NuScale Power

RAIO-0318-59269

March 26, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 168 (eRAI No. 8977) on the NuScale Design Certification Application

REFERENCES:

1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 168 (eRAI No. 8977)," dated August 12, 2017
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 168 (eRAI No.8977)," dated October 11, 2017

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

The Enclosure to this letter contains NuScale's supplemental response to the following RAI Question from NRC eRAI No. 8977:

- 19-27

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

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

Sincerely,

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

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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8977

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8977

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

eRAI No.: 8977
Date of RAI Issue: 08/12/2017

NRC Question No.: 19-27

Regulatory Basis
10 CFR 52.47(a)(27) states that a Design Certification (DC) application must contain a Final Safety Analysis Report (FSAR) that includes a description of the design-specific Probabilistic Risk Assessment (PRA) and its results. 10 CFR 52.47(a)(23) states that a DC application for light-water reactor (LWR) designs must contain an FSAR that includes a description and analysis of design features for the prevention and mitigation of severe accidents (e.g., challenges to containment integrity caused by core- concrete interaction, steam explosion, high-pressure melt ejection, hydrogen combustion, and containment bypass). For staff to make a finding that the applicant has performed an adequate evaluation of the risk from severe accidents in accordance with Standard Review Plan (SRP) 19.0, the applicant is requested to respond to the questions below.

Request for additional information

a. The applicant used a large release frequency metric of less than 10-6 large releases per year and defined a large release as an acute exposure of greater than 200 rem to an individual located at a distance of 0.167 miles from the reactor for 96 hours. SRP 19.0 directs the staff to determine whether the applicant has adequately demonstrated that the risk associated with the design compares favorably against the Commission's goals. In order to make this finding, the applicant is requested to add information to Chapter 19 of the NuScale FSAR to demonstrate its large release frequency metric, including its large release definition, is equivalent to or less than the Commission's Safety Goal Policy's quantitative health objective for prompt fatality risk.
b. The applicant is requested to clarify the text in Chapter 19 of the FSAR by adding the following:
    a. Identify the scenarios in which the applicant compared the predicted dose directly against the large release definition of 200 rem at 0.167 miles to classify whether the scenario results in a large release.
    b. Identify the scenarios in which the applicant compared the predicted radionuclide release against the MACCS back-calculated radionuclide release equivalent to the large release definition of 200 rem at 0.167 miles to classify whether the scenario results in a large release.

c. For at-power accidents, "Probabilistic Risk Assessment Large Release Frequency Definition," ER- P000-7004-R0, and "Release Fraction Determination for PRA Large Release," ER-P000-7005, describe (1) the use of MACCS to translate the large release definition of 200 rem over 96 hours into an equivalent environmental radionuclide release and (2) a hand calculation showing that releases from a leaking containment (as opposed to a failed containment) are smaller than this (i.e., less than a large release). In the FSAR, the applicant used the iodine release fraction as the metric for this comparison. The applicant is requested to add clarifying information to Chapter 19 of the FSAR describing how the following were addressed in this comparison: (1) other aspects of the environmental release such as release timing, release rate, other radionuclides (e.g., cesium) and (2) other potentially important phenomena such as changes in wind direction during the 96- hour exposure period.

d. "Code Manual for MACCS2," NUREG/CR-6613, Vol. 1, states "The dispersion of a plume of material released in the wake of a building is subject to a large degree of uncertainty. For that reason, MACCS should not be used for estimating doses at distances of less than 0.5 km [0.31 miles] from laboratory or industrial-facilities." The applicant's discussion on page 10 of "Probabilistic Risk Assessment Large Release Frequency Definition," ER-P000-7004-R0, indicates that the applicant recognized this uncertainty and attempted to address it by applying a building wake model to both the short and long faces of the reactor building and identifying the largest dose. The applicant is requested to add information to Chapter 19 of the FSAR describing its validation of the assumptions and input used in its MACCS predictions of plume concentration at 0.167 miles from the reactor for its large release assessment. The information should include a discussion of its parameterization of the spatially dependent dispersion parameters (sigma-y and sigma-z) in MACCS's Gaussian plume model and its treatment of meteorological phenomena such as building wake, plume lift, and meander, as applicable.

