SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT TR-108601-P, REVISION 4,

“STATISTICAL SUBCHANNEL ANALYSIS METHODOLOGY, SUPPLEMENT 1 TO TR-0915-17564-P-A, REVISION 2, SUBCHANNEL ANALYSIS METHODOLOGY,”

NUSCALE POWER, LLC

Proprietary information pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 2.390, “Public inspections, exemptions, requests for withholding,” has been redacted from this document. Redacted information is identified by blank space enclosed within bolded double brackets, as shown here: **[[ ]]**.

1.0 INTRODUCTION

By letter dated December 30, 2021 (Reference 1), as supplemented by letters dated April 25, 2022, December 13, 2022, October 12, 2023, and November 6, 2023 (References 4, 6, 11, and 13 respectively), NuScale Power, LLC (NuScale) submitted a request for review and approval of Topical Report (TR)-108601-P, Revision 4, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” to the U.S. Nuclear Regulatory Commission (NRC). The purpose of the TR is to establish NuScale’s statistical methodology for determining a critical heat flux (CHF) limit. The list of key correspondence between the NRC and NuScale is provided in Table 1 below.

Table 1: List of Key Correspondence

Sender	Document	Document Date	Reference
NuScale	Topical Report, Revision 0	December 30, 2021	2
NRC	Completeness Determination - Request for Supplemental Information	February 28, 2022	3
NuScale	Topical Report, Revision 1	April 25, 2022	4
NRC	Completeness Determination	May 4, 2022	5
NuScale	Topical Report, Revision 2	December 13, 2022	6
NRC	Schedule Letter Update	December 21, 2022	7
NuScale	Topical Report, Revision 3	October 12, 2023	11
NRC	Audit Report	November 1, 2023	12
NuScale	Topical Report, Revision 4	November 6, 2023	13

2.0 REGULATORY EVALUATION

General Design Criterion 10, “Reactor design,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50 , “Domestic Licensing of Production and Utilization Facilities,” states that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits

(SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SAFDLs are those limits placed on certain variables to ensure that fuel does not fail. One such SAFDL is associated with critical boiling transition (CBT), which is defined as a transition from a boiling flow regime that has a higher heat transfer coefficient to a flow regime that has a significantly lower heat transfer coefficient. Because the heat production rate is maintained, the reduction in the heat transfer coefficient results in a surface temperature increase, and if that increase is large enough, the surface may weaken or melt, which, in a nuclear power plant, could result in fuel failure.

In order to ensure that CBT does not occur, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [Light-Water Reactor] Edition," Section 4.4, "Thermal and Hydraulic Design," Revision 2 (Reference 8), describes two SAFDLs:

(a) there should be a 95-percent probability at the 95-percent confidence level that the hot [fuel] rod in the core does not experience a DNB [departure from nucleate boiling] or boiling transition condition during normal operation or AOOs
(b) at least 99.9 percent of the fuel rods in the core will not experience a DNB or boiling transition during normal operation or AOOs.

Typically, the SAFDL (a) is associated with pressurized-water reactors and the SAFDL (b) is associated with boiling-water reactors. Demonstrating that such a SAFDL has been satisfied relies on more than justifying that the CBT correlation can accurately predict the phenomena because there are uncertainties in the prediction of CBT that are independent of those uncertainties related to the fidelity of the CBT model. Hence, there needs to be a general methodology in which an approved CBT can be used such that the SAFDL is satisfied. Consistent with the above regulations and guidance, the objective of the NRC staff review in this safety evaluation (SE) is to determine if the use of NuScale's statistical subchannel analysis methodology along with an approved CBT model will ensure that the SAFDL (a) will be satisfied.

3.0 TECHNICAL EVALUATION

The NRC staff previously reviewed and approved NuScale's Subchannel Analysis Methodology (NSAM) in TR-0915-17564-P-A, Revision 2 (Reference 9). As supplement 1 to the NSAM, NuScale modified the NSAM with the addition of a statistical methodology in Revision 0 of its Statistical Subchannel Analysis Methodology (SSAM) in TR-108601-P (Reference 2) and requested that the NRC staff review and approve the SSAM. NuScale supplemented the SSAM in Revision 1 (Reference 4), Revision 2 (Reference 6), Revision 3 (Reference 11), and Revision 4 (Reference 13). Although NuScale requested NRC staff approval of the SSAM, the SSAM submittal does not contain all of the necessary documentation to define the SSAM; instead, that documentation is spread across both the SSAM and the NSAM submittals (Reference 13 and Reference 9, respectively). Specifically, each section/subsection of the SSAM submittal does one of three things:

(1) It references to the corresponding section/subsection in the NSAM and does not modify that section/subsection (i.e., **no change**).

(2) It references to the corresponding section/subsection in the NSAM and not only maintains all of the information in that section/subsection, but also adds additional information (i.e., **supplement**).

(3) It references to the corresponding section/subsection in the NSAM and completely replaces that section/subsection (i.e., **replacement**).

The SSAM submittal does not clearly specify which of these three actions is being taken for each section; therefore, Table 2 below clarifies which action applies to each section of the SSAM submittal.

Table 2: NuScale's Statistical Subchannel Analysis Methodology Documentation

Section	No Change	Supplement	Replacement
2.0	X		
2.1	X		
2.2	X		
2.3	X		
2.4	X		
3.0		X	
3.1	X		
3.2		X	
3.3		X	
3.4		X	
3.5	X		
3.6		X	
3.7			X
3.8	X		
3.9	X		
3.10			X
3.10.1			X
3.10.2	X		
3.10.3			X
3.10.4	X		
3.10.5			X
3.10.6			X
3.10.7			X
3.10.8	X		
3.10.9	X		
3.11	X		
3.12			X
3.13			X
3.14	X		
3.15		X	
4.0	X		
5.0	X		
6.0		X	

Section	No Change	Supplement	Replacement
6.1	N/A[1]		
6.2	N/A[1]		
6.3	X		
6.4		X	
6.4.1			X
6.4.2	X		
6.4.3			X
6.4.4	X		
6.4.5	X		
6.4.6	X		
6.4.7	X		
6.4.8	X		
6.5	X		
7.0		X	
7.1	X		
7.2			X
7.3			X
7.4			X
7.5		X	
8.0		X	

The NRC staff notes that TR-108601-P (the SSAM) does not include updated examples to Sections 6.1, 6.2, 6.3, 6.4.2, 6.4.4 through 6.4.8, and 6.5. As indicated in Section 6.0 of the SSAM, most of these sections are not updated in the SSAM since no changes are needed to their content. However, Section 6.1 and Section 6.2 are identified as “(N/A)” in the table above. Section 6.1 lists input values used in the example calculations in the NSAM. These inputs are defined during the application of the methodology for a specific design. The example calculations in Section 6.4.1 and Section 6.4.3 of the SSAM use input values consistent with the US460 design. Section 6 of the SSAM only recreates the sensitivities impacted by the updates to the radial and axial nodalization. Section 6.2 in the NSAM discusses radial nodalization that is not applicable to the SSAM (see Section 3.7).

