RAIO-1117-57291

November 20, 2017

Docket: PROJ0769

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. 8990 (eRAI No. 8990) on the NuScale Topical Report, "Loss-of-Coolant Accident Evaluation Model," TR-0516-49422, Revision 0

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 8990 (eRAI No. 8990)," dated September 19, 2017
2. NuScale Topical Report, "Loss-of-Coolant Accident Evaluation Model," TR-0516-49422, Revision 0, dated December 2016

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. 8990:

- 15.06.05-7

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 8990 (eRAI No. 8990). 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 Darrell Gardner at 980-349-4829 or at dgardner@nuscalepower.com.

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8G9A
Samuel Lee, NRC, OWFN-8G9A
Rani Franovich, NRC, OWFN-8G9A

Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 8990, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 8990, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-1117-57292

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 8990, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 8990, nonproprietary

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Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 8990
Date of RAI Issue: 09/19/2017

NRC Question No.: 15.06.05-7

Title 10 of the Code of Federal Regulations (10 CFR) Part 52, Section 47 (a)(2) states, “A description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished.” Likewise, 10 CFR Part 50, Appendix K, II.4 – Required Documentation, requires that, “To the extent practicable, predictions of the evaluation model, or portions thereof, shall be compared with applicable experimental information.”

As stated in RG 1.203, an evaluation model (EM) is the calculational framework for evaluating the behavior of the reactor system during a postulated transient or design-basis accident. As such, the EM may include one or more computer programs, special models, and all other information needed to apply the calculational framework to a specific event, as illustrated by the following examples:

(1) Procedures for treating the input and output information (particularly the code input arising from the plant geometry and the assumed plant state at transient initiation).
(2) Specification of those portions of the analysis not included in the computer programs for which alternative approaches are used.
(3) All other information needed to specify the calculational procedure.

The entirety of an EM ultimately determines whether the results are in compliance with applicable regulations. Therefore, the development, assessment, and review processes must consider the entire EM.

During a Loss of Coolant Accident, the primary heat transfer processes include condensation heat transfer to the containment vessel (CNV) inside wall, conductive heat transfer though the CNV wall and convective heat transfer from the CNV outside wall to the reactor cooling pool. These heat transfer capabilities are critical to cool the reactor core and remove decay heat. The Loss-of-Coolant Accident (LOCA) Evaluation Model topical report did not clearly define how each of these heat transfer processes are calculated in the NRELAP5 code models and did not clearly describe the impact of uncertainty in these models and processes on ability of the CNV to function and provide emergency core cooling system (ECCS) condensate flow back to the reactor pressure vessel (RPV).

During any RPV liquid space LOCA, part of the high energy fluid released from the RPV will flash to steam and expand into the CNV volume. During any RPV steam space LOCA, the high pressure RPV steam will expand into the CNV volume. Regardless of the break location, blowdown ensues and when the differential pressure difference between the RPV and CNV reaches the design blocking pressure, the Reactor Recirculation Valves (RRV) and Reactor Vent Valves (RVV) are all designed to open to equalize the pressure and initiate the ECCS function of the CNV. After these valves open, the added rapid liquid volume flows from the RRVs and steam volume flows from the RVVs, causing the pressures between these two volumes to equalize in a short time {{ }}[2(a)(c).]

NuScale uses their version of RELAP5-3D (NRELAP5) to evaluate the single and two phase liquid flows between the RPV and CNV. However, the application of RELAP5 to the unique NuScale design, which incorporates a high pressure CNV space that functions as both a containment and ECCS, is a new application of RELAP5 that requires detailed and complete descriptions of the models, equations and methods used to calculate (1) steam temperature and pressure in the CNV, and (2) heat transfer from the CNV steam space via condensation to the CNV wall.

