UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

August 2, 2019

Ms. Margaret M. Doane
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: INTERIM LETTER – CHAPTERS 3, 6, 15 AND 20 OF THE NRC STAFF'S SAFETY EVALUATION REPORT WITH OPEN ITEMS RELATED TO THE DESIGN CERTIFICATION APPLICATION REVIEW OF THE NUSCALE SMALL MODULAR REACTOR

Dear Ms. Doane:

During the 665th meeting of the Advisory Committee on Reactor Safeguards, July 10-12, 2019, we met with representatives of NuScale Power, LLC (NuScale) and the NRC staff to review Chapter 3, "Design of Structures, Components, Equipment and Systems;" Chapter 6, "Engineered Safety Features;" Chapter 15, "Transient and Accident Analyses;" and Chapter 20, "Mitigation of Beyond-Design-Basis Events;" of the safety evaluation report (SER) with open items associated with the NuScale design certification application (DCA). Our NuScale Subcommittee also reviewed these chapters on June 18-20, 2019, and July 9, 2019. During these meetings, we had the benefit of discussions with NuScale and the NRC staff. We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The barrier analysis used for turbine missile protection is a different approach than previously accepted. We await the staff's review before commenting.

2. The emergency core cooling system (ECCS) valve test program currently underway is required to provide confidence for valve functionality and performance.

3. NuScale's power module (NPM) can experience a return-to-power under accident analysis assumptions, but does not violate any specified acceptable fuel design limits. This potential operational condition should be precluded in the long term.

4. We have not identified any additional major issues at this time for Chapters 3, 6, 15 and 20.

BACKGROUND

NuScale submitted a DCA for its small modular reactor on December 31, 2016. The staff's Phase 2 SER chapters related to the DCA include open items. In addition to a description of the staff review and its bases for acceptance of the DCA, the SER chapters also identify the information a combined license applicant must provide.

Our Phase 3 review is being conducted on a chapter-by-chapter basis to identify technical issues that may merit further consideration by the staff. This process can aid in the resolution of concerns and facilitates timely completion of the DCA review. This letter addresses the staff's SER and the DCA for NPM for Chapter 3, Revision 1; Chapter 6, Revision 2; Chapter 15, Revision 2; and Chapter 20, Revision 2; as well as supplementary material, including responses to staff requests for additional information.

DISCUSSION

For this interim letter, we make the following observations on selected elements of the design addressed in these chapters.

DCA Chapter 3 – Design of Structures, Components, Equipment and Systems

This chapter documents the analytical methods, testing procedures, tests and analyses that the applicant used to ensure the structural and functional integrity of the piping systems, mechanical equipment, reactor vessel, reactor internals, and their supports under static and dynamic loadings, including those caused by normal operation and postulated events. It addresses how the design conforms to General Design Criteria. Individual sections discuss conformance to the applicable criteria: seismic classification of systems, structures and components (SSCs) important to safety; the analyses and tests performed to demonstrate acceptability of the SSCs under bounding seismic load spectra; and the capability of the NuScale design to withstand wind and tornado loadings and floods. In their review, the staff concludes that the design meets the applicable regulations in these areas.

Section 3.5 of the SER addresses protection of safety-related SSCs from missiles. Missiles generated by a turbine failure could potentially impact the Reactor Building and the Control Building. NuScale analyzes missiles impacting the Reactor Building concrete wall and the Control Building wall and grade slab to demonstrate that these are effective barriers to protect critical SSCs and related safety functions within those buildings. This is a different approach than has been previously licensed for turbine missile protection. At this time, the staff has not completed their review of additional information submitted by the applicant in response to staff requests on this topic, and it remains an open item. Our review and comment of this topic will await completion of that effort.

In our June 19, 2019, Subcommittee meeting with respect to the NuScale methodology for stability analysis of the NPM, we noted that there may be two-phase density-wave flow oscillations which would cause thermally induced fatigue of the steam generator tubes. NuScale and the staff have agreed to assure that these oscillations do not compromise the design limits and challenge tube integrity.

Other chapter sections address Protection against Dynamic Effects Associated with Postulated Pipe Rupture (including Leak Before Break); Design of Category I Structures; Environmental Qualification of Mechanical and Electrical Equipment; and ASME Code Class 1, 2, and 3 Piping Systems, Piping Components and Associated Supports. The staff concludes that, pending resolution of confirmatory items, the NuScale design meets the applicable requirements in these areas.

DCA Chapter 6 – Engineered Safety Features

This chapter discusses the engineered safety systems that are part of the NPM: specifically, the containment systems, the ECCS, control room habitability, fission product removal and control systems, and in-service inspection and testing of systems and components.