No change means that the SSAM and NSAM share the same information. For example, the information contained in Section 7.1 of the SSAM would be identical to that in Section 7.1 of the NSAM. The documentation of this information would not be found in the SSAM submittal (Reference 13), but only in the NSAM topical report (Reference 9).

Supplement means that the SSAM contains all of the information in the NSAM, as well as the additional information provided in the SSAM submittal. For example, the information contained in Section 7.5 of the SSAM would contain all of the information in Section 7.5 of the NSAM as well as that in Section 7.5 of the SSAM submittal. The documentation of this information would be found in the SSAM submittal (Reference 13) and in the NSAM topical report (Reference 9).

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[1] Sections 6.1 and 6.2 provide an example calculation using the NSAM and do not prescribe any of the SSAM methodology. Further, the example is not an example calculation of SSAM, hence it is labeled as N/A. However, the example may still be useful in understanding the SSAM.

Replacement means that the SSAM contains no information from the NSAM, and only contains the information in the SSAM submittal. For example, the information contained in Section 7.2 of the SSAM contains no information from Section 7.2 of the NSAM. The documentation of this information would only be found in the SSAM submittal (Reference 13) and would not include any information in the NSAM topical report (Reference 9). This also includes new sections contained in the SSAM and not in the NSAM.

The NRC staff focused its review on the SSAM, including both information in the SSAM submittal (Reference 13) and in the NSAM topical report (Reference 9). Therefore, the NRC staff has formatted this SE to match the outline of both submittals and specifies whether **no change**, **supplement**, or **replacement** applies to the information.

2.0 Background (**No Change**)

The NRC staff previously reviewed and approved the background information in the NSAM topical report (Reference 9). Because this information in the SSAM is the same as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.0 General Application Methodology (**Supplement**)

The NRC staff previously reviewed and approved the general application methodology in the NSAM topical report (Reference 9). Much of the same methodology approved in the NSAM would be applicable to the SSAM. However, the NSAM was approved for various radial nodalizations (including one-eighth core symmetric nodalization), and many of these radial nodalizations are not intended to be used for the SSAM. Therefore, each subsection of Section 3 is addressed below.

3.1 Nuclear Safety Engineering Disciplines (**No Change**)

The NRC staff previously reviewed and approved the nuclear safety engineering disciplines information in the NSAM topical report (Reference 9). Because this information in the SSAM is the same as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.2 Core Design Limits (**Supplement**)

The NRC staff previously reviewed and approved NuScale’s methodology for core design limits in the NSAM topical report (Reference 9). Much of the same methodology approved in the NSAM would be applicable to the SSAM. The deviation from the approved methodology in the SSAM is the change to the basemodel, which is discussed in Section 3.7. Except for the changes related to the basemodel addressed in Section 3.7 below, because of the applicability of the previous review, the NRC staff has determined that no additional review is required.

3.3 Critical Heat Flux Correlation (**Supplement**)

The NRC staff previously reviewed and approved the CHF application methodology described in the NSAM topical report (Reference 9). Much of the same methodology approved in the NSAM would be applicable to the SSAM. The NSAM discusses an approved CHF correlation (NSP2) and provides the details of that correlation, including its approved domain. The SSAM is not limited to a single CHF correlation but could be used with any approved correlation provided that the five conditions listed in Section 3.3 have been satisfied at a minimum. Any approved CHF correlation would need to be consistent with how the correlation was originally developed (e.g., nodalization, losses/resistances, flow areas, modeling impacting flow patterns, etc.) and changes to that evaluation model not described in the NSAM or SSAM would require additional NRC staff review and approval, which is consistent with NSAM Condition 1 and repeated in Section 4 of the SSAM SE. Because these conditions are consistent with the previous application of CHF correlations, the NRC staff has determined that the CHF application method of the SSAM is acceptable.

3.4 Thermal Margin Results Reporting (**Supplement**)

The NRC staff previously reviewed and approved the thermal margin figures of merit described in the NSAM topical report (Reference 9). The same figures of merit approved in the NSAM would be applicable to the SSAM. Additionally, NuScale clarified that the SSAM can determine the penalty factors using either deterministic or statistical methods. Because the SSAM is primarily a statistical methodology, and the penalty factors are the primary influence on the main figure of merit (the minimum critical heat flux ratio (MCHFR) from the VIPRE-01 calculation) of that methodology, the NRC staff has determined that the figures of merit of the SSAM described in this section are acceptable.

3.5 Geometry Design Input (**No Change**)

The NRC staff previously reviewed and approved the geometry design input information in the NSAM topical report (Reference 9). Because this information in the SSAM is the same as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.6 Fuel Design-Specific Inputs (**Supplement**)

The NRC staff previously reviewed and approved the fuel design-specific inputs in the NSAM topical report (Reference 9). Much of the same description of inputs approved in the NSAM would be applicable to the SSAM. However, the SSAM does include some modeling changes. These changes are addressed in Section 3.7 of this SE. With the expectation of those differences discussed in Section 3.7 of this SE being adequately addressed, because of the applicability of the previous review, the NRC staff has determined that no additional review is required.

3.7 Basemodel (**Replacement**)

While the NRC staff previously reviewed and approved the basemodel section in the NSAM topical report (Reference 9), this material is not directly applicable to the SSAM due to the changes in the basemodel itself. To perform the review of the basemodel, the staff focused on the three main areas described in the SSAM submittal (Reference 13) and the staff's evaluation is provided below.

Radial Nodalization

While the NSAM had multiple radial nodalization schemes approved, only one radial nodalization scheme is requested for approval in the SSAM submittal. This scheme models one full assembly at the center of the core with nodalization at the subchannel level. This assembly is surrounded on four sides by other assemblies which are modeled with the nodalization at the lumped subchannel level (i.e., multiple fuel subchannels are lumped into a single subchannel for computation). Each of these assemblies is further surrounded by other assemblies which are modeled with the nodalization at a lumped assembly level (i.e., all subchannels in the fuel assembly are lumped into a single subchannel for computation). This nodalization scheme is similar to the basemodel and the Lump51 model from the one-eighth nodalization approved in the NSAM topical report.

