RAIO-0818-61404

August 16, 2018

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. 9158 (eRAI No. 9158) on the NuScale Topical Report, "Non-Loss of Coolant Accident Analysis Methodology," TR-0516-49416, Revision 1

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 9158 (eRAI No. 9158)," dated April 02, 2018
2. NuScale Topical Report, "Non-Loss of Coolant Accident Analysis Methodology," TR-0516-49416, Revision 1, dated August 2017

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. 9158:

- 15.00.02-5

The response for the remaining questions of RAI No. 9158, eRAI No. 9158 will be provided by September 28, 2018.

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 9158 (eRAI No. 9158). 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 Paul Infanger at 541-452-7351 or at pinfanger@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. 9158, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9158, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0818-61437

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvalis, Oregon 97330, Office: 541.360.0500, Fax: 541.207.3928
www.nuscalepower.com

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9158, proprietary

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvalis, Oregon 97330, Office: 541.360.0500, Fax: 541.207.3928
www.nuscalepower.com

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9158, nonproprietary

NUSCALE
Power for all humankind

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 9158
Date of RAI Issue: 04/02/2018

NRC Question No.: 15.00.02-5
Assessment of NRELAP5 Using SIET Fluid Heated Test Facility (TF-2) Data (EC-T050-3638)

TR-0516-49416-P supports the conclusions in the NuScale FSAR, which under 10 CFR 52.47 must describe the facility, present the design bases and the limits on its operation, and present a safety analysis of the structures, systems, and components and of the facility as a whole.

RG 1.203 describes the EMDAP, which the NRC staff considers acceptable for use in developing and assessing EMs used to analyze transient and accident behavior. Step 7 of the EMDAP discusses the identification and performance of SETs and IETs to complete the database against which the EM will be assessed. Furthermore, Step 17 discusses the determination of the applicability of the model to simulate system components and states that before performing integrated analyses, the various EM options, special models, and inputs should be determined to have the inherent capability to model the major systems and subsystems required for the particular application.

The staff audited document EC-T050-3638, “Assessment of NRELAP5 Using SIET Fluid Heated Test Facility (TF-2) Data,” the purpose of which is to assess the NRELAP5 modeling of heat transfer and pressure drop on the primary and secondary sides of the helical coil SG. As described in that document, the NRELAP5 simulation of the experiments used a number of assumptions and heat transfer modeling options. The comparison of NRELAP5 calculations to the test data indicates that:

- Case 1 (using heat transfer geometry {{ }}$^{2(a),(c)}$) shows the best agreement with the heated tests.
- The low primary flow tests were {{ }}$^{2(a),(c)}$.

Low flow is an inherent characteristic of the NPM response during a non-LOCA event, particularly during the periods exhibiting the stall-and-chug response. Consequently, this aspect of the findings and the recommendation should be implemented to determine if modifications to the non-LOCA evaluation model are needed.

Information Requested:

TR-0516-49416-P, Section 5.3.5 discusses the modeling of the NPM SG and the use of SIET test data, including the impact of nodalization studies. However, neither EC-T050-3638 nor TR-0516-49416-P, Section 5.3.5 discuss how the information gained from the experimental benchmarking studies was implemented in the NPM model. Describe how the findings and recommendation noted above have resulted in any modeling changes to the NuScale power module for non-LOCA events, or provide a summary of the studies showing that the existing model is adequate. Update TR-0516-49416-P as appropriate.

NuScale Response:

Background

The NRELAP5 assessment of the SIET TF-2 test data was updated. The primary changes in the updated assessment compared to the original assessment that was summarized in the LOCA evaluation model topical report (TR-0516-49422) and Non-LOCA methodology topical report (TR-0516-49416) are summarized below:

- A heat balance was performed on the diabatic experimental data. The helical coil steam generator (HCSG) primary and secondary side heat transfer rates with uncertainties were calculated and compared. {{ }}$^{2(a),(c)}$
- HCSG nodalization sensitivity studies were performed with finer and coarser nodes on the HCSG secondary side.
- {{ }}$^{2(a),(c)}$
- Modeling errors were corrected, including the HCSG pitch to diameter (P/D) ratio input. This change was discussed in the response to RAI_9519/15.06.05-20.
- NRELAP5 Version 1.4 was used in the revised SIET TF-2 assessment.

In this RAI response, {{ }}$^{2(a),(c)}$ Then results of the updated assessment are summarized. Finally, results of nodalization sensitivity calculations for SIET TF-2 and NPM are discussed to show the existing plant modeling approach is adequate.

