September 13, 2018

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. 398 (eRAI No. 9317) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 398 (eRAI No. 9317)," dated March 22, 2018

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 Questions from NRC eRAI No. 9317:

- 06.02.01.01.A-8
- 06.02.01.01.A-9
- 06.02.01.01.A-10
- 06.02.01.01.A-11
- 06.02.01.01.A-12

NuScale RAIO-0918-61761, RAI No. 377, eRAI No. 9380, RAIO-0917-56266, RAI No. 8777, eRAI No. 8777 and RAIO 1117-57291, RAI No. 8990, eRAI No. 8990 are referenced within this response.

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 398 (eRAI No. 9317). 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
Omid Tabatabai, NRC, OWFN-8G9A
Samuel Lee, NRC, OWFN-8G9A

Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9317, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9317, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0918-61766

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9317, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9317, nonproprietary

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

eRAI No.: 9317
Date of RAI Issue: 03/22/2018

NRC Question No.: 06.02.01.01.A-8

NRELAP5 NIST-1 CNV Model Benchmarking with HP-02 Test Data

To make its safety findings, the staff must understand and assess the ability of the applicant's analytical tools used in the safety analyses to meet the aspects of GDCs 16, 38, and 50; Part 52.47 and Part 50.43(e) relevant to the containment design basis. Specifically, the staff must assess the ability of the applicant's NRELAP5 model to predict the safety-significant phenomena in order for the staff to conclude that the code results are valid over the applicable range of accident conditions. The thermal-hydraulic phenomena pertinent to NuScale FSAR Section 6.2 containment design basis accident (DBA) analyses are the heat transfer from the containment vessel (CNV) to reactor pool (including condensation on the inner surface of the CNV), conduction through CNV wall (represented by the heat transfer plate (HTP) in NIST-1), and the convection to the reactor pool (CPV in NIST-1). The staff needs to understand and assess the conservatism of the licensing-basis models, constitutive correlations, and input parameters used for the applicant's NPM DBA containment response analyses, as well as the experimental data used to validate the accident phenomenology. In this regard, the staff has reviewed the NIST-1 HP-02 test data analysis as submitted by the RAI 8783 response along with the HP-02 test information included in the Loss-of-Coolant Accident Evaluation Model (LBLOCAEM) topical report (TR-0516-49422-P, Rev. 0).

HP-02 is a separate effects high pressure steam condensation test. Figures 7-76, 7-80, and 7-84 in Section 7.5.4 of the LBLOCAEM topical report compare the containment pressures computed by NRELAP5 with the test data, for HP-02 test data Runs 1, 2, and 3. There is a consistent trend of an increasing over-prediction of pressure by NRELAP5 as the CNV test pressure increases. The peak CNV pressure predicted by NRELAP5 is about 20% higher than the measured value for the highest pressure test, Run 3. The cause of the pressure discrepancy is not clear to the staff (e.g., caused by heat loss, by a pressure effect in modeling the steam condensation, by temperature dependence of thermal conductivity, or by some other phenomena not modeled by NRELAP5). This discrepancy is safety significant as HP-02 is the only steam condensation test available to the staff whose results can be used to validate NRELAP5 heat transfer modeling across the CNV wall – a basic component of the NPM heat removal system. Therefore, NuScale is requested to address the following five questions regarding NIST-1, HP-02 tests to further the staff's understanding of NRELAP5's capability to model the NIST-1 CNV conservatively or realistically. The regulatory bases and the SRP acceptance criteria identified above are applicable to all questions in this RAI.

Provide additional NRELAP5 analyses that include heat losses and other phenomena that may have been neglected in the original analyses (Runs 1, 2, and 3). Include plots that clearly show the impact of modeling changes.

NuScale Response:

Background /Overview

The NRELAP5 assessment of the NIST-1 HP-02 test was revised. The revised assessment was performed with NRELAP5 v1.4, addressed instrument non-conformances identified after the prior assessment work was complete, corrected minor modeling errors, and included additional information to respond to requests for additional information.