The ECCS includes five valve systems, three of which are reactor-vent-valves mounted on the reactor pressure vessel upper head that are directly connected to the pressurizer steam space and discharge to containment, and two reactor-recirculation-valves mounted on the side of the reactor pressure vessel in the downcomer that open to the containment. All five valves are closed during normal plant operation and open following the receipt of an actuation signal resulting from applicable accident conditions. Those valves also open on a loss of direct current (DC) power, and therefore are not dependent on a power source for actuation.

The ECCS valves are sophisticated in their design in that they incorporate a DC powered solenoid trip valve for actuation in combination with an integrated hydraulic and spring mechanical valve to allow flow from the reactor pressure vessel to containment for blowdown and depressurization. Inadvertent ECCS valve actuation is one of the anticipated operational occurrences (AOOs) analyzed in Chapter 15. The staff is currently reviewing the ability of this system to perform its safety function. NuScale is in the process of conducting valve testing to demonstrate compliance with the regulatory requirements. Successful completion of this ECCS valve test program is required to provide confidence that the valves will function as designed.

DCA Chapter 15 – Transient and Accident Analyses

This chapter discusses the set of design basis events (DBEs) that the NPM, as designed and constructed, must withstand without loss of SSCs needed to maintain core cooling and containment integrity.

The staff presented 11 unresolved issues without a clearly defined, mutually understood path towards resolution. The final status of the review is based on resolution of these unresolved issues, as well as the remaining open items.

In addition, the loss-of-coolant accident (LOCA) and Non-LOCA topical report methodologies, which are the basis for the Chapter 15 analyses, are also under review. Completion of these reviews is treated as an open item. We note that the above two methodologies yield significantly different estimates for minimum critical heat flux ratio at steady-state conditions. The staff should ensure that these differences are resolved before approving these methodologies.

Design basis events (DBEs) are analyzed until the module protection system actuation places the reactor in a stable shutdown condition, typically achieved within a few seconds to a few minutes of event initiation. Long-term cooling is evaluated generically for all events. This generic evaluation includes combinations of alternating current (AC) and DC power availability (available or unavailable). This multiple-scenario evaluation identifies the worst-case conditions when no credit is taken for nonsafety-grade AC or DC power.

Long-term cooling of the NPM can be achieved by passive safety system features, including the decay heat removal system (DHRS) and the ECCS. Both systems are enabled by valves that fail safe on loss of power. Proper, reliable actuation of these valves is crucial to guarantee passive long-term cooling. As noted previously, NuScale is conducting an important series of tests for the ECCS valves to demonstrate functionality and performance.

ECCS valve actuation relies on detecting high water level in the containment. NuScale plans to use a sensor never used under comparable conditions in the nuclear power industry. The staff should ensure that the level instrument is qualified to continuously measure the empty dry containment level, as well as accurately measure water level, when water enters the containment.

Chapter 15 assumes that some nonsafety-grade components may be used as backup for safety-grade components with similar function, e.g., main steam isolation valves and main feedwater valves. The staff has evaluated this type of event and concurs with the NuScale conclusion that this implementation is consistent with prior pressurized water reactor applications and is acceptable.

The staff has identified an open item related to the physical mechanisms that may result in non-uniform distribution of dissolved boron in the reactor vessel and containment after ECCS valve actuations. These mechanisms need to be understood to ensure that boron dilution in the core is limited and that subcriticality is maintained.

As part of the generic long-term cooling evaluation, NuScale has analyzed the possibility of return-to-power events. Several concurrent conditions must be present to lose shutdown margin: (1) the highest-worth control rod fails to insert on demand and remains withdrawn; (2) large moderator temperature reactivity feedback, which typically occurs close to the end of cycle; (3) low decay heat, otherwise the resulting small steam void levels would prevent criticality; and (4) significant overcooling following a reactor trip, resulting in temperatures lower than expected by either normal operator control or passive DHRS actuation. Both the applicant and the staff have performed an extensive evaluation of this type of event, including multiple sets of initial conditions and reactor parameters. These evaluations confirm that return to power is possible, and the expected power levels are small, generally on the order of 2 percent of nominal power. At this power level, core-coolability criteria are satisfied with sufficient margin. This event is the subject of an exemption request to General Design Criterion (GDC) 27, which is currently under review and consideration by the staff.

The standard review plan recommends adherence to conservative specified acceptable fuel design limits (SAFDLs) for AOOs, and it allows less stringent fuel design limits for lower frequency postulated accidents such as a LOCA. NuScale has chosen to apply the more conservative SAFDLs for both AOOs and postulated accidents to ensure compliance with the staff requirement that the SAFDL criteria (e.g., not exceeding critical heat flux under any circumstances) be applied to any event that may result in a return-to-power because of uncertainties in the event progression in the long term.

