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

March 24, 2020

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

SUBJECT: NUSCALE AREA OF FOCUS - HELICAL TUBE STEAM GENERATOR DESIGN

Dear Ms. Doane:

During the 671st meeting of the Advisory Committee on Reactor Safeguards, March 5-6, 2020, we completed our helical tube steam generator design area of focus review for the NuScale design certification application as discussed in our September 25, 2019 letter. Our NuScale Subcommittee also reviewed this matter on February 4, 2020. During these meetings, we had the benefit of discussions with NuScale and the staff. We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The design and performance of the steam generators have not yet been sufficiently validated because of uncertainties associated with unstable density wave oscillations (DWO) on the steam generator secondary side.
2. Accelerated wear of the alloy 690TT steam generator tubing material is a potential concern.
3. Having determined that steam generator integrity is not resolved, NuScale and the staff have proposed the following solutions.
    a. The staff has proposed that the steam generator design not receive finality in the NuScale design certification.
    b. NuScale has proposed a combined license (COL) item and Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) to address steam generator DWO.
4. Successful completion of these activities will address our concerns on steam generator performance at the design stage. Some uncertainty will remain until a NuScale Power Module is built and operated.

BACKGROUND

The NuScale nuclear power module steam generator is integral to the upper reactor vessel structure. The helical coil steam generator design is unique, with steam generation inside the tubes and primary system pressure external to the tubes, which introduces different failure modes. Traditional burst analysis that applies to recirculating or once-through steam

generators with the primary coolant inside the tubes does not apply. For the NuScale steam generator, a new failure mode would be tube collapse, limiting potential subsequent primary-to-secondary leakage rates compared to a double-ended break. A single steam generator tube rupture has been evaluated in Chapter 15 of the Design Certification Application with acceptable dose consequences. However, if steam generator integrity is not accurately characterized this may not be the limiting event. This also suggests that the estimate of containment bypass under such conditions may be underestimated in the probabilistic risk assessment.

DISCUSSION

Potential Steam Generator Thermal Hydraulics Issues

Experimental data and NuScale's analytic model cannot preclude, at this time, unstable steam generator DWO. It should be noted that the large thermal inertia of the primary side will likely mitigate against any effect of these potential oscillations on the primary system. In addition, we are concerned about control of a steam generator with sustained large flow oscillations, should they be possible, and the possibility of moisture carry-over that may affect the turbine.

The applicant estimated the maximum amplitude of flow oscillation based on the oscillations observed in a subset of the Società Informazioni Esperienze Termoidrauliche (SIET)-TF2 stability tests. These tests were performed to identify the threshold for instability by reducing the flow in small steps until unstable oscillations developed; thus, the SIET-TF2 instabilities were small and controlled. Actual oscillations may be larger than those observed in these tests. Differences between these scaled experiments and the actual design of the steam generator introduce uncertainty about the applicability of the data. Historically in two-phase flow experiments, small configuration differences have resulted in behavior observed in experiments that were not observed in the actual reactor. Thus, some uncertainty will remain until a NuScale Power Module is built and operated.

The staff has proposed that the steam generator design not receive finality in the NuScale design certification rule, and that this issue be resolved as part of the COL process. In addition, the applicant has proposed a COL item and associated ITAAC that will ensure the stability characteristics of the steam generator will be well understood and the final design of the steam generator and operating conditions will provide sufficient confidence that the flow will not oscillate at full power operation, including uncertainties and relaxation due to wear.

Thermal-Mechanical Issues

The applicant has performed a scoping study to evaluate the impact of DWO on American Society of Mechanical Engineers (ASME) Code calculations of steam generator fatigue. The applicant concluded that the oscillation-induced stresses were below applicable ASME Code allowables in the tube itself. Preliminary analyses of the tube-to-tubesheet welds using bounding DWO transient definitions resulted in alternating stresses above the ASME Code endurance limit.

The scoping calculations included analytical conservatisms, enabling NuScale to conclude that, when more realistic calculations are performed, the final alternating stress due to DWO in this region is expected to be below the ASME Code endurance limit. An ITAAC requires the

inspection of the Design Report in which this evaluation will be documented. The COL applicant is also expected to address loads on the inlet flow restrictors and tubes during oscillations due to pressure drop through inlet flow restrictors if flow reverses during DWO.

Potential Materials Issues

The selection of thermally treated alloy 690 (690TT) for the tubing material is appropriate based on performance in current pressurized-water reactors. However, while alloy 690TT is highly resistant to stress corrosion cracking, it is more susceptible to wear caused by vibration between the tube and support assemblies. Tube wear is a degradation mechanism that could lead to failure. This phenomenon can be rapid and for alloy 690TT controlling variables are not well understood. The wear rate for alloy 690TT is significantly greater than that for alloy 600 under similar conditions. Accelerated wear rates may occur if unstable steam generator conditions were to manifest themselves. Additional tube wall thickness margin has been incorporated as a design feature to address these concerns. The applicant has not presented sufficient detail regarding their tubing wear model. However, the uniqueness of the design strongly suggests that additional testing may be necessary to validate the design.

Summary

The design and performance of the steam generators have not yet been sufficiently validated because of uncertainties associated with unstable DWO on the steam generator secondary side. Accelerated wear of the alloy 690TT steam generator tubing material is also a potential concern.

Having determined that steam generator integrity is not resolved, NuScale and the staff have proposed the following solutions. The staff has proposed that the steam generator design not receive finality in the NuScale design certification. NuScale has proposed a COL item and ITAAC to address steam generator DWO.

Successful completion of these activities will address our concerns on steam generator performance at the design stage. Some uncertainty will remain until a NuScale Power Module is built and operated. We look forward to interacting with the staff on the resolution of these items.

Sincerely,

/RA/

Matthew W. Sunseri
Chairman

Additional Comments by ACRS Member Vesna B. Dimitrijevic

I agree with the technical conclusions of my colleagues in this letter. However, I disagree with the proposed solution that would include issuing the NuScale design certification, in which the steam generator design would not receive finality. The reason for this disagreement is that, in my opinion, the steam generator integrity is too significant of a safety issue to not have received finality in the NuScale design certification.

The steam generator is an integral part of each NuScale power module. Its integrity is directly related to the containment integrity. Without clarity on the steam generator integrity, it would be premature to conclude that the NuScale design ensures adequate protection of public health and safety; more specifically, that the NuScale design meets the Commission containment performance goal.

In addition, the design of the steam generators is an essential part of the NuScale power module innovative design, and, in my opinion, reaching resolution on major concerns related to the steam generator performance should also be an essential part of the design certification and not be postponed to the COL stage.

Based on the above, I believe that the steam generator integrity should be addressed before issuance of the design certification by either resolving the issue, or by providing a risk-informed argument why it does not present a safety concern.

REFERENCES

1. U. S. Nuclear Regulatory Commission, “NuScale Power, LLC, Design Certification Application – Safety Evaluation With No Open Items for Chapter 3, ‘Design of Structures, Systems and Components and Equipment’,” January 8, 2020 (ML19337A787).

2. NuScale Power, Design Certification Application, Chapter 3, “Design of Structures, Systems, Components and Equipment,” Revision 3, September 5, 2019 (ML19248B833).

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, “Safety Evaluation of the NuScale Topical Report TR-0516-49417-P, Revision 0, ‘Evaluation Methodology for Stability Analysis of the NuScale Power Module’,” September 20, 2019 (ML19266A463).

5. 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).

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