SIET TF-2 Diabatic Tests Heat Balance Analysis

The heat balances for the 18 cases from the original SIET TF-2 assessment were evaluated. These test data points are listed in Table 1.

First, the control volume used for the energy balance and method to account for data uncertainties are discussed. Then the results of the energy balance comparisons and further investigation of specific cases are summarized.

Control Volume used for Heat Balance Analysis

To perform a heat balance analysis, temperatures and pressures must be known at the inlet and outlet of the chosen control volume so the fluid enthalpies at these locations can be calculated.
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}}2(a),(b),(c)

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

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

Figure 1. Control volume for experimental data heat balance analysis

Primary and Secondary Heat Transfer Rates and Uncertainties

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

The primary side heat transfer rate is calculated as:

$$q_1 = w_1(h_{1in} - h_{1out}) \quad \text{Eq. 1}$$

The primary side heat transfer rate expanded uncertainty is calculated as:

$$\begin{aligned} Uq_1 &= 2\sqrt{\left(\frac{\partial q_1}{\partial w_1}\frac{Uw_1}{2}\right)^2 + \left(\frac{\partial q_1}{\partial h_{1in}}\frac{Uh_{1in}}{2}\right)^2 + \left(\frac{\partial q_1}{\partial h_{1out}}\frac{Uh_{1out}}{2}\right)^2} \\ &= 2\sqrt{\left[(h_{1in} - h_{1out})\frac{Uw_1}{2}\right]^2 + \left(w_1\frac{Uh_{1in}}{2}\right)^2 + \left(w_1\frac{Uh_{1out}}{2}\right)^2} \\ &= 2\sqrt{\left(h_{1in}\frac{Uw_1}{2}\right)^2 + \left(h_{1out}\frac{Uw_1}{2}\right)^2 - 2h_{1in}h_{1out}\left(\frac{Uw_1}{2}\right)^2 + \left(w_1\frac{Uh_{1in}}{2}\right)^2 + \left(w_1\frac{Uh_{1out}}{2}\right)^2} \end{aligned} \quad \text{Eq. 2}$$

Where:

Uq_1 : uncertainty in primary side heat transfer rate (kW)

w_1 : primary side flowrate, kg/s

Uw_1 : primary side flowrate expanded uncertainty, kg/s

h_{1in} : primary side inlet enthalpy, kJ/kg

Uh_{1in} : primary side inlet enthalpy expanded uncertainty, kJ/kg

h_{1out} : primary side outlet enthalpy, kJ/kg

Uh_{1out} : primary side outlet enthalpy expanded uncertainty, kJ/kg

The maximal and minimal primary side heat transfer rates are based on the uncertainty are then:

$$q_{1max} = q_1 + Uq_1 \quad \text{Eq. 3}$$

$$q_{1min} = q_1 - Uq_1 \quad \text{Eq. 4}$$

The secondary side heat transfer rate is calculated as:

$$\begin{aligned} q_2 &= (w_{fw1} + w_{fw2} + w_{fw3} + w_{fw4} + w_{fw5})h_{stm} - w_{fw1}h_{fw1} - w_{fw2}h_{fw2} - w_{fw3}h_{fw3} \\ &\quad - w_{fw4}h_{fw4} - w_{fw5}h_{fw5} \\ &= w_{fw1}(h_{stm} - h_{fw1}) + w_{fw2}(h_{stm} - h_{fw2}) + w_{fw3}(h_{stm} - h_{fw1}) + w_{fw4}(h_{stm} - h_{fw4}) \\ &\quad + w_{fw5}(h_{stm} - h_{fw5}) \end{aligned} \quad \text{Eq. 5}$$

The secondary side heat transfer rate expanded uncertainty when all rows are active is calculated as:

$$\begin{aligned} Uq_2 &= 2\sqrt{\sum_{X=1}^{5}\left[\left(\frac{\partial q_2}{\partial w_{fwX}}\frac{Uw_{fwX}}{2}\right)^2\right] + \sum_{X=1}^{5}\left[\left(\frac{\partial q_2}{\partial h_{fwX}}\frac{Uh_{fwX}}{2}\right)^2\right] + \left(\frac{\partial q_2}{\partial h_{stm}}\frac{Uh_{stm}}{2}\right)^2} \\ &=2\sqrt{\sum_{X=1}^{5}\left\{\left[(h_{stm} - h_{fwX})\frac{Uw_{fwX}}{2}\right]^2\right\} + \sum_{X=1}^{5}\left[\left(w_{fwX}\frac{Uh_{fwX}}{2}\right)^2\right] + \left[\sum_{X=1}^{5}(w_{fwX})\frac{Uh_{stm}}{2}\right]^2} \\ &= 2\sqrt{\sum_{X=1}^{5}\left[\left(h_{stm}\frac{Uw_{fwX}}{2}\right)^2 + \left(h_{fwX}\frac{Uw_{fwX}}{2}\right)^2 - 2h_{stm}h_{fwX}\left(\frac{Uw_{fwX}}{2}\right)^2 + \left(w_{fwX}\frac{Uh_{fwX}}{2}\right)^2\right] + \left[\sum_{X=1}^{5}(w_{fwX})\frac{Uh_{stm}}{2}\right]^2} \end{aligned} \quad \text{Eq. 6}$$

where:

Uq_2 : uncertainty in secondary side heat transfer rate (kW)

h_{stm} : secondary side common outlet (steam) enthalpy, kJ/kg

Uh_{stm} : secondary side common outlet (steam) enthalpy expanded uncertainty, kJ/kg

w_{fwX} : row X (X=1 to 5) feedwater mass flowrate, kg/s

Uw_{fwX} : row X (X=1 to 5) feedwater mass flowrate expanded uncertainty, kg/s

h_{fwX} : row X (X=1 to 5) feedwater enthalpy, kJ/kg

Uh_{fwX} : row X (X=1 to 5) feedwater enthalpy expanded uncertainty, kJ/kg

The maximal and minimal secondary side heat transfer rates based on the uncertainty are then:

$$q_{2max} = q_2 + Uq_2 \quad \text{Eq. 7}$$

$$q_{2min} = q_2 - Uq_2 \quad \text{Eq. 8}$$

Table 1 lists the upper and lower bounds of the heat transfer rates of the primary side and secondary side after the uncertainties for each diabatic test case are calculated.

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

Table 1. SIET TF-2 diabatic tests heat balance 95% uncertainty analysis results

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

Note 1: Negative heat transfer rate means the uncertainty is greater than the mean value of the heat transfer rate, so the mean value minus uncertainty could be negative.

Further Evaluation of Cases TD0003, TD0010

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

Table 2. Conditions at riser inlet and pressure vessel head for test TD0010

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

Note: These are the average values over the last 150 seconds of the tests.

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

Summary of Revised SIET TF-2 Assessment Results

The SIET TF-2 assessment was performed on the test cases {{

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

An update to the summary of the SIET TF-2 assessment calculation results in the LOCA topical report was provided with the response to RAI 9519/15.06.05-20.

Low Primary Flow Cases

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

the Non-LOCA methodology topical report (TR-0516-49416), Section 5.3.5.2 was revised as indicated at the end of this response and LOCA evaluation model topical report (TR-0516-49422) was revised as indicated in the markup at the end of the response to RAI 9519/15.06.05-20.

SIET TF-2 Diabatic Tests Nodalization Sensitivity Study

In the NRELAP5 baseline case for the SIET TF-2 assessment, each tube bank of the HCSG secondary side and the tube heat structures are modeled with {{

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

Two nodalization sensitivity studies were performed in the updated SIET TF-2 assessment on the HCSG secondary side and tube heat structures. In the first study, the HCSG secondary side and heat structures of each tube bank were modeled with {{

}}2(a),(b),(c) is adequate and refining the nodalization in the middle zone and top zone does not make improvements on the predicted results.

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

Figure 2. SIET TF-2 Nodalization Sensitivity Study Representative Result - Secondary Void Fraction

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

Figure 3. SIET TF-2 Nodalization Sensitivity Study Representative Result - Primary Heat Transfer Coefficient

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}}[2(a),(b),(c)]

Figure 4. SIET TF-2 Nodalization Sensitivity Study Representative Result - Secondary Heat Transfer Coefficient

Summary of Steam Generator Nodalization Sensitivity Calculations

The NRELAP5 code was validated against the SIET TF-2 test using a model {{

}}[2(a),(b),(c)] To demonstrate that the coarse nodalization is sufficient, four independent nodalization studies were performed: 1) SIET TF-2 diabatic test sensitivity calculations, 2) SIET TF-1 sensitivity calculations to examine the effect of nodalization on the secondary side predictions, 3) a comparison of secondary side predictions for a decrease in feedwater temperature event, and 4) a comparison of secondary side predictions for a main steam line break event. The SIET TF-2 sensitivity calculations are described in this response. {{

}}[2(a),(b),(c)] The nodalization sensitivity studies results described in Section 5.3.5.4 of the

Non-LOCA methodology topical report (TR-0516-49416) were revised to incorporate changes as indicated at the end of this response. Based on these validation results and sensitivity calculations it is concluded that the approach for modeling the HCSG in the NPM is adequate.

