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RAIO-0519-65641

May 20, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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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 16, 2018

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,

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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:

NuScale submitted a response to RAI 9447, Question 03.11-19 on November 16, 2018 (ML18320A254). On December 19, 2018, NuScale participated in an NRC public meeting to discuss technical issues associated with the NuScale Design Certification Application (DCA) review and to promote a common understanding of the technical issues associated with RAI 9447. Based on NRC feedback, NuScale submits herein a supplemental response to clarify certain information, as follows:

- The minimum bioshield open vent area to relieve HELB pressure used in the analysis is 52.8 ft^2 and the provided bioshield open vent area is 56.7 ft^2.
- High-density polyethelene (HDPE) rather than flame-retardant HDPE is specified in the bioshield design.
- The temperature limits for HDPE blocks, and the necessity for a COL Item for inspection and testing were addressed in the NuScale supplemental response to RAI 9294 Question 12.03-26 (ML19059A477).

Supplemental information regarding HDPE density, radiation shielding design, fire loading, and bioshield handling has been added to Tier 2 Final Safety Analysis Report Sections 3.7.2, 3.7.3, Appendix 3C, 9.1.5, 9.5.1, and 12.3.

The specific number of HDPE radiation shielding panels is not an important parameter for radiation shielding; therefore, it is not included in Tier 1. The parameters relevant for shielding are presented in Tier 2 FSAR Table 12.3-6.

As discussed in the NuScale supplemental response to RAI 9294, the normal operating temperature of the airspace underneath the bioshields does not exceed 120 degrees Fahrenheit. Any failure associated with the non-safety reactor building ventilation system will be addressed as a maintenance issue.

As stated in the NuScale supplemental responses to RAI 9294 (ML19059A477) and 9298 (ML18346A693), the HDPE radiation shielding panels are expected to be life-of-the-plant components for normal operations; thus, not requiring inspection, testing, or replacement. In the event of plant transients or events that could impact the HDPE radiation shielding panels, any resultant degradation of the HDPE will be evaluated as part of the maintenance activities and subsequent radiation surveys.

Bioshield Evaluation

After the SEB audit, NuScale updated the structural analysis and design of the horizontal and vertical bioshields by performing two sets of SAP2000 finite element models. A third SAP2000 model was prepared for the analysis of panels. Therefore, issues inherent to equivalent static analysis are no longer valid.

The structural analyses for the horizontal slab of the bioshield are developed by modeling the bioshield slab with SAP2000 and using a Nonlinear Dynamic Time History Analysis. Base acceleration time histories in three directions are based on the synthetic time histories that were matched to the corresponding 4-percent in-structure response spectra in the same direction in accordance with the guidelines of SRP 3.7.1. The nonlinearities in the model are due to both the compression-only gap elements and the tension-only bolt elements. The compression-only gap elements are used to model the slab sitting on the bay walls, while the tension-only bolt elements are used to model the 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 resisted 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 studied. The stacked configuration of the bioshields during refueling is considered in addition to the standalone-unstacked configuration. The weight of the vertical bioshield is applied to the free edge of the slab. The combined dead and live loads are calculated as a distributed load on the slab.

Because the two horizontal bioshields are anchored together in the stacked configuration, there will not be any sliding between the two slabs; therefore, no friction forces develop between them. 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. This means that 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 flow. Therefore, 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 bioshields applied to one edge is doubled as well.

The analysis model for the vertical bioshields is 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 the bay wall, and is performed using a Nonlinear Dynamic Time History Analysis. 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. Stacked configuration effects for the vertical bioshield are not included because the response would be no different from that of a single bioshield.

The analysis of the panels in the vertical bioshield is performed using a time history dynamic analysis of a rectangular panel subjected to both pressure and out-of-plane seismic excitation. The same north-south acceleration time history developed for the bioshield is used for the panel. The panel is assumed to be simply supported on all edges. One plate and its tributary mass (half of the HDPE mass) are included for modeling purposes because the panels include two steel plates separated by HDPE.

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. Demand/capacity ratios for different components and design checks for different failure modes are provided in FSAR Section 3.7.3.

NuScale is incorporating the following paragraph in the DCA: “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 because 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 safe shutdown earthquake conditions. Thus, the bioshield will not collapse or fail and strike or impair the integrity of a safety-related or Seismic Category I structure, system, or component under it.”

From the SEB audit, the NRC posted questions about this and other RAI responses with regard to the bioshield and its impact on plant design. The following are excerpts from the audit conclusion with responses posted below.

RAI 9447

- Just before figure on response, explain what the meaning of “preliminary reanalysis” is?

  "Preliminary reanalysis" referred to the GOTHIC calculations to assess the environmental conditions under the bioshield. The bioshield update was being performed concurrently with the update to the equipment qualification (EQ) calculation for the top-of-module area. This was done in parallel because the bioshield design and EQ analysis were inputs to each other. The EQ calculation was not approved as final at the time of the bioshield design completion. Therefore, the acceptability of the bioshield vent paths could not be substantiated with a signed-as-approved document from EQ. The term "preliminary" in the RAI response is referring to this situation and the “reanalysis” is the EQ analysis being performed. This analysis is now complete.

RAI 8838 Question 1

- What is the temperature expected (line break) if the vent on the back wall is shut?

There is no vent on the pool walls. There is a vent on the north and south walls primarily to mitigate pressure rather than temperature. The temperature expected from a main steam line break is about 540 degrees Fahrenheit for less than 30 seconds, reducing to about 150 degrees Fahrenheit in less than 10 minutes. The pressure is limited to less than 1 psi differential within this region.

- In lifting plate table, does the demand include safety factor, As it part of load handling?

  The language regarding lifting plate and rigging / load handling is removed.

- Analysis and design of module support structure?

  This question is not related to the bioshield; this was related to RAI 8838.

RAI 9160 Question 03.02.01-4:

- Guide pin considered as restraint? If so clearly describe in the model.

  The guide pins are not credited for restraining the bioshield in any fashion. They are placed on top of horizontal slabs as an aid for aligning the bolt holes when placing one bioshield on top of another.

- Rigging group to verify the pick point? Why it is mentioned when rigging points have been evaluated.

  NuScale removed the language regarding rigging.

- Effect of HDPE on radiation. Information shows that HDPE emits gas due to radiation. If there is no venting in the HDPE panel then expansion of gas may produce stress?

  The radiation panels are not hermetically sealed because the front and rear face of the panel are bolted. Air will move through the connection points even if the material is a tight fit.

- Welded connection should go in steel structures in the DCD . Weld design code is addressed but not structural steel design code for other steel members of vertical face and brackets.

  This question refers to FSAR Section 3.7.3.3.1, where welding is discussed in the description of "Reinforced Concrete Properties and Slab Capacity." The information is moved into the description of "Structural Steel Material Properties," with appropriate modifications for vertical assembly and reference to the code for steel components.

- What temperature used for the SS steel?

  It is checked for 212 degrees Fahrenheit. Allowable material properties are adjusted according to temperature. This information is added in the FSAR.

Impact on DCA:

FSAR Sections 3.7.2, 3.7.3, 9.1, 9.5, 12.3, and Appendix 3C, FSAR Tables 3.7.2-35, 3.7.3-8, 3.7.3-10 through -14, 3C-3, 3C-4, 3C-6, and 3C-7, FSAR Figures 3.7.2-176a through 3.7.2-176d, and 3.7.3-4a through 3.7.3-4c, have been revised as described in the response above and as shown in the markup provided in this response.

