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RAIO-0319-64867

March 14, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 447 (eRAI No. 9508) on the NuScale Design Certification Application

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 447 (eRAI No. 9508)," dated May 01, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 447 (eRAI No.9508)," dated September 13, 2018

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. 9508:

- 15-7

Enclosure 1 is the proprietary version of the NuScale Supplemental Response to NRC RAI No. 447 (eRAI No. 9508). 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

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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9508, proprietary

Enclosure 2: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9508, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0319-64868

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9508, proprietary

Enclosure 2:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9508, nonproprietary

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

eRAI No.: 9508

Date of RAI Issue: 05/01/2018

NRC Question No.: 15-7

10 CFR 50 Appendix A, GDC 34, Residual heat removal, and NuScale's PDC 34, in FSAR Section 3.1.4.5, state,

"A system to remove residual heat shall be provided. The system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the reactor coolant pressure boundary are not exceeded."

As discussed in FSAR Section 15.0.5, there are two systems to remove decay heat: the DHRS and the ECCS. The Long Term Cooling technical report, TR-0916-51299, which addresses long term decay heat removal after ECCS actuation, and supports the FSAR Chapter 15 analyses, states, "…during long-term cooling, maintaining a collapsed liquid level in the riser above the core and demonstrating cladding temperatures remain acceptably low indicate that MCHFR is not challenged."

The RCS water mass is a function of the reactor power and there may be an initial power in which the water level drops below the riser after a reactor trip. If the RCS level drops below the riser, but not low enough to actuate the ECCS, it is unclear to the staff if fuel cladding temperatures would remain low enough to preserve the SAFDLs consistent with PDC 34. The staff is requesting the applicant address this potential scenario involving the interruption of continuous RCS natural circulation and, if necessary, demonstrate that cladding temperature remains acceptable low indicating that MCHFR is not challenged in a similar manner to that evaluated in the LTC report. If credit is taken for degraded DHRS heat removal capability (i.e., intermittent RCS natural circulation) the applicant should provide experimental data which validates the degraded DHRS heat removal capability.

NuScale Response:

The original NuScale response as submitted in NuScale correspondence RAIO-0918-61781 and dated September 13, 2018, is augmented with the following information.

Following reactor scram, normal operating procedure will ensure RCS temperature and inventory are kept sufficiently high by using the secondary plant systems and makeup injection to maintain level in the pressurizer. However, for scenarios where the module is under extended decay heat removal system (DHRS) cooling with no makeup injection available, e.g., during a loss of power, it is possible for the primary coolant to shrink below the top of the riser causing a disruption to the normal RCS circulation path. This scenario is referred to as riser uncovery. The following topics related to riser uncovery are discussed in this response: riser uncovery phenomena, NRELAP5 1D modeling of riser uncovery, DHRS performance, and core critical heat flux (CHF) and criticality potential during riser uncovery.

<u>Riser Uncovery Phenomena</u>

Immediately following actuation, DHRS heat removal well exceeds core decay heat due to the large temperature gradient between the reactor coolant system (RCS) and reactor pool. Coolant temperature and level will decrease over time which can lead to riser uncovery and a disruption to normal RCS circulation. The earliest timing of riser uncovery is on the order of a few hours depending on assumed conditions, e.g., initial RCS inventory mass and decay heat. For example, system analysis of a nominal DHRS cool down with two condensers shows that riser uncovering begins approximately 3 hours after reactor trip, starting from an initial pressurizer level of 50% and assuming the ANS 1973 decay heat standard with actinides.

During the time prior to riser uncovery, DHRS operation has driven the module to cold (less than 420°F) and depressurized conditions. Core temperatures are subcooled with no voiding in the core region. Decay heat is being transferred from the core to the DHRS by flow through the normal RCS circulation path. Once the riser becomes uncovered, the primary loop normal circulation path is disrupted, and an internal circulation flow path is established within both the riser and downcomer (Figure 1). Within the riser, a heated column is expected to develop and travel upwards from the core through the center of the riser, while colder liquid travels downwards along the riser wall back into the core region. This internal flow path transfers decay heat into the downcomer through the riser wall. Within the downcomer, liquid heated by the riser wall is expected to travel upwards into the steam generator region, transfer energy to the DHRS through the steam generator (SG) tubes, and then circulate downwards.

This mechanism for transferring decay heat to the DHRS is self-balancing. If internal recirculation and riser heat transfer are insufficient to remove decay heat, coolant in the riser will remain sufficiently heated to sustain some normal circulation in addition to some internal circulation. In the long term, quasi-equilibrium conditions will be established at the coolant level, temperature, and flow necessary to remove decay heat through the DHRS.

{{

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

Figure 1. Internal circulation within riser and downcomer after riser uncovery.

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NRELAP5 1D Modeling of Riser Uncovery

Safety analysis methodologies using NRELAP5 have developed 1D models for the riser and downcomer flow paths as the majority of evaluated events feature single direction flow within these channels. These models cannot calculate internal circulation within the riser or downcomer when riser uncovery occurs. To evaluate the behavior of these models during riser uncovery, two scenarios are developed using DHRS cooldown cases from long term cooling analysis. {{

}}2(a),(c)

Comparisons for riser collapsed level (Figure 2), RCS flow (Figure 3 and Figure 4), core outlet liquid and saturation temperatures (Figure 5), and system pressure (Figure 6) are shown below. These results are from a long term cooling scenario where conditions are biased to maximize RCS temperature. {{

}}2(a),(c) Both scenarios are shown to provide sufficient decay heat removal with the module remaining in cold and depressurized conditions.