In the LOCA evaluation model topical report and the NRELAP5 theory manual (SwUM-0304-17023, Revision 4), the application of the condensation heat transfer correlations is not sufficiently clear. The staff needs more information on the NRELAP5 wall heat transfer computation processes. An initial list of items needed is as follows:

1. NuScale has indicated that the {{

   }}[2(a)(c).] of application to theNuScale power module (NPM). Please provide detailed numerical calculation procedures on how the Shah and {{ }}[2(a)(c).] are actually used in the NRELAP5 code. Please provide Re#, film thickness, Nu#, condensation heat transfer correlation (HTC), and overall HTC calculations for three consecutive nodes in the top, middle, and bottom portions of the CNV where steam is condensing on the CNV wall and then flowing down the CNV wall as a thin film.
2. Please identify the specific CNV nodes in the LOCA results where the majority of the condensation is occurring (i.e., for nodes 500-22, 500-21, and 500-20, which are linked with heat structures (HSs) 5104-014, 5014-013, and 5014-012, respectively) and provide the following for those nodes:
   a. Describe the method used to calculate the Reynolds number for the node as an input for the determination of the steam condensation heat transfer coefficient;
   b. Provide equations used to calculate the heat transfer coefficient, film flow and thickness, and total steam condensation rate from the top to the bottom and the node average heat removal based on the dimensionless vapor velocity parameter, J_g;
   c. Provide boundary conditions used to ensure that the correct film flow rate per unit periphery is determined at each node interface and is then transferred to the next node down the CNV;

NuScale Power

d. Specify any limits imposed on steam condensation heat transfer or heat removal rate; and
e. Describe how NRELAP5 calculates heat convection and conduction to the CNV wall surfaces below the liquid water level inside the CNV.

3. The staff needs to better understand event progression during the period just after ECCS opens and peak CNV pressure is reached for a liquid space LOCA (e.g., chemical volume and control system [CVCS] 100% break). For the three CNV nodes and associated HSs identified in Item 2, list key calculation steps used in the NRELAP5 code with results and show how computations are implemented for equations in Section 2.6.2.5 of the theory manual for condensation heat transfer.
4. Describe the equations, models and methods used in NRELAP5 to calculate the transient heat flow from the inside surface of the CNV to the ultimate heat sink pool outside the CNV. Describe the initial boundary conditions applied to solving the transient heat conduction equation for the CNV. For the heat structures referenced above, describe how heat energy is conducted through the CNV wall to the pool and provide an assessment of the number of mesh points used.
5. Repeat the process (items 1-4) for a similar location of the NIST-1 heat transfer plate (HTP) with three corresponding nodes from the representative test, HP-06b "CVCS discharge pipe break," where condensation heat transfer is highest.
6. Since the {{

}}2(a)(c)., please provide an uncertainty band based on the uncertainty analysis using NuScale-specific experimental data or any other applicable and credible separate effects test data.
7. The {{

}}2(a)(c). did not have enough resolution for NRC staff to reach a conclusion. In particular the NRC staff seeks a better understanding of the period before the peak CNV pressure is reached for a liquid space LOCA (CVCS 100% break). Please demonstrate the relative effects of heat transfer mechanisms on the peak containment pressure {{ }}2(a)(c). with better resolution.

NuScale Response:

1. Introduction

Due to its significance in reactor core cooling and decay heat removal, the detailed discussion on the containment vessel (CNV) wall heat transfer during a postulated NuScale Power Module (NPM) loss-of-coolant accident (LOCA) is presented. {{

}}2(a),(c)

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

As described in Section 6.8 of Reference 1, the newest published version of the {{

}}2(a),(c)

A brief description of the NRELAP5 solution in a staggered mesh is given in Section 2 of this response. The volume-centered flow rates or mass fluxes needed to evaluate wall the heat transfer for a given heat transfer mode is calculated from junction flow rates and cell flow areas. A detailed description of the evaluation of the wall heat transfer with {{

}}2(a),(c) Section 5 provides a general overview of the heat transfer across the CNV wall along with the problem initiation. Section 6 discusses how the condensation rate is related to the liquid film flow between CNV hydrodynamic volumes or cells. Section 7 introduces the equations used to calculate the condensation heat transfer coefficient based on {{

}}2(a),(c) in three consecutive nodes representing the upper, middle, and lower CNV elevations. Section 8 describes the temperature differences across key thermal resistances along the heat transfer path between the CNV and the reactor pool or ultimate heat sink (UHS). The effect of conduction nodalization on the key results such as CNV pressure, condensate liquid level, and wall heat flux at selected heat structures are also discussed for the NPM LOCA. The discussion presented in Section 9 repeats the analysis steps for the NIST-1 facility based on the HP06b discharge line break tests.

