July 29, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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11555 Rockville Pike
Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 401 (eRAI No. 9447) on the NuScale Design Certification Application

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 401 (eRAI No. 9447)," dated March 28, 2018
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 401 (eRAI No.9447)," dated November 20, 2018
3. NuScale Power, LLC Supplemental Response to NRC "Request for Additional Information No. 401 (eRAI No. 9447)," dated May 20, 2019

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. 9447:

- 03.11-19

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 Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9447

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 9447

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

eRAI No.: 9447

Date of RAI Issue: 03/28/2018

NRC Question No.: 03.11-19

This is a follow-up RAI to eRAI 9160.

General Design Criterion 4, "Environmental and dynamic effects design bases," in part, requires that SSCs important to safety be designed to accommodate the effects of and be compatible with environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss of coolant accidents.

In 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," the U.S. Nuclear Regulatory Commission (NRC) established specific requirements for the environmental qualification (EQ) of certain electric equipment important to safety located in a "harsh" environment (see DSRS 3.11).

NuScale's FSAR Tier 2, Chapter 3 analysis in part provides environmental conditions (e.g., pressure and temperature) during a design basis event (e.g., high energy line break (HELB)) used to qualify equipment that is required to perform a design function related to safety and could be subject to these environmental conditions. In particular, NuScale's FSAR Chapter 3 provides the environmental conditions during a HELB outside containment and under the bioshield (e.g., a harsh environment).

NuScale's FSAR Tier 2 Chapter 3 (e.g., Table 3.11-1) lists equipment in zone G (outside containment and under the bioshield) "…that will experience the environmental conditions of design basis accidents for which it must function to mitigate said accidents, and that will be qualified to demonstrate operability in the accident environment for the time required for accident mitigation with safety margin to failure." (EQ Category A). A similar equipment list can be found in FSAR Tier 1, Table 2.8-1. Safety-related equipment under the bioshield is associated with systems that are essential for emergency reactor shutdown, containment isolation, and decay heat removal. These systems are required to be environmentally qualified to meet their intended design function related to safety.

NuScale's FSAR Chapter 3 describes that the environmental conditions of design basis accidents under the bioshield are established assuming a vented bioshield (Appendix 3C and Figure 3C-3). In a response to RAI 9160, the applicant describes that the bioshield relieves (i.e., vents) the high pressure and temperature environment under the bioshield by opening relief panels. The panels are required to change position from normally closed to open in order to vent the atmosphere under the bioshield into the reactor building. The panels are hinged and provide one-way relief (venting) in response to a HELB under the bioshield.

NuScale's response to RAI 9160 describes in part that all the bioshield functions, including the venting function, are nonsafety-related. If the function of a component or part is nonsafety-related, the staff expects that its failure to function could not prevent the satisfactory performance of a safety-related function. As discussed above, NuScale's FSAR Chapter 3 safety analysis, which establishes the environmental conditions under the bioshield for items related to safety, currently assumes a vented bioshield (e.g., opening nonsafety-related relief panels discussed in response to RAI 9160). Therefore, the staff requests NuScale to assess the failure of the venting function (i.e., nonsafety-related bioshield relief panels do not open) and its impact on the performance of equipment important to safety (e.g., safety-related). As part of the response, because the FSAR Chapter 3 safety analysis currently assumes a vented bioshield and the bioshield vents (relief panels) are nonsafety-related, FSAR Chapter 3 safety analysis (e.g., under the bioshield HELB environmental conditions for pressure and temperature) should be revised assuming bioshield venting is not achieved by the relief panels. Otherwise, NuScale will need to provide additional information to justify reliance on the bioshield relief panels (vents) in its safety analysis.

NuScale Response:

As discussed with the staff on July 17, 2019, the following supplemental response addresses staff feedback from the previously submitted response to RAI 9447.

1. <u>Question</u>

The staff wants to understand the bolting configuration between stacked and unstacked. There are two of the bolts that need clarification. There are the 4 long bolts going all the way through, the two alignment pins, and then two shown that only go through one slab, but are not anchored.

Response

Although there are three bolt holes at each corner, only two of them are used for both stacked and unstacked configurations. FSAR Tier 2, Section 3.7.3.3.1.1 has been updated for clarity as follows:

"The bioshield slab is anchored to the NPM bay walls with four 2-inch vertical bolts on each wall. Two bolts are needed, at each corner of the bioshield slab, for both stacked and unstacked configurations."

2. Question

Which calculation documents the sentence below from Section 3.0:

The three time histories (in the three directions) that were used as base acceleration in the analysis are based on the synthetic time histories that were matched to the corresponding 4% ISRS in the same direction based on the guidelines of the SRP 3.7.1.

Response

The time histories are back-calculated from the enveloped ISRS given in the bioshield calculation. A comparison plot is added in the calculation showing how the response spectra generated from the artificially created time histories compare against the demand ISRS.

3. Question

Add a stacked and unstacked bioshield drawing to the FSAR.

Response

A stacked and unstacked configuration of the bioshield is added to the FSAR. FSAR Tier 2, Figure 3.7.3-2a shows an isometric view of the bioshield design in an unstacked configuration and Figure 3.7.3-2b shows an elevation view of the bioshield design in a stacked configuration.

4. Question

Where are the lifting points or the lifting place?

Response

The lifting points are not specified at this stage. COL Item 3.7-16 is added as follows:

"A COL applicant that references the NuScale Power Plant design certification will determine the means and methods of lifting the bioshield. A COL applicant will demonstrate that bioshield components and connections can withstand the bioshield loads and appropriate load factors."

