## NuScaleDCRaisPEm Resource

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**Subject:** RE: Request for Additional Information No. 194, RAI 8884 (3.9.2)
**Attachments:** Request for Additional Information No. 194 (eRAI No. 8884).pdf

Attached please find NRC staff's request for additional information concerning review of the NuScale Design Certification Application. Note that Question 12 has been deleted.

Please submit your technically correct and complete response within 60 days of the date of this RAI to the NRC Document Control Desk.

If you have any questions, please contact me.

Thank you.

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# Request for Additional Information No. 194 (eRAI No. 8884)

Issue Date: 08/21/2017
Application Title: NuScale Standard Design Certification - 52-048
Operating Company: NuScale Power, LLC
Docket No. 52-048
Review Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
Application Section: 3.9.2

QUESTIONS

03.09.02-1

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Regulatory guides (RG) describe methods that the NRC considers acceptable to use in implementing the agency's regulations. Per RG 1.20 Rev. 3, evaluate all components potentially susceptible to flow-induced vibration and flow-excited resonances. Comprehensive Vibration Assessment Program (CVAP) Technical Report TR-0716-50439-P, Rev. 0, Section 2 (NuScale Power Module Design Overview for Flow Induced Vibration) describes the reactor internals assessed for flow-induced vibration. Some components are not fully assessed. Also, some flow-induced vibration (FIV) and potential lock-in phenomena are not addressed. Addressing all FIV mechanisms will ensure the safe operations of the reactor internals during the design life; therefore, the NRC staff cannot reach a safety finding until the mechanisms are evaluated.

Provide additional FIV assessments:

(a) Vortex shedding over the upper edge of the upper riser, with possible lock-in to upper riser shell modes as well as acoustic cavity resonances. ("Lock-in" refers to a constructive feedback between the flow instability and the acoustic mode over the certain range of flow velocity, leading to strong amplification of the fluctuating pressures in the flow instability and acoustic mode.)
(b) Vortex shedding and lock-in with global and local structural modes of the overall upper riser hanger assembly
(c) Vortex shedding and lock-in-with global and local structural modes of the control rod drive system (CRDS) support structure and control rod assembly (CRA) guide tube support plate
(d) Vortex shedding and lock-in with global and local structural modes of the CRA guide tube assemblies
(e) Vortex shedding from downcomer flow over the capsule holders and the lower core support lock plate assemblies, along with potential lock-in with acoustic annulus/lower cavity modes. Also assess possible lock-in of vortex shedding from the upper support blocks with annulus acoustic cavity modes
(f) Vortex shedding from core flow over lower core plate ligaments and potential lock-in to structural and acoustic cavity modes
(g) Lock-in of pressurizer spray nozzle jet flow fluctuations with steam volume acoustic resonances. Clarify if the jet plume is subsonic, transonic, or supersonic. Assess nozzle structure high cycle fatigue.

Update the CVAP technical report to include the requested information.

03.09.02-2

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Regulatory guides (RG) describe methods that the NRC considers acceptable to use in implementing the agency's regulations. Per RG 1.20 Rev. 3, prototype designs should consider all possible significant FIV loads. Describe analysis methods and provide benchmarking of analysis methods. Section 3.2.2 (Vortex Shedding) of CVAP TR-0716-50439 only a brief summary of the VS assessments is provided and no benchmarking is discussed. Also, several components and possible lock-in scenarios are not included. Without the detailed description of analysis and addressing all FIV mechanisms, the NRC staff cannot reach a safety finding.

Evaluate structures and acoustic volumes for lock-in with vortex shedding sources (see Question 03.09.02-1). Note that flow vortices can form for flow over cavities and steps, along with the reinforcing vortices shed from bluff bodies and foils that NuScale discusses in Rev. 0 of CVAP TR-0716-50439. Note also that vortices can lock into acoustic volume modes as well as the structural modes that NuScale discusses in Rev. 0 of CVAP TR-0716-50439. Provide detailed assessments of all evaluated components, including those described in Questions 03.09.02-1, along with end-to-end (final vibration/strain/pressure) uncertainty/bias assessments based on comparisons to available measurements. If measurements of NuScale components are not yet available, benchmark the modeling and analysis methodology(s) quantitatively against other components as similar to NuScale components as is practical, such as separate effects testing. Provide expected date(s) for test report submission(s). Include susceptible structural and/or acoustic mode shapes and frequencies, assumed damping, and flow velocity calculations. Provide plots of nondimensional flow velocity (U/fD) vs. mass damping ratio for the limiting modes of all evaluated components. Consider the full range of flow, temperature, and pressure conditions associated with normal steady-state and anticipated transient operation, where normal operation spans the full range of possible load-based power levels and flow conditions.

Update the CVAP technical report to include the requested technical information.

