NuScale Power

RAIO-0618-60387

June 12, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 422 (eRAI No. 9512) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 422 (eRAI No. 9512)," dated April 13, 2018

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

The Enclosures to this letter contain NuScale's response to the following RAI Questions from NRC eRAI No. 9512:

- 15.04.03-2
- 15.04.03-3
- 15.04.03-4
- 15.04.03-5
- 15.04.03-6

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 422 (eRAI No. 9512). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 3) supports this request. Enclosure 2 is the nonproprietary version of the NuScale response.

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

If you have any questions on this response, please contact Paul Infanger at 541-452-7351 or at pinfanger@nuscalepower.com.

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8G9A
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9512, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9512, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0618-60389

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9512, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9512, nonproprietary

NuScale Power™

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9512
Date of RAI Issue: 04/13/2018

NRC Question No.: 15.04.03-2

General Design Criterion 10, "Reactor design," in Title 10 of the Code of Federal Regulations (10 CFR) Part 50, Appendix A, requires 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). GDC 13 requires the provision of instrumentation to monitor variables and systems over their anticipated ranges of normal operation, including the effects of AOOs, and of appropriate controls to maintain listed variables and systems within prescribed operating ranges.

According to TR-0915-17564-P, “Subchannel Analysis Methodology,” the operating boundary conditions that are input into the subchannel analysis must account for measurement uncertainty. The staff understands that if biases are applied to parameters in the transient code input, biases for those parameters need not be applied in the subchannel analysis. However, when considering a steady-state analysis such as a static control rod misalignment, the proper biases should be applied in the subchannel analysis. The staff audited engineering calculation {{ }}[2(a),(c)] “Subchannel Analysis of a Control Rod Misalignment,” which supports FSAR Section 15.4.3, and notes that the applied system pressure bias of {{ }}[2(a),(c)] psia is not consistent with the 70 psia bias specified in FSAR Tier 2, Table 15.0-6, “Module Initial Conditions Ranges for Design Basis Event Evaluation.” Using a bias of the incorrect magnitude could produce non- limiting results for the minimum critical heat flux ratio (MCHFR) or linear heat generation rate evaluation. Therefore, please confirm whether the correct reactor coolant system pressure bias was applied in the subchannel analysis for this event. If it was not, either provide a revised analysis, or justify why the current analysis results remain valid. Update the FSAR as necessary.

In addition, the staff requests clarification of whether the {{ }}[2(a),(c)] bias in core inlet temperature listed in {{ }}[2(a),(c)] is consistent with a 10°F bias in RCS average temperature, as specified in FSAR Tier 2, Table 15.0-6. If it is not, provide a revised analysis that uses a core inlet temperature bias consistent with a 10°F bias in RCS average temperature, or justify why the current analysis results remain valid. Update the FSAR as necessary.

Finally, the staff notes that the system pressure and core inlet temperature values and biases, along with other key inputs to the subchannel analysis, influence MCHFR and are therefore necessary for the staff's safety finding with respect to GDC 10 and 13. Therefore, update the FSAR to include the key inputs and assumptions for the control rod misalignment subchannel analysis, including, but not limited to, the primary side parameters identified in FSAR Table 15.0-6.

NuScale Response:

The subchannel analysis of the control rod assembly (CRA) misalignment event described in FSAR Section 15.4.3 was revised to include temperature and pressure biases consistent with FSAR Table 15.0-6. The pressure bias was revised to 70 psia and the core inlet temperature bias was revised to 10°F to correspond to the minimum reactor coolant system average temperature range specified in Table 15.0-6, with an additional 10 °F bias applied on the core inlet temperature. The peak linear heat generation rate remained unchanged after the revision. However, the minimum critical heat flux ratio was updated as shown in the markup provided with this response.

A key inputs table for the CRA misalignment event was added to the FSAR as shown in the markup provided with this response.

Impact on DCA:

FSAR Section 15.4.3,Table 15.4-11, and Table 15.4-33 have been revised as described in the response above and as shown in the markup provided with this response.

power is lost. For this event, this scenario is non-limiting because of the immediate loss of power to the CRDMs. This results in the drop of the CRAs, terminating the event.

- Loss of EDSS, EDNS and LOAC - Power to the MPS is provided by the highly-reliable DC power distribution system (EDSS), so this scenario results in an actuation of RTS and all of the engineered safety features. This scenario is non-limiting because of the immediate reactor trip.