5. Question

From 9447 Supplemental Response, submitted May 2019:

What does the sentence from bottom of page 6 mean that starts "One plate and its tributary mass…"?

Response

The radiation panel is comprised of a ¼" steel plate, 4" of high-density polyethelene (HDPE), and another ¼" steel plate. The radiation panels have a continuous angle steel along the top and bottom, each assumed to carry half the weight of the panel. The model of the radiation panel included one ¼" steel plate and 2" of HDPE to determine the loads on 1 angle steel.

6. Question

Appendix 3C 32 and 33 - From audit question 3. The ACI code defines short term (150) and long term (240). How long does it take to get below ACI limit (150)?

Response

See the response to Question 24 below.

7. Question

Table 3.7.3-14 in the response page 27 the .88 ratio, steel structural member, where does it occur?

Response

This D/C ratio occurs in the 5x5x1/2” HSS tubes at the highest stress point determined in the model. This corresponds to an area element about the center of the vertical piece. The D/C ratio has been updated to 0.92, as shown in the attached mark-up of FSAR Tier 2, Table 3.7.3-14.

8. **Question**

Also, the note in Table 3.7.3-14 says area provided is 2” but that is not an area.

Response

The note in FSAR Tier 2, Table 3.7.3-14 has been replaced with the following:

“The two hinge plates each 1" thick, are acceptable by comparison to the one 2" thick vertical hinge plate. The base of the horizontal hinge plates are wider than the vertical hinge plate.”

9. **Question**

Is there a qualification for the vertical panel seismic restraint weldment (upper right hand corner of bioshield drawing - Sh13 of 13.)?

Response

Section 5.4.6 of NuScale's calculation has been added to qualify the vertical bioshield’s seismic restraint plate (the smallest steel cross section), the restraint plates weld, and the seismic restraint’s anchors into the concrete. The other sections of the seismic restraint are sized to envelope the design stresses seen from the seismic restraint plate.

10. **Question**

Three models, SAP 2000, coupled, vertical - which one was used and where are the results of the time histories? Provide figure(s) showing spectrum analysis. Were dynamic analysis used first, then used accelerations in a static model?

Response

There are three groups of SAP2000 models: 1) for the horizontal bioshield, 2) for the vertical bioshield, and 3) another model for the steel panel plates on the vertical bioshields. All of these models use time history dynamic analysis using the synthetic time histories that were generated to match ISRS based on SRP 3.7.1. The models for the horizontal and vertical bioshields are nonlinear in nature due to compression only supports on the bay walls as well as tension only supports representing the concrete anchors.

There are no response spectrum analysis in the models. The effects of the other loads such as dead load, live load, pressure load, and sloshing loads are considered using separate static load cases and the results combined with the dynamic analysis results at each time step.

11. <u>Question</u>

What were the maximum accelerations used for the bioshield stacked and unstacked case?

<u>Response</u>

The maximum relative and absolute accelerations have been included in NuScale's calculation, as Tables 5-10 and 5-11. For a summary,

The maximum relative accelerations:

Horizontal bioshield - EW = 0.32g NS = 1.54g Vert = 6.0g

Vertical bioshield - EW = 2.53g NS = 10.85g Vert = 8.22g

The maximum absolute accelerations:

Horizontal bioshield - EW = 0.98g NS = 1.72g Vert = 7.03g

Vertical bioshield - EW = 2.38g NS = 9.7g Vert = 7.92g

12. <u>Question</u>

Stacked vertical panel is not supported - does it interact with other vertical bioshield piece - what is the displacement and why is it acceptable? Calculation did not address. Need a response in the calculation. In a stacked condition, the integrity is maintained.

<u>Response</u>

A seismic restraint for the stacked bioshield vertical piece is included in the design. This restraint is subjected to the loads as the original seismic restraint, so its design is similar.

Member sizes and number of concrete anchors have been adjusted to account for the stacked position restraint.

13. Question

Fix sleeve size on third sheet 1 ¾” vs 2 “?

Response

The sleeve has been re-sized to 2 1/4" to accommodate the bolt.

14. Question

Add drawings to DCA of stacked and unstacked conditions with annotations

Response

See response to Question 3 above.

15. Question

FSAR should have seismic analysis of stacked case added.

Response

A detailed description is added to FSAR Tier 2, Section 3.7.3.3.1.1, as follows:

"For the horizontal slab model, stacked configuration of the bioshields during refueling is considered in addition to the single bioshield. Since the two horizontal bioshields are anchored together during the stacked configuration, there will not be any sliding between the two slabs; therefore, no friction forces are developed. Because the two slabs are only pinned on the two edges, they will not act as a composite section even though they move together in the vertical direction. The two slabs are compatible in all directions without acting as a composite section because there are no shear studs between the two slabs to resist the shear force. To model the stacked configuration, only one slab is modeled but the mass and stiffness of the slab is doubled to account for both slabs. To double the slab stiffness, the modulus of elasticity is doubled. For the stacked configuration, the weight of the vertical assembly applied to one edge is also doubled.

The analysis models for the vertical assembly are developed by incorporating the vertical bioshield finite element model to the previously defined horizontal bioshield model to accurately simulate the boundary conditions of the vertical bioshield. This model uses the same boundary conditions at the interface of the horizontal slab and bay wall. Compression-only gap elements are also used at the bottom corners of the vertical bioshield in the east-west direction where the structure is guided through C-channel supports. Both cracked and uncracked concrete conditions are evaluated for the horizontal slab. The stacked bioshield is also restrained to the wall with C-channel supports. Stacked configuration effects for the vertical bioshield show the same dynamic characteristics as a single bioshield configuration. There is no interaction between the stacked bioshields."

