July 26, 2019

Docket No. 52-048

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

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 427 (eRAI No. 9408) on the NuScale Design Certification Application

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 427 (eRAI No. 9408)," dated April 17, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 427 (eRAI No.9408)," dated July 25, 2018
3. NuScale Power, LLC Response to NRC "Request for Additional Information No. 427 (eRAI No.9408)," dated February 8, 2019
4. NuScale Power, LLC Response to NRC "Request for Additional Information No. 427 (eRAI No.9408)," dated July 26, 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. 9408:

- 03.09.02-73

A majority of the responses to RAI No. 427, eRAI No. 9408, questions were previously provided in References 2, 3 and 4. The response to question 03.09.02-74 will be provided by July 31, 2019.

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 427 (eRAI No. 9408). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. 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 Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9408, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9408, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0719-66457

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9408, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9408, nonproprietary

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

eRAI No.: 9408
Date of RAI Issue: 04/17/2018

NRC Question No.: 03.09.02-73

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 the NuScale reactor design, the control rod drive shafts (CRDS) and in-core instrument guide tubes (ICIGT) are exposed to cross flow above the upper riser. NuScale has evaluated the possibility of shed vortices induced by the cross-flow locking in to structural resonances of the CRDS and ICIGT using guidelines from the ASME Boiler and Pressure Vessel Code III Nonmandatory Appendix N-1300 (Flow-induced vibration of Tubes and Tube Banks). During the audit from May 16, 2017, through November 2, 2017, the staff finds that NuScale estimates small margins of safety for vortex shedding (VS) lock-in for both the CRDS and ICIGT structures, but does not plan to test either component until after prototype manufacturing. The proposed "factory testing" is limited to modal analysis in air conditions. There are several potential non-conservative aspects to NuScale's VS analyses that may reduce or eliminate the reported margins of safety against VS lock-in, including those below.

- NuScale uses averaged velocity in the cross-flow region from a computational fluid dynamics (CFD) Reynolds Averaged Navier Stokes (RANS) analysis of the reactor flow (the peak velocity is nearly twice as high as the averaged velocity). Using averaged velocity will estimate lower FIV forces which will be non- conservative.
- NuScale assumes that the holes in the CRDS support plates provide rigid in-plane boundaries on the ICIGT and CRDS structures, when there appear to be substantial clearances in the CRDS holes (to allow shaft motion), and small clearances in the ICIGT support holes (but not small enough to ensure rigid in-plane boundaries). These clearances are cited in the Turbulent Buffeting (TB) degradation analyses, which state that the estimated RMS displacements due to TB are smaller than the radial clearances.

- Coarse beam finite element (FE) structural models were used to estimate CRDS and ICIGT modal frequencies without mesh convergence studies. Resonance frequencies calculated from FE models decrease as mesh density is increased, and may be biased high in NuScale's analyses.

NuScale's TB degradation assessments may also be nonconservative given the concerns below.

- As with VS analyses, NuScale appears to use averaged instead of peak velocities as inputs to their assumed forcing functions. However, the assumed forcing functions, as delineated in Section 3.2.3 of the CVAP, are based on peak (also referred to as free stream), not averaged velocities.
- NuScale uses a simple formula to estimate average crossing frequencies. Crossing frequency is defined as an effective modal participation-weighted mean frequency of the structure in M.K. Au-Yang's "Flow- Induced Vibration of Power and Process Plant Components: A Practical Workbook," 2001, ASME Press. The estimated crossing frequency for the CRDS is about half that of the first resonance frequency, which may not be conservative and correspondingly reduces the number of damage cycles by half.
- It appears that NuScale has used simplified random analysis procedures for some of the TB assessments (such as the Brenneman method) which have not been shown to be bounding or implemented appropriately.
- While the TB degradation documents assume nominal clearances between the CRDS and ICIGT and CRDS support plate holes, the VS documents assume zero clearance and rigid boundaries in the radial direction. If the CRDSs and ICIGTs are indeed contacting the hole edges, additional wear and impact damage will occur.

NuScale is requested to provide the following regarding the CRDS and ICIGT structures. Alternatively, NuScale may propose other options to resolve the staff's concerns identified above.

1. Quantify the impacts of the potential non-conservatisms in the VS lock-in evaluations on fatigue and wear damage including: maximum vs. averaged cross-flow velocities, use of active boundaries in the CRDS plates in spite of large clearances, and potentially unconverged FE structural models. Provide data from any detailed analyses and/or tests which substantiate the VS analysis inputs.

2. Quantify the impacts of the apparent non-conservatisms in the TB evaluations on fatigue and wear damage including: possible use of averaged rather than peak velocities for forcing functions, use of active boundaries in spite of large clearances, potentially unconverged FE structural models, and crossing frequencies which are less than the fundamental resonance frequency of the structures. Or, provide justification regarding why these potential non-conservatisms do not exist. If simplified random analyses are used (such as the Brenneman method), demonstrate that those methods are implemented appropriately and are bounding using a simple, but representative, benchmark problem.

