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

September 26, 2018

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

SUBJECT: SAFETY EVALUATION OF THE NUSCALE POWER, LLC TOPICAL REPORT TR-0915-17564-P, REVISION 1, "SUBCHANNEL ANALYSIS METHODOLOGY"

Dear Ms. Doane:

During the 656th meeting of the Advisory Committee on Reactor Safeguards, September 6-7, 2018, we reviewed the NRC staff's safety evaluation report of NuScale Power, LLC (NuScale) topical report TR-0915-17564-P, Revision 1, "Subchannel Analysis Methodology." Our NuScale Subcommittee also reviewed this matter on August 24, 2018. During these meetings, we had the benefit of discussions with the staff and representatives of NuScale. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATION

Topical report TR-0915-17564-P, Revision 1, provides an acceptable methodology for performing steady-state and most transient and accident analyses, subject to the staff's limitations and conditions. The staff's safety evaluation report should be issued.

BACKGROUND

Applicants use "subchannel" analysis methodologies and nuclear methods to design and determine reactor core performance under steady-state and normal operations, as well as anticipated operational occurrences and selected accidents. Approved methods and correlations are used to calculate thermal-hydraulic parameters and margins for use in safety evaluations including Chapters 4, "Reactor," and 15, "Transient and Accident Analyses," of a design certification application, and to demonstrate compliance with applicable general design criteria in 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

NuScale proposes to use the VIPRE-01 code series for its subchannel analysis methodology in support of its design certification application. Two VIPRE-01 code versions, MOD-01 and MOD-02, have been previously approved by the NRC. VIPRE-01 MOD-01 was generically approved by the NRC subject to five conditions. The NRC generic safety evaluation report for the subsequent VIPRE-01 MOD-02 code includes four additional conditions. NuScale plans to use the latest MOD-02 version of the VIPRE-01 code, subject to the nine conditions, with its own nuclear analysis methods and critical heat flux (CHF) correlations, NSP2 and NSP4. In our June 15, 2018 letter report, we recommended issuance of the staff's safety evaluations on the NuScale nuclear analysis methods and CHF correlations.

DISCUSSION

NuScale submitted in February 2017, topical report TR-0915-17564-P, Revision 1, "Subchannel Analysis Methodology," as supplemented by additional information submitted in late 2017 and early 2018. This topical report describes the subchannel analysis methodology based on the NRC-approved VIPRE-01 MOD-02 code for application to steady-state and transient analyses, and the qualification of the methodology for use in the NuScale design certification application. For the NuScale power module (NPM) reactor core and reflector, VIPRE-01 calculates core flow distributions, coolant conditions, fuel rod temperatures, the critical heat flux ratio, and thermal margins for steady state, and specified operational transients and abnormal events (but not loss-of-coolant accidents). Core boundary conditions are provided by calculations from NuScale's reactor systems analysis code, NRELAP5. Uncertainties are treated independently in a deterministic, biased-conservative manner, that is, no credit is taken for statistical randomness. The subchannel analysis methodology was demonstrated using generic, cycle-independent radial power and bounding axial power distributions, with prototypical thermal-hydraulic conditions expected for steady-state operation and transients in the NPM. However, the topical report did not seek approval of these input variables or calculation results.

The staff's review of the topical report addressed the general applicability of VIPRE-01 to an NPM for steady-state and transient subchannel analyses; the fulfillment of the NRC's nine conditions, in the SERs for VIPRE-01 MOD-01 and MOD-02; the independence of the methodology for any specific CHF correlation; the applicability if methodology requirements are met with an NRC-approved CHF correlation; and the appropriate treatment of uncertainties in the methodology.

<u>Condition 1: Post-CHF Application Limitation</u>

For pressurized-water reactors, the first condition generally limits application of VIPRE-01 to licensing calculations for heat transfer regimes up to CHF. Under conservative assumptions for the natural-circulation NPM, a hot channel exit quality greater than zero is predicted. However, core average exit fluid conditions remain subcooled and the reactor generally operates in a pressurized-water reactor regime, thereby satisfying Condition 1 under steady state conditions and selected transients.