In order to demonstrate that this radial nodalization could accurately capture the critical linear heat generation rate (LHGR), NuScale performed a sensitivity study in Section 6.4.1 of the SSAM submittal (Reference 13). That study demonstrated that the radial nodalization proposed resulted in **[[** **]]** compared to a full core radial nodalization. Because of this and because a full core radial nodalization is a radial nodalization approved in the NSAM, the NRC staff has determined that the radial nodalization is acceptable.

Future Changes to Radial Nodalization

NuScale requested the flexibility to make limited changes to the approved radial nodalization depending on the circumstances and given that certain conditions were satisfied. Based on the previously approved radial nodalization in the NSAM, the criteria stated in the SSAM submittal, the understanding that the change would be limited to relative minor changes in the meshing, and the understanding that, consistent with current practice, the resulting nodalization would be symmetric, the NRC staff has determined that limited changes would be acceptable.

Axial Nodalization

In the NSAM topical report (Reference 9), the axial nodalization was refined in the upper portion of the fuel assembly to better resolve the region in which CHF is expected to occur. In Section 6.4.3 of the SSAM submittal (Reference 13), NuScale's sensitivity study demonstrated that a variety of node sizes **[[** **]]** result in similar simulations and values of the critical LHGR that are within **[[** **]]** of each other. While the **[[** **]]** node size has a critical LHGR value that is close to the others, some of the local parameters calculated in this run, **[[**such as the equilibrium quality**]]** seem far from the other test cases, suggesting that this run should not be considered fully converged.

During the NRC staff's review of the NSAM topical report (Reference 9), for the approved nodalization scheme **[[**

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The NRC staff agrees that the nodalization sensitivity study demonstrates that for the simulation performed, the **[[ ]]** nodalization is sufficient to resolve the phenomena impacting CHF. However, the NRC staff also recognizes that the variation between similar node sizes represents an uncertainty. While the single sensitivity study in the SSAM submittal (Reference 13) and the NSAM topical report (Reference 9) has the **[[ ]]** nodalization as being the most conservative, this conservatism is likely to change to a different node size if a different scenario is simulated. Given the variation between the variety of node sizes which can be considered converged solutions of the simulation, the NRC staff has determined that a 1 percent uncertainty would be necessary to be applied to the critical LHGR to account for the impact of nodalization.

In an effort to remove the need to directly address this uncertainty, NuScale investigated whether the **[[ ]]** nodalization always results in a conservative value. NuScale sampled across the application domain and compared the critical LHGR results from the **[[ ]]** axial mesh with those of **[[ ]]** axial mesh. In all instances, the **[[ ]]** axial mesh produced a conservative result compared to the **[[ ]]** axial mesh, and that conservatism was consistent with the NRC staff's determination of a 1 percent uncertainty. Because NuScale's sensitivity study demonstrated that the **[[ ]]** axial mesh always results in a conservative prediction of the critical LHGR by approximately the same magnitude as the staff's estimation of the axial mesh uncertainty, the staff found that using a **[[ ]]** axial mesh would not require a further consideration of the axial mesh uncertainty. Because NuScale is using an axial nodalization that has been demonstrated to be converged by a sensitivity study, is within the general range of axial nodalization of CHF analysis, and results in a conservative prediction of the figure of merit whose conservatism counterbalances the axial mesh size uncertainty, the NRC staff has determined that the axial nodalization is acceptable.

Axial Modeling

NuScale changed the axial domain compared to that used in the NSAM topical report (Reference 9). For the SSAM, the VIPRE model extends from the bottom of the lower core plate to above the upper core plate (whereas in the NSAM, the top of the lower core plate and the bottom of the upper core plate defined the boundaries of the VIPRE model). In this modeling extension, NuScale focused specific attention on ensuring an accurate estimation of the crossflow lateral losses in these newly encompassed sections. Because these new geometries are within the capability of VIPRE-01 to model and because NuScale ensured that the crossflows in these new geometries were adequately calculated and that the lateral loss terms of these new geometries had minimal impact on the MCHFR, the NRC staff has determined that the new axial modeling is acceptable.

3.8 Boundary Conditions (**No Change**)

While NuScale has changed the modeling boundary of the SSAM compared to the NSAM by including of the flow through both core plates, many of the boundary conditions themselves remain unchanged.

Inlet Flow

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the mass inlet flow rate in the NSAM topical report (Reference 9). This inlet flow rate is based on the total core flow minus the flow lost to the bypass. Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

Inlet Enthalpy

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the inlet enthalpy in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

System Pressure

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the system pressure in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

Bypass Flow

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the bypass flow in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

Inlet Flow Distribution

In Section 3.7.3 of the SSAM submittal (Reference 13), NuScale identified a change to the inlet flow distribution. In the NSAM topical report (Reference 9), the inlet flow distribution was at the bottom of the fuel pins. However, due to the change in the boundaries of the model, the inlet flow distribution for the SSAM is applied at the bottom of the lower core plate. Applying a reduction to the inlet flow at the bottom of the fuel pins has a much larger impact on CHF performance than applying that same reduction at the bottom of the lower core plate, as the flow is given significantly more time to equalize, and the penalty diminishes greatly before the flow enters the fuel pins.

NuScale provided additional justification that the modeling of the fuel assembly in the region below the fuel pins was adequate. In Section 3.7.3 of the SSAM submittal, NuScale provided a discussion of the crossflow in the newly modeled portions of the assembly (i.e., core plate and bottle nozzle). That analysis demonstrates **[[** **]]** in the fuel bottle nozzle has a minimal impact on the figure of merit. Further, NuScale performed a sensitivity analysis in Section 6.4.4 of the SSAM submittal which demonstrates that reductions in the flow into the hot assembly, when considering both top and bottom peaked power shapes, have minimal influence on the critical LHGR.

Because NuScale demonstrated that the new modeling below the fuel pins is reasonable and because NuScale is still applying the 5 percent flow reduction, which accounts for uncertainties in the flow distribution going into the hot assembly, the NRC staff has determined that the new treatment of the inlet flow distribution is acceptable.

Inlet Temperature Distribution

The NRC staff previously reviewed and approved NuScale's methodology for calculating the inlet temperature distribution in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.9 Turbulent Mixing (**No Change**)

The NRC staff previously reviewed and approved NuScale's methodology for calculating turbulent mixing in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.10 Radial Power Distribution (**Replacement**)

The NRC staff previously reviewed and approved NuScale's methodology for the radial power distribution in the NSAM topical report (Reference 9). Like the previously approved method in the NSAM, the SSAM also makes use of a conservative radial power distribution that accounts for the worst distribution throughout the cycle, and that distribution bounds the technical specification limits on the radial peaking factor. Additionally, like the previous NSAM, the radial power distribution is held constant through the transient. Because this methodology, which is applied in the SSAM, is the same methodology as approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

However, additional details on the application of the radial power distribution are different in the application of the SSAM. Therefore, the NRC staff evaluated each aspect of the radial power distribution, as presented below.

