November 1, 2019 Docket No. 52-048

U.S. Nuclear Regulatory Commission
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**SUBJECT:** NuScale Power, LLC Submittal of Supplemental Turbine Missile Barrier Design Closure Plan Actions (Final Safety Analysis Report, Tier 2, Section 3.5.1.3)

**REFERENCES:**

1. Letter from NuScale Power, LLC to the Nuclear Regulatory Commission, "NuScale Power, LLC Submittal of Updated Closure Plan for Turbine Missile Barrier Design Safety Review Issues (Final Safety Analysis Report, Tier 2, Section 3.5.1.3)," dated September 13, 2019 (ML19259A152)
2. Letter from NuScale Power, LLC to the Nuclear Regulatory Commission, "NuScale Power, LLC Submittal of Turbine Missile Barrier Design Closure Plan Actions (Final Safety Analysis Report, Tier 2, Section 3.5.1.3)," dated May 31, 2019 (ML19151A834)
3. NuScale Power, LLC Response to the Nuclear Regulatory Commission, "NuScale Power, LLC Response to NRC Request for Additional Information No. 503 (eRAI No. 9596) on the NuScale Design Certification Application," dated October 31, 2018 (ML18304A306)
4. Letter from NuScale Power, LLC to the Nuclear Regulatory Commission, "NuScale Power, LLC Submittal of Changes to Tier 1 and Tier 2 of the NuScale Final Safety Analysis Report to Support Safeguarding Essential SSC from Turbine Missiles Using Barriers," dated June 25, 2018 (ML18176A394)

The purpose of this submittal is to address the actions identified in the Turbine Missile Barrier Design Closure Plan (Reference 1).

The information in this letter supersedes the information previously provided in References 3 and 4, except for the Final Safety Analysis Report (FSAR) changes in those submittals as they have already been incorporated into the Design Certification Application (DCA) Revision 3.

The attachment and enclosures to the letter provide the requested information.

The attachment to the letter provides a summary of NuScale's protection against the bounding turbine missile.

Enclosure 1 provides a nonpublic markup of FSAR pages incorporating revisions to affected sections, in redline/strikeout format. NuScale will include these changes as part of a future revision to the NuScale Design Certification Application. Enclosure 2 is the public version.

NuScale requests that the security-related information in Enclosure 1 be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390.

This letter makes no regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions, please contact Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

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Attachment: "Summary of NuScale's Approach to Protection against Turbine Missiles"

Enclosure 1: Changes to the NuScale Final Safety Analysis Report Section Part 2, Tier 2, Section 1.8, "Interfaces with Certified Design," Section 1.9, "Conformance with Regulatory Criteria," Section 3.5.1, "Missile Protection," Section 3.5.3, "Barrier Design Procedures," Section 3.8.4, "Other Seismic Category I Structures," Section 10.2, "Turbine Generator," and Part 9, "Withheld Information," nonpublic Version

Enclosure 2: Changes to the NuScale Final Safety Analysis Report Section Part 2, Tier 2, Section 1.8, "Interfaces with Certified Design," Section 1.9, "Conformance with Regulatory Criteria," Section 3.5.1, "Missile Protection," Section 3.5.3, "Barrier Design Procedures," Section 3.8.4, "Other Seismic Category I Structures," Section 10.2, "Turbine Generator," and Part 9, "Withheld Information," public Version

## Summary of NuScale's Approach to Protection against Turbine Missiles

The NuScale design employs a barrier approach, in combination with physical separation of redundant safety-related equipment for protection against postulated turbine missiles. The bounding turbine missile for the NuScale design is defined as half of the last stage portion of the turbine rotor with the weight of the blades. The rotor piece was selected as the bounding turbine missile based on an evaluation of kinetic energy and total penetration distance as compared to a turbine blade or turbine blade with a piece of the rotor attached. The rotor portion analyzed is a semicircular steel section that has a 24 inch radius, weighs 3568 pounds, and travels at 476 mph (based on a 190 percent destructive overspeed of a 3600 rpm turbine). The 190 percent destructive overspeed was selected based on the guidance in the Design-Specific Review Standard for NuScale SMR Design (DSRS) 3.5.1.3, "Turbine Missiles." As shown in FSAR, Figure 3.5-1, "Plan View of Partial NuScale Plant Showing Turbine Missile Trajectory", the turbines in the NuScale design are unfavorably oriented.