2. NRELAP5 Solution Method

NRELAP5 solves the {{

}}2(a),(c)

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}}2(a),(c)

3. Evaluating Condensation Wall Heat Transfer

The total heat flux to/from a given NRELAP5 volume consists of various components described by a {{

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}}2(a),(c)

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}}2(a),(c)

4. {{

}}2(a),(c)

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}}2(a),(c)

5. CNV Wall Heat Transfer Modeling in NPM

Figure 2 schematically shows the major heat transfer modes governing the heat transfer across the CNV wall. {{

}}2(a),(c)

{{

}}2(a),(c)

6. Net Liquid Flow and Condensate Rates in CNV Cells

In order to demonstrate the application of the {{

}}2(a),(c) inside the CNV as well as the key characteristics of the CNV wall heat transfer, the 100 percent chemical volume and control system (CVCS) charging line break is considered. The same scenario is also used to present the NPM LOCA event progression in Chapter 9 of Reference 1.

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}}2(a),(c)

7. Liquid Reynolds Number and {{

}}2(a),(c)

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}}2(a),(c)

8. Temperature Differences and Effect of Conduction Nodalization

The temperature differences corresponding to different heat transfer mechanisms depicted in Figure 3 are plotted in Figure 11 at different CNV elevations. {{

}}2(a),(c)

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}}2(a),(c)

9. NRELAP5 Assessment of NIST-1 HP06b Test

The HP06b test performed in the NIST-1 integral test facility simulates the single-ended break on the CVCS discharge line. The test has the same conditions as the HP06 test, but with a different simulated decay heat. The summary of the assessment results is given in Section 7.5.6.6 of Reference 1.

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}}2(a),(c)

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}}2(a),(c)

10. Summary

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}}2(a),(c) The following key points are highlighted in the response:

- With the large flow area and heated diameter of the CNV hydraulic volumes, the {{

  }}2(a),(c)

• {{

}}2(a),(c)

The plots requested in question 7 of the RAI are provided in Figures 22 to 27.

References:

1. TR-0516-49222, Revision 0, “Loss-of-Coolant Evaluation Model”, December 2016

2. SwUM-0304-17023, Revision 4, “NRELAP5 Version 1.3 Theory Manual”, December 2016

3. Bejan, A. 2003, “Convection Heat Transfer”, Third Edition, John Wiley & Sons, Inc.

Table 1. Geometrical summary of NPM CNV wall and connected hydrodynamic volumes

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}}2(a),(c)

Table 2. Distribution of condensation rate in NPM CNV at various times after break initiation

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}}2(a),(c)

Table 3. Liquid Reynolds number distribution on NPM CNV walls at selected times after break

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}}2(a),(c)

Table 4. Distribution of liquid film thickness on NPM CNV wall at selected times after break

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}}2(a),(c)

Table 5. Geometrical summary of NIST-1 HTP and connected hydrodynamic volumes

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}}2(a),(c)

Table 6. Distribution of condensation rate in NIST-1 CNV at various times after break initiation

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}}2(a),(c)

Table 7. Liquid Reynolds number distribution on NIST-1 HTP at selected times after break

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}}2(a),(c)

Table 8. Distribution of liquid film thickness on NIST-1 HTP at selected times after break

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}}2(a),(c)

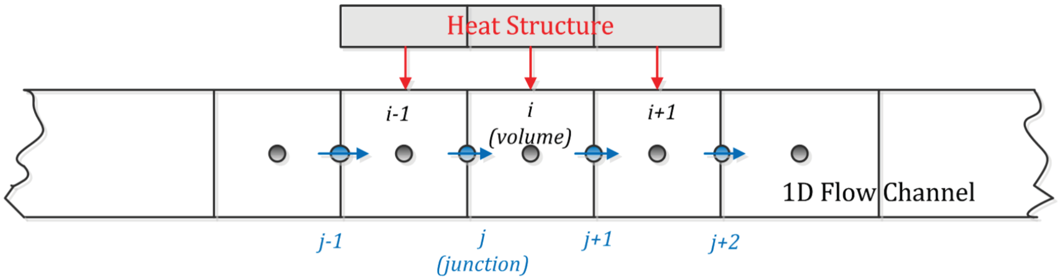

Figure 1. NRELAP5 Staggered Mesh with Heat Structure Coupling

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}}2(a)(c)