NuScale Response:

NuScale is supplementing its response to RAI 8977 (Question 19-27, Item c) provided in letter RAIO-1017-56550, dated October 11, 2017. This supplemental response is provided in response to discussions with the NRC in a public meeting held on January 16, 2018. The NuScale response to Item c that was provided in RAIO-1017-56550 is replaced, in its entirety, with the following response:

Item c): The following provides additional clarifications to support the MACCS analysis that produces an acute 200 rem whole body dose at the NuScale site boundary. Using the methodology outlined in Steps 1 through 5 below, an acute 200 rem whole body dose is determined to correspond to a total iodine core inventory release fraction to the environment of 2.9 percent. This iodine group release fraction threshold is then used to distinguish between Release Categories (RCs) 1 and 2.

1. Radionuclide groups are scaled relative to iodine, consistent with Table 11 of SAND2011-0128 for the gap release and in-vessel release phase based on PWR low burnup uranium dioxide fuel, and released directly to the environment.

    - The 69 radionuclides evaluated by the State-of-the-Art Reactor Consequence Analysis (SOARCA) are considered in the release to the environment.
    - The 69 radionuclides are grouped consistent with the SOARCA grouping.
    - The initial core inventory of the 69 radionuclides is consistent with the best estimate core inventory provided in Table B-5 of the Environmental Report.

2. The release begins immediately following core damage, which maximizes radionuclide inventory by minimizing radioactive decay.

    - Fission product pipe deposition, building retention (i.e., building filtration system or biological shield), and reactor pool scrubbing are not considered.
    - The release is assumed to occur at the ground level from the short face of the reactor building, which conservatively estimates the initial relative radionuclide concentration when building wake effects are considered.
    - An elevated release and plume buoyancy are not credited to decrease ground level air concentrations.
    - Plume meander at low wind speeds and stable atmospheric conditions is not credited to reduce the relative radionuclide concentration during plume transport and dispersion.

3. The release to the environment is assumed to have a two-hour duration which reduces the effect of wind shifts during the release.

    - The total release is divided into two equal one-hour segments. The release rate is held constant throughout each segment (i.e., each hour of the release contains the same release fraction).
    - The hourly wind direction, wind speed, atmospheric stability, and precipitation rate are based on meteorological data described in Section B.1.6.3 of the Environmental Report.

4. Dose receptors are assumed to be present at all azimuthal directions on the site boundary; they are also assumed to remain stationary.

    - A 96-hour absorption window at the site boundary is assumed, which corresponds to an upper bound for the range of time factors discussed in the Environmental Protection Agency document “PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents”
    - Protective actions are not considered (e.g., dose receptors do not perform sheltering or evacuation).

5. The acute 200 rem whole body dose is the mean dose over one year of MACCS meteorological trials. For each trial, the reported dose is the peak dose on the spatial grid.

The SAND2011-0128 release fractions are comparable to the NuScale design-specific release fractions from the design basis source term (FSAR Table 12.2-29). Additionally, following the methodology outlined in Steps 1 through 5, and replacing the SAND2011-0128 source term with the NuScale design basis source term release, results in a similar iodine large release fraction. Therefore, the SAND2011-0128 source term is judged to be applicable to the NuScale design for the purpose of determining the large release fraction threshold to the environment.

The following provides additional clarifications to support the evaluation of RC1. Rather than a MACCS calculation of RC1, a hand evaluation was used to determine the bounding environmental release associated with Technical Specification leakage from an intact containment.

- Radionuclide groups are scaled relative to iodine, consistent with Table 11 of SAND2011-0128 for the gap release and in-vessel release phase, based on PWR low burnup uranium dioxide fuel, such that the entire core inventory of iodine is released to containment (i.e., the SAND2011-0128 release fractions for all radionuclide groups are multiplied by approximately 3.3, with an upper bound of a 100 percent release for all radionuclide groups).