3.10.1 Static Standard Review Plan Section 15.4 Analyses (**Replacement**)

The radial power distribution can change during a scenario especially if that scenario results in control rod movement. However, the SSAM calculation methodology assumes that the radial power distribution is held constant. Therefore, an augmentation factor is needed to modify the radial power distribution such that the radial power experienced over the entire scenario is the maximum radial power that would be observed during the actual scenario. However, simply increasing the radial power at one location in the hot assembly would result in increasing the overall core power. Therefore, while NuScale does increase the radial power in the hot assembly, it also lowers power in an assembly far away from the hot assembly such that there is no change in total core power. The NRC staff finds that there is reasonable assurance that using the highest radial power anticipated during a scenario's entire event progression would result in an accurate or conservative analysis for those scenarios which are analyzed using static (i.e., steady-state) methods. Therefore, the NRC staff has determined that the application of the radial peaking augmentation factor is acceptable.

3.10.2 Time-Dependent Standard Review Plan Section 15.4 Analyses (**No Change**)

The NRC staff previously reviewed and approved NuScale’s methodology for calculating time-dependent safety analysis in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.10.3 Enthalpy Rise Hot Channel Factor (**Replacement**)

The NRC staff previously reviewed and approved NuScale’s methodology for the radial power distribution in the NSAM topical report (Reference 9). However, NuScale changed the methodology used in the SSAM such that portions of the previous approval are no longer applicable, specifically the equation for the enthalpy rise hot channel factor itself, the uncertainties associated with the equation, and the allowance for the peak $F_{\Delta H}$ rod to occur in a peripheral row.

An example of the enthalpy rise hot channel factor used for safety analysis is given in equation 3-8 of the SSAM. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2. The SSAM addresses the uncertainty of the enthalpy rise hot channel factor by modeling the uncertainties of the components that make up the factor. These uncertainties are evaluated by the NRC staff in Sections 3.10.5, 3.12.2, and 3.12.4 of this SE.

In the previously reviewed and approved NSAM topical report (Reference 9), NuScale created a special confirmation to ensure that the peak $F_{\Delta H}$ rod did not occur in a peripheral row. As stated in the NSAM topical report, NuScale did this because they determined that the outer row would be influenced by direct crossflow from the annulus channel between assemblies. As this channel is not simulated in CHF testing, there is no validation correlation for predicting CHF in this channel. As stated in the NSAM topical report, to ensure that a crossflow neighboring channel remains with the test configuration, NuScale constrained its design to ensure that a peak $F_{\Delta H}$ rod did not occur in a peripheral row.

It is permissible for the peak $F_{\Delta H}$ to occur in a peripheral assembly in the actual core design because the analysis forces the peak $F_{\Delta H}$ to occur at a limiting interior location, and moving the peak to a location closer to the edge of the fuel assembly would increase crossflow from other assemblies and result in increased cooling. Because the removal of this restriction is not a change in how the core will be analyzed, as the peak $F_{\Delta H}$ will occur near the center of the limiting assembly, but is a recognition that such an analysis is reasonably bounding for actual designs which may have the peak $F_{\Delta H}$ occurring at other locations within the assembly, NRC staff has determined that the removal of the restriction on the peak $F_{\Delta H}$ for actual core designs is acceptable.

3.10.4 Radial Flux Tilt (**No Change**)

The NRC staff previously reviewed and approved NuScale's methodology for calculating radial flux tilt in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.10.5 All Rods Out Power Dependent Insertion Limit Enthalpy Rise Hot Channel Factor (**Replacement**)

The All Rods Out Power Dependent Insertion Limit Enthalpy Rise Hot Channel Factor was used by NuScale to address changes in power over the entire transient, as only a single power level is used during the computational analysis of the transient. For the SSAM, NuScale chose to modify this method and applied the augmentation factor described in Section 3.10.1. The NRC staff has determined that no additional review is required because this section is no longer applicable to the SSAM and has been replaced with the information in Section 3.10.1.

3.10.6 Determining the Bounding Radial Power Distribution (**Replacement**)

In Section 6.4.2 of the NSAM topical report (Reference 9), NuScale provided a sensitivity study which confirmed that the radial power distribution far from the hot channel has negligible impact on the MCHFR results. NuScale used this study to justify the assumption that the use of a radial power distribution with the hot rod at the design peaking limit would be sufficient to bound any distribution in a cycle-specific core. Because the same assumption is applied in the SSAM as was approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM for this assumption.

The goal of the bounding radial power distribution is to result in a limiting value of MCHFR in the hot rod and subchannel, and not to represent the actual radial power in the core during a transient. To this end, NuScale considers a "flat" power distribution as a conservatism, as this distribution will limit the amount of turbulent mixing and diversion crossflow in the hot subchannel, resulting in a more limiting prediction of MCHFR. Because the same assumption is applied in the SSAM as approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM for this assumption.

In evaluating a core design, NuScale determines which assemblies could be limiting by considering the assembly peaking (i.e., the average power of the assembly compared to the average power of the average assembly in the core), and the rod peaking in the assembly. For an assembly to be close to limiting, the assembly peaking must be high, or else the power in the hot rod would not be sufficient to result in limiting behavior. Additionally, assemblies with high peaking of individual rods are not limiting because of the enhanced crossflow which enables these assemblies to have better internal heat transfer. Thus, the limiting assemblies must have flat peak-to-average ratios for the rods in the assembly and must occur at high assembly peaking values.

NuScale’s process for determining the limiting radial power distribution which will be used for the safety analysis relies on **[[**

]]. The NRC staff finds that NuScale’s process for determining the bounding radial power distribution would result in a radial power distribution which could reasonably be expected to be a bounding distribution for core designs; therefore, the NRC staff has determined that the generation of the bounding radial power distribution is acceptable.

3.10.7 Deterministic Radial Power Distribution (**Replacement**)

While this section was needed for the NSAM topical report (Reference 9), because of the different treatment of uncertainties in the SSAM submittal, this section in no longer needed. Uncertainties of the radial power distribution are discussed in Section 3.12.

