RAIO-0819-66717

August 23, 2019

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 Supplemental Response to NRC Request for Additional Information No. 9536 (eRAI No. 9536) 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. 9536 (eRAI No. 9536)," dated June 18, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 9536 (eRAI No.9536)," dated September 21, 2018
3. 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) supplemental response to the referenced NRC Request for Additional Information (RAI).

The Enclosures to this letter contain NuScale's supplemental response to the following RAI Question from NRC eRAI No. 9536:

- 15.06.06-2

Enclosure 1 is the proprietary version of the NuScale Supplemental Response to NRC RAI No. 9536 (eRAI No. 9536). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The proprietary enclosures have been deemed to contain Export Controlled Information. This information must be protected from disclosure per the requirements of 10 CFR § 810. 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 Matthew Presson at 541-452-7531 or at mpresson@nuscalepower.com.

Sincerely,

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

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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9536, proprietary

Enclosure 2: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9536, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0819-66718

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9536, proprietary

Enclosure 2:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9536, nonproprietary

NUSCALE™
Power for all humankind

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 9536

Date of RAI Issue: 06/18/2018

NRC Question No.: 15.06.06-2

GDC 10, *Reactor design*, requires that the reactor core and associated coolant, control, and protection systems be designed with appropriate margin to assure that specified acceptable design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). Additionally, radiological consequences of postulated accidents must meet the requirements of 10 CFR 52.47(a)(2)(iv)(A), 10 CFR 52.47(a)(2)(iv)(B), and GDC 19, *Control room*. FSAR, Tier 2, Section 4.4.1.1 states that the design basis for the thermal-hydraulic design of the reactor core includes providing adequate heat transfer from the fuel cladding to the reactor coolant by assuring that critical heat flux limits are met during normal operation, AOOs, and infrequent events. FSAR, Tier 2, Section 15.6.6.3.1 describes the use of the Hench-Levy and Griffith-Zuber critical heat flux (CHF) correlations in the evaluation of the inadvertent operation of emergency core cooling system event, which is identified as an AOO in FSAR, Tier 2, Table 15.0-1. FSAR, Tier 2, Section 15.6.6.3, states that the CHF data from the KATHY test loop was used to establish a 95/95 CHF ratio (CHFR) limit of 1.122 for the Hench-Levy CHF correlation, and that data collected at Stern Laboratories was used to establish a CHFR limit of 1.37 for the Griffith-Zuber CHF correlation.

NRC staff needs to establish a finding that the proposed CHF correlations are acceptable for performing safety analyses of the Nuclear Power Module with NuFuel-HTP2™ fuel, with a specified CHFR limit, over a specified range of applicability, and in accordance with a specified methodology. Accordingly, NRC staff requests that the applicant (1) submit a methodology, for NRC staff review, that describes the experimental data supporting the development of the CHFR limits, and that demonstrates the CHF models have sufficient validation as demonstrated through appropriate quantification of error, and (2) update the appropriate licensing documentation to consistently reflect the final CHFR limits.

NuScale Response:

Background:

NuScale Critical Heat Flux (CHF) database consists of data from a 5x5 assembly geometry with a prototypical rod geometry (STERN) and from a rod geometry/spacer design (KATHY). The tests have been performed with and without guide tubes; including uniform and chopped cosine axial power shapes.

The CHF modeling for the NuScale Loss-of-coolant-accident (LOCA) application is achieved via:

- Extending the Hench-Levy limit lines {{

}}2(a),(c) The correlations are developed from the test data from STERN and shown to conservatively predict the data from KATHY with prototypical spacer geometry.

LOCA Evaluation Methodology (EM) Topical Report Update:

The protection against the occurrence of CHF during LOCA assures that the minimum CHF ratio is greater than the analysis limit that conservatively bounds the STERN data predictions. Sections 2.2.1 and 2.2.2 of the LOCA licensing topical report (LTR) have been modified to include the term “analysis” limit instead of safety limit.