There are two buildings that contain safety-related equipment; the reactor building (RXB) and the control building (CRB).

The RXB was evaluated for both local and global effects of the bounding turbine missile. For the local effects, a finite element analysis (FEA) was performed to determine penetration depth of the missile into the barrier. In the FEA, the missile was impacted on the five foot thick reinforced concrete exterior wall (see FSAR, Figure 3.5-2, "Section View of RXB and TGB Showing Turbine Missile Barriers"). The FEA results show that the missile penetrates the wall a maximum of 51.2 inches. That value and the minimum projected area are used as inputs in the National Defense Research Council (NDRC) equations to determine the minimum thickness to prevent perforation and scabbing. The results show that some perforation and scabbing occur. However, damage is contained within the gallery space opposite the reactor pool, at either the 100 foot or 125 foot elevations of the RXB. Given the physical separation of the redundant safety-related equipment in the NuScale design, no single missile can prevent an essential system from performing its safety function. In addition, the majority of essential equipment requiring protection is located on top of the NuScale Power Module (NPM). The NPM is located behind an additional five foot thick barrier (i.e., the "RXB Pool Wall," shown in Figure 3.5-2) and is unaffected by the postulated bounding turbine missile. For the global effects, the FEA of the reactor building was used as well. An entire wall panel was modeled and evaluated for global effects from the bounding turbine missile to determine the overall response of the wall given the turbine missile impact. These analyses, local and global, demonstrate that while there is perforation from the bounding turbine missile, the wall retains its overall required strength for design basis loads.

The control building was also evaluated for both local and global effects of the bounding turbine missile. Similar to the local analysis of the RXB, a finite element analysis of the CRB was performed. In the analysis the bounding turbine missile was impacted on the three foot thick reinforced concrete CRB wall (see FSAR, Figure 3.5-3, "Section View of CRB and TGB Showing Turbine Missile Barriers"). As determined by the FEA, the bounding turbine missile was shown to penetrate the CRB exterior wall and exit with a residual velocity of 223 mph. This residual velocity was then applied non-orthogonally to the floor of the CRB. The missile was shown to be contained by the grade-floor slab of the building. The floor thickness was adequate to prevent perforation and scabbing. Since all safety-related equipment and the main control room are below the grade-floor slab, the CRB structure adequately protects against the postulated bounding turbine missile. Similar to the reactor building, the control building finite element analysis was used for the global assessment of the slab. This analysis also shows that while the bounding missile penetrates the exterior wall of the building, the wall and grade-level floor slab adequately retain their structural function so as not to compromise the function of safety-related equipment and the main control room.

Finally, an evaluation of the structures, systems and components (SSC) specified by Regulatory Guide 1.115 Appendix A was performed (FSAR Section 3.5.1.3.6, “Regulatory Guide 1.115 Appendix A Essential Systems”). This evaluation demonstrates that the bounding turbine missile does not prevent a safety function from being performed by providing appropriate barriers, SSC redundancy, and physical separation of the redundant SSC.

Given these results it is concluded that the NuScale design provides adequate protection against the postulated design basis turbine missile.

