RAIO-0518-60192

May 24, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 409 (eRAI No. 9509) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 409 (eRAI No. 9509)," dated April 05, 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 Enclosure to this letter contains NuScale's response to the following RAI Questions from NRC eRAI No. 9509:

- 15.04.02-3
- 15.04.02-4

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

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

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9509

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NuScale Response to NRC Request for Additional Information eRAI No. 9509

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

eRAI No.: 9509
Date of RAI Issue: 04/05/2018

NRC Question No.: 15.04.02-3

General Design Criterion (GDC) 13, "Instrumentation and control," in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, requires the provision of instrumentation to monitor variables and systems over their anticipated ranges of normal operation, including the effects of anticipated operational occurrences (AOOs), and of appropriate controls to maintain listed variables and systems within prescribed operating ranges. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," (SRP) Section 15.4.2, "Uncontrolled Control Rod Assembly Withdrawal at Power," provides the staff guidance in determining compliance with GDC 13, among several other GDC, and guides the reviewer to evaluate the sequence of events, including actuations of protection systems, to determine whether the sequence of events is justified, based upon the expected values of the relevant monitored parameters and instrument indications.

The May 24, 2017, response to RAI 8764 (ADAMS Accession No. ML17144A450) provided FSAR markups for FSAR Section 15.2, "Uncontrolled Control Rod Assembly Withdrawal at Power," and the related results. The markups of FSAR Table 15.4-3, "Sequence of Events (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)," show that the high reactor power limit is reached at 186 seconds. FSAR Section 15.4.2.3.3 also states that the high hot leg temperature limit, the high pressurizer limit, and high power limit are all reached during the reactor trip delay time.

However, the revised Figure 15.4-7, "Reactor Power (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)," shows that the reactor power remains under the high reactor power limit of 120 percent, which is consistent with the results presented in engineering calculation (EC)-0000-1999, "Uncontrolled Control Rod Assembly Withdrawal At Power Transient Analysis," the calculation supporting FSAR Section 15.2, which the staff audited. Therefore, update FSAR Table 15.4-3 and FSAR Section 15.4.2.3.3 to reflect the fact that the high reactor power limit is not reached.

NuScale Response:

FSAR Section 15.4.2.3.3 incorrectly described the high reactor power trip as actuating during the limiting uncontrolled control rod assembly (CRA) withdrawal event with respect to minimum critical heat flux ratio (MCHFR). Although the high reactor power trip does actuate for other uncontrolled CRA withdrawal cases, it does not actuate for the limiting MCHFR case. The text in FSAR Section 15.4.2.3.3 and Table 15.4-4 have been updated to correct this error. An additional inconsistency was corrected in Table 15.4-4 as shown in the markup.

Impact on DCA:

FSAR Section 15.4.2 and Table 15.4-4 have been revised as described in the response above and as shown in the markup provided in this response.

uncontrolled CRA withdrawal with respect to RCS pressure is provided in Table 15.4-27. Figure 15.4-6 through Figure 15.4-11 show the transient behavior of key parameters for an uncontrolled CRA withdrawal.

RAI 15.04.02-1, RAI 15.04.02-1S1, RAI 15.04.02-2, RAI 15.04.02-3

The withdrawal of the regulating bank results in a reactivity insertion that increases reactor power. The power increase leads to a rise in RCS temperature, pressurizer level, and RCS pressure. Feedback from the rising fuel and moderator temperatures partially counteracts the reactivity insertion, slowing the power increase. For uncontrolled CRA withdrawal cases with higher reactivity insertion rates, the MPS trips the reactor on high pressurizer pressure 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 prior to trip. The power increase in the limiting MCHFR case is terminated by a reactor trip after a signal delay. The high hot leg temperature limit~~,~~ and the high pressurizer pressure limit~~, and high power limit~~ are ~~all~~ reached during the reactor trip delay time. The MPS trips the reactor and actuates the DHRS during this event. The most limiting MCHFR occurs at the time of the power peak. The MCHFR remains above the design limit, and no fuel centerline melting is predicted for the uncontrolled CRA withdrawal.