Additional discussion is added to Section 6.11 of the LOCA LTR to include the origin of the extended Hench-Levy CHF correlation, how the revised pressure correction is derived, and how the non-uniform axial power shapes are accounted. The discussion regarding the KATHY assessments described in Appendix B of the LTR is included to demonstrate the extended Hench-Levy correlation conservatively predicts the KATHY CHF data. Furthermore, it is demonstrated that the extended Hench-Levy CHF correlation predicts the low flow data conservatively, when the correlation is used outside its application range. Therefore, it is concluded that the interpolation scheme is applied conservatively.

{{

}}2(a),(c)

In Section 7.3 of the LTR where the NRELAP5 assessment of the STERN CHF data is presented, it is shown that the predicted to measured critical power ratio of {{ }}2(a),(c) conservatively envelopes all of the STERN database including the low flow data within the extended Griffith-Zuber CHF correlation and the analysis limit of {{ }}2(a),(c) is established as the LOCA EM acceptance criterion for the minimum CHF ratio.

Impact on Topical Report:

Topical Report TR-0516-49422, Loss-of-Coolant Accident Evaluation Model, has been revised as described in the response above and as shown in the markup provided in this response.

5. After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

The NuScale LOCA EM addresses the first four criteria. The EM described in this document addresses ECCS performance in the NPM up to the time when a recirculation flow is established, pressures and levels in containment and the RPV approach a stable equilibrium condition (i.e., flow is recirculating in through the RRVs), core heat is removed by boiling in the core, and steam exits through the RVVs.

The NPM is designed so that there is no core uncovery or heatup for a design-basis LOCA. As a result, peak cladding temperature (PCT) will be well within the acceptance criterion of 2,200 degrees Fahrenheit (1,204 degrees Celsius). The parameters of interest are the collapsed liquid water level above the top of active fuel (TAF) and minimum critical heat flux ratio (MCHFR). These two criteria are more sensitive than PCT in the NPM design. Maintaining primary inventory and ensuring the core does not go into post-critical heat flux (CHF) heat transfer ensures that the 10 CFR 50.46(b) limitations for PCT, oxidation, and hydrogen production are protected.

There is no oxidation of the cladding as a result of a LOCA. There is no hydrogen generated from the chemical reaction of the cladding with water or steam because fuel temperatures are not high enough to initiate this chemical reaction. There are no changes in core geometry resulting from a LOCA that would prevent the core from being amenable to cooling. Therefore, the first four acceptance criteria are met when the collapsed liquid level is above the top of the active fuel and MCHFR is greater than the safetyanalysis limit for the entire time period covered by this EM (see Section 7.3.6).

The fifth criterion is also met during the shorter period this EM addresses. The longer-term evaluation for the fifth criteria is addressed by other NuScale methodologies (Reference11).

2.2.2 10 CFR 50 Appendix K

The ECCS performance is calculated in conformance with the required and acceptable features of ECCS EMs specified in 10 CFR 50 Appendix K, and is calculated for a number of cases to provide assurance that the most severe postulated LOCAs are identified. 10 CFR 50.46 provides two options for an acceptable LOCA EM. Paragraph 50.46(a)(i) allows for a best-estimate approach to be followed and Paragraph 50.46.(a)(ii) allows for the conservative deterministic approach detailed in 10 CFR 50 Appendix K. In view of the large safety margins in the NPM, the deterministic bounding approach in Paragraph 50.46(a)(ii) is used by NuScale.