16. Question

Make sure node numbers are correct-complete.

Response

The nodes listed as used for bioshield analysis have been verified.

17. Question

Lifting point on the slab - Design location? COL item?

Response

See response to Question 4 above.

18. Question

Clarify sentence about tributary and half weight of HDPE.

Response

The radiation panel is comprised of a ¼” steel plate, 4” of HDPE, and another ¼” steel plate. The radiation panels have a continuous angle of steel along the top and bottom, each assumed to carry half the weight of the panel. The model of the radiation panel included one ¼” steel plate and 2” of HDPE to determine the loads on 1 angle steel.

19. <u>Question</u>

Qualification of channel - basis should be in the calculation. Drawing is missing information, weld sizes, connections should be designed for channel restraint at bottom.

<u>Response</u>

Section 5.4.6 of the NuScale calculation has been added to qualify the vertical bioshield's seismic restraint plate (the smallest steel cross section), the restraint plates weld, and the seismic restraint's anchors into the concrete. The other sections of the seismic restraint are oversized to envelope the design stresses seen from the seismic restraint plate.

20. <u>Question</u>

FSAR page 3.9-411 should say 12 bioshields instead of 6

<u>Response</u>

The FSAR has been updated to state, "12 installed bioshields," as shown in the attached mark-up.

21. <u>Question</u>

From FSAR Tier 2, Table 3.7.3-14 Steel Structural member - what is it referring to?

<u>Response</u>

Table 3.7.3-14 is updated to state, "Steel structure member, HSS tube."

22. <u>Question</u>

Note in Table 3.7.3-14 says area is 2" but that is not an area.

<u>Response</u>

See response to Question 8 above.

23. <u>Question</u>

Same table - no D/C. Put * and explain.

Response

Added a footnote to FSAR Tier 2, Table 3.7.3-14 to state that D/C ratios are evaluated in real time at each time step.

24. Question

From previous audit question 3, How long does it take to get to ACI 349-06 code long term value of 150 F (duration of short term versus long term)? Explain page 3C-32. Is it short duration or long duration? EQ didn't look past 1000 seconds. Provide a sentence in DCA that this is a short term spike, if it is.

Response

ACI 349-06, E.4 defines the long and short-term concrete surface temperatures as 150 °F and 350 °F for normal operation and accident cases respectively. These limits are increased to 200 °F around local areas for normal operations and 650 °F for local areas from steam or water jets in the event of a pipe failure. Also, note that, in the ACI context, short-term is defined as 30 days.

The bioshield concrete is not subjected to temperatures over 150° F during normal operation. The EQ bounding curve for vapor space temperature increases to 560 °F in less than a minute but drops to 220 °F under 10 mins in Figures 3C-3 and 3C-4 for accident conditions which are within the allowable limits set by ACI. The curves are taken out to 1000 seconds as the accident has subsided and the temperatures have stabilized. This scenario assumes no RXB Ventilation Systems are operable and only uses passive vents. The design also assumes no operator actions for 72 hours. Beyond 72 hours, the plant operator will follow their emergency plans in deciding which action to take. If no action is taken, however, the pool area will pressurize due to pool heatup and open the RXB pool area emergency vent, causing the peak pool area bulk average vapor temperature to be 214°. The temperatures thus drop to under ACI normal operation limits within the 3-30 day period of operator action and ACI short term limit.

This is clarified in the RAI response; therefore, no FSAR updates have been provided.

25. Question

Seems to have editorial in the middle paragraph page 3.7-412(DCA)

Response

This error was a result of the PDF uploaded to the electronic reading room.

26. Question

DCA markup page 3.7-415, second para, Shear flow or shear force?

Response

FSAR text is changed to "shear force," as shown in the attached mark-up.

27. Question

Table 3.7.3-12 change title face plate to vertical assembly.

Response

The title of FSAR Tier 2, Table 3.7.3-12 is revised to, "Bioshield Vertical Assembly Self-Weight for Structural Analysis."

Impact on DCA:

FSAR Tier 2, Section 3.7.3.3.1, Tables 1.8-2, 3.7.3-8, 3.7.3-12, and 3.7.3-14, and Figures 3.7.3-2a and 3.7.3-2b have been revised as described in the response above and as shown in the markup provided in this response.