Figure 2. Heat transfer modes across the CNV wall

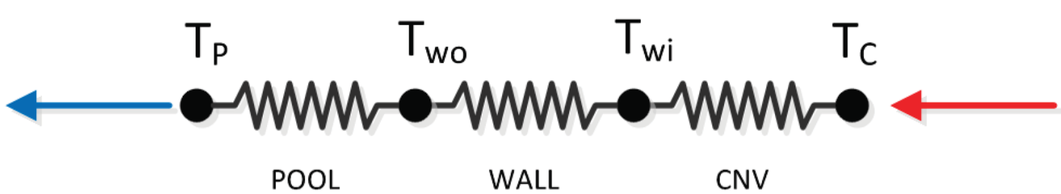

Figure 3. Thermal resistance network between CNV and UHS

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Figure 4. Condensation rate in various NPM CNV cells

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Figure 5. Condensation rate and net liquid flow in selected NPM CNV cells

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Figure 6. Liquid Reynolds number and condensate film thickness for upper NPM CNV levels

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Figure 7. Liquid Reynolds number and condensate film thickness for middle NPM CNV levels

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Figure 8. Liquid Reynolds number and condensate film thickness for lower NPM CNV levels

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Figure 9. Laminar flag in selected CNV heat structure and corresponding NPM CNV cells

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Figure 10. Condensation heat transfer coefficients at three different NPM CNV levels

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}}2(a),(c)

Figure 11. Temperature difference for each heat transfer mode through NPM CNV wall (CNV, WALL, and POOL denote the temperature difference between CNV fluid and CNV inner wall, CNV inner and outer walls, and CNV outer wall and reactor pool fluid, respectively)

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}}2(a),(c)

Figure 12. Effect of wall conduction nodalization on peak pressure and liquid level in NPM CNV

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Figure 13. Effect of wall conduction nodalization on NPM CNV outer surface heat flux

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Figure 14. Condensation rate in various NIST-1 CNV cells

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Figure 15. Condensation rate and net liquid flow in various NIST-1 CNV cells

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}}2(a),(c)

Figure 16. Liquid Reynolds number and condensate film thickness for upper NIST-1 HTP levels

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}}2(a),(c)

Figure 17. Liquid Reynolds number and condensate film thickness for middle NPM HTP levels

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}}2(a),(c)

Figure 18. Liquid Reynolds number and condensate film thickness for lower NPM HTP levels

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}}2(a),(c)

Figure 19. Laminar flag in selected HTP heat structure and corresponding NIST-1 CNV cells

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}}2(a),(c)

Figure 20. Condensation heat transfer coefficients at three different NIST-1 CNV levels

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}}2(a),(c)

Figure 21. Temperature difference for each heat transfer mode through NIST-1 HTP (CNV, WALL, and POOL denote the temperature difference between CNV fluid and CNV inner wall, CNV inner and outer walls, and CNV outer wall and reactor pool fluid, respectively)

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}}2(a),(c)

Figure 22. CNV heat transfer resistance contribution in NPM NRELAP5 calculation for HP-09

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}}2(a),(c)

Figure 23 CNV heat transfer resistance contribution in NPM NRELAP5 calculation for HP-06

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}}2(a),(c)

Figure 24 CNV inside and outside heat transfer coefficients in NPM NRELAP5 calculation for HP-09

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}}2(a),(c)

Figure 25 CNV heat transfer resistance contribution in NPM NRELAP5 calculation for HP-09 with 50% reduction in condensation heat transfer coefficient

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}}2(a),(c)

Figure 26 CNV heat transfer resistance contribution in NPM NRELAP5 calculation for HP-09 with 80% reduction in condensation heat transfer coefficient

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}}2(a),(c)

Figure 27 Impact of reduced CNV inside surface heat transfer coefficient on CNV pressure in NPM NRELAP5 calculation for HP-09

Impact on Topical Report:

There are no impacts to the Topical Report TR-0516-49422, Loss-of-Coolant Accident Evaluation Model, as a result of this response.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-1117-57292

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 methods by which NuScale develops its loss-of-coolant accident analysis of the NuScale power module.

   NuScale has performed significant research and evaluation to develop a basis for these methods 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. 8990, eRAI No. 8990. 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 11/20/2017.

Zackary W. Rad