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

April 29, 2020

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

SUBJECT: NUSCALE CHAPTER 15: OPEN ITEM CLOSURE AND AREA OF FOCUS REVIEWS – RETURN TO CRITICALITY AND BORON DISTRIBUTION

Dear Ms. Doane:

During the 672nd meeting of the Advisory Committee on Reactor Safeguards, April 8-10, 2020, we completed our review of Chapter 15, "Transient and Accident Analyses," of the staff's safety evaluation (SE) report without open items related to the design certification application (DCA) review of the NuScale small modular reactor. We also conducted our review of return to criticality and boron distribution focus areas for the NuScale DCA as discussed in our September 25, 2019 letter. During these meetings, we had the benefit of discussions with NuScale (the Applicant) and the staff. We also had the benefit of the referenced documents. This letter addresses our focus area review of return to criticality and boron distribution for the NuScale DCA. A finding relative to the requirements of Title 10 of the *Code of Federal Regulation* 52.53 awaits completion of all remaining reviews.

CONCLUSIONS AND RECOMMENDATIONS

1. We concur with the staff's conclusions in Chapter 15 of their Advanced SE Report: all open items, including those unresolved from the earlier SE, have been resolved. However, a new issue related to boron redistribution remains open.

2. Major conclusions from our focus areas are the following:

   - Return to Criticality – The low risk of event sequences associated with return to criticality makes the General Design Criterion (GDC) 27 exemption acceptable.

   - Boron Redistribution – The issue remains open. The Applicant and the staff are working on its resolution. We will review the final staff evaluation.

BACKGROUND

We documented our interim review of Chapter 15 in the "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," dated August 2, 2019. The staff performed a preliminary review of Chapter 15 and issued a SE report with open items, 11 of which were identified as unresolved open items because a resolution path had not yet been defined with sufficient regulatory certainty. Even though our letter did not identify any major issues, we raised concerns related to: 11 open items with an unresolved path to resolution; the potential for return to criticality events; boron redistribution in vessel and containment; the water level instrumentation used for emergency core cooling system (ECCS) actuation; and the use of non-safety-grade components as backup for safety-grade components with similar function. In December 2019, the staff issued their Advanced SE Report.

DISCUSSION

Chapter 15 of the final safety analysis report documents the analysis of design basis events and radioactive releases from the NuScale power module (NPM). The Applicant has followed the traditional approach in the Standard Review Plan in conjunction with the NuScale Design-Specific Review Standard to categorize the types of events analyzed. In addition, events related to special NPM characteristics have also been analyzed, including passive long-term cooling and return to power after shutdown. The staff has reviewed these analyses and performed confirmatory calculations. The staff found that the consequences of these events meet the relevant regulatory requirements. In our review of the staff evaluation of the Chapter 15 analyses, we have concentrated on the topics highlighted in this letter.

Unresolved Open Items from Interim Review

We reviewed the Phase 2 SE with open items in July 2019; it included many open items. The path to resolution of 11 of these was unresolved at the time. No specific serious problems had been identified at Phase 2, but these open items were tracked for several reasons: (a) calculations had been performed using topical report methodologies that had not yet been reviewed; (b) requests for additional information had been issued, but responses had not been received; or (c) changes in module protection system (mostly setpoints) had been proposed by the Applicant but not yet fully evaluated.

We have reviewed the staff's resolution of the 34 Phase 2 SE Report open items, including the 11 unresolved open items. We agree with the staff evaluation of these open items and their final resolution as documented in the Advanced SE Report without open items.

Return to Criticality

The possibility of the NPM becoming critical after shutdown under some extreme conditions has required NuScale to request an exemption to GDC 27. The staff has reviewed in detail this event, and we concur with their evaluation that the exemption to GDC 27 is acceptable. The risk associated with this event is extremely low because:

1. The probability of occurrence is very low. It requires that: (a) the control rod with the highest worth does not insert on demand and fails to insert for at least 24 to 48 hours; (b) the boron concentration is low, representative of end of cycle conditions, leading to a large moderator temperature reactivity coefficient; (c) core temperature becomes relatively cold, representative of ECCS cooling through a flooded containment (or if natural circulation is reestablished, which requires additional assumed failures like inadvertent actuation of coolant injection systems); and (d) the Xe concentration has had time to decay, which requires 24 to 36 hours after shutdown.

2. The staff confirmatory calculations agree with the Applicant's that the core returns to a power level of at most 2%, which maintains the fuel temperature low and does not challenge specified acceptable fuel design limits.

3. The return to criticality event is delayed at least 48 hours and, when it occurs, the progression is very slow. There are a number of operator actions that could be credited to terminate the event, including: (a) attempting to drive the stuck rod in; (b) adding boron to the vessel; or (c) flooding the containment with highly borated pool water.

We agree that, when operated in completely passive mode with no operator actions, the NPM can regain criticality under an extremely unlikely set of assumptions. Even though this is not a desirable situation, we concur with the staff in their SE of the acceptability of the GDC 27 exemption.