RAI 01-61, RAI 02.04.13-1, RAI 03.04.01-4, RAI 03.04.02-1, RAI 03.04.02-2, RAI 03.04.02-3, RAI 03.05.01.03-1, RAI 03.05.01.04-1, RAI 03.05.02-2, RAI 03.05.03-4, RAI 03.06.02-6, RAI 03.06.02-15, RAI 03.06.03-11, RAI 03.07.01-2, RAI 03.07.01-3, RAI 03.07.02-4S3, RAI 03.07.02-6S1, RAI 03.07.02-6S2, RAI 03.07.02-8, RAI 03.07.02-12, RAI 03.07.02-15S5, RAI 03.07.02-16S1, RAI 03.07.02-23S1, RAI 03.07.02-26, RAI 03.08.04-1S1, RAI 03.08.04-3S2, RAI 03.08.04-23S1, RAI 03.08.04-23S2, RAI 03.08.04-23S3, RAI 03.08.05-14S1, RAI 03.09.02-15, RAI 03.09.02-48, RAI 03.09.02-67, RAI 03.09.02-69, RAI 03.09.03-12, RAI 03.09.06-5, RAI 03.09.06-6, RAI 03.09.06-16, RAI 03.09.06-16S1, RAI 03.09.06-27, RAI 03.11-8, RAI 03.11-14, RAI 03.11-14S1, RAI 03.11-18, RAI 03.11-19S2, RAI 03.13-3, RAI 04.02-1S2, RAI 05.02.03-19, RAI 05.02.05-8, RAI 05.04.02.01-13, RAI 05.04.02.01-14, RAI 05.04.02.01-19, RAI 06.02.01.01.A-18, RAI 06.02.01.01.A-19, RAI 06.02.06-22, RAI 06.02.06-23, RAI 06.04-1, RAI 09.01.01-20, RAI 09.01.01-20S1, RAI 09.01.02-4, RAI 09.01.05-3, RAI 09.01.05-6, RAI 09.03.02-2S1, RAI 09.03.02-3, RAI 09.03.02-3S1, RAI 09.03.02-4, RAI 09.03.02-5, RAI 09.03.02-6, RAI 09.03.02-8, RAI 10.02-1, RAI 10.02-2, RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2, RAI 10.03.06-1, RAI 10.03.06-5, RAI 10.04.06-1, RAI 10.04.06-2, RAI 10.04.06-3, RAI 10.04.10-2, RAI 11.01-2, RAI 11.01-2S2, RAI 12.03-55S1, RAI 12.03-63, RAI 13.01.01-1, RAI 13.01.01-1S1, RAI 13.02.02-1, RAI 13.03-4, RAI 13.05.02.01-2, RAI 13.05.02.01-2S1, RAI 13.05.02.01-3, RAI 13.05.02.01-3S1, RAI 13.05.02.01-4, RAI 13.05.02.01-4S1, RAI 14.02-7, RAI 16-65, RAI 19-31, RAI 19-31S1, RAI 19-38, RAI 20.01-13

Table 1.8-2: Combined License Information Items

Item No.	Description of COL Information Item	Section
COL Item 1.1-1:	A COL applicant that references the NuScale Power Plant design certification will identify the site-specific plant location.	1.1
COL Item 1.1-2:	A COL applicant that references the NuScale Power Plant design certification will provide the schedules for completion of construction and commercial operation of each power module.	1.1
COL Item 1.4-1:	A COL applicant that references the NuScale Power Plant design certification will identify the prime agents or contractors for the construction and operation of the nuclear power plant.	1.4
COL Item 1.7-1:	A COL applicant that references the NuScale Power Plant design certification will provide site-specific diagrams and legends, as applicable.	1.7
COL Item 1.7-2:	A COL applicant that references the NuScale Power Plant design certification will list additional site-specific piping and instrumentation diagrams and legends as applicable.	1.7
COL Item 1.8-1:	A COL applicant that references the NuScale Power Plant design certification will provide a list of departures from the certified design.	1.8
COL Item 1.9-1:	A COL applicant that references the NuScale Power Plant design certification will review and address the conformance with regulatory criteria in effect six months before the docket date of the COL application for the site-specific portions and operational aspects of the facility design.	1.9
COL Item 1.10-1:	A COL applicant that references the NuScale Power Plant design certification will evaluate the potential hazards resulting from construction activities of the new NuScale facility to the safety-related and risk significant structures, systems, and components of existing operating unit(s) and newly constructed operating unit(s) at the co-located site per 10 CFR 52.79(a)(31). The evaluation will include identification of management and administrative controls necessary to eliminate or mitigate the consequences of potential hazards and demonstration that the limiting conditions for operation of an operating unit would not be exceeded. This COL item is not applicable for construction activities (build-out of the facility) at an individual NuScale Power Plant with operating NuScale Power Modules.	1.10
COL Item 2.0-1:	A COL applicant that references the NuScale Power Plant design certification will demonstrate that site-specific characteristics are bounded by the design parameters specified in Table 2.0-1. If site-specific values are not bounded by the values in Table 2.0-1, the COL applicant will demonstrate the acceptability of the site-specific values in the appropriate sections of its combined license application.	2.0
COL Item 2.1-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site geographic and demographic characteristics.	2.1
COL Item 2.2-1:	A COL applicant that references the NuScale Power Plant design certification will describe nearby industrial, transportation, and military facilities. The COL applicant will demonstrate that the design is acceptable for each potential accident, or provide site-specific design alternatives.	2.2
COL Item 2.3-1:	A COL applicant that references the NuScale Power Plant design certification will describe the site-specific meteorological characteristics for Section 2.3.1 through Section 2.3.5, as applicable.	2.3
COL Item 2.4-1:	A COL applicant that references the NuScale Power Plant design certification will investigate and describe the site-specific hydrologic characteristics for Section 2.4.1 through Section 2.4.14, except Section 2.4.8 and Section 2.4.10.	2.4

Table 1.8-2: Combined License Information Items (Continued)