As part of the updated assessment calculations, a diabatic boundary condition was applied to assess the impact of including shell wall heat losses on the containment pressure response. As part of evaluating the cause of NRELAP5 over-predicting the measured pressure response, the results from the diabatic boundary condition cases were compared to sensitivity calculation results with an adiabatic boundary condition on the outside wall surface of the containment shell. First, the approach to model the diabatic boundary condition is described. Next, NRELAP5 assessment results with the diabatic boundary condition, and the sensitivity calculation with the adiabatic boundary condition, are compared to the HP-02 experimental data. Based on these sensitivities, {{

}}2(a),(c)

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}}2(a),(c)

Updated HP-02 Assessment Calculation Results and Sensitivity to CNV Wall Boundary Condition

The CNV shell wall heat structures are modeled and initialized to capture the appropriate change in wall stored energy at the start of the transient. To model the diabatic boundary condition on the outside of the CNV shell, first the heat loss through the shell was estimated from the HP-02 measured test data, {{

}}2(a),(c)

Table 1 summarizes the heat losses estimated from the {{ }}2(a),(c), compared to the energy injected to the CNV, for HP-02 Runs 1, 2, 3 during the pseudo-steady-state period of these tests.

The insulation material on the outside of the CNV shell {{

}}2(a),(c)

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}}2(a),(c)

Table 1 - Summary of NIST-HP-02 CNV Heat Loss

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}}2(a),(c)

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}}2(a),(c)

Figure 1 - NRELAP5 CNV pressure response from CNV shell heat loss sensitivities against data for Run 1

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}}2(a),(c)

Figure 2 - NRELAP5 CNV pressure response from CNV shell heat loss sensitivities against data for Run 2

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}}2(a),(c)

Figure 3 - NRELAP5 CNV pressure response from CNV shell heat loss sensitivities against data for Run 3

NRELAP5 Treatment of Condensate Film Thickness

In the NIST-1 containment vessel with the containment shell and heat transfer plate, for an initially cold surface with the injection of steam, the expectation would be to have a nearly equally thick film thickness around the entire surface at a given elevation; this is illustrated on the left diagram of Figure 4 (although as time progresses the film thickness on the heat transfer plate and CNV shell will change due to the difference in heat sink boundary condition on the outside of the surfaces as the HTP is connected to the cold pool rather than insulated). In the NIST-1 NRELAP5 model, {{

}}2(a),(c)

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}}2(a),(c)

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}}2(a),(c)

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}}2(a),(c)

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}}2(a),(c)

Figure 4 - Representation of the HTP and CNV shell condensate thickness

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}}2(a),(c)

Figure 5 - Containment pressure response to condensate film thickness

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}}2(a),(c)

Figure 6 - Containment integrated mass transfer mechanisms (Run 3)

Summary

When the NRELAP5 models were updated to account for the heat loss from the containment shell consistent with the measured data during the HP-02 tests, {{

}}2(a),(c)

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}}[2(a),(c)] as described in response to eRAI 8777, Question 15.06.05-1 in NuScale letter RAIO-0917-56266, dated September 27, 2017.

Impact on DCA:

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

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eRAI No.: 9317

Date of RAI Issue: 03/22/2018

NRC Question No.: 06.02.01.01.A-9

Provide plots of the NRELAP5 computed: condensation heat transfer coefficients and associated Reynolds numbers, fluid temperatures, inner and outer wall surface temperatures, pool temperature, pool side convective heat transfer, and heat fluxes at the inner and outer surfaces of the HTP at three elevations (high, middle, low) for Runs 1, 2 and 3. Provide overlay plots of the computed temperatures at the HTP (T_{fluid}, T_{inner}, T_{outer}, T_{pool}) compared with NIST-1 data at consistent elevations. Provide overlay plots of steam flow rate and enthalpy, and condensation rate that compare NRELAP5 predictions with the NIST-1 data.

NuScale Response:

The question requests NRELAP5 results for several parameters. eRAI 9317, Question 06.02.01.01.A-10 requests similar parameters measured or derived from measured data during the quasi-equilibrium phase. For convenience, the NRELAP5 predicted and measured data parameters are presented together in this response where applicable. Results are provided below for Run 3, which is at a higher pressure as compared to Run 1 or Run 2. Similar results for Run 1 and Run 2 are available for audit as necessary.

Figure 7 shows the steam flow rate boundary condition. To indicate steam enthalpy, Figure 8 and Figure 9 show the steam pressure and temperature boundary conditions, respectively. As boundary conditions, these values are the same between the measured data and NRELAP5 input.

