October 26, 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. 9096 (eRAI No. 9096) on the NuScale Topical Report, "Evaluation Methodology for Stability Analysis of the NuScale Power Module," TR-0516-49417, Revision 0

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 9096 (eRAI No. 9096)," dated September 29, 2017
2. NuScale Topical Report, "Evaluation Methodology for Stability Analysis of the NuScale Power Module," TR-0516-49417, Revision 0, dated July 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. 9096:

- 01-50

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 9096 (eRAI No. 9096). 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
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9096, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9096, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-1017-56838

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Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9096, proprietary

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Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9096, nonproprietary

NuScale Power

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 9096
Date of RAI Issue: 09/29/2017

NRC Question No.: 01-50

Title 10 of the Code of Federal Regulations (CFR), Part 50, Appendix A, General. Design Criterion (GDC) 10, “Reactor design,” states that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. GDC12, "Suppression of reactor power oscillations," requires that oscillations be either not possible or reliably detected and suppressed. The Design-Specific Review Standard (DSRS), 15.9.A, “Design-Specific Review Standard for NuScale SMR Design, Thermal Hydraulic Stability Review Responsibilities,“ indicates that the applicant’s analyses should correctly and accurately identify all factors that could potentially cause instabilities and their consequences. The analyses should also demonstrate that design features that are implemented prevent unacceptable consequences to the fuel.

Section 5.5.6.4, "Drift Flux Model,” of the topical report (TR), TR-0516-49417-P, describes the PIM drift flux model and the required drift flux parameters. The drift flux model, Eqs. 5-60 and 5-61 of the TR, is based on the empirical correlation given by reference 12.1.30 [Collier, McGraw Hill,1972]," of the TR. The Chexal-Lellouche and Modified-Bestion correlations are well established drift-flux models, and commonly used in thermal-hydraulic systems codes for design and safety analyses. Comparison with these more common correlations, over an appropriate range of conditions including, mass flux, temperature, and pressure would provide a better understanding of the PIM drift flux model’s behavior and limitations.

A drift flux model is necessary to adequately model two-phase flow behavior, including voiding that would accompany subcritical boiling or flashing due to depressurization. In section 9.2 of the TR, PIM results from an unmitigated depressurization event show that an instability occurs due to voiding in the riser, which leads to large oscillations in reactor power, coolant flow and void fraction. The purpose of this depressurization simulation is to show that the low pressurizer pressure trip of the module protection system provides sufficient time to shut down the reactor before unacceptable instability behavior occurs. Section 10.1 of the TR indicates that the PIM analysis presented in section 9.2 confirms instabilities are possible when operating in the two-phase regime, furthermore, this analysis is the underlying basis for exclusion. Since the PIM simulation of the unmitigated depressurization also includes the two-phase behavior due to flashing in the riser, additional information is needed concerning the PIM drift-flux model used for these calculations.

In order to make an affirmative finding NRC staff requests NuScale to:

1. Provide the range of pressures over which the drift-flux correlation parameters reported in the Stability TR are valid.
2. Compare the drift flux correlation to commonly used correlations such as the Chexal-Lellouche and Modified-Bestion models.
3. Provide a comparison of differences between the drift-flux correlation and the commonly used correlations that shows the sensitivity of key figures of merit, including decay ratio and time for onset of instability, to the use of the drift-flux correlation.

NuScale Response:

Item 1:

The Zuber-Findlay correlation used to provide drift flux parameters input to PIM has been introduced by Collier (Ref. [1], Eqn. 3.10), and cited later in an EPRI report (Ref. [2], Table 2-2) as “General Drift Flux Correlation.” The references do not specify a range of validity beyond general applicability to LWR conditions. The correlation is presumed valid in the full range from atmospheric to critical pressure. The body of supporting data cited in the early literature (e.g. Ref [8]) covers a wide range of pressure up to 2500 psia.

Item 2:

The drift velocity is derived from balancing the forces of drag and gravity and the form is common to several correlations. As given by Ishii (Ref. [3]), using the TR nomenclature, the drift velocity for round pipes is:

$$V_{gj} = \sqrt{2}\left(\frac{g\sigma\left(\rho_f - \rho_g\right)}{\rho_f^2}\right)^{1/4} \tag{1}$$

The Zuber-Findlay correlation used in the TR approximates $\sqrt{2} = 1.41$, while other works, e.g. Lahey and Moody (Ref. [6], Eqn. 5.188) assign a multiplier of general value to adjust the data consistent with the choice of the concentration parameter since the drift flux parameter pair are not independent. Collier (Ref. [1]) cited experiments presented by Zuber et al. (Ref. [7]) as fitting Eqn. (1) with the concentration parameter of C_0 = 1.13.