References:

1. {{

}}2(a),(c)

Impact on Topical Report:

Topical Report TR-0516-49416, Non-Loss of Coolant Accident Analysis Methodology, has been revised as described in the response above and as shown in the markup provided in this response.

5.3.5 Steam Generator Modeling

5.3.5.1 Background

NuScale's LOCA Topical Report (Reference 2) Section 7.3 discusses the validation of NRELAP5 for helical coil SG (HCSG) modeling. The validation was mainly against SIET TF-1 and TF-2 test data. It was concluded that NRELAP5 showed reasonable to excellent agreement with test data for all phenomena at conditions that are important to non-LOCA analysis, as discussed in the following sections.

The validation is further investigated in this report to ensure the unique characteristics of the non-LOCA transients (comparing to LOCA) are identified and evaluated. Specifically, this investigation ensures the operating ranges expected during the non-LOCA transients are covered by the validated ranges. The modeling issues identified in the LOCA topical report are evaluated to ensure they do not affect the non-LOCA transients.

5.3.5.2 Helical Coil Steam Generator Modeling {{

}}2(a),(c)

In the LOCA topical report (Reference 2), NRELAP5 shows reasonable to excellent agreement with test data on the helical coil SGHCSG primary and secondary side, based on comparisons against the SIET TF-2 and SIET TF-1 test data.except {{

}}2(a),(c)

Figure 5-154 through Figure 5-159 show the secondary and primary flow rates for several cases of steam line breaks outside the CNV. {{

}}2(a),(c)

Figure 5-160 and Figure 5-161 show the secondary and primary flow rates for double-ended guillotine steam line break inside the CNV. {{

}}2(a),(c)

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}}2(a),(c)

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

Figure 5-154 Helical coil steam generator secondary flow – double-ended guillotine break outside of containment vessel

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

~~Figure 5-155 Helical coil steam generator primary flow – double-ended guillotine break outside of containment vessel~~

~~{{~~

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

~~Figure 5-156 Helical coil steam generator secondary flow – 7.5 percent break size outside of containment vessel~~

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

Figure 5-157 Helical coil steam generator primary flow – 7.5 percent break size outside of containment vessel

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

Figure 5-158 Helical coil steam generator secondary flow – 3.3 percent break size outside of containment vessel

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

Figure 5-159 Helical coil steam generator primary flow – 3.3 percent break size outside of containment vessel

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

Figure 5-160 Helical coil steam generator secondary flow – double-ended guillotine break inside containment vessel

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

Figure 5-161 Helical coil steam generator primary flow – double-ended guillotine break inside containment vessel

5.3.5.3 Helical Coil Steam Generator Operating Ranges vs. Validated Ranges

In the LOCA topical report (Reference 2), NRELAP5 also shows reasonable to excellent agreement with test data on the helical coil SG secondary side. {{

}}2(a),(c) Further evaluation is provided herein to ensure NRELAP5 is validated for DHRS operation.

Based on the typical helical coil SG secondary pressure, temperature and flow rate during DHRS operation, {{

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

Table 5-14 summarizes the helical coil SG operating range for non-LOCA transients vs. the validated range in NRELAP5. The majority of the helical coil SG secondary side operating range is covered by the validated range of NRELAP5. {{

}}2(a),(c) Therefore, the operating range of the helical coil SG primary side is sufficiently covered by the validated range of NRELAP5.

Table 5-14 Non-LOCA transients helical coil steam generator operating range vs. NRELAP5 validated range

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

5.3.5.4 Helical Coil Steam Generator Nodalization Sensitivity

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}}2(a),(c)

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0818-61437

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvalis, Oregon 97330, Office: 541.360.0500, Fax: 541.207.3928
www.nuscalepower.com

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 non-loss of coolant accident 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. 9158, eRAI No. 9158. 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 August 16, 2018.

Zackary W. Rad