The maximum RCS pressure case is an uncontrolled CRA withdrawal at power with a loss of normal AC power at transient initiation. The pressure for the maximum pressure case is demonstrated in Figure 15.4-12. The loss of AC power at the beginning of the transient trips the turbine and stops feedwater, reducing the heat removal by the secondary side. Simultaneously, the reactivity insertion causes a rapid rise in power. The reactor trips on high power rate, reaching the high pressurizer pressure setpoint almost simultaneously. The pressure continues to rise after the reactor trip, and peaks at the time a reactor safety valve (RSV) opens. Following the RSV opening and reactor trip, the RCS temperature and pressure steadily decrease. The maximum RCS pressure stays below the RPV design limit.

The uncontrolled CRA withdrawal at power cases that result in a reactor trip, actuate DHRS, and maintain stable core cooling.

15.4.2.4 Radiological Consequences

The normal leakage related radiological consequences of this event are bounded by the design basis accident analyses presented in Section 15.0.3.

15.4.2.5 Conclusions

The two applicable acceptance criteria for this AOO are met for the limiting uncontrolled CRA withdrawal cases. These acceptance criteria, followed by how the NuScale Power Plant design meets them are listed below.

1) The thermal margin limits departure from nucleate boiling ratio for pressurized water reactors as specified in SRP Section 4.4, subsection II.1, are met.

RAI 15.04.02-1, RAI 15.04.02-2, RAI 15.04.02-3

Table 15.4-4: Sequence of Events MCHFR Case - 75% Power (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)

Event	Time [s]
CRA bank begins to withdraw	0
High hot leg temperature limit reached	178
High pressurizer pressure limit reached	184
~~High reactor power limit reached~~	~~186~~
Reactor trip actuated	186
MCHFR occurs	187
Maximum RCS pressure occurs	191
DHRS valves fully open	21~~7~~6

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NRC Question No.: 15.04.02-4

GDC 10, "Reactor design," 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 AOOs. SRP Section 15.4.2 provides the staff guidance in determining compliance with GDC 10, among several other GDC, and guides the reviewer to ascertain that a full range of AOO conditions are analyzed and that the AOO calculation models are adequate. In addition, the specific acceptance criteria to ensure the SAFDLs are met include the departure from nucleate boiling ratio (for NuScale, minimum critical heat flux ratio [MCHFR]) being met and fuel centerline temperatures not exceeding the melting point.

FSAR Tier 2, Section 15.4.2.3.2, and Table 15.4-4, "Key Inputs for Limiting MCHFR Case (15.4.2 Uncontrolled CRA Withdrawal at Power)," discuss and provide input parameters and initial conditions for the limiting minimum critical heat flux ratio (MCHFR) case. FSAR Tier 2, Section 15.4.2.3.3, discusses the results for the limiting MCHFR and reactor coolant system pressure cases. 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 event results for the limiting LHGR case.

NuScale Response:

FSAR Section 15.4.2 did not describe the case that was used to determine the limiting linear heat generation rate for the uncontrolled control rod assembly withdrawal at power. A description of the inputs and high-level discussion of the results have been added to the FSAR as shown in the attached markups.

Impact on DCA:

FSAR Section 15.4.2 and Table 15.4-31 have been revised as described in the response above and as shown in the markup provided in this response.

described in Reference 15.4-1. See Section 15.0.2 for a discussion of the VIPRE-01 code and evaluation model.

15.4.2.3.2 Input Parameters and Initial Conditions

RAI 15.04.01-3, RAI 15.04.02-4

A spectrum of initial conditions is analyzed to find the limiting reactivity insertion due to an uncontrolled CRA withdrawal. Key inputs of the uncontrolled CRA withdrawal evaluation are provided in Table 15.4-5 for the limiting MCHFR case, and in Table 15.4-28 for the limiting RCS pressure case, and Table 15.4-31 for the limiting linear heat generation rate (LHGR) case. The following initial conditions and assumptions ensure that the results have sufficient conservatism.

RAI 15.04.02-1, RAI 15.04.02-2, RAI 15.04.02-4

- Initial power level: 25 percent, 50 percent, 75 percent, and 102 percent of nominal power are analyzed in the uncontrolled CRA withdrawal evaluation. The power level for the limiting MCHFR and RCS pressure cases is 75 percent of nominal power. The power level for the limiting RCS pressure and LHGR cases isand 102 percent of nominal power, respectively.