**Enclosure 1:**

Changes to the NuScale Final Safety Analysis Report Section Part 2, Tier 2, Section 1.8, “Interfaces with Certified Design,” Section 1.9, "Conformance with Regulatory Criteria," Section 3.5.1, “Missile Protection,” Section 3.5.3, “Barrier Design Procedures,” Section 3.8.4, “Other Seismic Category I Structures," Section 10.2, "Turbine Generator," and Part 9, “Withheld Information,” nonpublic Version

Security-Related Information – Withhold Under 10 CFR § 2.390

**Enclosure 2:**

Changes to the NuScale Final Safety Analysis Report Section Part 2, Tier 2, Section 1.8, “Interfaces with Certified Design,” Section 1.9, "Conformance with Regulatory Criteria," Section 3.5.1, “Missile Protection,” Section 3.5.3, “Barrier Design Procedures,” Section 3.8.4, “Other Seismic Category I Structures," Section 10.2, "Turbine Generator," and Part 9, “Withheld Information,” public Version

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

| | Item No. | Description of COL Information Item | Section |
|---|---|---|---|
| RAI 02.04.13-1<br>RAI 03.04.01-4 | COL Item 3.4-2: | A COL applicant that references the NuScale Power plant design certification will develop the on-site program addressing the key points of flood mitigation. The key points to this program include the procedures for mitigating internal flooding events; the equipment list of structures, systems, and components subject to flood protection in each plant area; and providing assurance that the program reliably mitigates flooding to the identified structures, systems, and components. | 3.4 |
| RAI 02.04.13-1 | COL Item 3.4-3: | A COL applicant that references the NuScale Power plant design certification will develop an inspection and maintenance program to ensure that each water-tight door, penetration seal, or other "degradable" measure remains capable of performing its intended function. | 3.4 |
| RAI 02.04.13-1 | COL Item 3.4-4: | A COL applicant that references the NuScale Power plant design certification will confirm that site-specific tanks or water sources are placed in locations where they cannot cause flooding in the Reactor Building or Control Building. | 3.4 |
| RAI 02.04.13-1 | COL Item 3.4-5: | A COL applicant that references the NuScale Power Plant design certification will determine the extent of waterproofing and dampproofing needed for the underground portion of the Reactor Building and Control Building based on site-specific conditions. Additionally, a COL applicant will provide the specified design life for waterstops, waterproofing, damp proofing, and watertight seals. If the design life is less than the operating life of the plant, the COL applicant will describe how continued protection will be ensured. | 3.4 |
| RAI 02.04.13-1 | COL Item 3.4-6: | A COL applicant that references the NuScale Power Plant design certification will confirm that nearby structures exposed to external flooding will not collapse and adversely affect the Reactor Building or Seismic Category I portion of the Control Building. | 3.4 |
| RAI 03.04.02-1<br>RAI 03.04.02-2<br>RAI 03.04.02-3 | COL Item 3.4-7: | A COL applicant that references the NuScale Power Plant design certification will determine the extent of waterproofing and damp proofing needed to prevent groundwater and foreign material intrusion into the expansion gap between the end of the tunnel between the Reactor Building and the Control Building, and the corresponding Reactor Building connecting walls. | 3.4 |
| RAI 02.04.13-1<br>RAI 10.02-3<br>RAI 10.02.03-1<br>RAI 10.02.03-2<br>RAI 03.05.03-4 | COL Item 3.5-1: | A COL applicant that references the NuScale Power Plant design certification will demonstrate that the site-specific turbine missile parameters are bounded by the ~~DC~~design certification analysis, or provide a missile analysis using the site-specific turbine generator parameters to demonstrate that barriers adequately protect essential ~~SSC~~structures, systems, and components from turbine missiles. Parameters to verify are limiting turbine missile spectrum (rotor and blade material properties); turbine rotor design, geometry and number of blades; final design of the reactor building exterior wall; final design of the control building exterior wall and grade-level slab; and location of the turbines with respect to the reactor building and control building. | 3.5 |
| RAI 02.04.13-1<br>RAI 03.05.01.03-1 | COL Item 3.5-2: | A COL applicant that references the NuScale Power Plant design certification will address the effect of turbine missiles from nearby or co-located facilities. | 3.5 |
| | COL Item 3.5-3: | A COL applicant that references the NuScale Power Plant design certification will confirm that automobile missiles cannot be generated within a 0.5-mile radius of safety-related structures, systems, and components and risk-significant structures, systems, and components requiring missile protection that would lead to impact higher than 30 feet above plant grade. Additionally, if automobile missiles impact at higher than 30 feet above plant grade, the COL applicant will evaluate and show that the missiles will not compromise safety-related and risk-significant structures, systems, and components. | 3.5 |
| RAI 03.05.02-2 | COL Item 3.5-4: | A COL applicant that references the NuScale Power Plant design certification will evaluate site-specific hazards for external events that may produce more energetic missiles than the design basis missiles defined in ~~FSAR~~ Tier 2, Section 3.5.1.4. | 3.5 |

