitivity Cases, Containment Pressure

{{

}}$^{2(a),(b),(c),ECI}$

Figure 39 HP06b Discharge Coefficient Sensitivity Cases, Containment

Table 7 Summary of HP-06 and HP06b Test Initial Conditions

{{

}}$^{2(a),(b),(c),ECI}$

Table 8 Summary of HP-06 and HP-06b Test Maximum Containment Pressure, Measured and Predicted Values

{{

}}$^{2(a),(b),(c),ECI}$

RAI 9494, Question 06.02.01.01.A-16, Part (g)

The top-down portion of the NIST-1 facility scaling analysis has been revised to include {{

}}$^{2(a),(c)}$ The dimensional analysis based on the {{

}}$^{2(a),(c)}$ provided the groups representing various processes governing the mass/energy balance inside both RCS and CNV. The detailed summary of the revised top-down scaling analysis for quantifying the distortions in the NIST-1 facility is also provided in the responses to eRAI-9208, Question15.06.05-14, provided by NuScale letter RAIO-0219-64682, dated February 27, 2019, as well as eRAI-9390, Question 15.06.05-19, provided by NuScale letter RAIO-0219-64680, dated February 27, 2019. The distortion analysis is also performed as a part of the revised top-down scaling analysisconsidering NPM and as-build NIST-1 facility with **ideal initial and boundary** conditions based on NRELAP5 simulations of

- 100 percent discharge line break on the CVCS line (HP06)
- 100 percent high point vent line break (HP07)
- inadvertent opening of a single RVV (HP09)

While the distortion analysis documented in the Distortion Report considered the NPM and the as-performed NIST-1 IET data.

As described in the top-down scaling analysis, {{

}}$^{2(a),(c)}$

{{

}} 2(a),(c)

Through the distortion analysis in the Distortion Report, it is shown that the impact of this distortion on the peak CNV pressure was minimal in the HP-06, HP-06b, and HP-09 tests. The significant impact is observed for the HP-07 test with a low CNV pressurization rate. All the tests showed impact on long-term RPV and CNV pressures. The scaling distortions quantified for the steam space breaks such as HP-07 do not indicate that such breaks causing slower CNV pressurization would be more limiting for the peak containment pressure.

Impact on DCA:

There are no impacts to the DCA as a result of this response.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0319-64798

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

1. I am the Director, Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale.
2. I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:
    a. The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.
    b. The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.
    c. Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.
    d. The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.
    e. The information requested to be withheld consists of patentable ideas.
3. Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying Request for Additional Information response reveals distinguishing aspects about the method by which NuScale develops its containment response analysis.

    NuScale has performed significant research and evaluation to develop a basis for this method and has invested significant resources, including the expenditure of a considerable sum of money.

    The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

    If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

4. The information sought to be withheld is in the enclosed response to NRC Request for Additional Information No. 465, eRAI 9494. The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.
5. The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).
6. Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:
    a. The information sought to be withheld is owned and has been held in confidence by NuScale.
    b. The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.
    c. The information is being transmitted to and received by the NRC in confidence.
    d. No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.
    e. Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 8, 2019.

Zackary W. Rad