3.10.8 Axial Power Distribution (**No Change**)

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the axial power distribution in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.10.9 Standard Review Plan Section 15.4 Analyses (**No Change**)

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the limiting axial power shape in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.11 Numerical Solution (**No Change**)

The NRC staff previously reviewed and approved NuScale’s methodology for calculating the numerical solution in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.12 Statistical Method and Treatment of Uncertainties (**Replacement**)

In its uncertainty quantification (UQ) analysis, NuScale determined the appropriate probability distribution based on certain factors and applied that distribution to the value of specific variables. In general, the NRC staff finds that assuming that measurements are normally disturbed is reasonable, and that applying a uniform distribution when the probabilities of a bounded distribution are unknown can be acceptable. However, the staff is unaware of any approach that could be used to determine conservative distributions and, therefore, reviewed the uncertainty models chosen, including the probability distributions chosen, based on if those distributions accurately or conservatively capture the uncertainty in their corresponding parameters in the subsections below.

3.12.1 Uncertainty in Analysis Method (**Replacement**)

The following uncertainties are focused on the analysis method itself.

3.12.1.1 Computer Code Uncertainty (**Replacement**)

The computer code uncertainty is a general uncertainty applied to a computer code that was meant to capture uncertainties due to the fidelity of the computational models in predicting the physics as well as uncertainties due to the change of the continuous equations of physics into discretized equations and the resulting sensitivities to radial and axial nodalization. Instead of considering a single code, NuScale has followed the general practice of separating the overall uncertainty into two independent uncertainties.

The uncertainties associated with the computational model's ability to correctly predict physics are quantified through comparison to experimental data, in particular, quantified through comparison to CHF data (as discussed in Section 3.12.1.2). Historically, these physics-based uncertainties have dominated the overall uncertainty. In scientific modeling and simulation, evaluating these uncertainties is commonly called validation.

The uncertainties associated with using discretized equations instead of continuous equations (e.g., impacts of mesh) are not quantified directly, but instead are treated by ensuring that the mesh size used is reasonable. As these uncertainties have historically been smaller, this practice has been considered acceptable for CHF analysis. In scientific modeling and simulation, evaluating these uncertainties is commonly called verification.

Given the direct treatment of physics-based uncertainties and the use of mesh sensitivities to ensure that the axial and radial nodalization adequately resolves the solution, the NRC staff has determined that the computer code uncertainty has been adequately quantified.

3.12.1.2 Critical Heat Flux Correlation Uncertainty (**Replacement**)

The CHF correlation uncertainty is quantified as the variability in the correlation's predicted accuracy of the CHF test data. The measured-to-predicted values from CHF testing are assumed to be a representative sample from the population of all possible measured-to-predicted values and, therefore, that sample can provide useful information for any future UQ analysis, such as using the variance from the sample as an estimate of the variance of the underlying population or using the distribution of the sample as an estimate of the distribution of the underlying population.

However, as noted by NuScale, the main figure of merit for the CHF validation is the 95/95. The 95/95 is an estimate of the 95th percentile of the validation population using a method that has a 95 percent confidence level. And while the 95/95 of the sample will not change without additional data, because this value is used as an analytical limit, it is common for that limit to be increased to account for other uncertainties. Thus, NuScale has committed to adjusting the sample of measured-to-predicted data in any UQ analysis such that the 95/95 of the adjusted sample matches the approved limit for the given CHF correlation. Because the measured-to-predicted values represent the uncertainty in the CHF correlation and their distribution would be adjusted to ensure that the adjusted distribution maintains the approved design limit, the NRC staff has determined that CHF correlation uncertainty has been adequately quantified.

3.12.2 Uncertainty in Operating Conditions (**Replacement**)

The following uncertainties are focused on the plant operating conditions which are the boundary conditions of the computational model.

3.12.2.1 Core Thermal Power (**Replacement**)

Equation 3-12 in the SSAM provides the basic formula for evaluating the core thermal power. However, NuScale has not provided a final method or value for determining the values in this equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.2.2 Core Inlet Flow (**Replacement**)

Equation 3-13 in the SSAM provides the basic formula for evaluating the core inlet flow. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.2.3 Core Inlet Temperature (**Replacement**)

Equation 3-14 in the SSAM provides the basic formula for evaluating the core inlet temperature. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.2.4 Core Exit Pressure (**Replacement**)

Equation 3-15 in the SSAM provides the basic formula for evaluating the core exit pressure. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.2.5 Enthalpy Rise Measurement Uncertainty (**Replacement**)

This section discusses the enthalpy rise measurement uncertainty. However, NuScale has not provided a final method or value for determining this value. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.3 Uncertainty in Physical Data Inputs (**Replacement**)

The following uncertainties (Section 3.12.4 – Section 3.12.10) are focused on the physical data inputs used in the VIPRE model.

3.12.4 Enthalpy Rise Engineering Uncertainty (**Replacement**)

This section discusses the enthalpy rise engineering uncertainties. However, NuScale has not provided a final method or value for determining these values. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.5 Heat Flux Engineering Uncertainty (**Replacement**)

Equation 3-16 in the SSAM provides the basic formula for evaluating the heat flux engineering uncertainty. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.6 Linear Heat Generation Rate Engineering Uncertainty (**Replacement**)

The NRC staff previously reviewed and approved NuScale's methodology for calculating the linear heat generation rate uncertainty in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, and because this uncertainty is not related to CHF but used in ensuring the preclusion of fuel melt, the NRC staff has determined that no additional review is required for the SSAM.

3.12.7 Radial Power Distribution (SIMULATE5) Uncertainty (**Replacement**)

NuScale determined that any uncertainty in the neutronic computer code which is used to calculate the radial power distribution has been accounted for by biasing the radial peaking limit in the hot rod and in the hot subchannel and having these at the radial peaking analysis limit. Previous sensitivity studies have shown that the rod powers a few rows away from the hot subchannel have a negligible impact on the MCHFR, thus, having the hot subchannel be at the limiting radial powers would result in the limiting condition. The NRC staff previously reviewed and approved this reasoning in the NSAM topical report (Reference 9). Because the assumption applied in the SSAM is the same assumption as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.12.8 Fuel Rod and Assembly Bow Uncertainty (**Replacement**)

The following two uncertainties are focused on fuel rod bow and assembly bow.

3.12.8.1 Fuel Rod Bow Uncertainty (**Replacement**)

Equation 3-17 in the SSAM provides the basic formula for evaluating the fuel rod bow uncertainty. However, NuScale has not provided a final method or value for determining the values in the equation. Such a method or value would need to be reviewed and approved prior to application of the SSAM. This is captured in condition and limitation 2.

3.12.8.2 Assembly Bow Uncertainty (**Replacement**)

The NRC staff previously reviewed and approved NuScale's methodology for assessing assembly bow penalty and that it was not needed in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.12.9 Core Inlet Flow Distribution Uncertainty (**Replacement**)

While the location of core inlet flow has been changed from that in the NSAM topical report due to the change in modeling of the core, the NRC staff has determined that this change would not impact the modeling of the core inlet flow distribution uncertainty. Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.12.10 Core Exit Pressure Distribution Uncertainty (**Replacement**)

While the location of core exit pressure has been changed from that in the NSAM topical report due to the change in modeling of the core, the NRC staff has determined that this change would not impact the modeling of the core exit pressure distribution uncertainty. Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.13 Bias and Uncertainty Application within Analysis Methodology (**Replacement**)

The following sections summarize NuScale's treatment of biases and random uncertainties.