15.4.3.3 Control Rod Assembly Misalignment Analysis

15.4.3.3.1 Evaluation Models

There is no plant thermal hydraulic analysis required for the CRA misalignments given the steady-state nature of the plant thermal hydraulic conditions of the events. The steady-state core analyses are performed using SIMULATE5 to provide power distributions as input to the subchannel analyses. A discussion of SIMULATE5 is provided in Section 4.3.

The subchannel core CHF analysis is performed using VIPRE-01. VIPRE-01 is a subchannel analysis tool designed for general-purpose thermal-hydraulic core analysis under normal operating conditions, operational transients, and events of moderate severity. See Section 15.0.2.3 for a discussion of the VIPRE-01 code and evaluation model.

15.4.3.3.2 Input Parameters and Initial Conditions

RAI 15.04.03-2

The key inputs for the primary side conditions for the subchannel analysis of the CRA misalignment are provided in Table 15.4-33. The limiting CRA misalignment presented in this section occurs when all CRAs are withdrawn, except for one that is inserted to the 25% power PDIL. The following input parameters and initial conditions are considered in this CRA misalignment analysis to ensure a conservative calculation:

- The misaligned CRA is assumed to be inserted 6 steps past the PDIL to account for CRA position indication uncertainty. The added insertion steps maximize the misalignment, providing the most conservative power asymmetry.
- The full range of initial power conditions are analyzed for this misalignment scenario, including: 25%, 50%, 75%, and 100% initial power.
- The most positive and negative axial offset values are considered in the analysis.
- The BOC, MOC, and EOC core conditions are analyzed.

15.4.3.3.3 Results

A static misalignment results in a change in local power shapes and peaking, but the overall power of the core does not change. The thermal hydraulic boundary conditions of the core are at steady-state such that there is no plant thermal hydraulic transient analysis required for input to the subchannel analysis. Instead,

RAI 15.04.03-2

Table 15.4-11: Control Rod Misoperation (15.4.3) - Limiting Analysis Results

Acceptance Criteria	Limit	Analysis Value
MCHFR CRA misalignment	1.284	~~2.638~~2.509
MCHFR Single CRA withdrawal	1.284	1.614
MCHFR CRA drop	1.284	1.641
Peak LHGR CRA misalignment	21.22 kW/ft	7.10 kW/ft
Peak LHGR Single CRA withdrawal	21.22 kW/ft	7.84 kW/ft
Peak LHGR CRA drop	21.22 kW/ft	8.42 kW/ft

RAI 15.04.03-2

Table 15.4-33: Key Inputs for Limiting Control Rod Assembly Misalignment (15.4.3 Control Rod Misoperation, Control Rod Assembly Misalignment)

Parameter	Nominal	Bias
Initial power	160 MW	+2%
RCS flowrate	See Table 15.0-6 for range	1180 lbm/s (low)
RCS pressure	1850 psia	+70 psia
Core inlet temperature	487.4 °F (low)[1]	+10 °F

[1] This nominal core inlet temperature corresponds to the biased RCS average temperature of 535 °F and biased low RCS flowrate.

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9512
Date of RAI Issue: 04/13/2018

NRC Question No.: 15.04.03-3

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” (SRP) Section 15.4.3, “Control Rod Misoperation (System Malfunction or Operator Error),” provides guidance to the staff in determining compliance with GDC 10, among several other GDC, and states that for each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.

While auditing {{ }}[2(a),(c)] which supports FSAR Section 15.4.3, the staff noted that open design item (ODI)-16-1030 requires verification that the low power hold point is at 25 percent power because the subchannel analysis does not postulate a misalignment event that occurs below this hold point. To ensure the case that results in a limiting fuel rod condition is presented, do one of the following: confirm the low power hold point is at 25 percent power, provide an analysis for a case with all control rod assemblies (CRAs) fully withdrawn except for one CRA fully inserted, or provide justification that such a case is less limiting than the misalignment case presented in the FSAR. Update the FSAR as appropriate.

Furthermore, while auditing {{ }}[2(a),(c)], the staff noted that the axial power shape and system boundary conditions correspond to {{ }}[2(a),(c)] power, while the limiting radial augmentation factor is for {{ }}[2(a),(c)]. {{ }}[2(a),(c)] further states that using the {{ }}[2(a),(c)], but the staff notes that the axial power peaking increases with decreasing power. Given the reduced axial power peaking at {{ }}[2(a),(c)] power, please provide justification that assuming an axial power shape and/or boundary conditions associated with a lower power level would not be limiting for this event. Update the FSAR as necessary.