Item No.	Description of COL Information Item	Section
COL Item 3.7-10:	A COL applicant that references the NuScale Power Plant design certification will perform a site-specific configuration analysis that includes the Reactor Building with applicable configuration layout of the desired NuScale Power Modules. The COL applicant will confirm the following are bounded by the corresponding design certified seismic demands: 1) The in-structure response spectra of the standard design at the foundation and roof. See FSAR Figure 3.7.2-107 and Figure 3.7.2-108 for foundation in-structure response spectra and Figure 3.7.2-113 for roof in-structure response spectra. 2) The maximum forces in the NuScale Power Module lug restraints and skirts. See Table 3B-28. 3) The site-specific in-structure response spectra for the NuScale Power Module at the skirt support will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-156 and Figure 3.7.2-157. The site-specific in-structure response spectra for the NuScale Power Module at the lug restraints will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-158 through Figure 3.7.2-163. 4) The maximum forces and moments in the ~~east and~~ west wing wall~~s~~ and pool wall~~s~~. See ~~FSAR Table 3.7.2-32~~Table 3B-22b and Table 3B-23b. 5) Not used.~~The site-specific in-structure response spectra for the fuel storage racks will be shown to be bounded by the in-structure response spectra in Figure 3-6 through Figure 3-14 of TR-0816-49833.~~ 6) The site-specific in-structure response spectra shown immediately below will be shown to be bounded by their corresponding certified in-structure response spectra: • Reactor Building north exterior wall at EL 75′-0″: bounded by in-structure response spectra in Figure 3.7.2-110 • Reactor Building west exterior wall at EL 126′-0″: bounded by in-structure response spectra in Figure 3.7.2-112 • Reactor Building crane wheels at EL 145′-6″: bounded by in-structure response spectra in Figure 3.7.2-114 • Control Building east wall at EL 76′-6″: bounded by in-structure response spectra in Figure 3.7.2-119a and Figure 3.7.2-119b • Control Building south wall at EL 120′-0″: bounded by in-structure response spectra in Figure 3.7.2-121a and Figure 3.7.2-121b If not, the standard design will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.	3.7
COL Item 3.7-11:	A COL applicant that references the NuScale Power Plant design certification will perform a site-specific analysis that~~, if applicable,~~ assesses the effects of soil separation. The COL applicant will confirm that the in-structure response spectra in the soil separation cases are bounded by the in-structure response spectra shown in FSAR Figure 3.7.2-107 through Figure 3.7.2-122.	3.7
COL Item 3.7-12:	A COL applicant that references the NuScale Power Plant design certification will perform an analysis that uses site-specific soil and time histories to confirm the adequacy of the fluid-structure interaction correction factor.	3.7
COL Item 3.7-13:	A COL applicant that references the NuScale Power Plant design certification will perform a site-specific analysis that assesses the effects of non-vertically propagating seismic waves on the free-field ground motions and seismic responses of Seismic Category I structures, systems, and components.	3.7
COL Item 3.7-14:	A COL applicant that references the NuScale Power Plant design certification will demonstrate that the site-specific seismic demand is bounded by the FSAR capacity for an empty dry dock condition.	3.7
COL Item 3.7-15:	A COL applicant that references the NuScale Power Plant design certification will determine the appropriate site-specific number of interaction planes for soil structure interaction.	3.7
COL Item 3.7-16:	A COL applicant that references the NuScale Power Plant design certification will determine the means and methods of lifting the bioshield. A COL applicant will demonstrate that bioshield components and connections can withstand the bioshield loads and appropriate load factors.	3.7

in-place bioshield. The bioshield lifting slings meet the requirements described in Section 9.1.5 under "Lifting Devices Not Specifically Designed."

RAI 03.11-19S2

COL Item 3.7-16: A COL applicant that references the NuScale Power Plant design certification will determine the means and methods of lifting the bioshield. A COL applicant will demonstrate that bioshield components and connections can withstand the bioshield loads and approriate load factors.

RAI 03.11-19S1

The bolts used for securing the horizontal portion of the bioshield to the operating bay and pool walls are safety related, and designed in accordance with ACI 349 as they anchor into a concrete structure. The bioshield is designed as a Seismic Category II structure, which is analyzed and designed to prevent its failure under SSE conditions, such that the bioshield will not collapse or fail and strike or impair the integrity of the safety related or Seismic Category I SSC under it.

RAI 03.02.01-4, RAI 03.11-19, RAI 03.11-19S1, RAI 03.11-19S2

Each bioshield is comprised of a horizontal slab supported by the bay walls and a hanging vertical ~~face plate~~assembly attached to the horizontal slab. The horizontal slab consists of ~~21.5~~23.5-in. thick reinforced 5000 psi concrete. ~~with a 2-in. layer of high-density polyethylene on the top.~~ The concrete is~~and high-density polyethylene are~~ encapsulated in 1/4-in. stainless steel plates for a total thickness of two feet. The vertical ~~plate~~assembly is constructed of a stainless steel tube framing system and ~~stainless steel face plates~~a series of radiation shielding panels. The radiation shielding panels are designed to help ensure occupational radiation exposure is as low as reasonably achievable as described in FSAR Chapter 12. Radiation shielding panels are composed of 4-inch borated HDPE panels with 5 percent boron content. The HDPE is encased in stainless steel plate and angle assemblies clamped together with bolts. The clamped assembly restricts flame and adequate oxygen from causing combustion of the HDPE panels. Off-gassing of the HDPE panels during operation is allowed as the clamped assemblies are not hermetically sealed. The encasement of the HDPE eliminates it as a fire load. The vertical ~~plate~~assembly is vented for heat removal during normal operation ~~via two fire and pressure rated louvered vents, and~~as well as for heat and pressure mitigation in the event of a high energy line break and slow leak, high temperature event above the NPM ~~via hinged pressure relief panels providing one way ventilation~~. The vents are arranged on the vertical portion of the bioshield in a staggered manner, providing a minimum ventilation area of 52.8 ft^2 to allow continuous ventilation of the operating bay~~for normal operation are located two feet off the surface of the pool, with one vent on the left and one on the right side of the front face of the vertical portion of the bioshield. The pressure relief panels cover the space between the vents for normal operation and all the way up the vertical face of the bioshield. A solid design is used as a representative weight for the structural analysis~~.