03.09.02-3

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. In section 4.1 (Separate Effects Testing) of CVAP TR-0716-50439 only a brief summary of the planned separate effects testing is provided. Without the detailed description of analysis and testing, the NRC staff cannot reach a safety finding.

Provide the CVAP Measurement Program Report and all Test Plans or Preliminary Results Reports, which should include separate effects testing operating conditions, test durations, instrument types and locations, applicable testing hold points, and pre-test predictions of the expected and allowable experimental results, considering bias errors and random uncertainties (B/U). Explain how end-to-end B/U (vibration/strain/pressure) calculated from comparing pre-test predictions to the test results, as well as bias errors associated with differences between the effects testing and full-scale operation (e.g., air-filled instead of water/steam-filled SG tubes, low instead of high temperature/pressure operation), have been applied to the design FIV analysis results and how updates will be/have been made to the margin of safety estimates. Explain how any reductions in margin of safety will be/have been addressed. Finally, Section 6.2 of ER-A010-2085, Rev. 0 states: "Preliminary FIV analysis indicated that the CRAGT [control rod assembly guide tube] is the most susceptible component within the RVI [reactor vessel internals] to FIV degradation. A test program (to) measure the component's deformation under flow has been outlined in Ref. 1.5.45 (TSD-T070-8245, Rev. 3, "Flow induced vibration of NuScale Control Rod Assembly Guide Tube")." However, following this discussion the following appears: "To minimize the expense of the RVI development efforts, it is desired to minimize the scope and quantity of the separate effects testing. This effort will push the majority of the testing work to the pre-operational tests." Explain what specific testing work is being deferred to pre-operational testing and reconcile this statement with the previous comment that '…the CRAGT is the most susceptible component … to FIV degradation." What are the potential impacts of deferring the testing to the pre-operational tests? How will the CRAGT FIV analysis be assured by deferring testing? How will NuScale demonstrate the reliability of the CRAGT structure prior to placing it inservice for pre-operational and start-up testing? Describe the overall reactor conditions for the pre-operational test phase for CRAGT testing.

03.09.02-4

Per RG 1.20 Rev. 3, describe analysis methods and quantify bias errors and uncertainties. Bias errors and uncertainties can be estimated by comparison of analysis and test results (i.e. benchmarking). Section 3.1.1 (Structural Natural Frequency and Mode Shapes) of CVAP TR-0716-50439 only a brief summary is provided, and no benchmarking is discussed. Without the detailed description of analysis and testing, the NRC staff cannot reach a safety finding.

Provide detailed information on structural natural frequencies and mode shapes for all components evaluated for FIV, along with bias/uncertainty (B/U) assessments based on comparisons to available measurements. In particular compare mode shapes and natural frequencies of the SG assembly in the SIET TF-2 (NP-ER-A014-1630, Rev. 1, "SIET Helical coil steam generator test program, electrically heated test facility design") to simulations made using modeling procedures consistent with those used to model the NuScale SG. If measurements of other NuScale components are not available, benchmark the modeling and analysis methodology(s) quantitatively against other components as similar to NuScale components as is practical. Given the comments made in Appendices G.2, G.3, and G.4 of EC-A014-3306, Rev. 1 regarding the potential design changes to tube supports that may affect the tube boundary condition modeling, give particular attention to uncertainty of natural frequency simulations and bias/uncertainty associated with boundary condition variability. Note this request is irrespective of the cited margins of safety in the CVAP.

03.09.02-5

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. Section 3.1.2 (Flow Velocity) of CVAP TR-0716-50439 only a brief summary is provided, and no benchmarking is discussed. RG 1.20 Rev. 3 outlines the level of detail needed, including a description of the analysis methods and comparison of analysis and test results to establish bias errors and uncertainties (i.e. benchmarking). Without the detailed description of analysis and testing, the NRC staff cannot reach a safety finding.

Provide detailed information on flow velocities for all components evaluated for FIV, along with uncertainty/bias assessments based on comparisons to available measurements (such as the completed "separate effects testing" cited in Section 3.1.2.3). Computational fluid dynamics (CFD)-based velocities are preferred, as they should include the effects of any pressure gradients and blockages on flow distributions. Provide limiting velocities for the full range of flow, temperature, and pressure conditions associated with normal steady-state and anticipated transient operation (note that full power/maximum flow rate may not be the limiting condition for lock-in, fluid-elastic instability, and other strong FIV sources). In particular, provide velocity measurements from the testing program described in Section 3.5.5 of ER-A010-2158, Rev. 0 (i.e. "The flow path through the control rod assembly guide tubes (CRAGT), including the control rod assembly (CRA) cards and the CRDS and ICIGT [in-core instrument guide tube], which pass through the CRAGT, is the most tortuous of any section of the RVI…Therefore a testing program has been developed to determine the necessary flow information, including velocities, necessary to support FIV analysis of the CRAGT.")  Also include information for Emergency Core Cooling and Decay Heat Removal conditions. Note this request is irrespective of the cited margins of safety in the CVAP.