The NPM is designed to reduce the consequences of design-basis LOCAs compared to existing light water reactors for which 10 CFR 50 Appendix K was developed. Consequently, many of the phenomena that are the subject of 10 CFR 50 Appendix K requirements are not encountered in design-basis NPM LOCAs in the NPM. That is, certain phenomena have been designed out of the NPM and, therefore, a number of

10 CFR 50 Appendix K Required and Acceptable Feature	NuScale LOCA EM
I.A.5 Metal-Water Reaction Rate: The rate of energy release, hydrogen generation, and cladding oxidation from the metal-water reaction shall be calculated using the Baker-Just equation (Baker, L., Just, L.C., "Studies of Metal Water Reactions at High Temperatures, III. Experimental and Theoretical Studies of the Zirconium-Water Reaction," ANL-6548, page 7, May 1962). This publication has been approved for incorporation by reference by the Director of the Federal Register. A copy of the publication is available for inspection at the NRC Library, 11545 Rockville Pike, Two White Flint North, Rockville, Maryland 20852-2738. The reaction shall be assumed not to be steam limited. For rods whose cladding is calculated to rupture during the LOCA, the inside of the cladding shall be assumed to react after the rupture. The calculation of the reaction rate on the inside of the cladding shall also follow the Baker-Just equation, starting at the time when the cladding is calculated to rupture, and extending around the cladding inner circumference and axially no less than 1.5 inches each way from the location of the rupture, with the reaction assumed not to be steam limited.	Calculated cladding temperatures for design basis LOCAs are well below the level where cladding oxidation occurs on a time scale of a LOCA event for the NPM (see the results of LOCA break spectrum calculations in Section 9.0). Therefore, this requirement is not relevant to the NuScale design, which precludes fuel temperature reaching CHF and any significant fuel cladding heatup. For the NuScale LOCA EM, core coverage and an MCHFR greater than the safetyanalysis limit (see Section 7.3.6) precludes the occurrence of cladding oxidation. Therefore, the required features of I.A.5 are excluded from the NuScale LOCA EM.
I.A.6 Reactor Internals Heat Transfer: Heat transfer from piping, vessel walls, and non-fuel internal hardware shall be taken into account.	The NRELAP5 plant model explicitly represents all major reactor internal heat structures. Heat structures are also included for the primary and secondary system pressure boundary materials. See Section 5.1.2 for details of the internal heat structures represented in the NuScale LOCA EM. Therefore, the required features of I.A.6 are included in the NuScale LOCA EM.
I.A.7 Pressurized Water Reactor Primary-to-Secondary Heat Transfer: Heat transferred between primary and secondary systems through heat exchangers (steam generators) shall be taken into account. (Not applicable to boiling water reactors (BWRs).)	Heat transfer through the steam generator (SG) tubes is included in the EM. The model is validated using experimental data from Società Italiana Esperienze Termoidrauliche (SIET) tests (see Section 7.4) and NIST-1 tests (see Section 7.5). Therefore, the required features of I.A.7 are included in the NuScale LOCA EM.

The second equation describes the rate of change of ^{239}Np. The production of ^{239}Np is from the beta decay of ^{239}U, and ^{239}Pu is formed from the decay of ^{239}Np. $\Psi(t)$ is the solution from the NRELAP5 fission source. The implemented model yields the result quoted in the 1979 Standard (Reference 48), the 1994 Standard (Reference 49), and the 2005 Standard (Reference 50) as demonstrated by Figure 6-4.

Table 6-4. ANS-79 actinide model constants.