RAI 03.07.02-26, RAI 03.08.04-1S1, RAI 03.08.04-33, RAI 03.08.04-33S1, RAI 03.11-19, RAI 03.11-19S1

Table 3.7.2-35: Analysis Model Summary

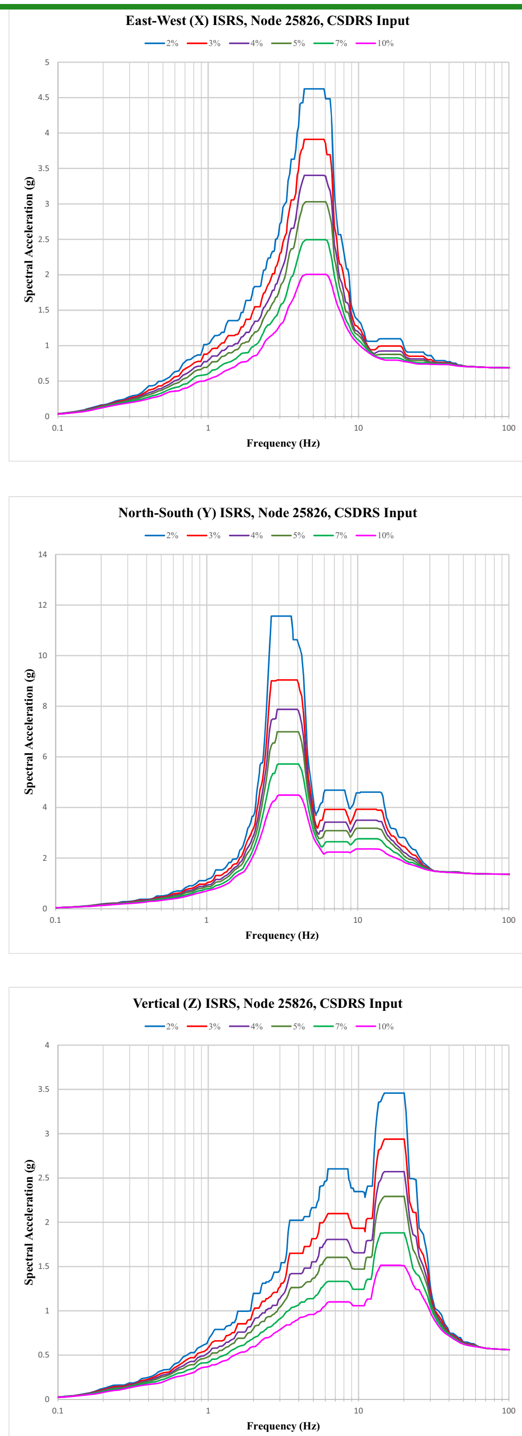
No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
1	RXB stand-alone bldg	Uncracked & cracked	SAP2000	N/A	N/A	Static analysis	Member forces	Sections: 3.7.2.1.1.1, 3.7.2.1.2.1, 3.8.4.1.1, 3.8.4.3, 3.8.4.4.1, 3.8.5.4.1.2; Figures: 3.7.2-4, 3.8.4-15 through -20	Tables: 3B-2 through -25; Figures 3B-7 through -47
2	RXB stand-alone bldg	Uncracked & cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic SSI analysis using 7% material damping	Member forces	Sections: 3.7.2.1.1.3, 3.7.2.1.2.1, 3.7.2.1.2.4, 3.7.2.4, 3.7.2.11, 3.7.5.1.4, 3.8.4.3, 3.8.5.4.1.2; Figures 3.7.2-15 through -21 & -35 (SASSI Input); Table 3.7.2-8 (SASSI Input)	Tables: 3B-2 through -25; Figures 3B-7 through -47
3	RXB stand-alone bldg	Uncracked & cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic ISRS generation using 4% material damping	ISRS	Sections: 3.7.2.1.1.3, 3.7.2.1.2.1, 3.7.2.1.2.4, 3.7.2.4, 3.7.2.5, 3.7.2.5.3, 3.7.2.9, 3.7.5.1.4, 3.8.4.3; Figures 3.7.2-15 through -21 & -35 (SASSI Input); Table 3.7.2-8 (SASSI Input)	Figures: 3.7.2-99 through -103
4	RXB stand-alone bldg	Uncracked	ANSYS	Wall accelerations are based on soil types 7, 8, and 11 w CSDRS Input.	CSDRS: Capitola	Slosh heights in reactor pool and determine fluid-structure interaction effects of the RXB Pool	Accelerations, fluid pressures	Sections: 3.7.2.1.1.2, 3.7.2.1.2.4, 3.7.5.1.4, 3.8.4.3; Figures: 3.7.2-32 through -35, 3.8.5-8 through -14	Table 3.7.2-8; Figures 3.7.2-36 through -39

Table 3.7.2-35: Analysis Model Summary (Continued)

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
26	Reactor Building crane (RBC)	N/A	ANSYS	Analysis based on RXB ISRS	Analysis based on RXB ISRS	Structural analysis of RBC	Member forces	Section 9.1.5	Not presented
27	RXB bioshield - partial model	Cracked & uncracked	SAP2000	Analysis based on RXB ISRS	Analysis based on RXB ISRS	Structural analysis of bioshield	Member forces	Sections: 3.7.3, 3.7.3.3.1~~2~~; Figures: 3.7.2-176a through 3.7.2-176d, 3.7.3-1through 3.7.3-4~~ & -2~~; Tables 3.7.3-8 through -14~~2~~	Table 3.7.3-14
28	Reactor Flange Tool Refueling Configuration	Cracked & uncracked	ANSYS	Soil Type 7 (with CSDRS Input)	CSDRS: Capitola	Determine core plate time histories and ISRS, as well as reactions for structural components	Reaction forces, moments, ISRS, time histories	Sections: 3.8.4.1.15, 3.8.4.3.1.12, 3.8.4.4.2, 3.8.4.5 Figures: 3.8.4.34, 3.8.4.35, 3.8.4.36	Tables: 3.8.4-21, 3.8.4-22, 3.8.4-23; TR-0916-51502 Tables 8-8 and 8-9; Figures B-34 through B-39

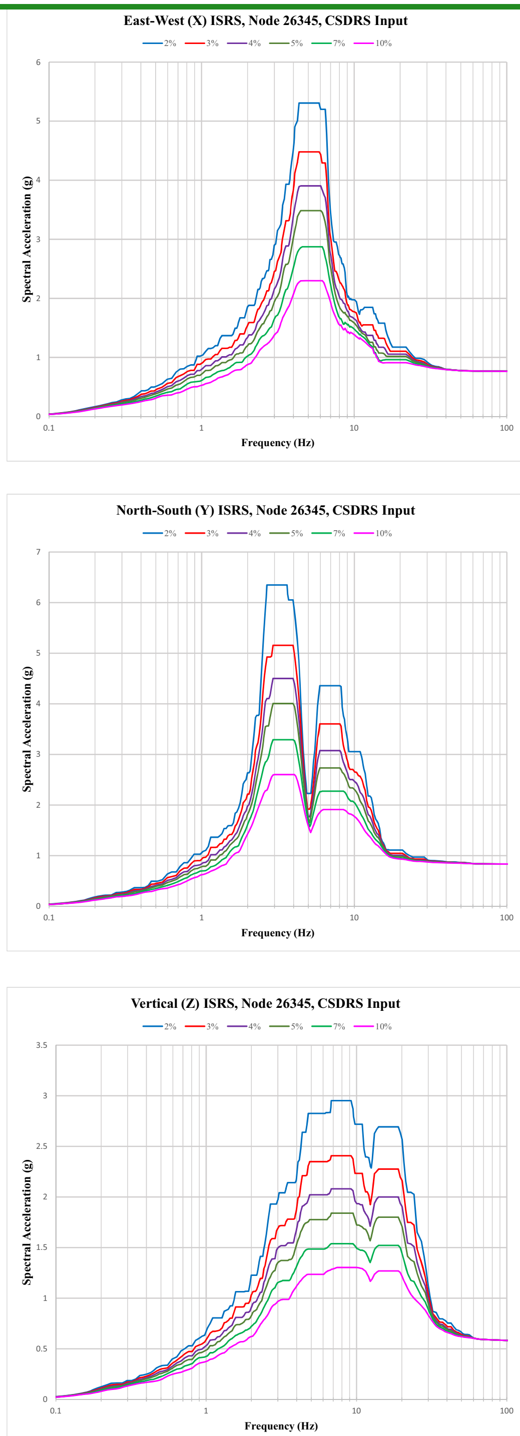
RAI 03.11-19S1

Figure 3.7.2-176a: In-Structure Response Spectra at the Northwest Corner of the Bioshield