Collier (Ref. [1], equation 3.19) also suggested the use of an alternative form of the drift velocity, which suits slug flow, as:

$$V_{gj} = 0.35\sqrt{\frac{g(\rho_f - \rho_g)D_{hyd}}{\rho_f}} \qquad (2)$$

The slug flow form of the drift velocity, Eqn. (2), has been adopted by Bestion (Ref. [4]) with a different multiplier. Instead of 0.35, the Modified Bestion uses a factor of 0.188 instead of 0.35 and the vapor density instead of liquid density in the denominator. Thus, the drift velocity according to Modified Bestion is obtained from:

$$V_{gj} = 0.188\sqrt{\frac{g(\rho_f - \rho_g)D_{hyd}}{\rho_g}} \qquad (3)$$

The drift velocity obtained from Eqn. (2) or in Eqn. (3) for the NPM riser is unrealistically too high due to the large hydraulic diameter apparently outside the range of application anticipated by the correlation.

The Modified Bestion correlation (Ref. [4]) specifies a concentration parameter that is always greater than unity, which is obtained from:

$$C_0 = 1.2 - 0.2\sqrt{\frac{\rho_g}{\rho_f}} \qquad (4)$$

which is the same as given by Ishii (Ref. [3], Eqn. 68) for round tubes. At the nominal pressure of 128 bar, the vapor and liquid saturation densities are ρ_g = 76.54 kg/m^3 and ρ_f = 641.75 kg/m^3, respectively. The corresponding concentration parameter according to Eqn. (4) is C_0 = 1.13, which is the same as Collier's. {{

}}2(a),(c)

It should be noted that Ishii (Ref. [3], Eqn. 71) applies a void-dependent factor such that

$$C_0 = \left(1.2 - 0.2\sqrt{\frac{\rho_g}{\rho_f}}\right)\left(1 - e^{-18\alpha}\right) \qquad (5)$$

to account for void concentration near the wall for low void fraction. The resulting concentration parameter for low void fraction is well below unity which is not physical for the NPM riser for which the flow is adiabatic and the bubbles originate in the center of the riser pipe as they exit the hot region of the core. Since the concentration parameter in the NPM riser must be greater than unity, Eqn. (5) is not applicable.

The Chexal-Lellouche correlation (Ref. [5]) is valid for diabatic flow which is the case for the reactor core but not in the riser. At low void fraction, the Chexal-Lellouche correlation allows for low values of the concentration parameter, reflecting the fact that bubbles generated at the heated surface wall are slower than the bulk flow. This behavior disqualifies the Chexal-Lellouche correlation from application to the NPM riser.

In conclusion, limitations of the Chexal-Lellouche and Modified Bestion correlations preclude them from use in the NPM riser. The drift flux parameters used in the TR demonstrations do not have these limitations. Moreover, the magnitude of the drift flux parameters used in the TR were shown to be reasonable and follow the trends of applicable correlations. {{

}}2(a),(c)

Item 3:

The NPM protection system was demonstrated in the PIM calculation of the depressurization induced instability to occur prior to the instability inception. The magnitude of the following oscillation as it grows to a stable limit cycle was examined for variation in the drift flux parameters as reported in response to RAI 9017. It was demonstrated that the important parameters of instability inception time and ultimate oscillation magnitude are not significantly impacted by the widely-varied drift flux parameters by forcing homogeneous equilibrium condition (C_0 = 1 and V_{gj} = 0) as a maximum possible sensitivity check. The physical interpretation of the limit cycle magnitude is that {{

}}2(a),(c) This mechanism is independent of the vapor-liquid slip.

Nomenclature

α Void fraction

ρ_g Saturated vapor density

ρ_f Saturated liquid density

σ Surface tension

D_{hyd} Hydraulic diameter

C_0 Drift flux concentration parameter

V_{gj} Drift velocity

g Gravitational acceleration

References:

1. J.G. Collier, Convective Boiling and Condensation, McGraw Hill, London, 1972J.
2. M. Heazler and D. Abdollahian, “NATBWR: A Steady-State Model for Natural Circulation in Boiling Water Reactors,” EPRI NP-2856-CCM, February 1983.
3. M. Ishii, “One-Dimensional Drift-Flux Model and Constitutive Equations for Relative Motion between Phases in Various Two-Phase Flow Regimes,” ANL-77-47, October 1977.
4. A. Wysocki et al., “The Modeling of Advanced BWR Fuel Designs with the NRC Fuel Depletion Codes PARCS/PATHS,” Nuclear Technology, 190:3, 323-335.
5. B. Chexal and G. Lellouche, “A Full-Range Drift-Flux Correlation for Vertical Flows,” EPRI NP-3989-SR, EPRI, June 1985.
6. R. T. Lahey, Jr. and F. J. Moody, “The Thermal-Hydraulics of a Boiling Water Reactor,” Second Edition, ANS 1993.
7. N. Zuber, F. W. Staub, G. Bijwaard, and P. G. Kroeger, “Steady state and transient void fraction in two-phase flow systems,” GEAP 5417 (1967).
8. N. Zuber and J. A. Findlay, Average Volumetric Concentration in Two-Phase Flow Systems," Journal of Heat Transfer, November 1965.

Impact on Topical Report:

There are no impacts to the Topical Report TR-0516-49417, Evaluation Methodology for Stability Analysis of the NuScale Power Module, as a result of this response.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-1017-56838

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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 methodology by which NuScale develops its stability analysis of the NuScale power module..

    NuScale has performed significant research and evaluation to develop a basis for this methodology 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. 9096, eRAI No. 9096. 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 10/26/2017.

Zackary W. Rad