RAI 03.11-19S1, RAI 03.11-19S2

The bioshields are attached to the bay walls and outer pool wall using ~~1.5~~2-in. diameter removable anchor bolts. Figure 3.7.3-1 shows ~~six~~12 installed bioshields. Figure 3.7.3-2a shows an isometric view with the single bioshield configuration and Figure 3.7.3-2b shows an elevation view with the stacked bioshield configuration.~~and Figure 3.7.3-2 shows a vertical faceplate.~~

Reinforced Concrete Properties and Slab Capacity

Table 3.7.3-8 contains the section dimensions used for the design of the bioshield. Table 3.7.3-9 shows the concrete and reinforcement design values used for capacity calculations. The values are obtained from ACI 349 (Reference 3.7.3-4). The minimum concrete cover for cast-in-place members is based on Section 7.7.1 of ACI 349.

The capacities for the bioshield slab are shown in Table 3.7.3-10 and are calculated based on the provisions of ACI 349. The individual equations used for out of plane moment and shear capacity are referenced in Table 3.7.3-10. The anchor bolt capacities for tension and shear are developed using the equations from Appendix D of ACI 349.

RAI 03.11-19S1

~~The welded connections between the vertical and horizontal component of the bioshield are designed based on the provisions of Chapter J of AISC 360 (Reference 3.7.3-5).~~

Structural Steel Material Properties

RAI 03.11-19

~~The vertical component is constructed of ASTM A240 Type 304L stainless steel plates and tube steel in order to resist corrosion. The yield strength and tensile strength of Type 304L stainless steel is 25 ksi and 70 ksi respectively. Yield strength decreases due to increasing temperature. The operating environment underneath the bioshield is expected to be higher than the ambient building temperature. Therefore, a yield strength of 21.4 ksi, corresponding to a temperature of 200 °F, is used.~~The vertical assembly of the bioshield is constructed from steel tube members of HSS 5x5x1/2" in the horizontal and vertical directions. The tube steel material is SA-564 Type 630 condition H1150 high strength stainless steel with yield strength of 105 ksi and a tensile strength of 135 ksi. The stainless steel liner plate that protects the horizontal bioshield from corrosion and the radiation panel's ¼" closure plate is made from A240 Type 304. The framing members of the bioshield radiation panel are made from A276 stainless steel. The yield strength of A240 Type 304 is 25 ksi and the tensile strength is 70 ksi. A276 stainless steel has a yield strength of 25 ksi and a tensile strength of 70 ksi.

RAI 03.11-19S1

The welded connections between the vertical and horizontal component of the bioshield are designed based on the provisions of Chapter J of AISC 360 (Reference 3.7.3-5).

In-Structure Response Spectra

RAI 03.11-19, RAI 03.11-19S1

In-structure response spectra were developed for multiple locations in the RXB in Section 3.7.2. Two nodes from that model were selected to use for the design of bioshields. These nodes are shown in Figure 3.7.3-3. Plots of the ISRS with 4 percent damping at these nodes are shown in ~~Figure 3.7.3-4~~Figure 3.7.3-4a through Figure 3.7.3-4c. These figures envelop CSDRS and CSDRS-HF curves and include the effects of any sensitivity analysis cases such as considering the effects of soil separation and different soil-structure analysis (SSI) methods, i.e., the 7P Extended Subtraction Method (7P ESM) and the Direct Method (DM). The ISRS with multiple damping ratios for these nodes are shown in Figure 3.7.2-176a through Figure 3.7.2-176d also considering same effects.

RAI 03.11-19, RAI 03.11-19S1

~~The calculated natural frequency value is used to identify the maximum accelerations in all three directions on the bioshield slab during an earthquake event. The acceleration obtained from these ISRS is used for the design.~~

3.7.3.3.1.1 Evaluation

RAI 03.11-19, RAI 03.11-19S1, RAI 03.11-19S2

The self-weight of the bioshield was calculated using material densities and the dimensional properties. There are two structural components of the bioshield: the horizontal slab and vertical ~~face plate~~assembly. The horizontal slab rests on the interior pool walls as shown in Figure 3.7.3-1. The ~~face plate~~vertical assembly is ~~welded to the steel plate on the bottom of the slab~~attached to the front edge of the horizontal bioshield through eight pins. Table 3.7.3-11 summarizes the weight of the slab and Table 3.7.3-12 summarizes the weight of the assembly~~face plate~~. The bioshield slab is anchored to the NPM bay walls with four 2-inch vertical bolts on each wall. Two bolts are needed, at each corner of the bioshield slab, for both stacked and unstacked configurations.

RAI 03.11-19

The total weight of the bioshield used for design is twice the total calculated weight of each bioshield because they can be stacked on one another during refueling and maintenance. In addition, a 50 psf live load is included to account for the load due to plant personnel bolting and unbolting the bioshield during refueling and maintenance. The bioshield area is not expected to be a high traffic area during normal operation. ~~The total weight used for design is 383 kips.~~

RAI 03.11-19S1

The structural analysis and design of the horizontal slab and vertical assembly was performed by generating two sets of SAP2000 finite element models. A time history analysis is performed for both model sets. The time histories are based on the synthetic time histories that were matched to the corresponding

4-percent ISRS in the same direction given in Figure 3.7.3-4a through Figure 3.7.3-4c.

RAI 03.11-19S1, RAI 03.11-19S2

The models incorporate compression-only gap elements to model concrete slab sitting on bay walls and tension-only elements to model anchor bolts. In the horizontal directions, friction forces between the slab and bay walls are conservatively ignored, and it is assumed that the only anchor bolts resist the shear. Thus, the only restraints in the horizontal directions are at the bolt locations. The north and south edges of the slab are free in all directions. Both cracked and uncracked concrete conditions are evaluated. The weight of the vertical bioshield is applied to the free edge of the slab.