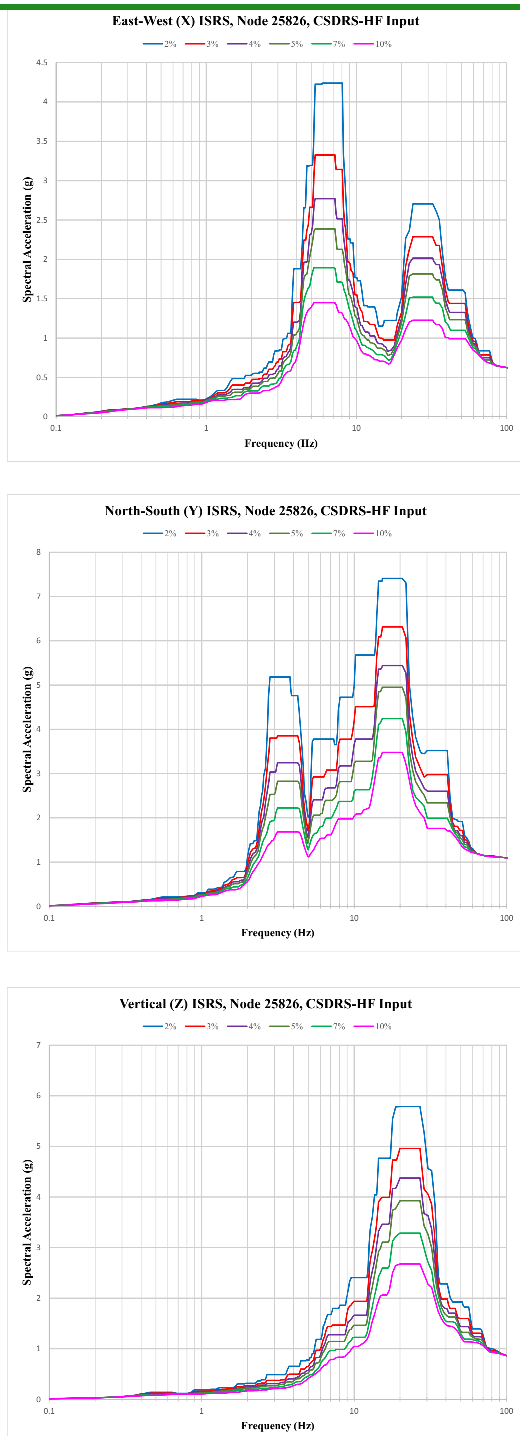
RAI 03.11-19S1

Figure 3.7.2-176b: In-Structure Response Spectra at the Northeast Corner of the Bioshield



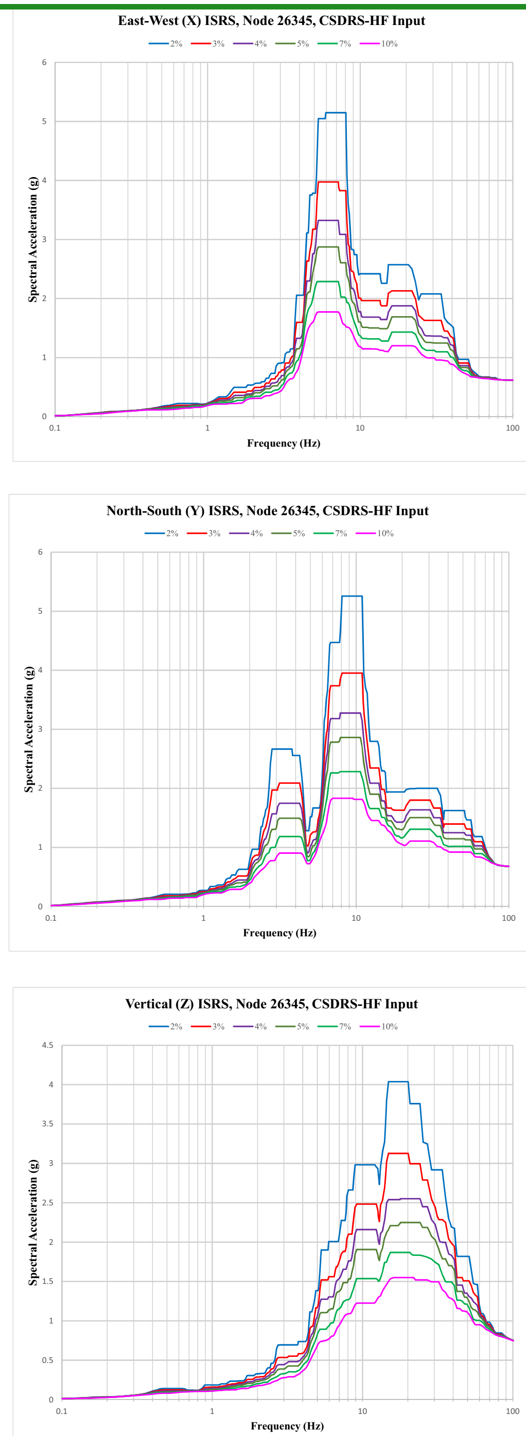
RAI 03.11-19S1

Figure 3.7.2-176c: In-Structure Response Spectra at the Northwest Corner of the Bioshield – High Frequency



RAI 03.11-19S1

Figure 3.7.2-176d: In-Structure Response Spectra at the Northeast Corner of the Bioshield – High Frequency



for the standard plant are normally composed of two SSE events, with 10 maximum stress-cycles each, for a total of 20 full cycles. This is considered equivalent to the cyclic load basis of one SSE and five OBEs.

Alternatively, the number of fractional vibratory cycles equivalent to that of 20 full SSE vibratory cycles with an amplitude not less than one-third of the maximum SSE amplitude may be used when derived in accordance with IEEE 344 (Reference 3.7.3-8).

3.7.3.3 Procedures Used for Analytical Modeling

For the decoupling of the subsystem and the supporting system, the following criteria are used:

- if $R_m < 0.01$, decoupling can be done for any R_f
- if $0.01 \leq R_m \leq 0.1$, decoupling can be done if $0.8 \geq R_f \geq 1.25$
- if $R_m > 0.1$, a subsystem model should be included in the primary system model

where,

$$R_m = \frac{\text{total mass of supported subsystem}}{\text{total mass of supporting subsystem}}$$

$$R_f = \frac{\text{fundamental frequency of supported subsystem}}{\text{dominant frequency of support motion}}$$

RAI 03.11-19, RAI 03.11-19S1

The Reactor Building (RXB) structural weight is greater than 500,000 kips (see Table 3.7.2-13). As such, a subsystem can be decoupled if the weight is less 5000 kips. The larger subsystems, the NPM and the RBC, have weights on the order of 2000 kips and could be uncoupled. However, they are both coupled in the RXB model. The fuel storage racks have a loaded weight less than 2000 kips, and each bioshield is less than ~~200~~230 kips. Therefore these SSC are decoupled.

Distributed systems (cable trays, piping, heating ventilation and air conditioning) and individual components will not have significant weights that would challenge the $R_m < 0.01$ criterion.

3.7.3.3.1 Bioshields

RAI 03.11-19, RAI 03.11-19S1

The bioshields are nonsafety-related, not risk-significant, Seismic Category II components that are placed on top of each module bay at the 125-ft~~'~~ elevation to provide an additional radiological barrier to reduce dose rates in the RXB and support personnel access. Bioshields are removed while a NPM is being detached and refueled. During that time, the removed bioshield is placed on top of an in-place bioshield. The bioshield lifting slings meet the requirements described in Section 9.1.5 under "Lifting Devices Not Specifically Designed."

RAI 03.11-19S1

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

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~~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 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 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

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 installed bioshields 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

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 face plate. The bioshield slab is anchored to the NPM bay walls with four 2-inch vertical bolts on each wall.

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

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 studied. The weight of the vertical bioshield is applied to the free edge of the slab.

RAI 03.11-19S1

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 E-W direction where the structure is guided through C-channel supports. Both cracked and uncracked concrete conditions are evaluated for the horizontal slab.

RAI 03.11-19S1

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 member and connections.

RAI 03.11-19S1

~~The slab is treated as a simply supported beam for simplified design. The combined dead and live load are treated as a distributed load along the simplified beam. The slab will exhibit one-way bending due to the fact that it is mounted directly on the two opposite buttress walls. Therefore, the maximum shear and bending for the slab is obtained from Table 3-23 of AISC Steel Construction Manual (Reference 3.7.3-6).~~

RAI 03.11-19, RAI 03.11-19S1

~~The frequency of the bioshield is based on two bioshields stacked one on top of the other. This is a conservative scenario for the seismic response. Using the parameters shown in Table 3.7.3-8 and Table 3.7.3-10, and the design weight of each bioshield, the natural vertical frequency is determined to be 11.42 Hz~~. ~~This frequency is close to the peak of the ISRS, therefore the peak acceleration is used for the design. The natural north-south frequency of bioshield slab is 337.36 Hz. Therefore the acceleration at 100 Hz from the ISRS is used. The natural east-west frequency of the bioshield slab is 44.24 Hz and is used. The accelerations used in the three directions are shown in Table 3.7.3-13.~~

RAI 03.11-19, RAI 03.11-19S1

~~Load combination 9-6 from ACI 349 (this is load combination 10 in Table 3.8.4-1) is used to calculate maximum shear and moment in the horizontal slab.~~

RAI 03.11-19

~~In addition to the slab, the capacity of the anchor bolts is checked. The anchor bolt material is ASTM A193 Grade B7 due to its temperature and corrosion resistance. The ultimate tensile stress of ASTM A193 Grade B7 steel is 125 ksi. The bioshield slab is anchored to the NPM bay walls with four 1.5-in. vertical~~

~~bolts on each wall and to the NPM pool wall with eight 1.5-in. bolts in the horizontal direction.~~

RAI 03.11-19S1

3.7.3.3.1.2 Demand-to-Capacity Ratios

Table 3.7.3-14 shows the summary of demand-to-capacity ratios for the bioshield without any reduction for steel strength due to temperature. AISC N690 requires the decrease in steel strength to be taken into account when the structural component or system is exposed to sustained temperatures in excess of 250 degrees Fahrenheit. While this strength adjustment is not mandated by code as the maximum temperature of the bioshield will be 212 degrees Fahrenheit, the highest D/C of 0.88 for steel structural members would increase to 0.92.