3. Provide the expected RMS displacements due to both VS loading and TB analyses (reflecting any updates based on responses to items 1 and 2 along with fatigue and wear damage estimates due to impact and fretting. Fatigue analyses should include assessments of alternating stress intensities at welds and other joints computed using standard concentration and weld factors. Explain the effects on VS and TB due to any static deflections of the structures due to cross flow, gravity, thermal, buoyancy and other effects which may reduce or eliminate clearances between the CRDS and ICIGT structures and holes in the CRDS support plates.

4. The NuScale CVAP measurement program consists of factory testing for the CRDS and ICIGT. Provide a summary of the factory test plan for the CRDS and ICIGT structures, including details on the test structures, boundary conditions, instrumentation, planned tests, pre-test estimates, and acceptance criteria.

Update the comprehensive vibration assessment program report TR-0716-50439, as appropriate to include a summary of the requested information.

NuScale Response:

The issues were evaluated by NuScale and resulted in revised turbulent buffeting (TB) and vortex shedding (VS) analyses. The evaluation reflects a change to the turbulent buffeting analysis wherein the reactor vessel internals (RVI) assembly as a whole has now been evaluated for turbulence-induced motion. The TB and VS analyses also include a design change to add a sleeve over the control rod drive (CRD) shaft between the baffle plate and the uppermost CRD shaft support, and add welds between each in-core instrument guide tube (ICIGT) and the first CRD support that it passes through in the riser.

Due to the design change to sleeve the CRD shaft in the region where it is exposed to cross flow, and the addition of welds near the region where the ICIGT is exposed to cross flow, the CRD shaft is no longer susceptible to VS, and ICIGT safety margin is greater than 100%. Therefore, factory testing is no longer required to validate the component mode shapes and frequencies.

Average velocities were used in the VS assessments based on the velocity definition of “mean velocity” provided in ASME Appendix N-1312 (Nomenclature) for use in section N-1320 (Vortex Shedding) of Section III of the ASME Code. Although the Code specifies use of a mean, incident velocity for VS evaluations, the VS calculation uses the velocity at the plane of the component, meaning that the velocity evaluated is for a region with a smaller flow area and thus a higher velocity than the Code requires. This assumption is bounding.

The issue related to the effectiveness of the CRD support for VS analyses has been eliminated based on the design change to weld the ICIGTs to the first CRD shaft that it passes through in the riser; thus eliminating clearances and creating a fixed boundary condition. Additionally, the CRD shaft is now sleeved and no longer susceptible to vortex shedding.

For the VS evaluation, a mesh sensitivity study of each component analyzed using a finite element model, including the ICIGT, was performed. The difference in the natural frequency for the two mesh refinements is less than approximately 1%, demonstrating that adequate mesh has been selected for the modal analyses.

The turbulent buffeting analysis of the RVI consists of the evaluation of the RVI assembly (the combination of structures, dominated by the riser, extending from the baffle plate to the lower core supports) and three individual components: the ICIGT, the CRD shafts, and the control rod assembly guide tube (CRAGT). The motion of the RVI assembly can contribute to relative motion between the CRD shafts or ICIGT and their supports (the supports are part of the RVI assembly). The CRAGT and the CVCS injection line are fully supported by the RVI assembly and thus do not move relative to it due to RVI motion.

The clearances of the CRD shaft and ICIGT supports were re-evaluated based on the RAI questions and issues. The ICIGT supports were found to be tight enough to establish effective coupling between the shaft and the support due to the squeeze film effect of viscous damping from fluid in the annular gap. For the ICIGT this damping was {{ }}$^{2(a),(c)}$ and justifies the use of lateral restraints at the support locations in the ICIGT model. The CRD shaft supports were found to be too loose to establish effective coupling between the shaft and the support from viscous effects. The assumption of one inactive support was therefore revised to five inactive supports. The three remaining active supports were selected to be approximately evenly spaced based on the judgment that long spans through multiple supports are unlikely to occur without contact for a relatively flexible shaft with {{ }}$^{2(a),(c)}$ diametrical clearances. When evaluating wear or impact fatigue, the location of the inactive supports is used. Sliding wear and impacts are evaluated using the vibration estimates that assume no contact at these locations. This is bounding because sliding or impacts tend to provide a form of support and reduce relative motion compared to the unsupported case. For the upper span of the ICIGT where vortex shedding due to cross flow on the structure could occur, the ICIGT is welded at the supports that bound this span.

