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

September 20, 2019

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

SUBJECT: SAFETY EVALUATION OF THE NUSCALE TOPICAL REPORT TR-0516-49417-P, REVISION 0, "EVALUATION METHODOLOGY FOR STABILITY ANALYSIS OF THE NUSCALE POWER MODULE"

Dear Ms. Doane:

During the 665th and 666th meetings of the Advisory Committee on Reactor Safeguards, July 10-12, 2019 and September 4-6, 2019, we reviewed the staff's safety evaluation report of NuScale topical report, TR-0516-49417-P, Revision 0, "Evaluation Methodology for Stability Analysis of the NuScale Power Module." Our NuScale Subcommittee also reviewed this topical report on June 19, 2019. During these meetings, we had the benefit of discussions with NuScale and the staff. We also had the benefit of the referenced documents.

## CONCLUSION AND RECOMMENDATIONS

1. When used in compliance with the 16 limitations imposed by the staff, the methods documented in this stability topical report are acceptable for performing stability analyses of the NuScale power module (NPM). The safety evaluation should be issued.

2. Prototypical steam generator tests and scoping staff analyses show that two-phase density-wave flow oscillations inside the tubes are possible with the current design, which could challenge thermal fatigue limits. NuScale and the staff are aware of the issue and are committed to resolving it prior to completion of the review.

## DISCUSSION

The NuScale stability topical report presents a thorough review of the possible instability modes that may affect the NPM. NuScale concludes that the dominant mode is the riser natural-circulation instability. The staff has reviewed the impact of these possible modes and agrees with this conclusion.

To properly model the unique features of the NPM and its stability response, NuScale developed a dedicated computer code. The PIM code models the core, riser, and steam

generators (SGs) using numerical methods that, given the experience with boiling water reactor (BWR) instability modelling, are known to be accurate for instability calculations. The staff has reviewed the PIM code and found it acceptable.

NuScale has performed 19 stability tests in their NuScale Integrated System Test facility at various power levels. These tests confirm that NuScale's normal operating conditions are stable. The PIM code shows good agreement with these experimental data which confirms that the most stable operating condition is full power. At very low power, the stability margin degrades, but the NPM remains stable as long as the core riser remains free of voids.

NuScale has imposed an exclusion region in the operating domain to ensure stable operation. This region is defined by maintaining a margin to boiling conditions in the core riser section of the NPM. A protection system trip will be implemented by comparing the core exit thermocouple temperature to the saturation temperature derived from the pressurizer pressure. The staff has reviewed this solution and found it acceptable.

In response to a request for additional information (RAI), NuScale presented results from the SIET-TF2 prototypical SG tests, which exhibited unstable two-phase density-wave flow oscillations in the secondary side; i.e., inside the tubes where boiling occurs. The NuScale SG configuration is unique because in most SGs boiling occurs outside the tubes, which results in lower pressure drops and tends to minimize flow oscillations. The SGs have tube-inlet flow restrictors designed to minimize the possibility of unstable oscillations; however, they were found to be effective for some, but not all, test conditions. NuScale has committed to resolve this issue to minimize the possible impact of thermal fatigue on the SG. If the design allows flow oscillations, movement of the boiling boundary would create temperature oscillations in the tubes, potentially inducing thermal fatigue. The staff reviewed the SIET-TF2 SG tests and performed scoping calculations with the current tube design. These indicate that the SG tube flow is likely to oscillate, potentially with large amplitude; NuScale stated that their calculations show different trends. This issue is under review. If this oscillatory behavior is confirmed, then the ASME Code calculations for the SG must account for it.

Tube-flow oscillations will affect the SG heat transfer and induce pulses of cold/hot water in the NPM core, which will result in power oscillations. However, oscillations in the secondary side are of relatively short period (3 to 10 seconds), which should have minor impact on the primary side, where oscillations have periods of 100 to 500 seconds. In addition, by the nature of the flow oscillation, each of the approximately 1000 SG tubes is expected to oscillate with a random phase; therefore, the cumulative impact on the primary side is greatly reduced by averaging over all the SG tubes.

The staff was concerned that control-system instabilities could drive oscillations of all tubes in-phase. NuScale contends that this phenomenon will be precluded by tuning of the control system during initial testing. After reviewing all the available information, the staff's safety evaluation finds that NuScale analyses give reasonable assurance that core thermal margins will be maintained during the worst-case allowable secondary-side flow oscillations. We concur with the staff evaluation.

Even though core integrity is not compromised, the staff should ensure that NuScale's solution to the SG tube flow oscillation issue minimizes the potential of SG tube fatigue. We also note that resolution of this issue cuts across multiple disciplines. In this case, the staff in charge of the stability review communicated with the mechanical engineering staff and both are following up the eventual solution. However, this serves as an example for other topics where

compartmentalization of the review by chapter and disciplines may result in issues not being addressed due to lack of proper or timely communications. We plan to conduct our final phase of the NuScale design certification application review using a more structured, multi-discipline process that complements the chapter-by-chapter reviews already completed. We will provide our proposal for this revised process under separate cover.

A validated calculational tool to estimate the stability of the SG secondary-side flow stability is needed to increase confidence in reliable operation of the NuScale design. NuScale is in the process of developing a tube-flow stability map using NRELAP5, after further benchmarking against the TF-2 test results. The staff should review these new analyses, and we look forward to further discussion on this topic.

**SUMMARY**

The staff's safety evaluation concludes that, when exercised in compliance with the 16 limitations, the methods documented in the stability topical report are acceptable for performing stability analyses of the NPM. We concur with the staff's evaluation, and it should be issued.

Sincerely,

/RA/

Peter Riccardella
Chairman

**REFERENCES**

1. U. S. Nuclear Regulatory Commission, "NuScale Power, LLC, Safety Evaluation for NuScale Topical Report TR-0516-49417-P, Revision 0, "Evaluation Methodology for Stability Analysis of NuScale Power Module," September 11, 2019 (ML19254C858).

2. NuScale Power, LLC Topical Report TR-0516-49417-P, "Evaluation Methodology for Stability Analysis of the NuScale Power Module," Revision 0, July 31, 2106 (ML16250A851).

3. NuScale Power, LLC Response to NRC Request for Additional Information No. 9181 (e.RAI No. 9171) on NuScale Topical Report, "Evaluation Methodology for Stability Analysis of NuScale Power Module," TR-0516-49417, Revision 0, February 16, 2018 (ML18047A737).

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