RAI 15.04.02-1, RAI 15.04.02-2, RAI 15.04.06-1

- Reactivity insertion rate: The positive reactivity inserted by the CRA withdrawal is modeled as a constant reactivity addition beginning at the transient initiation. The maximum rod speed of 15 inches/min corresponds to a maximum reactivity insertion of 21 pcm/s. However, to bound the reactivity insertion from possible boron dilution scenarios, a maximum reactivity insertion of 35 pcm/s is analyzed.
  - The reactivity insertion rate for the limiting MCHFR case is 0.9 pcm/s.
  - The reactivity insertion rate for the limiting RCS pressure case is 15.2 pcm/s.

RAI 15.04.02-4

  - The reactivity insertion rate for the limiting LHGR case is 35.0 pcm/s.
- Time in cycle: The BOC core conditions are implemented in the limiting uncontrolled 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 an uncontrolled CRA withdrawal.
- The turbine bypass system is not credited in this analysis to minimize heat removal by the secondary side.
- Conservative scram characteristics are used, including a maximum time delay, holding the most reactive rod out of the core, and using a bounding control rod drop rate.
- Allowances for instrument inaccuracy are accounted for in the analytical limits of mitigating systems in accordance with the guidance provided in Regulatory Guide (RG) 1.105.

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

15.4.2.3.3 Results

RAI 15.04.01-3

The sequence of events for a limiting uncontrolled CRA withdrawal with respect to MCHFR is provided in Table 15.4-4. The sequence of events for a limiting uncontrolled CRA withdrawal with respect to RCS pressure is provided in Table 15.4-27. Figure 15.4-6 through Figure 15.4-11 show the transient behavior of key parameters for an uncontrolled CRA withdrawal.

RAI 15.04.02-1, RAI 15.04.02-1S1, RAI 15.04.02-2, RAI 15.04.02-3

The withdrawal of the regulating bank results in a reactivity insertion that increases reactor power. The power increase leads to a rise in RCS temperature, pressurizer level, and RCS pressure. Feedback from the rising fuel and moderator temperatures partially counteracts the reactivity insertion, slowing the power increase. For uncontrolled CRA withdrawal cases with higher reactivity insertion rates, the MPS trips the reactor on high pressurizer pressure 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 prior to trip. The power increase in the limiting MCHFR case is terminated by a reactor trip after a signal delay. The high hot leg temperature limit~~,~~ and the high pressurizer pressure limit~~, and high power limit~~ are ~~all~~ reached during the reactor trip delay time. The MPS trips the reactor and actuates the DHRS during this event. The most limiting MCHFR occurs at the time of the power peak. The MCHFR remains above the design limit, and no fuel centerline melting is predicted for the uncontrolled CRA withdrawal.

The maximum RCS pressure case is an uncontrolled CRA withdrawal at power with a loss of normal AC power at transient initiation. The pressure for the maximum pressure case is demonstrated in Figure 15.4-12. The loss of AC power at the beginning of the transient trips the turbine and stops feedwater, reducing the heat removal by the secondary side. Simultaneously, the reactivity insertion causes a rapid rise in power. The reactor trips on high power rate, reaching the high pressurizer pressure setpoint almost simultaneously. The pressure continues to rise after the reactor trip, and peaks at the time a reactor safety valve (RSV) opens. Following the RSV opening and reactor trip, the RCS temperature and pressure steadily decrease. The maximum RCS pressure stays below the RPV design limit.

RAI 15.04.02-4

The maximum LHGR case for an uncontrolled CRA withdrawal at power assumes a loss of normal AC power occurring at the reactor trip to allow power to be maximized. The rapid increase in power causes a high power rate trip. This case results in the limiting power peak and thus a higher fuel temperature as evidenced by the LHGR. The LHGR remains below the design limit, so no fuel centerline melting is predicted for the uncontrolled CRA withdrawal.

The uncontrolled CRA withdrawal at power cases that result in a reactor trip, actuate DHRS, and maintain stable core cooling.

RAI 15.04.02-4

Table 15.4-31: Key Inputs for Limiting Linear Heat Generation Rate Case (15.4.2 Uncontrolled Control Rod Assembly Withdrawal at Power)

Parameter	Nominal	Bias
Initial power	160 MW	+2%
RCS flowrate	See Table 15.0-6 for range	1175.0 lbm/s (low[1])
RCS pressure	1850 psia	+70 psia
Pressurizer level	60%	+8%
MTC	0.0 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.