RAI 03.11-19S1

~~Table 3.7.3-14 shows the summary of demand to capacity ratios for the bioshield.~~

3.7.3.4 Basis for Selection of Frequencies

When practical, components are designed (or specified) so that the fundamental frequencies of the component are less than one half or more than twice the dominant frequencies of the support structure. However, equipment will be tested or analyzed to demonstrate that it is adequate for design loads considering the fundamental frequencies of the equipment and the support structure.

3.7.3.5 Analysis Procedure for Damping

Damping values used for seismic analysis of SSC are in accordance with Table 3.7.1-7. Component modal damping of piping systems is described in Section 3.12.3.2.2.

3.7.3.6 Three Components of Earthquake Motion

Seismic demand is obtained for the three orthogonal (two horizontal and one vertical) components of earthquake motion from the ISRS. Each component of the earthquake motion is considered in the seismic analysis of subsystems. When the total response of the substructure is needed, it is normally obtained by combining the three directional responses using the SRSS method. The 100-40-40 rule, which typically produces higher demand, is an acceptable alternative to the SRSS method.

3.7.3.7 Combination of Modal Responses

For the response spectrum method of analysis, the maximum responses such as accelerations, shears, and moments in each mode are calculated regardless of time. If the frequencies of the modes are well separated, the SRSS method is used; however, where the structural frequencies are not well separated, the modes are combined in accordance with Regulatory Guide 1.92 "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Rev. 3.

RAI 03.11-19S1

Table 3.7.3-8: Bioshield Nominal

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	21 ft 6 in
Bioshield distance between slab anchor bolts	22~~1~~ ft ~~1 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

Table 3.7.3-10: Moment and Shear Capacity of Horizontal Slab

Description	Parameters	Value
Out-of-plane moment capacity $\phi M_N = \phi_M M_N$	ϕM_N (kip-ft/ft)	~~206~~246
Shear capacity provided by concrete $\phi V_c = \phi_v 2bd\sqrt{(fc')}$	$\phi_v V_c$ (kip/ft)	~~21~~25
Shear capacity provided by stirrups[1] $\phi V_s = \phi_v((A_{st(s)} f_y d)/s_s)$	$\phi_v V_s$ (kip/ft)	~~27~~32
In-plane shear capacity by concrete[2] $\phi V_{conc} = \phi A_{cv}(\alpha_c \sqrt{(f_c')})$	$\phi_v V_{conc}$(kip/ft)	~~27~~31
In-plane shear capacity[2] $\phi V_{in\text{-}plane}$=minimum of $\phi A_{cv}(\alpha_c \sqrt{(f_c')} + \rho_t f_y)$ or $\phi_v 8 A_{cv} \sqrt{(f_c')}$	$\phi_v V_{in\text{-}plane}$ (kip/ft)	~~109~~122

Note:
1. Section 11.5.7.2 of ACI 349 (Reference 3.7.3-4)
2. Section 21.7.4.1 of ACI 349 (Reference 3.7.3-4)

RAI 03.11-19, RAI 03.11-19S1

Table 3.7.3-11: Bioshield Slab Self-Weight

~~Material~~	~~Density~~	~~Material Thickness~~	~~Section Width~~	~~Section Length~~	~~Section Area~~	~~Total Weight~~
	~~lb/ft³~~	~~in~~	~~ft~~	~~ft~~	~~ft²~~	~~kip~~
~~Steel~~	~~490.75~~	~~1/4~~	~~24.5~~	~~20.5~~	~~502.25~~	~~[1]10.35[1]~~
~~Concrete~~	~~150~~	~~21.5~~				~~135.00~~
~~HDPE~~	~~60.56~~	~~2~~				~~5.08~~
					~~Total~~	~~150.44~~

~~Notes:~~

~~[1]Total weight of steel is the weight of two plates (top and bottom of slab)~~

Material	**Density (pcf)**	**Thickness (in)**	**Area (ft^2)**	**Weight (kips)**
Concrete	150	23.5	502.25	147.5
Steel	490	0.25	1175.5	12.0
Misc.	N/A	N/A	N/A	8.4
Total				167.9

RAI 03.11-19, RAI 03.11-19S1

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

~~Material~~	~~Density~~	~~Material Thickness~~	~~Section Width~~	~~Section Height~~	~~Section Area~~	~~Total Weight~~
	~~lb/ft³~~	~~in~~	~~ft~~	~~ft~~	~~ft²~~	~~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~~[1]	~~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/ft³)	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

Table 3.7.3-13: Not Used~~Horizontal Bioshield Accelerations~~

~~Node~~	~~Excitation Direction~~	~~Frequency~~	~~Acceleration @ 4% Damping~~
		~~Hz~~	~~G~~
~~26191~~	~~East-west~~	~~44.28~~	~~0.737~~
	~~North-south~~	~~100.00~~	~~1.305~~
	~~Vertical~~	~~14.45~~	~~2.077~~
~~26674~~	~~East-west~~	~~44.28~~	~~0.813~~
	~~North-south~~	~~100.00~~	~~0.842~~
	~~Vertical~~	~~9.20~~	~~2.027~~

RAI 03.11-19, RAI 03.11-19S1

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~~1.844	~~206~~3.142	~~kip-ft/ft~~in^2/ft	~~0.60~~0.59
Concrete slab	~~out-of-plane shear~~Rebar in the N-S direction	~~23.62~~0.997	~~48~~3.142	~~kip/ft~~in^2/ft	~~0.49~~0.32
~~Slab anchor bolt~~Concrete slab	~~Tension~~Out-of-plane shear (E-W)	~~198.52~~32.2	~~663.75~~41.61	kips/ft	~~0.30~~0.77
Concrete slab	~~Shear~~Out-of-plane shear (N-S)	~~467.53~~20.2	~~796.5~~42.07	kips/ft	~~0.59~~0.48
~~Wall~~Slab anchor bolt	Tension + shear	~~486.16~~	~~922.5~~	~~kip~~	~~0.53~~0.52
Bioshield connection between horizontal and vertical piece - pin	Shear (double-ended)	~~385.85~~118.0	~~796.5~~191.0	kip	~~0.48~~0.62
~~Bent plate fillet weld~~Bioshield connection between horizontal and vertical piece - pin	~~Tension~~Bearing	~~37.6~~118.0	~~59.39~~154.0	kip	~~0.63~~0.77
~~Hoist ring anchorage~~Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece; headed studs	~~Interaction tension + shear~~Shear + tension	~~-~~	~~-~~		~~0.78~~0.68
~~Vertical component slot weld~~Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece	Weld ~~capacity~~	~~23.28~~8.4	~~47.25~~31.5	ksi~~kip~~	~~0.49~~0.27
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	Area provided is 2" thick and is acceptable because vertical hinge plate is acceptable and is 1.5" thick.				OK
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	Weld	16.2	31.5	ksi	0.51
Front plate assembly	Bending	576.0	1080.0	kip-ft	0.53
Steel structure member	von Mises stress	84.9	96.6	ksi	0.88
Steel structure member	Weld	6.65	31.5	ksi	0.21

RAI 03.08.04-23S4, RAI 03.11-19, RAI 03.11-19S1

Figure 3.7.3-4a: In-Structure Response Spectra at the Bioshield in X-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping

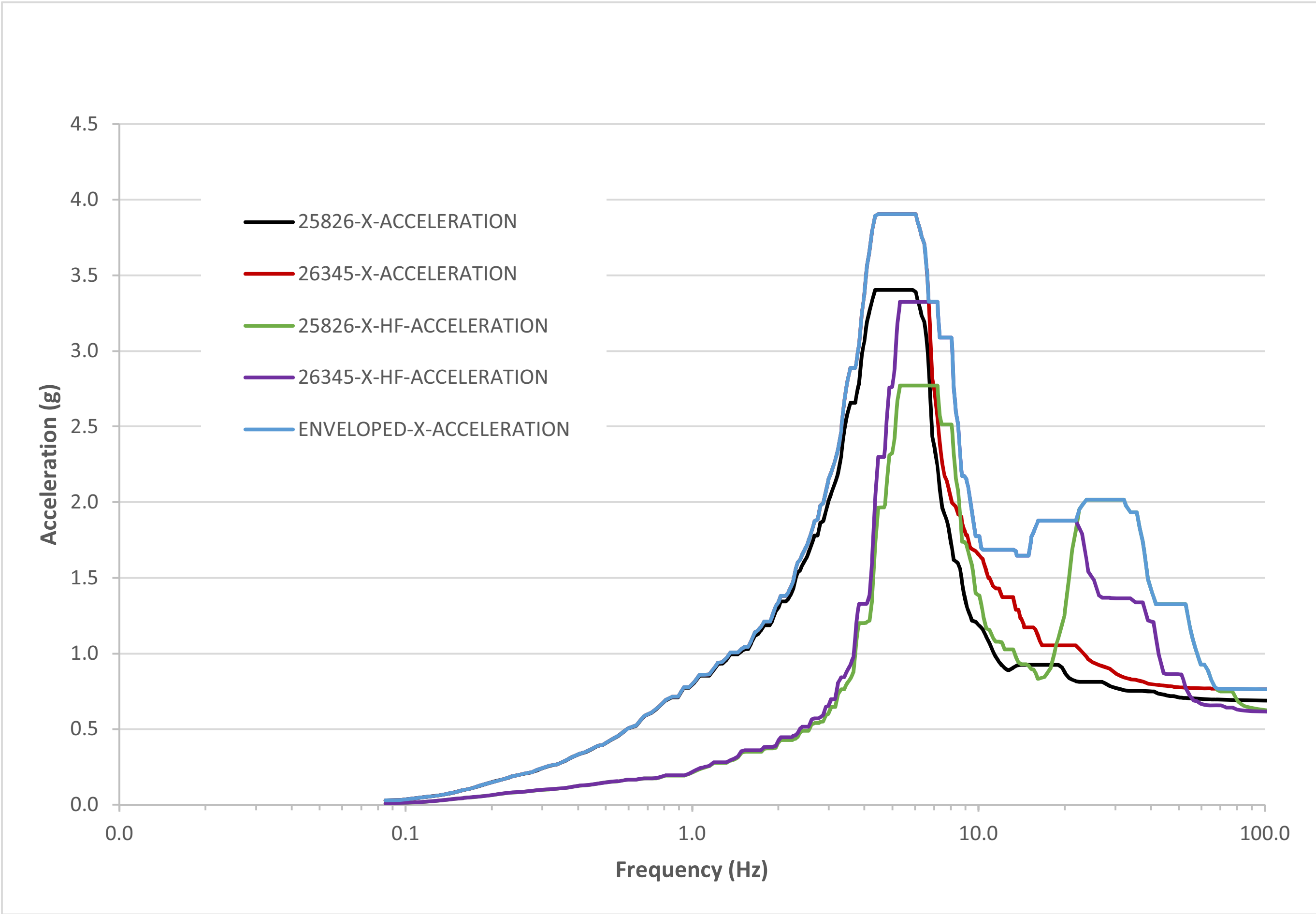
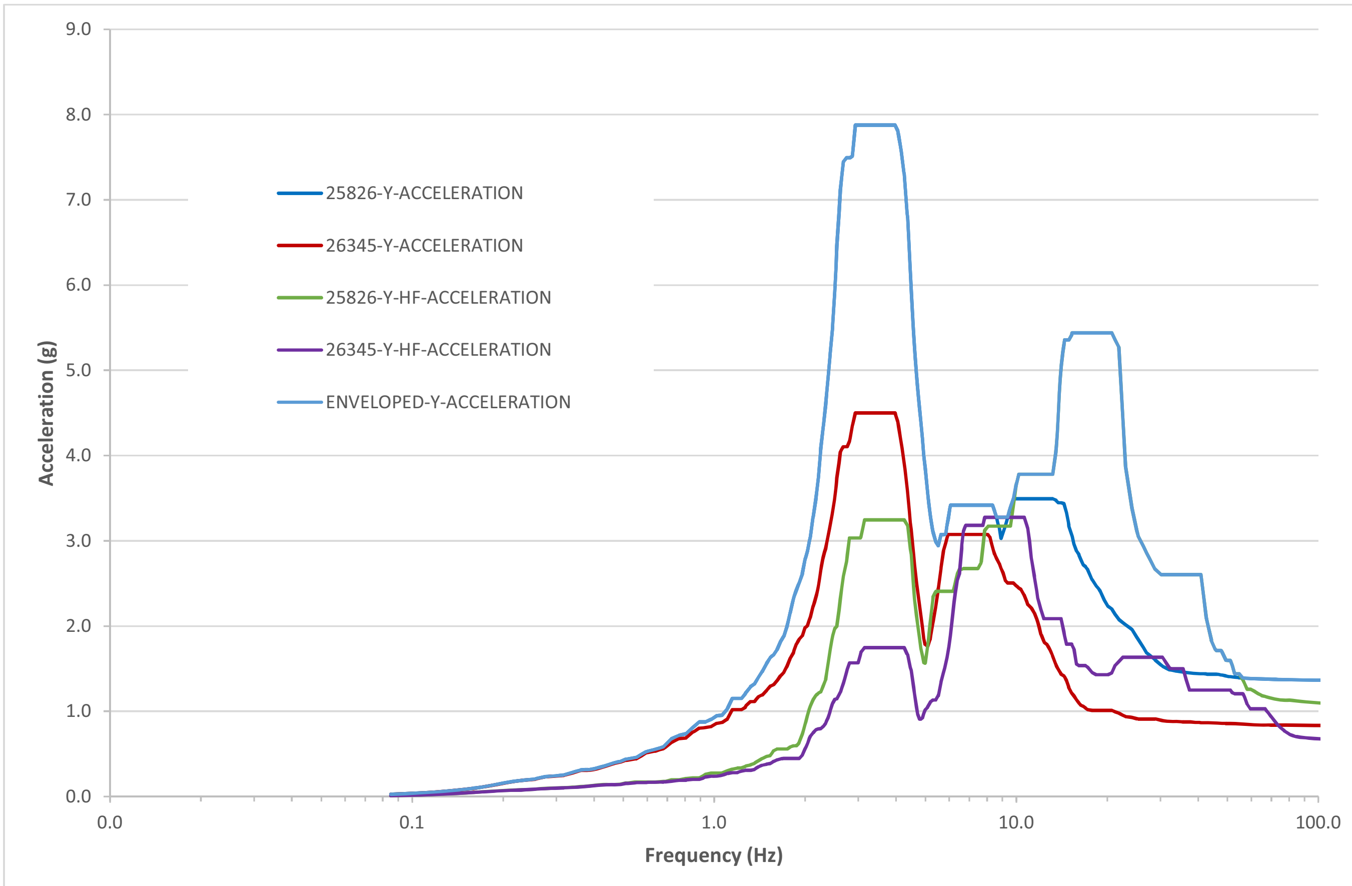
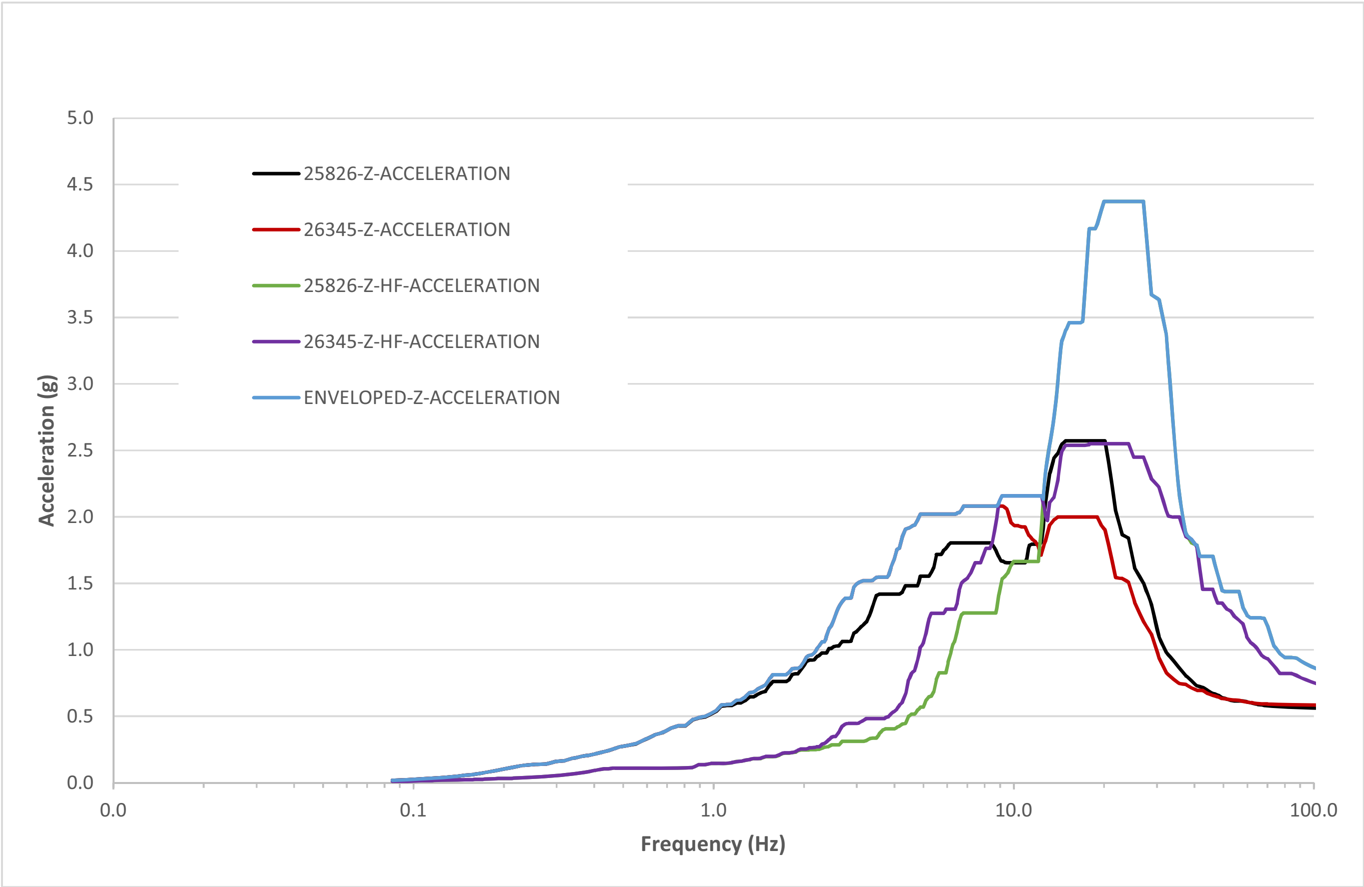