Update the CVAP technical report to include the requested information.

03.09.02-6

10 CFR 52.47 requires design certification applicants to demonstrate how operating experience insights have been incorporated into the plant design.  The NRC has published a lessons learned document regarding the failures of the SONGS replacement steam generators (EA-13-083, 20 Sep 2013, ADAMS ML13263A271).  The key conclusion is that tube motion due to Fluid Elastic Instability and/or random vibration caused contact and wear, particularly for in-plane motion of the U-bend region (an unexpected occurrence).   The root cause was insufficient contact forces between tubes and support plates, retainer bars and Anti-Vibration Bars (AVBs) leading to much longer free tube lengths and lower resonance frequencies as well as more wear at the interfaces.  Without the detailed description of SG tube and support design and analysis, the NRC staff cannot reach a safety finding.

Given the NRC SONGS SG failure lessons learned document, provide a quantitative description of how the NuScale SG design will not experience problems similar to those of the SONGS replacement SG.  Consider random (turbulent buffeting and internal turbulent swirling two-phase flow) and tonal (vortex shedding, FEI, etc.) vibration of the tubes, tube support bar assembly, supper tube support bar, and lower tube support cantilevers.  Explain how sufficient tube to structure contact forces are ensured to avoid longer than expected unsupported tube sections and lower resonance frequencies.  Provide the tolerances/fits between tubes and tube support bar assembly, tube support bar/cantilevers, and other constraints at normal and transient operating conditions, including extreme thermal hydraulic conditions.  Show that calculated internal secondary coolant void fraction and damping estimates are conservative, particularly in steam and multi-phase flow sections.  How long do the separate effects or startup testing need to be to gather sufficient statistics to confirm the fatigue usage analyses (1E6 cycles are unlikely to be sufficient, unless contact occurs at each cycle)?  How will inspection be done given the difficulties of examining such tightly packed systems?

Update the CVAP technical report to include the requested information.

03.09.02-7

Per RG 1.20 Rev. 3, describe analysis methods and quantify bias errors and uncertainties.  Bias errors and uncertainties can be estimated by comparison of analysis and test results (i.e., benchmarking).  Section 3.2.4 (Acoustic Resonance) of CVAP TR-0716-50439 only a brief summary of the AR assessments is provided and no benchmarking is discussed.  Without the detailed description of analysis and testing, the NRC staff cannot reach a safety finding.

Provide detailed assessments of all evaluated acoustic cavities subject to flow-induced resonance, including those described in Question 03.09.02-1, along with end-to-end (final vibration/strain/pressure) uncertainty/bias assessments based on comparisons to available measurements. If measurements of NuScale components are not available, benchmark the modeling and analysis methodology(s) quantitatively against other components as similar to NuScale components as is practical.  Note that acoustic resonance (AR) is not limited to branch lines in piping and can occur in cavities and annuli (such as the annulus containing the SG) within the pressure vessel.  A detailed assessment of the decay heat removal system (DHRS) steam lines with 29% factor of safety is needed.  Include susceptible acoustic mode shapes and frequencies, assumed damping, and flow velocity calculations.  Provide plots of resonance frequencies vs. expected flow speeds for all evaluated cavities.  Consider the full range of flow, temperature, and pressure conditions associated with normal steady-state and anticipated transient operation, where normal operation spans the full range of possible load-based power levels and flow conditions. Note this request is irrespective of the cited margins of safety in the CVAP. Update the CVAP technical report to include the requested information.

03.09.02-8

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Section 3.2.5 (Leakage Flow Instability) of CVAP TR-0716-50439 is incomplete. Only a brief summary of the leakage flow instability (LFI) assessments is provided. However, a longer description of LFI issues that may occur in the NuScale internals is provided in EC-A010-2230, Rev. 0. In that document, the following components are listed as potentially being susceptible to LFI: SG tube inlet flow restrictor, CRDS, ISP to CRDS, ICIGT, and Riser Section Slip Joint. In the conclusions of the document the following statements are made: "Unlike acoustic resonance and flutter/gallop, no generically valid acceptance criteria could be identified for LFIV as (1) this complex phenomenon is very sensitive to the structure geometry and the flow conditions and (2) analytical methods involve complex mathematical equations and computational simulations that may need to be validated with testing. As a result, a thorough literature review needs to be performed to identify papers that would apply to the NuScale components geometry and flow characteristics." Without the detailed description of the LFI analysis, the NRC staff cannot reach a safety finding. Provide the subsequent literature review and any updates to the LFI assessments of the potentially susceptible components. Also, provide the results of the separate effects test that was performed to assess LFI for the inlet SG flow restrictor. Provide the test results along with the chosen flow restrictor design.