## Table 1.9-3: Conformance with NUREG-0800, Standard Review Plan (SRP) and Design Specific Review Standard (DSRS) (Continued)

| SRP or DSRS Section, Rev: Title | AC | AC Title/Description | Conformance Status | Comments | Section |
|---|---|---|---|---|---|
| SRP 3.5.3, Rev. 3: Barrier Design Procedures | II.1.A | For Local Damage Prediction - Concrete | Departure~~Conforms~~ | NuScale uses a finite element analysis for predicting penetration distance of turbine missiles in concrete, rather than the modified National Defense Research Council (NDRC) formula specified in Section II.1.A. In some locations perforation and scabbing is predicted. However, given the physical separation of the redundant safety-related equipment, there is no turbine missile that can prevent essential systems from performing their function.~~None.~~ | 3.5.3 |
| SRP 3.5.3, Rev. 3: Barrier Design Procedures | II.1.B | For Local Damage Prediction - Steel | Conforms | None. | 3.5.3 |
| SRP 3.5.3, Rev. 3: Barrier Design Procedures | II.1.C | For Local Damage Prediction - Composite sections | Not Applicable | This acceptance criterion specifies provisions when using composite or multi-element barriers. NuScale does not use composite or multi-element barriers. | Not Applicable |
| SRP 3.5.3, Rev. 3: Barrier Design Procedures | II.2 | For Overall Damage Prediction | Partially Conforms | This acceptance criterion is applicable except for reference to subtier ANSI/AISC N690-1994 with Supplement 2 (2004). NuScale uses the 2012 version of this standard. | 3.5.3 |
| SRP 3.6.1, Rev 3: Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment | II.1 | Separation of High and Moderate Energy Fluid Systems From Essential Systems/Components | Conforms | None. | 3.6.1 |
| SRP 3.6.1, Rev 3: Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment | II.2 | High and Moderate Energy Fluid Systems Are Enclosed | Conforms | None. | 3.6.1 |

are ASME Class 1 or 2 and therefore not credible missile sources as discussed in Section 3.5.1.1.1.

A control rod drive mechanism (CRDM) housing failure, sufficient to create a missile from a piece of the housing or to allow a control rod to be ejected rapidly from the core, is non-credible. The CRDM housing is a Class 1 appurtenance per ASME Section III.

### 3.5.1.3 Turbine Missiles

The NuScale design employs a barrier approach for protecting essential structures, systems and components (SSC) against the effects of turbine missiles. This approach relies on concrete barriers, in combination with physical separation of redundant safety-related equipment, to meet the requirements of 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 4, "Environmental and Dynamic Effects Design Bases," for protecting SSC important to safety.