Figure 3.7.3-4b: In-Structure Response Spectra at the Bioshield in Y-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping



RAI 03.08.04-23S4, RAI 03.11-19, RAI 03.11-19S1

Figure 3.7.3-4c: In-Structure Response Spectra at the Bioshield in Z-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping



Note: The core damage event described in FSAR Section 15.10 is a special event that is outside of the scope of the EQ program.

FSAR Section 15.7.4 - radiological consequences of fuel handling accidents. This covers the FHAs within the RXB pool area.

Infrequent Events (IE)

FSAR Section 15.6.2 - radiological consequences of failure of small lines carrying primary coolant outside of containment. Similar to FSAR Section 15.6.5, this covers chemical and volume control systems (CVCS) pipe rupture events that are postulated inside or outside of containment.

Other Design Basis Events

FSAR Section 3.6 - high energy line breaks (HELB) outside containment. This covers HELB outside of containment that are not already addressed by FSAR Sections 15.1.5, 15.2.8, or 15.6.5, such as the postulated rupture of the module heatup system (MHS) piping in the gallery areas of the RXB.

FSAR Section 3.6 - moderate energy line breaks (MELB) outside containment.

Normal and Bounding Conditions

Containment vessel and reactor building pressure and humidity experienced during the indicated DBE are shown in Table 3C-7. Equipment that is required to perform a design function related to safety, and could potentially be subjected to the design basis environments, is qualified to these conditions for the required operating time.

RAI 03.11-19S1

RPV and containment vessel metal temperatures in the lower (liquid) space with corresponding liquid temperatures for the bounding DBAs are shown on Figure 3C-1. RPV and containment vessel metal temperatures in the upper (vapor) space with corresponding vapor temperatures for the bounding DBAs are shown on Figure 3C-2. The average vapor temperatures at the top of module for the bounding DBAs, and assuming a vented bioshield, are shown on Figure 3C-3. Refer to Section 3.7.3 for a description of the bioshield. The maximum vapor temperatures for elevation 145' in the RXB from the same bounding DBAs are shown on Figure 3C-4.

3C.5.5 Design Basis Event Radiation Doses

RAI 03.11-1, RAI 03.11-4

NuScale Topical Report, TR-0915-17565-P (Reference 3C-5) provides the methodology for determining the accident source terms for equipment following design basis events. The limiting event and associated source terms from the design basis accidents discussed above were used to determine total integrated doses for equipment qualification.

RAI 03.11-1, RAI 03.11-4, RAI 03.11-16, RAI 03.11-19S1, RAI 12.02-24S1

Table 3C-6: Normal Operating Environmental Conditions

Zone	Temperature (°F)	Pressure (psig) (Nominal)	Maximum Relative Humidity (%) [1]	60 Years Integrated N Dose (Rads)		60 Years Integrated γ Dose (Rads) (Includes fission γ, N-γ, coolant)		Water Level (ft. above RXB pool floor)
A	487 (lower RPV wall)	<(-14.6)[2]	0	2.4~~1~~2E8		~~9.01E10~~6.21E10		47' (inside CNV for refueling)
B	491 (RPV wall) 295 (CNV wall)	<(-14.6)[2]	0	~~6.71E8~~5.93E8		~~4.51E10~~3.11E10		47' (inside CNV for refueling)
C	551 (RPV wall)	<(-14.6)[2]	0	~~1.10E9~~9.44E8		~~4.11E7~~2.69E7		47' (inside CNV for refueling)
D	618 (outside top of PZR) 295 (CNV wall)	<(-14.6)[2]	0	~~6.00E7~~4.92E7		~~3.01E6~~2.49E6		47' (inside CNV for refueling)
E	581 (surface of MS piping)	<(-14.6)[2]	0	~~4.77E7~~3.70E7		~~2.26E6~~2.00E6		47' (inside CNV for refueling)
F	295 (upper CNV volume)	<(-14.6)[2]	0	~~3.55E7~~2.47E7		1.51E6		-
G	140	0	<100	~~1.85E6~~5.45E5		~~4.35~~1.81E4		-
H	105	0	<100	above bioshield	~~2.65E1~~4.50E2	above bioshield	~~1.60~~4.13E3	-
				EL 145	~~5.50E0~~3.52E1	EL 145	~~3.90E2~~1.80E0	
I	140	0 plus submergence head	N/A	pool center	0	pool center (coolant only)	4.93E3	69' (normal operating level outside CNV)
				next to operating module	~~8.70E7~~9.09E7	next to operating module	~~1.53E10~~1.77E10	
J	105	0	<100	0		~~6.53E04~~5.56E4		-
K	85	0	<100	0		~~1.58E01~~5.00E1		-
L	85	0	<100	0		~~1.58E01~~5.00E1		-
M	105	0	<100	0		~~5.26E00~~4.30E1		-
N	105	0	<100	0		-		-

Notes:

1. Normal service relative humidity outside of the containment vessel is shown as <100%; the relative humidity inside the containment vessel is 0% because the environment is normally maintained in a vacuum.
2. The pressure inside the CNV is maintained less than the saturation pressure corresponding to the reactor pool pressure; this results in a vacuum.
3. The boron concentration in the pool areas will be nominally 1800 ppm. EPRI primary water chemistry guidelines show the pH of a pool with 1800 ppm boron concentration to be 4.75.