NuScale Response:

FSAR Section 15.4.3 evaluates control rod misoperation design basis events, including the evaluation of control rod assembly misalignment permutations within the allowable ranges of operation. NuScale's module protection system comprises an actuation analytical limit for high reactor power at 25% and 120% rated thermal power (RTP) as tabulated in FSAR Table 15.0-7. This actuation for the reactor startup or heatup sequence confirms the low power hold point. Additionally, the event case in which all control rod assemblies (CRAs) are fully withdrawn with the exception of one CRA fully inserted is evaluated in the CRA drop analysis, another type of control rod misoperation evaluated in FSAR Section 15.4.3. The limiting case for the CRA drop is presented in FSAR Section 15.4.3.5 and is shown to be more limiting for minimum critical heat flux ratio (MCHFR) than the limiting CRA misalignment case as presented in FSAR Table 15.4-11.

The subchannel evaluation of the CRA misalignment is characterized by the core operation at hot full power steady-state conditions, where the limiting radial power augmentation comes from a 25% RTP misalignment. It is shown in FSAR Figure 4.4-10 that the MCHFR decreases with increasing core power level, which considers all axial power shapes within the axial offset window in FSAR Figure 4.3-3. Therefore, using the combination of the limiting radial power augmentation (25% RTP misalignment) with the axial power shape from the steady-state conditions that result in the most conservative MCHFR (100% RTP) is limiting for MCHFR.

Impact on DCA:

There are no impacts to the DCA as a result of this response.

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9512
Date of RAI Issue: 04/13/2018

NRC Question No.: 15.04.03-4

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs. SRP Section 15.4.3 provides guidance to the staff in determining compliance with GDC 10, among several other GDC, and states that for each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.

The staff notes that a maximum (least negative) MTC is typically limiting for a single CRA withdrawal event because it minimizes reactivity feedback that mitigates the power increase. FSAR Tier 2, Table 15.4-6, “Key Inputs for Single CRA Withdrawal with Limiting MCHFR,” indicates that the moderator temperature coefficient (MTC) value used in the single CRA withdrawal analysis is a power-dependent value (-6 pcm/°F) based on the initial power level of 75%. However, based on FSAR Tier 2, Figure 4.3-13, “Moderator Temperature Coefficient of Reactivity at Full Power,” and Figure 4.3-14, “Moderator Temperature Coefficient of Reactivity at Zero Power,” the maximum MTC at an RCS temperature of 535°F (the temperature assumed in the analysis) is about -5 pcm/°F. Furthermore, the analysis in FSAR Section 15.4.2, “Uncontrolled Control Rod Assembly Withdrawal at Power,” assumes an MTC value of 0 pcm/°F for the analysis at 75 percent power.

Therefore, provide further justification that the -6 pcm/°F MTC is bounding and conservative for the single CRA withdrawal analysis, or alternatively, provide a new analysis using a bounding value for MTC, such as 0 pcm/°F. Update the FSAR as necessary.

In addition, Table 15.4-6 does not list the initial RCS flow assumed for the analysis. Because initial RCS flow affects MCHFR, update the table to include the value for initial RCS flow.

NuScale Response:

Figure 4.3-13 and Figure 4.3-14 demonstrate representative moderator temperature coefficients (MTCs) for a range of moderator temperatures and soluble boron concentrations (achieved by a spectrum of power levels and times in cycle). The range of conditions used to develop these figures can extend beyond the ranges of the applicable MTC and corresponding analytical limits implemented in the safety analyses. As a result, representative values in Figure 4.3-13 and Figure 4.3-14 cannot be used directly to derive the least negative MTC for the single control rod assembly (CRA) withdrawal event.

The maximum (least negative) values in Figure 4.3-13 occur for low moderator temperatures at zero percent power; these conditions aren't applicable for the limiting single CRA withdrawal event, which is analyzed nominally between 25 percent and 100 percent power. The MTCs applied for this event are power-dependent (based on the initial power of the analysis) and are derived by determining the least negative value for average moderator temperatures above 530 °F, which conservatively bounds the average moderator temperature lower analytical limit of 535 °F.