The CRD shaft and ICIGT are vertically aligned structures, therefore gravity related effects do not contribute to closing the annular gaps between the supports and the shafts. This includes weight and buoyancy. Cross flow is applied to the ICIGT above the upper riser, but the supports on either side of the cross flow are welded to the ICIGT. The CRD shaft does not experience cross flow because it is inside the CRD shaft sleeve above the upper riser. Therefore, cross flow does not contribute to closing annular gaps between the structures and their supports. Thermal expansion is less than the clearances for the CRD shaft and the ICIGT. There are two main effects that contribute to static deflection of the shaft relative to the supports. The first is manufacturing effects that result in the real structure not being perfectly aligned over the length of the CRD shaft or the ICIGT. A perfectly straight shaft over this distance and perfectly aligned supports across this distance are unlikely. The second is the stiffness of the structure. The structure is not stiff enough to maintain perfect alignment across the entire CRD shaft or ICIGT length with no supports.

The use of average velocity as an input for the annular flow power spectral density (PSD) is appropriate based on the formulation of the PSD in the literature source. This is described in detail on page 118 of the reference:

Au-Yang, M. K., 1980, “Dynamic Pressure Inside a PWR - A Study Based on Laboratory and Field Test Data,” Nuclear Engineering and Design, Vol. 58, pp. 113-125.

For tube bundle PSD equations (both axial and crossflow), the velocity input to be used per the literature sources is the gap velocity (the velocity at the minimum cross sectional area in the direction of flow). For an axial flow tube bundle, the gap velocity is constant and equal to the free stream velocity. The velocity through the CRD shaft support plates (which is higher due to the reduced flow area) is used along the entire length of the axial flow section for the CRD shafts and ICIGTs. For the ICIGTs in the riser turn, where the crossflow PSD is used, the free stream velocity from the CRD shaft support structure in the riser is also used, which bounds the radial gap velocity at the upper riser turn. The conservatively high velocities are used to generate the PSDs consistent with the literature intent of using the free stream or gap velocities as an input.

The Brenneman method is a closed form solution of the coherence function integrated over two rectangular regions. As it is an exact solution to the integral, it does not introduce new assumptions or simplifications to the random vibration analysis. This method is well suited for random vibration analysis using finite element results, as elements are typically on the same scale as the correlation length. Integration is required on a scale smaller than an element in order to capture the rapid local changes in the coherence function. The Brenneman formulation of the integral is validated by an alternate method, using numerical integration of the coherence function for the ICIGT and CRD shaft. This alternate method demonstrates that the Brenneman formulation produces equivalent results to numerical integration.

For turbulent buffeting and vortex shedding, the main concern with respect to fatigue comes from effects between adjacent components. Motion at a fixed joint like a weld is very small and does not produce substantial stress in the weld. Bending stress mid-span was evaluated and found to not contribute significantly to fatigue usage, due to low amplitude. Therefore, weld stress concentration factors were not used in the fatigue analysis for turbulent buffeting.

The model for the ICIGT was shown to be converged in a mesh sensitivity study. Because the CRD shaft model has longer spans and the same element density, it was therefore not analyzed separately for convergence.

The motion of the CRD shaft and ICIGT relative to their supports is dominated by the motion of the supports (the RVI assembly) in the revised RVI turbulent buffeting analysis. The RVI assembly has a higher crossing frequency ({{ }}$^{2(a),(c)}$) than the highest mass participation mode ({{ }}$^{2(a),(c)}$). This is conservative with respect to cycle counts for impact fatigue.

For RVI turbulent buffeting, the analysis shows that fatigue due to impacts is negligible for components where relative motion is expected. Sliding wear of the CRD shaft/support wear pair and the ICIGT/support wear pair, if concentrated at one location over the life of the plant, is calculated to be appreciable. If the wear were to occur on the CRD shaft (as opposed to the support), it is more than the wall thickness, and for the ICIGT it is {{ }}$^{2(a),(c)}$ of the wall thickness. This is not an expectation for significant wear, because the calculation methods are bounding rather than best estimate. Concentrated wear is unlikely for the ICIGT because the local damping of the annular film at each support prevents relative motion. Concentrated wear on the CRD shaft is unlikely because the CRD shaft has smaller amplitude vibrations than the bounding estimates. Some of the control rods move vertically such that the same section of control rod is not always adjacent to the support. Wear is likely to occur at the support rather than on the ICIGT or CRD shaft because the material for the support is softer than the analyzed components. The result indicating the potential for wear is justification for inclusion of these support locations in the inservice inspection plan. Wear at the support locations will exceed wear on the ICIGT or CRD shaft. Inspection plan documents specify VT-3 examinations for multiple CRAGT locations, ICIGT supports, and for CRD shaft supports. If wear is found at the support locations, then the CRD shaft or ICIGT will also be examined. These examinations prevent a reactor module from operating with excessive RVI wear. Wear is a lifetime management issue that is not within the scope of the CVAP program.

Results of the updated VS and turbulent buffeting assessments described in this response are provided in Sections 3.2.2 and 3.2.3 of the NuScale Comprehensive Vibration Assessment Program (CVAP) technical report TR-0716-50439.

Impact on DCA:

The CVAP Technical Report TR-0716-50439 will be revised as described in the response above. The technical report is being submitted separately.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0719-66457

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 CVAP 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. 427, eRAI 9408. 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 July 26, 2019.

Zackary W. Rad