- The release to containment is assumed to remain airborne, and deposition in containment is not credited to reduce the airborne fraction of radionuclides in containment.

- All airborne radionuclides in containment are assumed to release directly to the environment (i.e., bypassing the reactor building) at the Technical Specification limit of 0.2 percent containment air weight per day over the 96-hour release duration.

As described in Item b) part a) of this response, containment bypass sequences that are not directly compared to the acute 200 rem whole body dose limit using MACCS calculations are conservatively assumed to result in large releases. These sequences are considered to be RC2.

FSAR Section 19.1.4.2.1.4 has been revised to provide additional detail on the evaluation of RC1 and RC2 and to reorganize the key points of the evaluation for clarity.

Impact on DCA:

FSAR Section 19.1.4.2.1.4 has been revised as described in the response above and as shown in the markup provided in this response.

Because the CNV is maintained at a vacuum, so that CNV leaks or isolation failures can be readily detected and addressed, small penetration failures or leaks are not considered as contributors to containment isolation failure.

Table 19.1-24 summarizes containment penetrations, the isolation method and treatment in the PRA.

19.1.4.2.1.4 Release Categories

The Level 2 event tree, provided as Figure 19.1-15, is completed by defining the end state of each sequence. The figure provides three end states, "CD", "NR" and "LR." The end state "CD" allows quantification of the CDF as it summarizes the sequences transferred from the Level 1 event trees. The end state "NR" represents a core damage sequence with intact containment; for this end state, the potential radionuclide release is due to allowable leakage as defined by the Technical Specifications. The "LR" end state represents a large release. Due to the small core used in the design, additional release categories to reflect a range of release possibilities were judged to be unnecessary. The release categories are:

- RC1 is core damage with successful containment isolation.
- RC2 is core damage with containment bypass or failure of containment isolation.

RAI 19-27S1

The large release frequency (LRF) is the quantified result of the Level 2 PRA, and is used to demonstrate conformance with the safety goal promulgated in NRC policy statement (Reference 19.1-36). While various definitions of “large release” have been considered, there is not an established consensus definition. The definition used in the NuScale PRA is based on a threshold radionuclide dose that could result in early injuries.

RAI 19-27S1

Specifically, NUREG-0396 (Reference 19.1-9) specifies 200 rem whole body dose as the dose at which significant early injuries start to occur. This dose was used as the basis for defining a “large release” in terms of a hypothetical individual located at the site boundary; in the NuScale PRA, the “site boundary” is a best-estimate distance and is defined as one-half of the shortest site dimension, which is approximately 884 feet (0.167 miles).

RAI 19-27S1

Based on simulation results using the MACCS code (Reference 19.1-10), and following Steps 1 through 5 below, it was determined that a release fraction of 2.9 percent of the iodine core inventory would cause an acute 200 rem whole body (red marrow) dose at the site boundary. MACCS plume dispersion results were compared to and found consistent with those provided by the ARCON96 code (described in Section 15.0.2) at and beyond the site boundary.

RAI 19-27S1

1) Radionuclide groups are scaled relative to iodine, consistent with Table 11 of SAND2011-0128 (Reference 19.1-63) for the gap release and in-vessel release phase based on PWR low burn-up uranium dioxide fuel, and released directly to the environment.

- The 69 radionuclides evaluated by the State-of-the-Art Reactor Consequence Analysis (SOARCA) (Reference 19.1-66) are considered in the release to the environment.
- The 69 radionuclides are grouped consistent with the SOARCA analysis.
- The initial core inventory of the 69 radionuclides is consistent with the best estimate core inventory provided in Table B-5 of the Environmental Report (Reference 19.2-16).

RAI 19-27S1

2) The release begins immediately following core damage; this maximizes radionuclide inventory by minimizing radioactive decay.

- Fission product pipe deposition, building retention (i.e., building filtration system or biological shield), and reactor pool scrubbing are not considered.
- The release is assumed to occur at the ground level from the short face of the RXB, which conservatively estimates the initial relative radionuclide concentration when building wake effects are considered.
- An elevated release and plume buoyancy are not credited to decrease ground level air concentrations.
- Plume meander at low wind speeds and stable atmospheric conditions is not credited to reduce the relative radionuclide concentration during plume transport and dispersion.