These analyses demonstrate that a return-to-power is highly unlikely; but, it is a situation that could leave the NPM in a critical, low power state in the long term. While these analyses predict the fuel remains within the SAFDL requirements for core coolability, this situation should not be allowed to persist or be considered as an acceptable final stable state for an NPM.

Consistent with the approach where nonsafety-grade components are used to backup failures in safety-grade components of similar function, measures should be taken in the NPM design and operation to preclude this situation in the long term (i.e., past 72 hours, when Chapter 15 rules do not apply) by giving credit to nonsafety-grade boron addition equipment.

The staff is continuing its review and is working with the applicant on a resolution path for all open items to ensure that all analyzed AOOs and postulated accidents satisfy the conservative SAFDL criteria.

DCA Chapter 20 – Mitigation of Beyond Design Basis Events (MBDBE)

This chapter outlines NuScale strategies to address the requirements in the pending MBDBE rule, 10 CFR 50.155. In addition, this chapter discusses NuScale's plans to address existing 10 CFR 50.54(hh)(2) requirements for loss of large area due to fire or explosion and associated procedure integration as well as emergency response planning. Design certification applicants can defer all MBDBE requirements to the combined license applicant. However, to reduce regulatory uncertainty for the combined license applicant, NuScale is voluntarily seeking NRC approval for its strategies to meet these requirements in the DCA.

In their review, the staff agreed with NuScale's proposed plans regarding 10 CFR 50.54(hh)(2) loss of large area, procedure integration, and emergency response. However, two open items precluded the staff from making a safety finding with respect to pending 10 CFR 50.155 requirements – the mechanisms responsible for flow fluctuations observed in DHRS operation and the potential for recriticality due to boron redistribution. The staff expects that on-going interactions will resolve these items.

The pending rule requires mitigation strategies for beyond design basis external events that are developed assuming a loss of all AC power concurrent with a loss of normal access to the ultimate heat sink or a loss normal access to the normal heat sink. Because of the enhanced safety margins or increased reliance on passive measures in new designs, it is reasonable to propose mitigating strategies that differ from those implemented in operating reactors. NuScale contends that their design is sufficiently robust to prevent damage to fuel in any NPM and the spent fuel pool and to maintain containment function for greater than 30 days. Consistent with prior applications, the staff has limited their review to the performance of permanently installed SSCs for 72 hours following a BDBE.

SUMMARY

The barrier analysis used for turbine missile protection is a different approach than previously accepted. We await the staff's review before commenting. The ECCS valve test program currently underway is required to provide needed confidence for valve functionality and performance. NuScale's power module can experience a return-to-power under accident analysis assumptions, but does not violate any SAFDLs. This potential operational condition should be precluded in the long term. We have not identified any additional major issues at this time for Chapters 3, 6, 15 and 20.

Members Riccardella and Sunseri did not participate in Chapter 3, Section 3.5 deliberations.

Sincerely,

/RA/

Peter C. Riccardella
Chairman

REFERENCES

1. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application - Safety Evaluation With Open Items for Chapter 3, ‘Design of Structures, Systems, Components and Equipment’,” May 21, 2019 (ML19140A381).

2. NuScale Power, Design Certification Application, Chapter 3, “Design of Structures, Systems, Components and Equipment,” Revision 1, March 15, 2018 (ML18086A153-171).

3. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application - Safety Evaluation With Open Items for Chapter 6, ‘Engineered Safety Features’,” May 20, 2019 (ML19130A046).

4. NuScale Power, Design Certification Application, Chapter 6, “Engineered Safety Features,” Revision 2, October 30, 2018 (ML18310A327).

5. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application – Safety Evaluation With Open Items for Chapter 15, “Transient and Accident Analyses,” July 9, 2019 (ML19168A103).

6. NuScale Power, Design Certification Application, Chapter 15, “Transient and Accident Analyses,” Revision 2, October 30, 2018 (ML18310A337).

7. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC Safety Evaluation for Topical Report TR-0516-49417-P, Revision 0, ‘Evaluation Methodology for Stability Analysis of the NuScale Power Module’,” May 15, 2019 (ML19135A412).

8. NuScale Power, Topical Report TR-0516-49417-P, “Evaluation Methodology for Stability Analysis of the NuScale Power Module,” Revision 0, July 31, 2016 (ML16250A851).

9. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application – Safety Evaluation With Open Items for Chapter 20, “Mitigation of Beyond-Design-Basis Events,” July 9, 2019 (ML19190A188).

10. NuScale Power, Design Certification Application, Chapter 20, “Mitigation of Beyond-Design-Basis Events,” Revision 2, October 30, 2018 (ML18310A343).

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