Isotope	$\lambda(s^{-1})$	η(MeV)
^{239}U	1.772	0.00299
^{239}Np	0.5774	0.00825

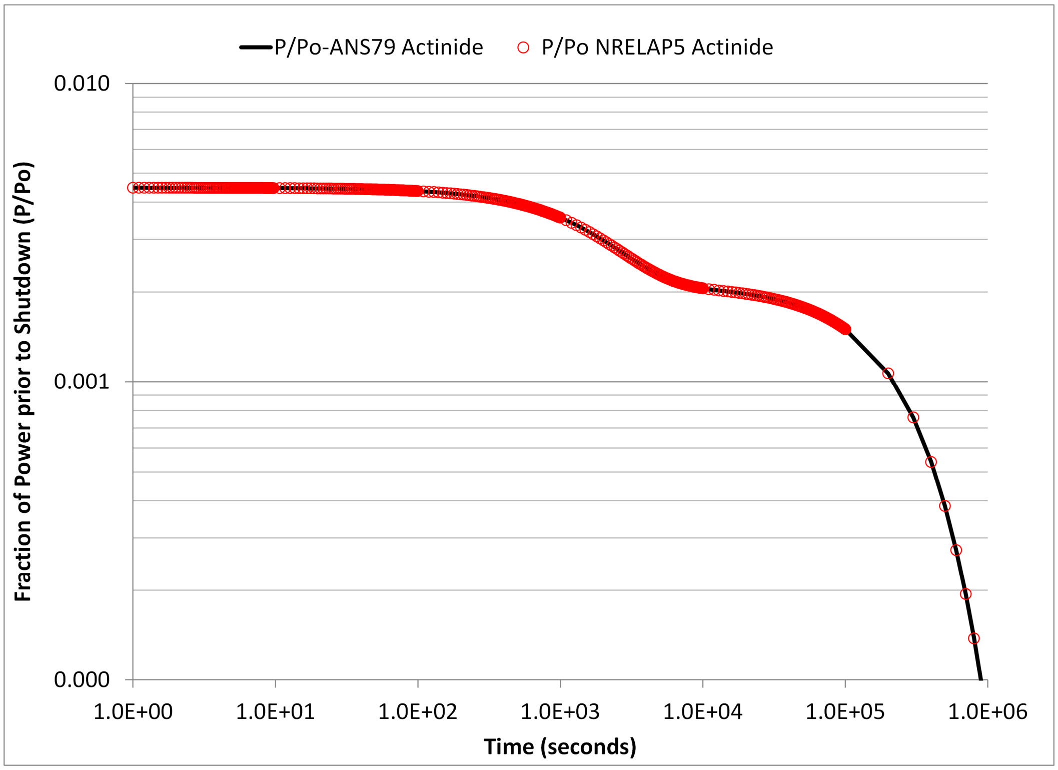

Figure 6-4. NRELAP5 ANS-79 implemented actinide heat curve

6.11 Critical Heat Flux Models

The CHF is calculated using a combination of the {{

}}2(a),(c)

{{

}}2(a),(c)

6.11.1 {{ }}2(a),(c)

{{

}}2(a),(c)

{{

}}2(a),(c)

{{

}}2(a),(c)

{{

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

Figure 7-58. Predicted versus measured Stern power

predict LOCA phenomena at both the NIST-1 and NPM scales. Limitations and modeling requirements were determined in this assessment process and are accounted for in the application of the LOCA methodology.

This topical report provides an example application of the LOCA EM in order to aid the reader's understanding of the context of the application of the NuScale LOCA EM. These calculations are presented for break spectra that cover a range of break locations, break sizes, single failures, equipment unavailability, and initial and boundary conditions. The nodalization and time-step sensitivity required by 10 CFR 50 Appendix K and additional sensitivity calculations that address the uncertainties in modeling of key phenomena are performed. The analyses conducted demonstrate that the NPM retains sufficient water inventory in the primary system such that the core does not uncover or experience a CHF condition during a LOCA such that the minimum CHF ratio is greater than the analysis limit of {{ }}2(a),(c) as described in Section 7.3.6, and that containment design pressure is not challenged. The PCT is shown to occur at the beginning of the LOCA event and cladding temperature decreases as the transient evolves. Because no fuel heatup occurs for any design-basis LOCAs, the following regulatory acceptance criteria from 10 CFR 50.46 are met:

- PCT remains below 2,200 degrees Fahrenheit (1,204 degrees Celsius).
- Maximum fuel oxidation is less than 0.17 times total cladding thickness.
- Maximum hydrogen generation is less than 0.01 times that generated if all cladding were to react.
- Coolable geometry is retained.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0819-66718

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 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. 9536, eRAI 9536. 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 23, 2019.

Zackary W. Rad