The 0 pcm/°F MTC used for the uncontrolled CRA withdrawal at power event in FSAR Section 15.4.2 represents an MTC analytical limit that bounds power levels greater than 25% RTP (i.e. not power-dependent).

The initial reactor coolant system flow was added to Table 15.4-8, Key Inputs for Single CRA Withdrawal with Limiting MCHFR, as shown in the markup provided with this response.

Impact on DCA:

FSAR Table 15.4-8 has been revised as described in the response above and as shown in the markup provided with this response.

RAI 15.04.03-4

Table 15.4-8: Key Inputs for Single CRA Withdrawal with Limiting MCHFR

Parameter	Normal	Bias
Initial power	75% of full power	Nominal
RCS flowrate	See Table 15.0-6 for range	1056.6 (low[1])
Pressurizer level	60%	-8%
RCS pressure	1850 psia	-70 psia
RCS average temperature	545 °F	-10 °F
MTC[1][2]	-6 pcm/°F	Least Negative
DTC	-1.4 pcm/°F	Least Negative

[1] RCS flow rate is near the minimum for 75% power.

[2] Power dependent MTCs are used in the single CRA withdrawal analyses. The -6pcm/°F value corresponds to the initial power of 75%.

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9512
Date of RAI Issue: 04/13/2018

NRC Question No.: 15.04.03-5

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs. SRP Section 15.4.3 provides guidance to the staff in determining compliance with GDC 10, among several other GDC, and states that for each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.

In auditing {{ }}[2(a),(c)] Revision 1, "Control Rod Misoperation Transient Analysis," one of the calculations supporting FSAR Section 15.4.3, the staff noted that the sensitivity cases to determine the limiting single CRA withdrawal case do not appear conclusive. In particular, only two cases {{ }}[2(a),(c)] were examined. Both {{ }}[2(a),(c)]. Therefore, it appears that more limiting cases initiating from {{ }}[2(a),(c)] may be possible by biasing parameters to further delay the {{ }}[2(a),(c)] and by considering other reactivity insertion rates.

In light of this observation, provide additional justification that the limiting single CRA withdrawal case has been identified. If a more limiting case is identified, update the FSAR as appropriate.

NuScale Response:

The single control rod assembly (CRA) withdrawal cases analyzed at {{ }}[2(a),(c)] relative to cases at 75% initial power due to the associated CRA positions. In the {{ }}[2(a),(c)] case that results in the highest peak power, the power has reached a maximum and has a downward trend at the time of scram due to the moderator temperature feedback. Thus, delaying the scram would not increase the peak power, and the most limiting result is obtained by maximizing the RCS temperature and pressure at the time of the power peak.

The CRA cases at 75% initial power do not result in a {{

}}[2(a),(c)] cases. However, the higher peaking factors associated with the core power distributions at 75% initial power result in higher local heat flux and more limiting MCHFR conditions. The most limiting result occurs at 75% power and is obtained by maximizing the scram delay.

Impact on DCA:

There are no impacts to the DCA as a result of this response.

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9512
Date of RAI Issue: 04/13/2018

NRC Question No.: 15.04.03-6

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that SAFDLs are not exceeded during any condition of normal operation, including the effects of AOOs. SRP Section 15.4.3 provides guidance to the staff in determining compliance with GDC 10, among several other GDC, and states that for each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. In addition, the specific acceptance criteria to ensure the SAFDLs are met include the departure from nucleate boiling ratio (for NuScale, MCHFR) being met and fuel centerline temperatures not exceeding the melting point.

FSAR Tier 2, Section 15.4.3, and the related Tables 15.4-6 and 15.4-8, "Key Inputs for CRA Drop with Limiting MCHFR," discuss and provide input parameters and initial conditions for the limiting MCHFR case. However, there is no discussion of the initial conditions or results of the maximum linear heat generation rate (LHGR) case, which provides conclusions regarding the fuel centerline melting acceptance criterion, aside from the LHGR value itself. To enable the staff to ensure that the limiting results for fuel centerline temperature have been identified, update the FSAR to include the key initial conditions and a high-level discussion of the single CRA withdrawal and rod drop event results for their respective limiting LHGR cases.

NuScale Response:

FSAR Section 15.4.3.4 did not describe the case that was used to determine the limiting linear heat generation rate (LHGR) for the single control rod assembly (CRA) withdrawal. A description of the inputs and high-level discussion of the results have been added to the FSAR as shown in the markups provided with this response.