RAI 03.11-1, RAI 03.11-4, RAI 03.11-16, RAI 03.11-19S1, RAI 06.02.01.01.A-18S1

Table 3C-7: Design Basis Event Environmental Conditions

Zone(3)	DBE	Temperature (°F)	DBE	Pressure (psig)(2)	DBE	Relative Humidity (%)	Water Level (ft. above RXB pool floor)	Water Spray (pipe rupture)
A	HELB	See Figure 3C-1	HELB	971.3~~58.4~~	All Events	100	24 (inside CNV to support ECCS operation)	-
B	HELB	See Figure 3C-1	HELB	971.3~~58.4~~	All Events	100	24 (inside CNV to support ECCS operation)	-
C	HELB	See Figure 3C-2	HELB	971.3~~58.4~~	All Events	100	-	Yes
D	HELB	See Figure 3C-2	HELB	971.3~~58.4~~	All Events	100	-	Yes
E	HELB	See Figure 3C-2	HELB	971.3~~58.4~~	All Events	100	-	Yes
F	HELB	See Figure 3C-2	HELB	971.3~~58.4~~	All Events	100	-	Yes
G	HELB	See Figure 3C-3	HELB	1.6~~2.5~~	All Events	100	-	Yes
H	Conditions resulting from HELB and fuel handling accident (FHA) in the pool area/top of module (TOM)	See Figure 3C-4	Conditions resulting from HELB and FHA in the pool area/ TOM	1.9~~2.75~~	Conditions resulting from HELB and FHA in the pool area/ TOM	100	-	-

Table 3C-7: Design Basis Event Environmental Conditions (Continued)

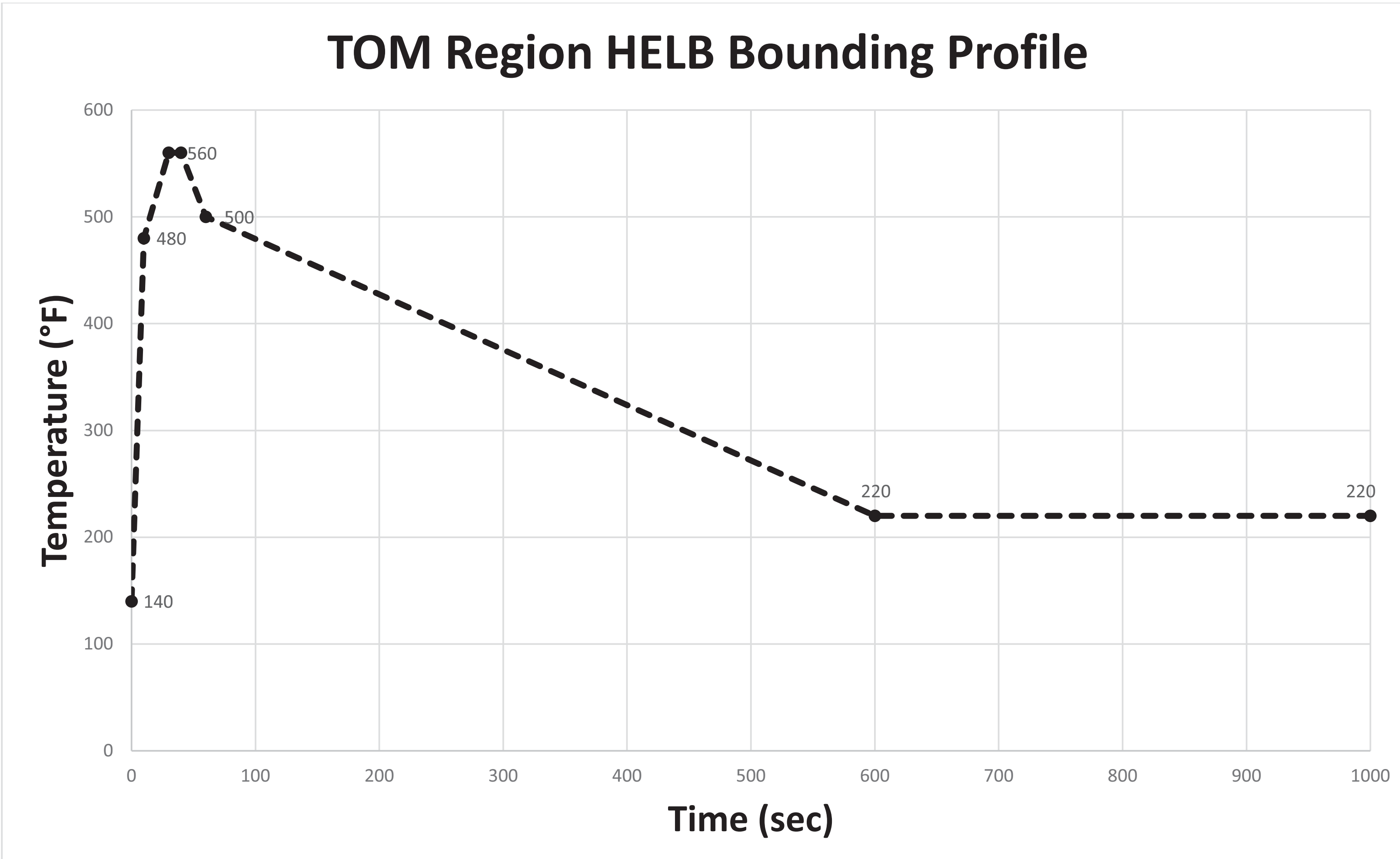
Zone(3)	DBE	Temperature (°F)	DBE	Pressure (psig)(2)	DBE	Relative Humidity (%)	Water Level (ft. above RXB pool floor)	Water Spray (pipe rupture)
I	Conditions resulting from HELB and FHA in the pool area/ TOM	212(1)	Conditions resulting from HELB and FHA in the pool area/ TOM	~~2.75~~1.9 (Equipment located below water level will be affected by hydrostatic pressure plus atmospheric overpressure)	Conditions resulting from HELB and FHA in the pool area/ TOM	N/A	75 (top of pool, not DBA condition)	-

Notes:

1. The long term pool temperature will remain at 212~~°~~ degrees F due to all modules being on DHRS from a loss of power. Equipment exposed to this environment will need to be qualified at 212~~°~~ degrees F for as long as the equipment is required as specified in Table 3.11-1.
2. Note 2 applies to Zones A through F only. Refer to TR-0516-49084 for the CNV pressure for the spectrum analyses of primary and secondary mass and energy releases. NRELAP5 was used for development of the pressure and temperature envelop for qualification of equipment within containment and has been shown to be equivalent to COMTEMPT-LT for this purpose.
3. DCA EQ Zones J, K, L, M, and N are preliminarily designated as harsh environments in the RXB because these areas contain high or moderate energy piping. Additionally, Zone J is harsh due to post-accident radiological equipment qualification exceeding source term doses > 1.0E4 Rads (60 year normal + 30 day accident dose) for electrical or mechanical equipment. Zone M is harsh due to post-accident radiological equipment qualification requirements exceeding source term doses of > 1.0E3 Rads (60 year normal + 30 day accident dose) for equipment with solid state circuitry.
4. The CNV post-accident pH for any postulated accident that results in core damage is 6.9 at 1000 ppm boron concentration and 8.3 at 200 ppm boron concentration. These values remain essentially unchanged between 25C and 200C.