RAI 03.11-19S2

For the horizontal slab model, stacked configuration of the bioshields during refueling is considered in addition to the single bioshield. Since the two horizontal bioshields are anchored together during the stacked configuration, there will not be any sliding between the two slabs; therefore, no friction forces are developed. Because the two slabs are only pinned on the two edges, they will not act as a composite section even though they move together in the vertical direction. The two slabs are compatible in all directions without acting as a composite section because there are no shear studs between the two slabs to resist the shear force. To model the stacked configuration, only one slab is modeled but the mass and stiffness of the slab is doubled to account for both slabs. To double the slab stiffness, the modulus of elasticity is doubled. For the stacked configuration, the weight of the vertical assembly applied to one edge is also doubled.

RAI 03.11-19S1, RAI 03.11-19S2

The analysis models for the vertical assembly are developed by incorporating the vertical bioshield finite element model to the previously defined horizontal bioshield model to accurately simulate the boundary conditions of the vertical bioshield. This model uses the same boundary conditions at the interface of the horizontal slab and bay wall. Compression-only gap elements are also used at the bottom corners of the vertical bioshield in the east-west direction where the structure is guided through C-channel supports. Both cracked and uncracked concrete conditions are evaluated for the horizontal slab. The stacked bioshield is also restrained to the wall with C-channel supports. Stacked configuration effects for the vertical bioshield show the same dynamic characteristics as a single bioshield configuration. There is no interaction between the stacked bioshields.

RAI 03.11-19S1, RAI 03.11-19S2

In all cases, the results of individual load cases are combined per applicable load combinations, and appropriate checks are performed per AISC and ACI standards for both members and connections.

RAI 03.11-19S1

RAI 03.11-19S1, RAI 03.11-19S2

Table 3.7.3-8: Bioshield Nominal Dimensions

Parameter	Length
Gross section width (east-west)	24~~3~~ ft 6~~1~~ in
Gross section length (north-south)	20 ft 6 in
Vertical bioshield height	30 ft
Vertical bioshield width	22~~1~~ ft 6 in
Bioshield distance between slab anchor bolts	22~~1~~ ft ~~1~~6 in
Clear distance between supports (NPM support walls)	19 ft 7 in
Depth of horizontal bioshield	2 ft

RAI 03.11-19, RAI 03.11-19S1, RAI 03.11-19S2

Table 3.7.3-12: Bioshield ~~Face Plate~~Vertical Assembly Self-Weight for Structural Analysis

~~Material~~	~~Density~~	~~Material Thickness~~	~~Section Width~~	~~Section Height~~	~~Section Area~~	~~Total Weight~~
	~~lb/ft^3~~	~~in~~	~~ft~~	~~ft~~	~~ft^2~~	~~kip~~
~~Plate~~	~~490.75~~	~~¼~~	~~21.5~~	~~30~~	~~645~~	~~13.29[1]~~
~~Member~~	~~Linear Weight~~	~~Horizontal Members~~	~~Section Width~~	~~Vertical Members~~	~~Section Height~~	~~Total Weight~~
	~~lb/ft~~	~~qty~~	~~ft~~	~~qty~~	~~ft~~	~~kip~~
~~HSS4X4X1/2~~	~~21.63~~	~~16[±]~~	~~22~~	~~12~~	~~30~~	~~15.4~~
					~~Total~~	~~28.69~~

~~Notes:~~

~~[1]Total weight of plate steel is the weight of two plates (front and back of vertical component)~~

Component	Quantity	Weight (lbs)	Total (lbs)
Radiation panels (HDPE density = 63 lb/ft^3)	9	4,700	42,300
Frame weldment	1	16,132	16,132
-	-	**Total**	**58,432 (60,000 used)**

RAI 03.11-19, RAI 03.11-19S1, RAI 03.11-19S2

Table 3.7.3-14: Summary of Bioshield Demand to Capacity Ratios

Component	Capacity Check	Demand	Capacity	Unit	D/C Ratio
~~Slab reinforcement~~Concrete slab	~~out-of-plane bending~~Rebar in the E-W direction	~~124.54~~1.728	~~206~~3.142	~~kip-ft/ft~~in^2/ft	~~0.60~~0.55
Concrete slab	~~out-of-plane shear~~Rebar in the N-S direction	~~23.62~~0.843	~~48~~3.142	~~kip/ft~~in^2/ft	~~0.49~~0.27
~~Slab anchor bolt~~Concrete slab	~~Tension~~Out-of-plane shear (E-W)	~~198.52~~34.1	~~663.75~~54.559	kips/ft	~~0.30~~0.63
Concrete slab	~~Shear~~Out-of-plane shear (N-S)	~~467.53~~19.3	~~796.5~~54.471	kips/ft	~~0.59~~0.35
~~Wall~~Slab anchor bolt	Tension + shear	~~486.16~~See note below	~~922.5~~See note below	~~kip~~	~~0.53~~0.66
Bioshield connection between horizontal and vertical piece - pin	Shear (double-ended)	~~385.85~~114.0	~~796.5~~191.0	kip	~~0.48~~0.60
~~Bent plate fillet weld~~Bioshield connection between horizontal and vertical piece - pin	~~Tension~~Bearing	~~37.6~~114.0	~~59.39~~154.0	kip	~~0.63~~0.72
~~Hoist ring anchorage~~Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece; headed studs	~~Interaction tension + shear~~Tension + shear	~~-~~See note below	~~-~~See note below		~~0.78~~0.71
~~Vertical component slot weld~~Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece	Weld ~~capacity~~	~~23.28~~8.1	~~47.25~~31.5	ksi~~kip~~	~~0.49~~0.26
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	The two hinge plates each 1" thick, are acceptable by comparison to the one 2" thick vertical hinge plate. The base of the horizontal hinge plates are wider than the vertical hinge plate.			N/A	OK
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	Weld	16.4	31.5	ksi	0.52
Bioshield connection between horizontal and vertical piece - edge plate on horizontal piece	Bending	576.0	1080.0	kip-ft	0.53
Steel structure member, HSS tube	Von Mises Stress	88.82	96.6	ksi	0.92
Steel structure member, HSS tube	Weld	7.25	31.5	ksi	0.23
Vertical bioshield panels	Von Mises Stress	16.95	22.0	ksi	0.77