RAI 19-27S1

3) The release to the environment is assumed to have a two-hour duration which reduces the effect of wind shifts during the release.

- The total release is divided into two equal one-hour segments. The release rate is constant throughout each segment (i.e., each hour of the release contains the same release fraction).
- The hourly wind direction, wind speed, atmospheric stability, and precipitation rate are based on meteorological data described in Section B.1.6.3 of the Environmental Report.

RAI 19-27S1

4) Dose receptors are assumed to be present at all azimuthal directions on the site boundary; they are also assumed to remain stationary.

- A 96-hour absorption window at the site boundary is assumed, corresponding to an upper bound for the range of time factors discussed in Environmental Protection Agency, "PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents" (Reference 19.1-40).

- Protective actions are not considered (e.g., dose receptors do not perform sheltering or evacuation).

RAI 19-27S1

5) The acute 200 rem whole body dose is the mean dose over one year of MACCS meteorological trials. For each trial, the reported dose is the peak dose on the spatial grid.

RAI 19-27S1

The 2.9 percent iodine group release fraction threshold is then used to distinguish between Release Categories 1 and 2.

RC1: core damage with successful containment isolation.

RAI 19-27, RAI 19-27S1

To ensure RC1 sequences are below the threshold of a large release, a bounding analysis is employed to envelope intact containment sequences. A calculation of the maximum possible iodine release fraction to the environment from a single module accident with intact containment, assuming the Technical Specification leak rate limit, is calculated to be 0.8 percent of the iodine core inventory; this is well below the threshold of a large release~~, which is defined in RC2~~. The leakage is calculated for a 96 hour time period, with the following conservatisms:

RAI 19-27S1

- ~~Core inventory is completely and instantaneously vaporized inside containment and remains airborne.~~
- ~~No credit for iodine or xenon deposition in the reactor vessel.~~
- ~~No credit for radionuclide deposition on the walls of the CNV.~~
- ~~Containment leakage rate is the maximum allowable at 0.20% of containment air weight per day over the entire release.~~
- ~~No credit for the biological shield above the reactor pool in deflecting or containing a release of radionuclides from an NPM.~~
- ~~No credit for reactor pool scrubbing.~~
- ~~No credit for RXB filtration systems.~~
- ~~No credit for RXB spray system.~~

RAI 19-27S1

- Radionuclide groups are scaled relative to iodine, consistent with Table 11 of SAND2011-0128 for the gap release and in-vessel release phase, based on PWR low burnup uranium dioxide fuel, such that the entire core inventory of iodine is released to containment (i.e., the SAND2011-0128 release fractions for all radionuclide groups are multiplied by approximately 3.3, with an upper bound of a 100 percent release for all radionuclide groups).

- The release to containment is assumed to remain airborne, and deposition in containment is not credited to reduce the airborne fraction of radionuclides in containment.
- All airborne radionuclides in containment are assumed to release directly to the environment (i.e., bypassing the RXB) at the Technical Specification limit of 0.2 percent containment air weight per day over the entire release duration.

RC2: core damage with containment bypass or failure of containment isolation

RAI 19-27S1

This release categoryRC represents the release associated with a core damage sequence that does not have successful isolation of the CNV, i.e., not categorized as "RC1." These sequences have a Level 2 end state of RC2 and are associated with a "large" release.

RAI 19-27S1

The large release frequency (LRF) is the quantified result of the Level 2 PRA, and is used to demonstrate conformance with the safety goal promulgated in NRC policy statement (Reference 19.1-36). While various definitions of "large release" have been considered, there is not an established consensus definition. The definition used in the PRA is based on a threshold radionuclide dose that could result in early injuries.