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}}2(a),(c)

Figure 7 - Steam flow rate boundary condition for Run 3

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}}2(a),(c)

Figure 8 - Steam pressure boundary condition for Run 3

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}}2(a),(c)

Figure 9 - Steam temperature boundary condition for Run 3

Figure 10 shows the predicted and measured containment level, which indicates condensation rate. {{

}}[2(a),(c)] Figure 11 shows the calculated condensation rate based on {{

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

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

Figure 10 - Containment Level for Run 3

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}}2(a),(c)

Figure 11 - Containment Condensation Rate for Run 3

Figure 12, Figure 13, and Figure 14 show the measured and predicted fluid and wall temperature profiles in the containment, heat transfer plate and cooling pool at lower, middle and upper elevations, respectively. The containment and cooling pool fluid temperatures are shown, with heat transfer plate temperatures near the CNV surface (TW-5x11), middle of heat transfer plate (TW-5x13) and near the cooling pool surface (TW-5x15). The radial position of the wall thermocouples are indicated within the legends of the associated figures. {{

}}2(a),(c)

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}}2(a),(c)

Figure 12 - Fluid and Wall Temperature Profile from CNV through HTP to CPV, Level 1 (Lower Elevation) for Run 3

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}}2(a),(c)

Figure 13 - Fluid and Wall Temperature Profile from CNV through HTP to CPV, Level 4 (Middle Elevation) for Run 3

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}}2(a),(c)

Figure 14 - Fluid and Wall Temperature Profile from CNV through HTP to CPV, Level 8 (Upper Elevation) for Run 3

Figure 15 shows the heat transfer plate heat fluxes on the containment side and cooling pool side calculated by NRELAP5 at levels 0, 1, 4, and 8. Figure 15 also shows the NRELAP5 average heat flux for levels 5 through 8, {{

}}2(a),(c)

Figure 16 shows the heat transfer plate containment side and cooling pool side heat transfer coefficients calculated by NRELAP5 at levels 0, 1, 4, and 8. Figure 16 also shows the heat transfer coefficient estimated from the data during the pseudo-steady state period. {{

}}2(a),(c)

Figure 17 shows the NRELAP5 calculated film Reynolds number at selected elevations in containment. The Reynolds numbers were calculated {{

}}2(a),(c)

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}}2(a),(c) as discussed in response to eRAI 9317, Question 06.02.01.01.A-8.

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}}2(a),(c)

Figure 15 - Heat Transfer Plate Heat Fluxes at Levels 0, 1, 4, and 8 for Run 3

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}}2(a),(c)

Figure 16 - Heat Transfer Plate Heat Transfer Coefficients at Levels 0, 1, 4, and 8 for Run 3

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}}2(a),(c)

Figure 17 - NRELAP5 Calculated Film Reynolds Number in Containment for Run 3

Impact on DCA:

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

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Date of RAI Issue: 03/22/2018

NRC Question No.: 06.02.01.01.A-10

For the equilibrium conditions after 2000 seconds for HP-02 Runs 1 to 3, use the calculated heat addition to the CNV based on the average rate at which steam is added to the CNV and condensing on the HTP plate, and convert the heat addition rate to an average heat flux on the portion of the HTP plate above the liquid level in the CNV. Based on the estimated average heat flux into the HTP wall, the measured bulk steam temperature, HTP inside wall temperatures, HTP grid temperatures, HTP outside wall temperature and pool temperature, please provide the estimates of average condensation heat transfer coefficient, HTP wall thermal conductivity, pool convective heat transfer coefficient, condensate rate, and CNV water level rise. Compare these average NIST-1 estimated values to the average NRELAP5 calculated values and explain any differences. Also identify the location of inner, outer, and embedded HTP grid thermocouples.

NuScale Response:

The response to eRAI 9317, Question 06.02.01.01.A-9 provided comparisons of the NRELAP5 predicted and measured condensate rate and containment water level rise. The containment side and cooling pool side heat flux and heat transfer coefficient during the quasi-steady period estimated from the HP-02 data and compared to the NRELAP5 results were also discussed in response to eRAI 9317, Question 06.02.01.01.A-9.

The heat transfer plate thermal conductivity was estimated from the measured data in HP-02 and compared to the NRELAP5 material input for HP-02 Run 1, Run 2 and Run 3, as shown in Figure 18, Figure 19, and Figure 20, respectively. The thermal conductivity was estimated from the data using {{

}}2(a),(c)

{{ }}2(a),(c) Table 2 provides the heat transfer plate grid thermocouple locations. The thermal conductivity of the heat transfer plate {{

}}2(a),(c) as discussed in response to eRAI 9317, Question 06.02.01.01.A-8.