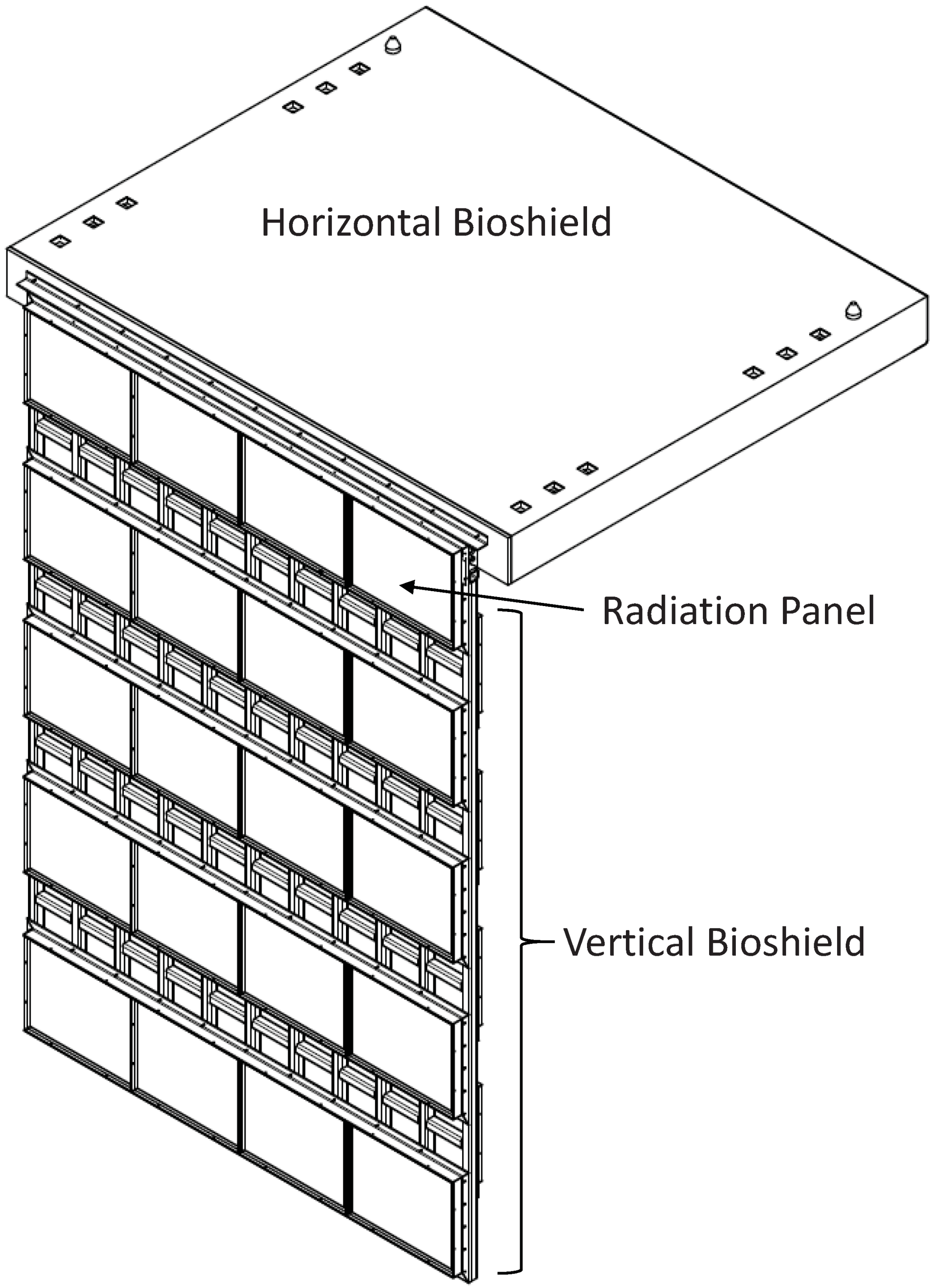
Table 3.7.3-14: Summary of Bioshield Demand to Capacity Ratios (Continued)

Component	Capacity Check	Demand	Capacity	Unit	D/C Ratio
Vertical bioshield seismic restraint	Weld	21.4	31.5	ksi	0.68
Vertical bioshield seismic restraint- concrete studs	Tension	216.6	353	kip	0.61
Vertical bioshield seismic restraint- concrete studs (stacked bioshield)	Tension	102.1	132.5	kip	0.77

Note: The D/C ratios are determined in real time and for each time step.

RAI 03.11-19S2

Figure 3.7.3-2a: Bioshield Conceptual Design (Isometric View)



RAI 03.11-19S2

Figure 3.7.3-2b: Bioshield Conceptual Design (Elevation View During Stacked Configuration)