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Specifically, NUREG-0396 (Reference 19.1-9) specifies 200 rem whole body dose as the dose at which significant early injuries start to occur. This dose was used as the basis for defining a "large release" in terms of a hypothetical individual located at the site boundary; in the PRA, the "site boundary" is a best-estimate distance and is defined as one-half of the shortest site dimension, which is approximately 884 feet (0.167 miles). Based on simulation results using the MACCS code (Reference 19.1-10) a release fraction of 2.9 percent of the Iodine core inventory would cause an acute 200 rem whole body (red marrow) dose at the site boundary using 2006 Peach Bottom meteorology under the following bounding assumptions:

RAI 19-27RAI 19-27S1

- Target person is standing in the middle of the release plume, at the site boundary,

RAI 19-27

- Building wake effects are modeled from the short face of the RXB to maximize initial radionuclide concentration,
- Release occurs over a 2-hour period to minimize reduction in radionuclide concentration due to wind shift during release,

RAI 19-27

- Release occurs immediately following core damage to maximize radionuclide inventory by minimizing radioactive decay,

- No credit for fission product pipe deposition, building retention (i.e., building filtration system or biological shield),
- No credit for reactor pool scrubbing,
- No credit for elevated release or plume buoyancy to decrease ground level air concentrations,

RAI 19-27

- No credit for reduced radionuclide concentration due to plume meander at low wind speeds,
- 96-hour absorption window at the site boundary, which corresponds to an upper bound for the range of time factors discussed in Reference 19.1-40.

RAI 19-27RAI 19-27S1

The following best-estimate assumptions were also used:

RAI 19-27

- Radionuclide classes are scaled relative to iodine based on the guidelines in Table 11 of SAND2011-0128 (Reference 19.1-63) for the gap release and in-vessel release phase of the proposed source term for PWRs using low burnup uranium dioxide,

RAI 19-27

- Release rate is constant throughout the two-hour release (i.e., each hour of the release contains the same release fraction),

RAI 19-27

- Release occurs in hourly segments and travels in the direction of the wind at the time of release,

RAI 19-27

- Wind direction, wind speed, and rain rate change hourly based on meteorological data.

RAI 19-27RAI 19-27S1

MACCS plume dispersion results were compared to and found consistent with those provided by the ARCON96 code (described in FSAR Section 15.0.2) at and beyond the site boundary.

19.1.4.2.1.5 Data Sources and Analysis

This section provides the sources of numerical data used in the Level 2 PRA. Initiating event frequencies, component failure rates, equipment unavailabilities, human error probabilities, and common-cause failure parameters are discussed.

Containment Event Tree Initiating Event Frequency

The frequency of the CET initiating event, "LEVEL2-ET", is the summation of contributions from all core damage sequences.

Component Failure Rates and Equipment Unavailability

19.1-59 EPRI 3002000507, Electric Power Research Institute, "Utility Requirements Document," Approved Version 13, ALWR Passive Plant, Electric Power Research Institute, Palo Alto, CA, December 2014.

19.1-60 NUREG/CR-5485, "Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment," U.S. Nuclear Regulatory Commission, June 1998.

19.1-61 NUREG/CR-5497 - 2012 Update, "Common Cause Failure Parameter Estimations," U.S. Nuclear Regulatory Commission, January 2012.

19.1-62 Microsemi Reliability Report, No. 51000001-11/05.13, May 2013.

RAI 19-27

19.1-63 SAND2011-0128, "Accident Source Terms for Light Water Nuclear Power Plants Using High-Burnup or MOX Fuel," Sandia National Laboratories, January 2011.

RAI 19-34

19.1-64 NUREG-1524, "A Reassessment of the Potential for an Alpha-Mode Containment Failure and a Review of the Current Understanding of Broader Fuel-Coolant Interaction Issues," U.S. Nuclear Regulatory Commission, July 1996.

RAI 19-13S1

19.1-65 NUREG-1570, "Risk Assessment of Severe Accident-Induced Steam Generator Tube Rupture," March 1998.

RAI 19-27S1

19.1-66 NUREG/CR-7110, "State-of-the-Art Reactor Consequence Analyses Project, Volume 1: Peach Bottom Integrated Analysis," Rev. 1, May 2013, U.S. Nuclear Regulatory Commission.