{{

}}2(a),(c)

Figure 2. Riser collapsed level (top of riser wall is 34.8 feet relative to top of active fuel).

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}}2(a),(c)

Figure 3. RCS flow.

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}}2(a),(c)

Figure 4. RCS flow zoomed {{ }}2(a),(c).

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}}2(a),(c)

Figure 5. Core outlet temperature and saturation temperature .

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}}2(a),(c)

Figure 6. RCS pressure .

DHRS Performance during Riser Uncovery

In general, DHRS performance is strongly dependent on RCS temperature. This allows a self-balancing equilibrium during extended DHRS operation where the RCS will stabilize at temperatures necessary to provide sufficient DHRS performance to remove core decay heat. Given the slow trend for decreasing level, there will be a transition in dominate heat transfer mechanism from the normal circulation path to internal circulation as normal circulation flow is slowly reduced to zero. During this transition, coolant temperature and thus level can only continue decreasing if the DHRS is still removing excess energy from the RCS. Complete riser uncovery implies that the internal circulation flow path is actively providing sufficient performance to remove decay heat. If heat transfer through the riser wall is insufficient to remove excess energy from the RCS, level will cease decreasing and equilibrium level will be established above the riser wall. However, at the physical extreme of the event progression, an intermittent natural circulation flow may be established where level oscillates between covering and uncovering the riser wall if internal circulation heat transfer alone proved insufficient to remove decay heat. The DHRS performance predicted by NRELAP5 is presented below.

As previously discussed, with NRELAP5 1D models {{

}}[2(a),(c)] As temperature decreases, DHRS performance is also reduced. Eventually RCS temperatures decreases to the point where DHRS heat removal matches decay heat. With the 1D model and {{

}}[2(a),(c)] this is only temporary until the module is sufficiently cooled. Long term, both modeling options show RCS conditions come to whatever level, temperature, and flow are necessary to reach equilibrium between DHRS heat removal and decay heat.

The amount of liquid covering the steam generator tubes is also presented as part of DHRS performance. Figure 8 presents downcomer collapsed level for both riser heat transfer models. An additional long term cooling scenario biased to minimize collapsed level is also presented. The results show that both riser heat transfer models predict similar levels of tube coverage and that the tubes remain {{ }}[2(a),(c)]

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}}2(a),(c)

Figure 7. Module heat balance (note that reactor power is the same in both cases).

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

Figure 8. Downcomer collapse level compared to SG tube elevation.

Core CHF and Recriticality

Regardless of timing, due to the nature of riser uncovery module conditions, the RCS will be cold (less than 420°F) and at decay heat levels. Under these conditions CHF is not a concern. For confirmation, {{ }}[2(a),(c)] (used in LOCA EM for evaluating CHF at low and stagnant flow conditions) is used to calculate the CHF ratio at various points during the transient: at the time of riser uncovery and after 24 hours from reactor scram for both cases with and without riser heat transfer modeled.

Results are presented for the long term cooling scenario biased to maximize RCS temperature. Decay heat is conservatively assumed constant at 2.5 MW for all calculations (value approximately 1 hour post-scram). A total peaking factor (F_Q) of 2.0 is conservatively assumed to calculate peak heat flux. {{

}}2(a),(c) Results are presented in Table 1 below.

Significant margin to CHF is shown for all cases. {{

}}2(a),(c) These results confirm that core CHF and temperatures are not a safety concern during riser uncovery.

The potential for recriticality during riser uncovery is also considered. For a long term cooling scenario biased to minimize RCS temperature, core average temperatures after 24 hours under DHRS cooling are {{

}}2(a),(c) This demonstrates that the core will remain subcritical during riser uncovery.

Table 1. CHF results during riser uncovery.

Parameter	**{{**		
Pressure (psia)			
Void Fraction			
Peak Core Heat Flux (kW/m^2)			
Critical Heat Flux (kW/m^2)			
CHFR			}}2(a),(c)

{{

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

Figure 9. Peak cladding temperature.

Summary

In the long term, DHRS performance is self-balancing and module conditions will be established at the level, temperature, and flow necessary to remove decay heat. Given the slow progression toward riser uncovery, complete riser uncovery implies that the DHRS is still removing excess energy from the RCS through the internal circulation flow path. Excess energy removal is required to further decrease temperature and reduce level below the top of the riser wall. A scenario where riser uncovery occurs intrinsically means internal circulation within the riser and downcomer provides sufficient performance to remove decay heat from the module through the DHRS.

The evaluated NRELAP5 {{ }}2(a),(c) both predict that module conditions reach equilibrium between DHRS heat removal and decay heat. Both models demonstrate significant margin to core CHF and cladding temperature safety limits with no potential for recriticality. {{

}}2(a),(c)

The following conclusions are based on this response:

- The self-balancing mechanism of the decay heat removal system heat removal during riser uncovery is understood.
- The applied 1D riser and downcomer models are sufficient to demonstrate equilibrium is reached between heat removal and decay heat.
- There is no safety concern during riser uncovery, with core CHF and fuel cladding temperatures showing significant margin to safety limits, and the core remaining subcritical.

Impact on DCA:

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

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0319-64868

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 long term cooling 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. 447, eRAI 9508. 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 March 14, 2019.

Zackary W. Rad