<u>Condition 2: CHF Correlation Requirement</u>

The second condition stipulates that an approved CHF correlation be used in VIPRE-01 in a range of applicability that considers the fuel assembly geometry, grid spacer design, pressure, coolant mass velocity, quality, and other relevant thermal-hydraulic conditions. NuScale's submittal and subsequent NRC approval of its NSP2 and NSP4 CHF correlations, developed using VIPRE-01 MOD-02, meets Condition 2.

<u>Condition 3: VIPRE-01 Modeling Assumptions and Correlations</u>

The third condition states that the applicant provide justifications for specific modeling assumptions, two-phase flow models, heat transfer and CHF correlations, and plant-specific data such as turbulent mixing coefficients, grid spacer loss coefficients, power distributions, flow input conditions, geometry and nodalization, etc. Sufficient information and justification, including sensitivity analyses, were provided to meet Condition 3. However, the staff did not approve specific input conditions, and in some instances methods, for these analyses. This should be addressed in the staff's review of the NuScale design certification application Chapters 4 and 15 analyses.

Condition 4: Courant Number Criterion

The fourth condition deals with numerical stability of VIPRE-01 under the application of steady-state subcooled boiling correlations to transient analysis and demands that a time step used for the flow velocity and axial nodalization result in a Courant number greater than 1. NuScale analyzed three design-basis transients to demonstrate this condition was met. Independent analyses by the staff supported the applicant's results, confirming that Condition 4 was met.

Condition 5: Quality Assurance

The fifth condition deals with quality assurance. NuScale used the industry-standard, as-approved, VIPRE-01 code with no modifications to the main program, and manages the software under its approved quality assurance program. The NuScale CHF correlations are implemented through a file library without modification to the VIPRE-01 source code. This meets Condition 5.

Condition 6: Qualification of VIPRE-01 MOD-02 Models

The sixth condition deals with justifying the selection of two-phase flow models over the range of expected two-phase flow conditions. Because the VIPRE-01 formulation is a three-equation, incompressible, homogeneous equilibrium model, subcooled boiling models and bulk void correlations may not be sufficient for cases with large relative phase velocities. NuScale uses a drift flux model to calculate void fraction. In sensitivity cases, for applicable design conditions, the model had negligible impact on void fractions and critical heat flux ratio in the hot channel. The staff determined that Condition 6 was met. We have additional comments on this matter under Condition 8.

Condition 7: GEXL Correlation

The seventh condition was related to application of the GEXL critical power ratio correlation for boiling water reactor fuel. The requirement is moot as NuScale does not intend to perform calculations for boiling water reactor fuel with VIPRE-01.

Condition 8: Code Limitations

The eighth condition is related to limitations identified in the VIPRE-01 code manual. In particular, the code should not be used to model cases involving large relative phase velocities, countercurrent flow, or conditions of radical flow regime changes. The staff determined that the applicant provided sufficient information to address concerns raised and met Condition 8. We discussed with the applicant and staff potential transients and accident scenarios that may result in flow instabilities, large local voiding or phase slip, and/or non-spatially symmetric perturbations, which coupled with reactivity feedback effects, may put further limits on the applicability of the VIPRE-01 methodology.

The staff did not impose quantitative limitations on the range of applicability of the VIPRE-01 code (i.e., for which kind of transients VIPRE-01 is not applicable). The staff has stated that the code applicability will be reviewed on a transient-specific basis during the review of design certification application Chapters 4 and 15. We expect that a thorough review of code applicability will be performed as part of the Chapters 4 and 15 evaluations.

Condition 9: Input Selection, Uncertainties, and Sensitivity Analyses

The ninth condition is to justify or quantify the input selections for licensing applications as the default values recommended by the code developers are for best-estimate use only. The staff performed confirmatory analyses on inlet flow boundary conditions for consistency with NRELAP5 and inlet flow sensitivity to thermal margins. Results allowed the staff to conclude that the deterministic, conservatively-biased treatment of uncertainties was appropriate, hence Condition 9 was met.

The staff imposed an additional condition to use an approved CHF correlation developed with the VIPRE-01 MOD-02 code as used in topical report TR-0915-17564-P. We concur.