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}}2(a),(c)

Figure 18 - HP-02 Run 1 Heat Transfer Plate Thermal Conductivity

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Figure 19 - HP-02 Run 2 Heat Transfer Plate Thermal Conductivity

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}}2(a),(c)

Figure 20 - HP-02 Run 3 Heat Transfer Plate Thermal Conductivity

Table 2 - Thermocouple locations within the heat transfer plate

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}}2(a),(c)

Impact on DCA:

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

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eRAI No.: 9317

Date of RAI Issue: 03/22/2018

NRC Question No.: 06.02.01.01.A-11

For the early portion of the HP-02 tests [times up to 500 seconds], provide comparison plots of NRELAP5 calculated steam temperature and pressure and compare to the NIST data. Address whether there are significant differences between NRELAP5 predictions and NIST-1 test data during this transient portion of the HP-02 Runs 1 to 3.

NuScale Response:

Comparison plots of NRELAP5 calculated steam pressure and temperature as compared to NIST-1 data for the first 500 seconds of the transient are provided by Figures 21 and 22, respectively. Run 3 is presented since it is the highest pressure case and the results for all three runs are similar. The trends for run 1 and 2 are similar to run 3. {{

}}2(a),(c)

As part of the updated assessment calculations, a diabatic boundary condition was applied to assess the impact of including shell wall heat losses on the containment pressure response. The response to eRAI 9317, Question 06.02.01.01.A-8 describes the approach used to calculate the ambient heat loss occurring during the HP-02 tests and to model the diabatic boundary condition. As discussed in response to eRAI 9317, Question 06.02.01.01.A-8, sensitivity calculation results show {{

}}2(a),(c)

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}}2(a),(c)

Figure 21 - HP-02 Run 3 CNV Early Transient Pressure Response (0-500 sec)

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}}2(a),(c)

Figure 22 - HP-02 Run 3 CNV Early Transient Steam Temperature Response (0-500 sec)

Impact on DCA:

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

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eRAI No.: 9317

Date of RAI Issue: 03/22/2018

NRC Question No.: 06.02.01.01.A-12

Provide a sensitivity study with NRELAP5 showing the impact of the number of nodes used for the HTP plate. For the early transient portion of the tests [times less than 500 seconds], show the temperature profile calculated by NRELAP5 and the steam condensation rate as a function of the number of nodes selected. Also, address based on this analysis whether the CNV wall noding selected for the NRELAP5 NPM model results in a conservative heat removal rate during the first 200 seconds after an RRV inadvertent opening transient.

NuScale Response:

The NRELAP5 assessment of the NIST-1 HP-02 test was revised. The revised assessment was performed with NRELAP v1.4, addressed instrument non-conformances identified after the prior assessment work was complete, corrected minor modeling errors, and included additional information to respond to requests for additional information. Results discussed in this RAI response are from the updated assessment calculations.

In the base calculations for the HP-02 assessment calculation, the heat transfer plate heat structure has {{

}}2(a),(c)

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}}2(a),(c)

Table 3 - Heat transfer plate radial nodalization sensitivities

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}}2(a),(c)

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}}2(a),(c)

Figure 23 - Containment pressure response to heat transfer plate radial nodalization

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}}2(a),(c)

Figure 24 - Run 3 Lower Elevation (Level 1 (29-33 inches)) heat transfer plate temperature profile to heat transfer plate radial nodalization

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}}2(a),(c)

Figure 25 - Run 3 Middle Elevation (Level 4 (111-115 inches)) heat transfer plate temperature profile to heat transfer plate radial nodalization

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}}2(a),(c)

Figure 26 - Run 3 Upper Elevation (Level 8 (219-224 inches)) heat transfer plate temperature profile to heat transfer plate radial nodalization

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}}2((a),(c)

Figure 27 - Containment integrated mass transfer rate response to heat transfer plate radial nodalization

References:

1. D. L. Aumiller, The Effect of Nodalization on the Accuracy of the Finite-Difference Solution of the Transient Conduction Equation, 2000 RELAP5 International Users Seminar

Impact on DCA:

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

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0918-61766

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 analyses by which NuScale develops its NIST-1 HP-02 testing.

    NuScale has performed significant research and evaluation to develop a basis for this analyses 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 RAI No. 398, eRAI No. 9317. 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 September 13, 2018.

Zackary W. Rad