FSAR Section 15.4.3.5 describes the CRA drop case that results in the limiting MCHFR. The case presented for the limiting MCHFR also results in the limiting LHGR for the CRA drop. The description of the inputs and results for the limiting CRA drop case have been revised in the FSAR to indicate that the same case is limiting for both MCHFR and LHGR, as shown in the markups provided with this response.

Impact on DCA:

FSAR Section 15.4.3,Table 15.4-10, and Table 15.4-32 have been revised as described in the response above and as shown in the markup provided with this response.

The MCHFR for the limiting static misalignment of a CRA is above the design limit and bounded by the MCHFR of the single CRA withdrawal, presented in Section 15.4.3.4.

15.4.3.4 Single Control Rod Assembly Withdrawal Analysis

15.4.3.4.1 Evaluation Models

The thermal hydraulic analysis of the plant response to a single CRA withdrawal is performed using NRELAP5. The NRELAP5 model is based on the design features of a NuScale module. The non-LOCA NRELAP5 model is discussed in Section 15.0.2. The relevant boundary conditions from the NRELAP5 analyses are provided to the downstream subchannel CHF analysis.

The subchannel core CHF analysis is performed using VIPRE-01. VIPRE-01 is a subchannel analysis tool designed for general-purpose thermal-hydraulic analysis under normal operating conditions, operational transients, and events of moderate severity. See Section 15.0.2 for a discussion of the VIPRE-01 code and evaluation model.

15.4.3.4.2 Input Parameters and Initial Conditions

RAI 15.04.01-3, RAI 15.04.03-6

A spectrum of initial conditions is analyzed to find the limiting reactivity insertion due to a single CRA withdrawal. Key inputs and the associated biases for the limiting single CRA withdrawal analyses are provided in Table 15.4-8 with respect to MCHFR, and Table 15.4-30 with respect to RCS pressure, and Table 15.4-32 with respect to LHGR. The following initial conditions and assumptions ensure that the results have sufficient conservatism.

- Initial power level: 25 percent, 50 percent, 75 percent, and 102 percent of nominal power are analyzed to find the limiting cases.
  - The initial power level for the limiting MCHFR case is 75 percent of nominal power.
  - The initial power level for the limiting RCS pressure case is 102 percent of nominal power.

RAI 15.04.03-6

  - The initial power level for the limiting LHGR case is 102 percent of nominal power.

RAI 15.04.03-6

- Reactivity insertion rate: The positive reactivity inserted by the CRA withdrawal is modeled as a constant reactivity addition beginning at the transient initiation. The uncontrolled CRA withdrawal evaluation considers reactivity addition rates up to 12 pcm/s. This value bounds the 10.48 pcm/s that corresponds to the maximum CRA withdrawal rate of 15 in./min. The reactivity insertion rate for the limiting MCHFR case is 2.5 pcm/s, and the limiting RCS pressure and LHGR cases is the maximum 12 pcm/s.

- Time in cycle: The BOC core conditions are implemented in the limiting CRA withdrawal cases. The least negative reactivity coefficients occur at the BOC, and provide the least amount of feedback to mitigate the power increase due to a CRA withdrawal.
- Conservative scram characteristics are used, including a maximum time delay and holding the most reactive rod out of the core.
- The turbine bypass system is not credited in this analysis to minimize heat removal by the secondary side.
- Allowances for instrument inaccuracy are provided for setpoints of mitigating systems in accordance with RG 1.105.
- The limiting axial and radial power shapes are used in the subchannel analysis to ensure a conservative evaluation of the SAFDLs.

The results from the thermal hydraulic evaluation are used as input to the subchannel analysis to determine the limiting MCHFR and LHGR for this event. The subchannel evaluation model is discussed in Section 15.0.2.

15.4.3.4.3 Results

RAI 15.04.01-3, RAI 15.04.03-1

The sequence of events for a single CRA withdrawal that results in the minimum MCHFR is provided in Table 15.4-7. The sequence of events for a single CRA withdrawal that results in the maximum RCS pressure is provided in Table 15.4-29. Figure 15.4-13 through Figure 15.4-19 and Figure 15.4-35 show the transient behavior of key parameters for this event.