SUMMARY

Topical report TR-0915-17564-P, Revision 1, provides an acceptable methodology for performing steady-state and most transient and accident analyses, subject to the staff's limitations and conditions. The staff's safety evaluation report should be issued.

Member Riccardella did not participate.

Sincerely,

/RA/

Michael L. Corradini
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, “U.S. Nuclear Regulatory Commission Safety Evaluation Report by the Office of New Reactors Topical Report TR-0915-17564-P, ‘Subchannel Analysis Methodology,’ Revision 1, NuScale Power, LLC Project No. 0769,” July 18, 2018 (ML18199A150).

2. NuScale Power, “NuScale Power, LLC Proprietary Marking Changes to ‘Subchannel Analysis Methodology’ topical report, Revision 1 (NRC Project No. 0769),” February 15, 2017 (ML17046A333).

3. NuScale Power, “NuScale Power, LLC Submittal of the NuScale Standard Plant Design Certification Application (NRC Project No. 0769),” December 31, 2016 (ML17013A229).

4. U.S. Nuclear Regulatory Commission, “Acceptance for Referencing of the Modified Licensing Topical Report, EPRI-NP-2511-CCM, Revision 3, ‘VIPRE-01: A Thermal Hydraulic Analysis Code for Reactor Cores’,” October 30, 1993 (ML18033A074).

5. U.S. Nuclear Regulatory Commission, “Acceptance for Referencing of Modified Licensing Topical Report, EPRI-NP-2511-CCM, ‘VIPRE-01: A Thermal Hydraulic Analysis Code for Reactor Cores’, Volumes 1, 2, 3 and 4,” May 31, 1986 (ML18033A075).

6. NuScale Power, “NuScale Power, LLC, Submittal of Topical Report ‘Critical Heat Flux Correlations,’ TR-0116-21012, Revision 1,” November 30, 2017 (ML17335A089).

7. U.S. Nuclear Regulatory Commission, “U.S. Nuclear Regulatory Commission Safety Evaluation by the Office of New Reactors Topical Report - 0116-21012, Revision 1 ‘NuScale Critical Heat Flux Correlations’ NuScale Power, LLC (Project No. PROJ0769),” June 21, 2018 (ML18172A165).

8. Advisory Committee on Reactor Safeguards, “Safety Evaluation of the NuScale Power, LLC Topical Report TR-0616-48793, Revision 0, ‘Nuclear Analysis Codes and Methods Qualification’ and Safety Evaluation of the NuScale Power, LLC Topical Report TR-0116-21012, Revision 1, ‘NuScale Power Critical Heat Flux Correlations’,” June 15, 2018 (ML18166A307).

9. NuScale Power, “NuScale Power, LLC Response to NRC Request for Additional Information No. 9099 on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” September 7, 2017 (ML17251A368).

10. NuScale Power, “NuScale Power, LLC Response to NRC Request for Additional Information No. 9086 on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” October 26, 2017 (ML17299A973).

11. NuScale Power, “NuScale Power, LLC Response to NRC Request for Additional Information No. 9080 (eRAI No. 9080) on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” November 9, 2017 (ML17313B205).

12. NuScale Power, “NuScale Power, LLC Response to NRC Request for Additional Information No. 9129 (eRAI No. 9129) on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” January 15, 2018 (ML18015A012).

13. NuScale Power, “NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 9080 (eRAI No. 9080) on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” March 2, 2018 (ML18061A108).

14. NuScale Power, SwUM-0304-17023, “NRELAP5 Code Manual Theory Manual: Models, Correlations and Solution Methods,” Revision 4, December 30, 2016 (ML17004A183).

12. NuScale Power, “NuScale Power, LLC Response to NRC Request for Additional Information No. 9129 (eRAI No. 9129) on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” January 15, 2018 (ML18015A012).

13. NuScale Power, “NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 9080 (eRAI No. 9080) on the NuScale Topical Report, ‘Subchannel Analysis Methodology,’ TR-0915-17564, Revision 1,” March 2, 2018 (ML18061A108).

14. NuScale Power, SwUM-0304-17023, “NRELAP5 Code Manual Theory Manual: Models, Correlations and Solution Methods,” Revision 4, December 30, 2016 (ML17004A183).

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