3.13.1 Statistical Methods (**Replacement**)

The following subsections contain general information on statistical methods that NuScale is applying in the SSAM. Because the information discussed in each subsection is general statistical information, the NRC staff has determined that no review is required.

3.13.1.1 Uniform Distribution (**Replacement**)

In this section, NuScale provides the general definition of a uniform distribution. Because this information is general statistical information, the NRC staff has determined that no review is required.

3.13.1.2 Normal Distribution (**Replacement**)

In this section, NuScale provides a discussion of the Box-Mueller transformation, a method used to generate pairs of normally distributed random numbers from pairs of uniformly distributed random numbers. Because this information is general statistical information, the NRC staff has determined that no review is required.

3.13.1.4 Quality Assurance Sampling (**Replacement**)

In this section, NuScale provides a discussion of determining estimates of the 95/95 level of population using a non-deterministic method. Because this information is general statistical information, the NRC staff has determined that no review is required.

3.13.2 Statistical CHF Analysis Limit (**Replacement**)

The statistical CHF analysis limit (SCHFAL) is the random variable used by NuScale to quantify the uncertainties that occur in the MCHFR value. This variable is calculated by combining the uncertainties in:

- the CHF correlation's predictive capability (i.e., the values of the correlation's prediction of validation data compared to the measured values) (Section 3.12.1.2)
- the fuel rod bow penalty (Section 3.12.8.1)
- the heat flux engineering uncertainty (Section 3.12.5)
- the impact of uncertainties in the MCHFR value at the state point at which the MCHFR is calculated (Section 3.13.3)

These uncertainties are combined using equation 3-24 in the SSAM in a Monte Carlo methodology. In this equation, fuel rod bow is treated as a penalty in that it always increases the SCHFAL, while the other terms are treated as variabilities as they can both increase and decrease the SCHFAL value.

The Monte Carlo sampling process is performed a specified number of times to ensure that a non-deterministic 95/95 value can be calculated. This value is the 95/95 limit. The details about its calculation are discussed in the subsections below.

3.13.2.1 Best-Estimate Model Reference State-Point (**Replacement**)

The Monte Carlo sampling procedure used by NuScale attempts to determine the uncertainty in the CHFR value over a space of values. To this end, it combines the two common Monte Carlo analysis types: (1) spatial sampling – sampling values over some defined space to determine the possible values of a variable and (2) probabilistic sampling – combining values from multiple random variables to generate a sample of a new random variable. While Monte Carlo is used to perform both types of analysis, the two analyses produce different results. In spatial sampling, the results of the analysis represent the possible values of the given variable. In probabilistic sampling, the results of the analysis represent a sample of a random variable which can be assumed to be a representative sample from the population for that random variable. While statistics from the output of probabilistic sampling are estimates of the parameters of the underlying population, statistics from the output of spatial sampling have no such meaning.

Combining both types of analysis into a single Monte Carlo analysis is possible if it can be shown that the spatial variation in the variable's value does not dramatically change over the space being considered. To demonstrate this, NuScale performed a sensitivity evaluation in which it compared a **[[**

]].

While NuScale's analysis does not conclusively prove that the results from spatial sampling can be used to generate bounding statistics, the NRC staff has determined that the analysis does use the best available methods and that the study provides reasonable evidence that the Monte Carlo sampling process is not impacted by the location of the state point (i.e., it is independent of the location in the application domain).

By demonstrating that its Monte Carlo sampling process is not impacted by the state point location, the NRC staff concludes that NuScale has demonstrated that the sampling process results in a representative sample of the underlying population of the CHFR values and, therefore, that the 95/95 is a reasonable estimate of the true 95th percentile from that population.

In this process, it is expected that the code may not converge on some very small percentage of runs. Based on Section 3.13.2 of the SSAM, it is the NRC staff's understanding that NuScale will investigate any such non-convergences and ensure that their occurrence is reasonable and thus that run should be ignored in the analysis (e.g., the state point that had been randomly chosen for the run is a non-physical state point and was randomly chosen due to the mathematically simplistic description of the application domain). Any non-convergence at a point at which the code would have been expected to result in convergence is an indication of a potential bug in the code.

3.13.3 ΔMCHFR Calculation Process (**Replacement**)

In order to determine the impact of uncertainties, NuScale is **[[**

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[[

]]. Therefore, the NRC staff concludes that the calculation and application of the ∆MCHFR value is acceptable for quantifying uncertainties of the variables which are used to generate the ∆MCHFR value.

3.13.4 Calculating the Statistical CHF Analysis Limit (**Replacement**)

Because NuScale uses well accepted non-parametric methods for determining the SCHFAL and uses those methods in a reasonable manner such that the SCHFAL will be accurately or conservatively predicted, the NRC staff concludes that the calculation of the SCHFAL is acceptable.

3.13.5 Summary of Bias and Uncertainty Treatment (**Replacement**)

This section of the SSAM submittal provides a table that summarizes the various uncertainties discussed in Section 3. Because this section is only a summary, the NRC staff has determined that no additional review is required as the regulatory evaluation of each uncertainty is discussed in the section of the SE associated with the specific uncertainty.

3.14 Mixed Core Analysis (**No Change**)

The NRC staff previously reviewed and approved NuScale's methodology for performing mixed core analysis in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

3.15 Methodology-Specific Acceptance Criteria (**Supplement**)

The NRC staff previously reviewed and approved NuScale's determination of methodology acceptance criteria in the NSAM topical report (Reference 9). Because the process of determination remains unchanged in the SSAM as was approved in the NSAM with one exception, the NRC staff has determined that no additional review is required for the SSAM for everything except the exception. The exception is related to NuScale's allowance for the MCHFR to occur in a peripheral subchannel and this is addressed in Section 3.10.3.1.

4.0 Transient-Specific Applications Methodologies (**No Change**)

The NRC staff previously reviewed and approved NuScale's methodology for transient-specific applications in the NSAM topical report (Reference 9). Because the methodology applied in the SSAM is the same methodology as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM. Further, the SSAM methodology only impacts the CHF limit to which the results of each transient would be compared and does not generally impact how each transient would be performed.