The withdrawal of a single CRA that results in a limiting MCHFR has an initial power of 75 percent. The withdrawal of the CRA results in a reactivity insertion that increases reactor power. The power increase leads to a rise in RCS temperature, pressurizer level, and RCS pressure. The CRA misalignment with the rest of the bank causes an asymmetry in the core, where power peaking increases in the location of the withdrawn CRA. Reactivity feedback from the rising fuel and moderator temperatures partially counteracts the reactivity insertion, slowing the power increase. For CRM cases with higher reactivity insertion rates, the MPS trips the reactor on high reactor power or high power rate. These cases are non-limiting because the reactor is tripped before the maximum amount of reactivity can be inserted. The limiting combination of reactivity insertion and reactivity feedback produces the maximum possible power increase without reaching the high reactor power or high power rate limits. The power increase is terminated by the high hot leg temperature trip. The RCS pressure reaches the high pressurizer pressure limit simultaneously.

RAI 15.04.03-1, RAI 15.04.03-6

The MPS high hot leg temperature signal trips the reactor and actuates the DHRS. The most limiting MCHFR (Figure 15.4-35) occurs at the moment before the power begins to decrease. The MCHFR remains above the design limit, and no fuel centerline melting is predicted for the withdrawal of a single CRA. The LHGR calculated for the single CRA withdrawal is below the calculated limits for cladding strain. The maximum RCS pressure occurs approximately 7 seconds later, and is followed by a steady decrease in RCS temperature and pressure. The limiting RCS pressure for a withdrawal of a single CRA occurs in a case that has an initial power of 102 percent, and assumes a loss of normal AC power occurring at the reactor trip. The loss of normal AC power contributes to a higher pressure peak due to the isolation of the secondary side, which minimizes the heat removal capability of the secondary side. This limiting pressure is plotted in Figure 15.4-20, and shows margin to the RPV design limit. The limiting LHGR occurs in a single CRA withdrawal case that has an initial power of 102 percent. The maximum reactivity insertion rate is assumed, which does not cause a high power rate trip like cases at lower initial powers. The pressurizer spray is assumed to function normally, which delays the trip on high pressure until after the power has peaked. This case maximizes power, resulting in a limiting LHGR. The LHGR remains below the design limit, so no fuel centerline melting is predicted for the single CRA withdrawal.

15.4.3.5 Control Rod Assembly Drop Analysis

15.4.3.5.1 Evaluation Models

The thermal hydraulic analysis of the plant response to a CRA drop is performed using NRELAP5. The NRELAP5 model is based on the design features of a NuScale module. The non-LOCA NRELAP5 model is discussed in Section 15.0.2. The relevant boundary conditions from the NRELAP5 analyses are provided to the downstream subchannel CHF analysis.

The subchannel core CHF analysis is performed using VIPRE-01. VIPRE-01 is a subchannel analysis tool designed for general-purpose thermal-hydraulic analysis under normal operating conditions, operational transients, and events of moderate severity. See Section 15.0.2.3 for a discussion of the VIPRE-01 code and evaluation model.

15.4.3.5.2 Input Parameters and Initial Conditions

RAI 15.04.03-6

A spectrum of initial conditions is analyzed to find the limiting MCHFR and limiting LHGR conditions for a single or multiple CRA drop. The initial conditions of the CRA drop evaluation result in a case that produces a conservative calculation of both MCHFR and LHGR. Key inputs and the associated biases for the limiting CRA drop analysis are provided in Table 15.4-10. The following initial conditions and assumptions ensure that the results have sufficient conservatism.

RAI 15.04.03-6

- The initial power for the limiting MCHFR ~~conditions~~and LHGR case is 102 percent of nominal power. Twenty-five percent, 50 percent, 75 percent, and 102 percent of nominal power are analyzed to find the limiting conditions for MCHFR and LHGR.