Update the CVAP technical report to include the requested information. Also include a drawing of the flow restrictor in the DCD.

03.09.02-9

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Regulatory guides (RG) describe methods that the NRC considers acceptable to use in implementing the agency's regulations. RG 1.20, Rev. 3 states that the vibration measurement program should include description of instrument types and locations. In section 4.2 (Lead Unit Factory Testing) of CVAP TR-0716-50439 only a brief summary of the planned lead unit factory testing is provided. Without the detailed description of the testing plan, the NRC staff cannot reach a safety finding.

Provide a detailed test plan for the lead unit factory testing. Include instrument types and locations and pre-test predictions of the expected and allowable experimental results, considering bias errors and random uncertainties. Update the CVAP technical report to include the requested information.

03.09.02-10

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. In section 4.3 (Lead Unit Initial Startup Testing) of CVAP TR-0716-50439 only a brief summary of the planned lead unit initial startup testing is provided. Also, no instrumentation is defined for this testing. Without the detailed description of the testing plan, the NRC staff cannot reach a safety finding.

Provide the CVAP Measurement Program Test Plan, including initial startup test operating conditions, test durations, instrument types and locations, applicable testing hold points, and pre-test predictions of the expected and allowable experimental results, considering bias errors and random uncertainties (B/U). Note that prototype reactor internals that may be subject to significant FIV necessitate instrumentation. In particular, provide instrumentation plans that will be used to measure susceptible SG tube vibration and contact statistics, ICIGT to CRDM support contact statistics, and DHRS steam piping vibration. Ensure that testing will also be performed for 1 million cycles for Emergency Core Cooling and Decay Heat Removal operations. Explain how end-to-end B/U (vibration/strain/pressure) calculated from comparing pre-test predictions to the test results will be applied to the design FIV analysis results and how updates will be made to the margin of safety estimates. If any margins of safety are not met, provide corrective actions and update the future inspection program to monitor components susceptible to structural failures. Provide details on how acceptance criteria will be checked. Update the CVAP technical report to include the requested information.

03.09.02-11

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Section 5 (Vibration Inspection Program) of CVAP TR-0716-50439 is incomplete. Only a brief summary of the planned inspection program is provided. Also, only visual inspections are planned for accessible components. Without the detailed description of the inspection plan, the NRC staff cannot reach a safety finding.

Provide a detailed inspection program, showing which components/regions are visually accessible, and explaining how the inspections will be performed. Explain how crack initiation will be evaluated for components which cannot be visually accessed. Update the CVAP technical report to include the requested information.

03.09.02-12

Question deleted..

03.09.02-13

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. TR-0716-50439, Rev. 0, Section 3.2.3 (Turbulent Buffeting) states that "thin or flexible structures are evaluated for fatigue." These criteria are vague. Without the detailed description of the analysis criteria, the NRC staff cannot reach a safety finding. Provide quantitative criteria for evaluating structures for fatigue. Update the CVAP technical report to include the requested information.

03.09.02-15

RG 1.20, Revision 3 states that a description of the vibration measurement and inspection phases of the comprehensive vibration assessment program should be submitted to the NRC. DCD Tier 2, Rev. 0, Section 3.9.2.4, COL Item 3.9-1 states that a COL applicant that references the NuScale Power Plant design certification will submit the results from the comprehensive vibration assessment program for the NuScale Power Module, in accordance with Regulatory Guide 1.20. Per RG 1.20, the details of the

CVAP needs to be submitted by the COL applicant to the NRC prior to the preoperational testing or initial startup testing. The staff requests the applicant to revise this COL item to: "A COL applicant will provide the comprehensive vibration assessment program for the NuScale Power Module to the NRC including the test procedures prior to the start of initial startup testing and the testing results, in accordance with Regulatory Guide 1.20."

03.09.02-16

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. DCD Tier 2, Rev. 0, Section 3.9.2.3 states "Pre-operational testing is performed with the NPM components prior to fuel loading, at any time during module construction when the testing can be assured to accomplish the objectives of the measurement program." Per RG 1.68, preoperational testing refers to test in the assembled plant prior to fuel load. If NuScale intends to perform factory tests instead of a preoperational test, the staff requests that the applicant use the proper terminology.

03.09.02-17

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. DCD Tier 2, Section 5.4.1 and TR-0716-50439-P, Rev, 0, "NuScale Comprehensive Vibration Assessment Program Technical Report" provide figures of the steam generator tubes and tube supports. The NRC staff needs additional information to understand the details of the tube support design. Therefore, the staff requests the applicant to provide sketches showing details of the steam generator tube supports including components such as tube support bracket, support backing strip. Provide a discussion of the clearance between components and identify these clearances on the sketches. Update the DCD or CVAP technical report to include the requested information.