5.0 VIPRE-01 Qualification (**No Change**)

The NRC staff previously reviewed and approved NuScale's VIPRE-01 qualification in the NSAM topical report (Reference 9). Because the qualification applied in the SSAM is the same qualification as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

6.0 Example Calculation Results (**Supplement**)

In general, the example calculation results in the NSAM are applicable to the SSAM. However, due to specific differences in nodalization, some changes were needed. Therefore, each subsection is addressed below.

6.1 General Inputs (**N/A**)

Section 6.1 provides an example calculation using the NSAM and does not describe any of the SSAM methodology. Further, the example is not an example calculation of the SSAM, hence it is categorized by the NRC staff as N/A as it does not have a direct impact on the approval of the SSAM. However, the example may still be useful in understanding the SSAM.

6.2 Steady-State Case (**N/A**)

Section 6.2 provides an example calculation using the NSAM and does not describe any of the SSAM methodology. Further, the example is not an example calculation of the SSAM, hence it is categorized by the NRC staff as N/A as it does not have a direct impact on the approval of the SSAM. However, the example may still be useful in understanding the SSAM.

6.3 Transient Cases (**No Change**)

The NRC staff previously reviewed and approved the transient case in the NSAM topical report (Reference 9). Because the transient case applied in the SSAM is the same as that approved in the NSAM, the NRC staff has determined that no additional review is required for the SSAM.

6.4 Sensitivity Analysis (**Supplement**)

The various aspects of the sensitivity analysis are addressed in the subsections below.

6.4.1 Radial Geometry Nodalization (**Replacement**)

In this analysis, NuScale performed a sensitivity of the radial nodalization using the **[[**

]].

6.4.2 Radial Power Distribution (**No Change**)

The NRC staff previously examined the sensitivity study for the radial power distribution in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

6.4.3 Axial Geometry Nodalization (**Replacement**)

This analysis is evaluated in Section 3.7 of this SE.

6.4.4 Inlet Flow Distribution (**No Change**)

The NRC staff previously examined the sensitivity study for the inlet flow distribution in the NSAM topical report (Reference 9). However, in those sensitivities, the NRC staff noted that **[[**

]].

Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM, and because of the sensitivity which demonstrated that large conservative changes to the inlet flow distribution resulted in a minimal impact to the critical LHGR, the NRC staff has determined that this sensitivity analysis demonstrates the minimal impact of flow maldistribution on MCHFR.

6.4.5 Turbulent Mixing Parameter (**No Change**)

The NRC staff previously examined the sensitivity study for the turbulent mixing parameter in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

6.4.6 Turbulent Momentum Parameter (**No Change**)

The NRC staff previously examined the sensitivity study for the turbulent momentum parameter in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

6.4.7 Grid Loss Coefficient (**No Change**)

The NRC staff previously examined the sensitivity study for grid loss coefficients in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

6.4.8 Numerical Solution Parameters (**No Change**)

The NRC staff previously examined the sensitivity study for the numerical solution parameters in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that study would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

6.5 General Input Sensitivity Analysis (**No Change**)

The NRC staff previously examined the general input sensitivity analysis in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the results of that analysis would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

7.0 Summary and Conclusions (**Supplement**)

The following section details the summary and conclusions of the SSAM.

7.1 VIPRE-01 Safety Evaluation Report Requirements (**No Change**)

The NRC staff previously examined the VIPRE-01 safety evaluation report requirements in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the satisfying of those requirements would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

7.2 Criteria for Establishing Applicability of Methodology (**Replacement**)

The criteria for establishing the applicability of the methodology are given below. The criteria for establishing the applicability of the methodology section of the SSAM are generally similar to the NSAM and represent the criteria that need to be satisfied at a minimum for the SSAM to be applicable. Changes or deviations from the evaluation model described in the NSAM and/or SSAM would require additional NRC staff review and approval.

7.2.1 General Criteria (**Replacement**)

The NRC staff previously examined the general criteria for establishing the applicability of the methodology in the NSAM topical report (Reference 9). However, in the SSAM, NuScale has removed the following requirements:

- The MCHFR must occur in a channel geometry for which there is a valid CHF correlation (a unit or guide tube or instrument tube cell).
- The MCHFR must not occur on a peripheral subchannel of an assembly when using the fully detailed one-eighth core model.
- The hot channel must occur adjacent to the hot rod.

As discussed in Section 3.10.3 above, the removal of these requirements is for actual core designs, which is acceptable because the simulated core used in the SSAM will bound the actual core, as the MCHFR will be forced to occur in the middle of the assembly resulting in a bounding statistical analysis. Because NuScale's general criteria will result in an accurate or conservative application of the methodology, the NRC staff has determined that the general criteria are acceptable.

7.2.2 Critical Heat Flux Correlation (**Replacement**)

The NRC staff previously examined the CHF correlation criteria for establishing the applicability of the methodology in the NSAM topical report (Reference 9). While NuScale has made some editorial changes to these criteria, the NRC staff finds that the criteria stated in the SSAM are substantively the same as those criteria approved in the NSAM and, therefore, the NRC staff has determined that the CHF correlation criteria are acceptable. See SE Section 3.3 for additional information.

7.2.3 Nuclear Analysis Discipline Interface (**Replacement**)

Because NuScale will confirm that the bounding analysis limits for each cycle are used in its analysis, the NRC staff has determined that the nuclear analysis discipline interface is acceptable.

7.2.4 Transient Discipline Interface (**Replacement)**

The NRC staff previously examined the transient discipline interface criteria in the NSAM topical report (Reference 9). While NuScale has made some editorial changes to these criteria, the NRC staff finds that the criteria stated in the SSAM are substantively the same as those criteria approved in the NSAM and, therefore, the NRC staff has determined that the transient discipline interface criteria are acceptable.

7.3 Cycle-Specific Confirmations (**Replacement**)

The NRC staff previously examined the cycle-specific confirmations criteria in the NSAM topical report (Reference 9). While NuScale has made some changes to these criteria, the NRC staff finds that the criteria stated in the SSAM are substantively the same as those criteria approved in the NSAM with one exception and, therefore, the NRC staff has determined that they are acceptable. The exception is the removal of the requirement for the hot rod to not be on the assembly periphery and it is addressed above in Section 3.10.3.

7.4 Key Fuel Design Interface Requirements (**Replacement**)

The NRC staff previously examined the key fuel design interface requirements in the NSAM topical report (Reference 9). Because of the similarities between the NSAM and SSAM approaches, the NRC staff finds that the satisfying of those requirements would be applicable to the SSAM and, therefore, the NRC staff has determined that no additional review is required for the SSAM.

7.5 Unique Features of the NuScale Design (**Supplement**)

The NRC staff previously examined the unique features of the NuScale design in the NSAM topical report (Reference 9). NuScale has updated this table consistent with the requested power uprate for its reactor. Because this table reflects the current design, the NRC staff has determined that no additional review is required for the SSAM.

