July 17, 2017

Docket: PROJ0769

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 15 (eRAI No. 8830) on the NuScale Topical Report, "Evaluation Methodology for Stability Analysis of the NuScale Power Module," TR-0516-49417, Revision 0

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 15 (eRAI No. 8830)," dated May 30, 2017
2. NuScale Topical Report, "Evaluation Methodology for Stability Analysis of the NuScale Power Module," TR-0516-49417, dated July 2016

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's response to the following RAI Question from NRC eRAI No. 8830:

- 29801

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Darrell Gardner at 980-349-4829 or at dgardner@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 8830

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NuScale Response to NRC Request for Additional Information eRAI No. 8830

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 8830
Date of RAI Issue: 05/30/2017

NRC Question No.: 29801

Title 10 of the Code of Federal Regulations (CFR), Part 50, Appendix A, General Design Criterion (GDC), 12- Suppression of reactor power oscillations, requires that oscillations be either not possible or reliably detected and suppressed. The Design-Specific Review Standard (DSRS), 15.9.A, “Design-Specific Review Standard for NuScale SMR Design, Thermal Hydraulic Stability Review Responsibilities,“ indicates that the applicant’s analyses should correctly and accurately identify all factors that could potentially cause instabilities and their consequences. The analyses should also demonstrate that design features that are implemented prevent unacceptable consequences to the fuel.

Section 8.2.5 of the topical report, TR-0516-49417-P, discusses reactivity and power distribution anomalies. The results indicate that the beginning of cycle (BOC) condition is more stable than the end of cycle (EOC) condition, which is the opposite of the expected core life behavior. The topical report discussion, however, does not address this inconsistency in the PIM method predictions when compared to earlier results in the report.

In order to make an affirmative finding associated with the above regulatory requirement important to safety, NRC staff requests NuScale to describe and justify the apparent inconsistency in relative stability performance for BOC vs. EOC. The discussion should address the impact of reactivity feedback coefficients on stability performance.

NuScale Response:

The effect of the reactivity feedback on stability is clarified in this response with regard to the inner modes of the system. There are two modes that are coupled in series and are therefore inseparable in the sense that they are excited simultaneously. These modes are the riser density wave mode and the cold leg inverted density wave mode. A perturbation of the primary coolant flow affects both modes and the net response depends on the relative importance of these two modes.

The riser mode has been studied analytically in the idealized case of perfect steam generator performance as a heat sink such that the coolant density in the cold leg remains invariant. In this case, the riser mode is shown to be unconditionally stable with very low decay ratio (<<0.1), and the decay ratio is not affected by power level. This observation was confirmed numerically in the course of the development of the PIM code. The negative coolant temperature reactivity feedback dampens the riser mode. This effect is less discernible unless the riser mode is dominant and significant.

The decay ratio has been shown to increase with decreasing power for normal operation (single-phase flow in the riser). This destabilizing effect is attributed to the inverted density wave in the cold leg. The density wave in the cold leg is labeled "inverted" because the direction of heat transfer and mass flow are both inverted relative to the common density waves in a boiling channel. It is observed from the numerical results of PIM under different conditions that in some runs two modes with different periods are discernible, where one period is close to the riser transit time, while the other is close to the loop transit time.

These are three different operating regions to consider the effect of reactivity feedback:

1. The high power (rated) condition under normal operation with single-phase flow in the riser. The inverted density wave mode is weak and the response to a flow is dominated by the density wave in the riser. Although the negative moderator temperature coefficient (MTC) is stabilizing in this case, the decay ratio is so low (<<0.1) that the reactivity feedback effect is not important.

2. The low power condition under normal operation. In this case, the inverted density wave mode is dominant and the decay ratio is moderate. The effect of the reactivity feedback is unimportant because the riser mode is dominated by the inverted density wave mode. The RAI refers to report Section 8.2.5 where runs were made with reactivity coefficients representative of beginning of cycle (BOC) and end of cycle (EOC) exposures. Figures 8.43 and 8.45, for flow responses under BOC and EOC respectively, indicate that the oscillation period is different. The same observation can be seen from Figures 8.44 and 8.46 for power response under BOC and EOC, respectively. The different oscillation periods point to the reactivity coefficient impacting the relative importance of the riser mode and the inverted density wave mode, not to the stability of the riser mode itself as a dominant response. It is important to note that the system is stable with a large decay ratio margin regardless of the reactivity coefficient.

3. Operation outside the normal range where the riser transitions to two-phase flow. This is the important case since it is the only condition where unstable oscillations were found to be possible. Under this condition, the riser density response with phase change is much larger than the liquid density change due to the same enthalpy perturbation. Thus amplified, the riser mode becomes dominant and the assertion regarding the effect of MTC in the topical report is relevant. Figures 9.8 and 9.13 under BOC and EOC, respectively, demonstrate the impact of the reactivity feedback. The BOC case experiences large oscillations that grow to a limit cycle, while the EOC case is stabilized. Figures 9.12 and 9.15 show a zoom of the flow responses in the two cases where large amplitude limit cycle flow oscillations is shown for the BOC conditions as contrasted with stable, yet relatively high decay ratio, at EOC. Figures 9.12 and 9.15 show the oscillation period to be indicative of the riser mode oscillation. It must be noted that even in this exercise with large amplitude limit cycle oscillations the CHF response indicated no violation of limits.

In summary, the stabilizing effect of the negative reactivity response is relevant only in the case where the riser mode is dominant, a condition that can be realized only outside normal operation where the riser flow is voided.

Impact on Topical Report:
There are no impacts to the Topical Report as a result of this response.