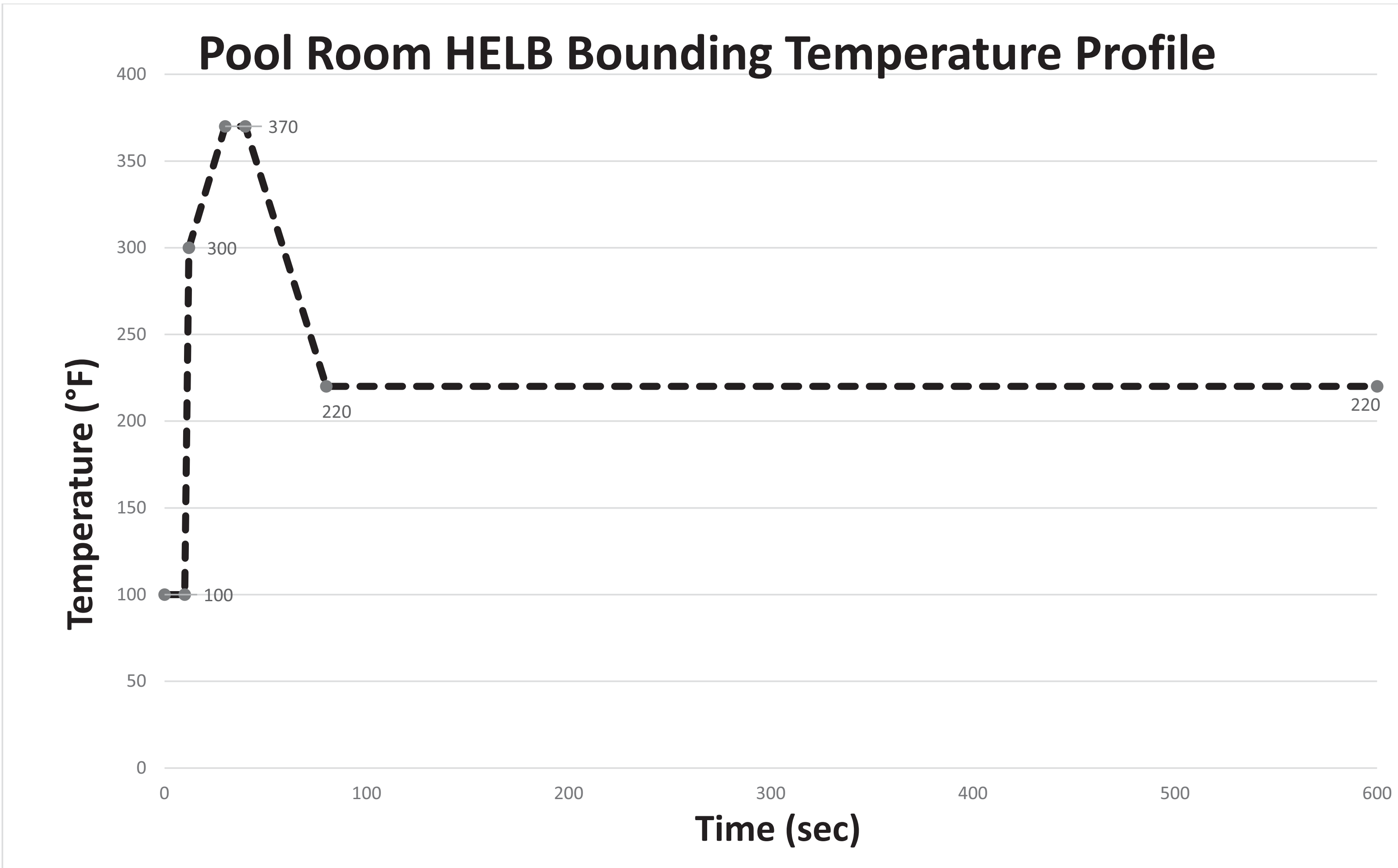
RAI 03.11-19S1

Figure 3C-3: Bounding Envelope for Average Vapor Temperature at Top of Module (Zone G)



RAI 03.11-19S1

Figure 3C-4: Bounding Envelope for Maximum Vapor Temperatures at Reactor Building El 145'-0 (Zone H)



load conditions, and bridge, trolley, and hoist position indicating the location of the RBC with respect to the building.

The RBC is controlled with the precision required for heavy load lifts necessary for normal plant operations. Variable speed controls are provided. When the load weighing system senses a heavy load during crane operation, the maximum speed of the hoists, bridge, and trolley is limited. As a load approaches a critical position, the control system limits the RBC to slow it to a predetermined maximum speed. See Table 9.1.5-1 for RBC travel speeds.

The RBC is operated to move an NPM between its installed operating position in the reactor pool to the refueling pool and back. Travel paths are determined and attributes entered into the RBC control system. Each task is specified and scheduled by the crane operator. Figure 9.1.5-1 shows the safe load paths.

Heavy load exclusion zones and safe load paths are defined in operating procedures and equipment drawings. Heavy load exclusion zones are marked in the plant areas where the load cannot be handled. This restriction reduces the probability of a heavy load drop that could result in safe shutdown equipment damage or result in a release of radioactive material that could cause unacceptable radiation exposures.

The position control system assists in the alignment of the RBC with the NPM for engagement with the RBC prior to performing lifting operations. Heavy load exclusion zones are dependent on whether or not there is a load on the RBC. The travel path is chosen to accommodate this information. Repeatability, proper load path, and proper locations are ensured by semi-automatic crane operation.

Refueling Operations

Refueling operations for an individual NPM is independent of the operating status of the remaining NPMs; only one NPM can be moved at a time. Section 9.1.4 presents the process of moving fuel assemblies into an open reactor vessel. This section presents the process of moving the NPM from the operating bay to the refueling pool and preparing the vessel for the fuel movement described in Section 9.1.4.

Immediately prior to the start of a refueling outage, the RBC, CFT, and RFT are prepared by performing pre-startup operational steps.

RAI 03.11-19S1

To access the NPM, the Bioshield above the NPM needs to be moved. ~~The Bioshield is lifted by the RBC at four points using a hoist ring that is threaded into an embedded plate anchored into the Bioshield slab.~~ The Bioshield is mounted on an adjacent Bioshield and restrained during refueling.

RAI 09.01.05-2, RAI 09.01.05-3, RAI 09.01.05-4, RAI 09.01.05-5, RAI 09.01.05-6

Traveling wall-mounted jib cranes are provided along the walls above the NPM bay areas to support refueling operations. The jib cranes are used to lift spool pieces

Containment Dome Enclosed by the Bioshield

The single reactor building houses the NPMs and maintains them partially immersed in the same UHS pool.

RAI 03.11-19, RAI 03.11-19S1

The exposed dome of each NPM containment is entirely enclosed by 3-hour rated fire barriers or the spread of fire to or from the area is eliminated by other means~~;~~ at the back by the structural pool wall, at either side by the integral, structural "wing" walls, and at the front and over the top by non-structural, removable bioshields. This configuration creates a separate fire area enclosing the top of each module thereby providing separation from other modules.

The fire area enclosed by the bioshield is a small area which cannot be practicably divided into multiple fire areas. This area must accommodate the mechanical and electrical penetrations, containment isolation valves and other valves required for safe shutdown. This area is therefore similar to the annulus area of a conventional reactor building in that it contains safe shutdown equipment for more than a single division. The arrangement of plant equipment and routing of conductors is such that redundant safe shutdown equipment cannot be divisionally separated by a 3 hour rated fire barrier. Practicable measures are taken under the bioshield to ensure that one division of safe shutdown equipment remains available to perform safe shutdown functions. Measures taken include:

- Divisional separation is provided to the extent practicable given the physical restraints of the area. Safe shutdown SSC are safety related; as a minimum, the separation guidance of RG 1.75 is followed.
- Minimal combustibles and no intervening combustibles are used. Cable is routed in suitable conduit or is of noncombustible construction.
- The use of redundant, hydraulically operated valves for safe shutdown are not dependent on power cables in the bioshield fire area.
- Divisionally separated hydraulic control units for the hydraulic valves are located outside of the bioshield fire area in separate 3-hour rated structural fire areas. The hydraulic fluid utilized is noncombustible.
- Smoke detection in the ventilation exhaust from each individual fire area enclosed by the bioshield alerts operators of the potential need for conservative actions.
- Use of a passive decay heat removal system allows safe shutdown (< 420 ~~°~~degrees F) prior to removal of bioshields for maintenance or refueling.
- Introduction of transient combustibles cannot occur until removal of the bioshields, which simultaneously allows manual fire suppression if necessary.

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- The distance between NPMs in their operating bays eliminates the spread of fire from one NPM to another when a bioshield has been removed.

Like the area inside containment, the fire area enclosed by the bioshield is evaluated in Appendix 9A as a special case.

are homogenized in the MCNP model. This simplification does not result in significant differences in dose rates. Figure 12.3-3 shows the homogenized regions and the general arrangement of the NPM shielding model.

The shielding thicknesses are selected to reduce the aggregate dose rate from significant radiation sources in surrounding areas to values below the upper limit of the radiation zone depicted in the zone maps (see Figure 12.3-1a though Figure 12.3-1i). Radiation zones are selected to facilitate personnel access for operation and maintenance.

12.3.2.4 Major Component Shielding Design Description

12.3.2.4.1 NuScale Power Module

An NPM is a self-contained nuclear steam supply system composed of a reactor core, a pressurizer, two steam generators integrated within the reactor pressure vessel, CRDMs and valves, and is housed in a compact steel containment vessel. The containment vessel is partially immersed in the reactor pool as shown in Figure 1.2-5.

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Biological shielding is provided above each NPM to allow personnel access above the 126' elevation in the RXB. The bioshield provides shielding using concrete and high-density polyethelene (HDPE).The bioshield design ~~is~~and the venting of radiolytically-generated gases from the HDPE shielding are described in Section 3.7.3.

The containment vessel, pool water, and pool wall provide shielding and attenuation. The pool wall thickness is used for attenuating radiation from the radiation sources associated with the NPM.

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COL Item 12.3-8: A COL applicant that references the NuScale Power Plant design certification will describe the radiation shielding design measures used to compensate for ~~the main steam and main feedwater piping~~major shield wall penetrations in accordance with FSAR Section 12.1.2.3.2 "Minimizing Radiation Levels in Plant Access Areas and Vicinity of Equipment," Section 12.3.1.2.3 "Penetrations," and Section 12.3.2.2 "Design Considerations."~~through the Reactor Building pool wall between the NuScale Power Module bays and the Reactor Building steam galleries near the 100 ft elevation (Shown on Figure 3.6-16 and Figure 3.6-17).~~

12.3.2.4.2 Main Control Room

The dose rate in the main control room during normal operations is negligible. The Control Building (CRB) room locations and elevations are shown in figures provided in Section 1.2. The CRB walls are designed to attenuate radiation from the RXB. As indicated by Table 15.0-12, the ~~G~~PDC 19 dose acceptance criteria for the control room are met for postulated accidents.