8.0 References (**Supplement**)

Because this section contains the appropriate references for the documents cited in the SSAM submittal (Reference 13), the NRC staff has determined that no additional review is required for the SSAM.

4.0 CONDITIONS AND LIMITATIONS

The following condition and limitation is provided in Section 5.0 of the NRC staff's SE for the approval of the NSAM (Reference 10). Because the SSAM is based on the approved NSAM, this same condition and limitation is applicable to the SSAM. The condition and limitation is reproduced below as condition and limitation 1 for convenience, with slight wording changes for clarity.

1. An applicant referencing [the SSAM] in the safety analysis must also reference an approved CHF correlation which has been demonstrated to be applicable for use with [the NSAM]. The basis for this Condition is provided in Section 4.1 of the [SE for the NSAM].

Based on the above evaluation, the following condition and limitation 2 is applicable specifically to the SSAM.

2. The SSAM relies on multiple submodels to calculate the statistical critical heat flux analysis limit. While some of these submodels have been reviewed and approved as part of the NRC staff's review and approval of the SSAM, the submodels listed below would need to be reviewed and approved before the application of this methodology for a licensing analysis. That review and approval may consist of approval of specific values for variables, approval of the model used for the variables, and/or approval of the method by which the model will be generated for those variables. Additionally, while the numerical inputs to the submodel must also be approved, it is often sufficient to ensure that the values are obtained from a trusted source. The submodels that require such NRC staff review and approval before application of the SSAM are:

    a. The maximum hot rod radial peaking analysis limit, including measurement uncertainties. An example of this is given in equation 3-8 of the SSAM.

    b. The models and values used to determine the core thermal power. This is given in equation 3-12 of the SSAM.

    c. The models and values used to determine the core inlet flow. This is given in equation 3-13 of the SSAM.

    d. The models and values used to determine the core inlet temperature. This is given in equation 3-14 of the SSAM.

    e. The models and values used to determine the core exit pressure. This is given in equation 3-15 of the SSAM.

    f. The models and values used to determine the enthalpy rise measurement uncertainty.

    g. The models and values used to determine the enthalpy rise engineering uncertainties.

    h. The models and values used to determine the heat flux engineering uncertainty. This is given in equation 3-16 of the SSAM.

    i. The models and values used to determine the fuel rod bow uncertainty. This is given in equation 3-17 of the SSAM.

5.0 CONCLUSIONS

The NRC staff reviewed the modifications to the original subchannel methodology, the NSAM (Reference 9), which resulted in the creation of the statistical subchannel methodology, the SSAM. The NRC staff's review of each of the sections of the SSAM is summarized in Section 3 of this SE. As part of this review, the NRC staff determined that either no additional review was required for the SSAM due to the similarity with the NSAM or that the change to the NSAM (either supplementation or replacement) to create the SSAM was acceptable. The NRC staff also determined that two conditions and limitations, specified in Section 4 of the SE, are applicable to the SSAM.

Given the acceptability of each of the individual sections of the SSAM and the previous acceptability of the NSAM on which the SSAM is based, the NRC staff finds that the SSAM as defined in Reference 13 and in this SE is an acceptable methodology to calculate the margin to fuel thermal limits such as the critical heat flux ratio through a statistical combination of the uncertainties, provided that the conditions and limitations have been satisfied.

6.0 REFERENCES

1. Letter from Shaver, M.W., NuScale, to Document Control Desk, NRC, “NuScale Power, LLC Submittal of Supplemental Topical Report ‘Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2,’ TR-108601, Revision 0,” dated December 30, 2021 (ML21364A133).

2. NuScale, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” TR-108601-P, Revision 0, dated December 2021 (ML21364A134 (Proprietary Version, Non-Publicly Available) and ML21364A133 (Nonproprietary Version, Publicly Available)).

3. Email from Bavol, B.M., NRC, to Norris, R., NuScale, “Completeness determination for NuScale Topical Report, TR-108601, Revision 0, ‘Statistical Subchannel Analysis Methodology,’” dated February 28, 2022 (ML22053A142).

4. NuScale, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” TR-108601-P, Revision 1, dated April 2022 (ML22115A223 (Proprietary Version, Non-Publicly Available) and ML22115A222 (Nonproprietary Version, Publicly Available)).

5. Email from Bavol, B.M., NRC, to Griffith, T., NuScale, “Completeness determination for NuScale Topical Report, TR-108601, Revision 1, ‘Statistical Subchannel Analysis Methodology,’” dated May 4, 2022 (ML22115A190).

6. NuScale, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” TR-108601-P, Revision 2, dated December 2022 (ML22347A315 (Proprietary Version, Non-Publicly Available) and ML22347A314 (Nonproprietary Version, Publicly Available)).

7. Letter from Smith, B.W., NRC, to Fosaaen, C.A., NuScale, “NuScale Topical Report ‘Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,’ TR-108601, Revision 2, Review Schedule letter Update,” dated December 21, 2022 (ML22350A029).

8. NRC, NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [Light-Water Reactor] Edition,” Section 4.4, “Thermal and Hydraulic Design,” Revision 2, dated March 2007 (ML070550060).

9. NuScale, “Subchannel Analysis Methodology,” TR-0915-17564-P-A, Revision 2, dated February 2019 (ML19067A257 (Proprietary Version, Non-Publicly Available) and ML19067A256 (Nonproprietary Version, Publicly Available)).

10. NRC, “Final Safety Evaluation for NuScale Power, LLC Topical Report 0915-17564, Revision 2, ‘Subchannel Analysis Methodology,’” dated December 4, 2018 (ML19067A256).

11. NuScale, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” TR-108601-P, Revision 3, dated October 12, 2023 (ML23285A342 (Proprietary Version, Non-Publicly Available) and ML23285A341 (Nonproprietary Version, Publicly Available)).

12. Memorandum from Joseph, S.K., NRC, to Jardaneh, M., NRC “Audit Summary for the Regulatory Audit of NuScale Power Topical Report Supplement Entitled “Statistical Analysis Subchannel Methodology,” TR-108601, Revision 1 Incorporating a Limited Scope Audit for “Rod Ejection Accident Methodology,” TR-0716-50350, Revision 2”, November 1, 2023 (ML23295A001).

13. NuScale, “Statistical Subchannel Analysis Methodology, Supplement 1 to TR-0915-17564-P-A, Revision 2, Subchannel Analysis Methodology,” TR-108601-P, Revision 4, dated November 6, 2023 (ML23310A123) (Proprietary Version, Non-Publicly Available) and ML23310A122 (Nonproprietary Version, Publicly Available)).