RAI 15.04.03-6

- Dropped CRA conditions: The CRA drop scenarios are analyzed to find the worst power peaking change after the drop. These relative peaking changes are applied to the entire transient in the subchannel analysis to ensure a conservative calculation of MCHFR. Due to the size of the NuScale core and relative rod worth, a CRA drop from higher power conditions will result in a substantial loss of power and subsequent negative power rate trip such that the transient power level remains well below the initial power level. Since the worst power peaking conditions are applied to the entire limiting CRA drop transient, the limiting MCHFR occurs at the transient initiation when initialized at 102 percent power. This case also results in the maximum LHGR.
- Time in cycle: The EOC core conditions are implemented in the limiting CRA drop cases. The most negative reactivity coefficients occur at the EOC and provide the most reactivity feedback to mitigate the power decrease due to a CRA drop.
- Conservative scram characteristics are used, including a maximum time delay and holding the most reactive rod out of the core.
- The turbine bypass system is not credited in this analysis to minimize heat removal by the secondary side.
- Allowances for instrument inaccuracy are provided for setpoints of mitigating systems in accordance with RG 1.105.
- The limiting axial and radial power shapes are used in the subchannel analysis to ensure a conservative evaluation of the SAFDLs.

The results from the thermal hydraulic evaluation are used as input to the subchannel analysis to determine the limiting MCHFR and LHGR for this event. The subchannel evaluation model is discussed in Section 15.0.2.

15.4.3.5.3 Results

RAI 15.04.03-1, RAI 15.04.03-6

The sequence of events for the bounding single CRA drop is provided in Table 15.4-9. Figure 15.4-21 through Figure 15.4-27 and Figure 15.4-36 show the transient behavior of key parameters for a single CRA drop. Following a CRA drop in the NuScale reactor, there is a rapid drop in the core reactivity and power. The high power rate limit is reached just after 1 second into the transient. The MPS sends a reactor trip signal, terminating the event. At lower powers, the power decrease is less pronounced, and the reactor does not trip. In the lower power cases, the regulating CRA bank brings the reactor back to the initial power after an initial power overshoot. However, these cases are non-limiting with respect to MCHFR and LHGR.

RAI 15.04.03-1

Exceeding the RPV design pressure is not a concern for the limiting rod drop case, which is demonstrated in the RCS pressure plot. The MCHFR for the limiting case, Figure 15.4-36, remains above the design limit. The LHGR calculated for the limiting rod drop case is below the limits for fuel melting and cladding strain.

RAI 15.04.03-6

Table 15.4-10: Key Inputs for CRA Drop with Limiting MCHFR and LHGR

Parameter	Nominal	Bias
Initial power	160 MW	+2%
RCS flow rate	See Table 15.0-6 for range	1176 lbm/s (low)
RCS pressure	1850 psia	+70 psia
RCS average temperature	545 °F	+10 °F
MTC	-43.0 pcm/°F	Most Negative
DTC	-2.25 pcm/° F	Most Negative

RAI 15.04.03-6

Table 15.4-32: Key Inputs for Limiting Linear Heat Generation Rate Case (15.4.3 Control Rod Misoperation, Single Control Rod Assembly Withdrawal)

Parameter	Nominal	Bias
Initial power	160 MW	+2%
RCS flowrate	See Table 15.0-6 for range	1175 lbm/s (low[1])
RCS pressure	1850 psia	+70 psia
Pressurizer level	60%	Nominal
MTC	-7.0 pcm/°F	Most Positive
FTC	-1.40 pcm/°F	Least Negative

[1] RCS flow rate is near the minimum for 102% power, and conservatively below the nominal range for 100% power.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0618-60389

NuScale Power, LLC
1100 NE Circle Blvd., Suite 200 Corvalis, Oregon 97330, Office: 541.360.0500, Fax: 541.207.3928
www.nuscalepower.com

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

1. I am the Director, Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale.
2. I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:
    a. The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.
    b. The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.
    c. Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.
    d. The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.
    e. The information requested to be withheld consists of patentable ideas.
3. Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying Request for Additional Information response reveals distinguishing aspects about the process and method by which NuScale develops its design basis analyses.

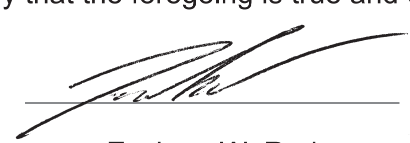
    NuScale has performed significant research and evaluation to develop a basis for this process and method and has invested significant resources, including the expenditure of a considerable sum of money.

    The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

    If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

4. The information sought to be withheld is in the enclosed response to NRC Request for Additional Information No. 422, eRAI No. 9512. The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.
5. The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).
6. Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:
    a. The information sought to be withheld is owned and has been held in confidence by NuScale.
    b. The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.
    c. The information is being transmitted to and received by the NRC in confidence.
    d. No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.
    e. Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on June 12, 2018.



Zackary W. Rad