Our conclusion on this topic is not unanimous. All members agree that return to criticality after scram is not a desirable situation, and the NuScale GDC 27 exemption should not become a precedent for future designs. Some members consider that the Applicant should have strengthened the safety-grade features of the design to prevent re-criticality without relying on an exemption. Options exist – for example, adding a safety-grade boron addition system, or possibly implementing a core nuclear re-design to minimize the worth of the stuck rod. Most members agree that the low risk associated with these event sequences resulting in return to criticality makes it acceptable because of the very low probability of occurrence, the lack of consequences to fuel integrity, and the high likelihood that operator action will terminate the event before the reactor returns to power.

Boron Distribution

As part of the long-term-cooling evaluation, the Applicant and the staff have evaluated the impact of boron redistribution between hot and cold regions in the NPM. As the coolant boils, boron tends to concentrate in the hot regions and is diluted in the cold regions where essentially-boron-free steam condenses. We are concerned specifically about boron dilution in the downcomer by steam condensation from the steam generators or from the vessel wall because it would provide a mechanism to insert unborated coolant in the core if natural circulation is re-established or when sudden ECCS flow starts by opening the recirculation valves. This could lead to a rapid return to power event with the possibility of core damage.

Chapter 15 analyses document the initial progression of events until the reactor is placed in a safe and stable condition. We are concerned, however, that conditions in which the riser is uncovered may continue to dilute the downcomer for extended periods of time and create the potential for return to power events. The Applicant, with NRC staff's review and approval, plans to prevent this event by: (a) updating actuation setpoints to minimize coolant level differences between the vessel and the containment; and (b) defining operator actions during the recovery portion of a long-term-cooling event. It is understood that the Combined License (COL) applicant will develop procedures to ensure the reactor remains subcritical during recovery procedures; however, these operator actions are not yet specifically reflected in the Generic Technical Guidelines. We will interact with the staff on these topics.

The Applicant has identified that this issue could affect their analysis of small break loss of coolant accidents. To minimize the likelihood of unborated water being driven into the core by sudden ECCS actuation, NuScale is considering modifying the actuation setpoints to minimize the coolant elevation differences between the vessel and containment. This setpoint change will require reanalysis of the affected Chapter 15 events, and it may affect the required accuracy of the instrumentation.

Containment and Vessel Level Instruments

In our August 2, 2019 letter, we observed that ECCS valve actuation relies on detecting high water level in the containment and emphasized that NuScale proposes a radar-based sensor never used under comparable conditions in the nuclear power industry. Because of limited experience of radar-based sensors in nuclear reactors, the staff will have to consider uncertainty on calibration drift until sufficient time in service experience is obtained. Given the importance of these measurements, the staff should ensure that the level instrument chosen by the COL applicant be qualified for the expected environment and operating history, including axial fluence distribution.

Other Review Items

Other items covered in the Phase 4 Advanced SE Report are listed below. We have reviewed these items with the staff and agree with their disposition:

- credit for non-safety-related equipment when it backs up a similar safety-related component;

- changes to design in Phase 4, including changes to Module Protection System and setpoints;

- methodology and analysis results for small break loss of coolant accidents (no large diameter pipes exist, so large breaks are not a design basis event) and ECCS performance;

- inadvertent opening of an ECCS valve event, including the treatment of valve opening pressure uncertainty values and the single failure criteria as it applies to the inadvertent actuation block valve; and

- long-term cooling, including passive decay heat removal system operation under normal shutdown and loss of coolant accident conditions and ECCS cooling with containment flooding.

SUMMARY

We concur with the staff's conclusions in Chapter 15 of their Advanced SE Report: all open items, including those unresolved from the earlier SE, have been resolved. However, a new issue related to boron redistribution remains open. Major findings from our focus area reviews are highlighted in our Conclusions and Recommendations section.

Sincerely,

Scott W. Moore Digitally signed by Scott W. Moore Date: 2020.04.29 14:18:54 -04'00'

Matthew W. Sunseri
Chairman

REFERENCES

1. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application – Safety Evaluation Report with No Open Items for Chapter 15, ‘Transient and Accident Analyses’,” January 28, 2020 (ML20028D595).

2. NuScale Power, Design Certification Application, Chapter 15, “Transient and Accident Analyses,” Revision 3, August 22, 2019 (ML19241A424).

3. Advisory Committee on Reactor Safeguards, “Proposed Focus Area Review Approach of the Advanced Safety Evaluation Report With No Open Items for the Design Certification Application of the NuScale Small Modular Reactor,” September 25, 2019 (ML19269B682).

4. Advisory Committee on Reactor Safeguards, “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,” August 2, 2019 (ML19204A278).

5. NuScale Power, “TR-1117-57216, NuScale Generic Technical Guidelines,” Revision 1, May 31, 2019 (ML19151A810).

6. U. S. Nuclear Regulatory Commission, “NUREG-0800, ‘Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants’,” Revision 6, March 29, 2007 (ML070810350).

7. U. S. Nuclear Regulatory Commission, “Design-Specific Review Standard for NuScale Small Modular Reactor Design,” December 21, 2015 (ML15355A295).

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