Regulatory Guide (RG) 1.115, refers to SSC important to safety as "essential" SSC and permits limiting the SSC considered for protection from postulated turbine missiles to those listed in Appendix A of RG 1.115. The Design-Specific Review Standard for the NuScale SMR Design (DSRS) 3.5.1.3, "Turbine Missiles," Section I.1 states, "Plants that use barriers to protect all essential SSCs specified in RG 1.115, would not have to rely on the turbine missile generation probabilities and turbine rotor integrity discussed in DSRS Section 10.2.3, 'Turbine Rotor Integrity.'" The analysis of the missile barriers is performed using the acceptance criteria in Standard Review Plan (SRP) 3.5.3, "Barrier Design Procedures." RG 1.115, Revision 2, Section B, "Protection against Turbine Missiles," cites shielding as one of the principal means of protecting against turbine missiles. Sections C.2.d and C.3 of RG 1.115 provide guidance for using barriers for protection. NuScale utilized this guidance as the basis for its approach. The acceptance criteria (Section II.6) of DSRS 3.5.1.3, "Turbine Missiles," indicates that both high and low trajectory turbine missiles be accounted for. This guidance also appears in RG 1.115. The use of barriers must also meet the acceptance criteria for penetration (and scabbing) of concrete described in RG 1.115 and SRP 3.5.3.

The basis for NuScale's approach is per RG 1.115. The first component of the safety evaluation is associated with the acceptance criteria when using barriers; no missile can compromise the final barrier, and concrete barriers should be thick enough to prevent backface scabbing (Section C.3 of RG 1.115). The second component of the safety evaluation is associated with conservatively allowing credit for the effect of physical separation of redundant or alternative systems (Section C.1 of RG 1.115). When no backface scabbing occurs, protection is considered adequate. However, when backface scabbing does occur, physical separation of redundant safety-related equipment ensures adequate protection from the bounding turbine missile.

The turbine generator building layout in relation to the overall site layout is shown on Figure 1.2-2. As shown in Figure 3.5-1, the turbine generator rotor shafts are physically oriented such that the reactor building (RXB), control building (CRB), and radiological waste building (RWB) are within the turbine trajectory hazard, thereby making the turbines unfavorably oriented with respect to the NuScale Power Modules (NPMs) as defined by RG 1.115, Revision 2. Appendix A of RG 1.115, Rev. 2 identifies essential SSC requiring protection from turbine missiles. For the NuScale design, these SSC are classified as A1 and A2 in Table 3.2-1 and are located in either the RXB or CRB. Table 3.2-1 provides a complete listing of these SSC. Essential SSC within the RXB are protected from turbine missile penetration by the RXB exterior wall. There is some perforation and scabbing, however given the physical separation of the redundant safety-related equipment, there is no turbine missile that can prevent essential systems from performing their function. Essential SSC in the CRB are located below grade and are protected by the CRB exterior wall and grade-level slab.

#### 3.5.1.3.1 Reactor Building (RXB)

The exterior wall of the RXB is the first barrier credited for protecting essential SSC within the building. The reinforced concrete RXB wall penetration shrouds shown in Figure 3.5-2 serve as an additional barrier for equipment located on the 100 ft elevation. However, these shrouds are conservatively not credited in the missile analysis, and the bounding turbine missile is analyzed to impact the exterior wall with no loss of velocity.

Detailed description of the RXB exterior walls:

- The exterior walls of the RXB are five feet thick. Appendix 3B.2.2.5 provides a description of the exterior wall at grid line E on the south side of the RXB and Figure 3B-23 shows the reinforcement.
- Table 3.8.4-10 provides the material properties of the concrete used.
- Appendix 3B.2.1 provides the structural material requirements of the RXB.
- Section 3.8.4.1.1 provides a description of the RXB with respect to its design category.
- Figures 1.2-16 and 1.2-19 show the RXB layout at the grade-level and elevation views.
- Table 3.8.4-1 defines the concrete design load combinations.

#### 3.5.1.3.2 Control Building (CRB)

The grade-level slab and the exterior wall of the CRB are the barriers credited for protecting essential SSC within the building. Essential SSC in the CRB are located below grade.

Detailed description of the CRB exterior walls and grade-level slab:

- The exterior walls of the CRB are three ft thick. Appendix 3B.3.2.2 provides a description of the exterior wall at grid line 4 on the east side of the CRB and Figure 3B-69 shows the reinforcement.
- The grade-level slab of the CRB is three ft thick. Appendix 3B.3.3.2 provides a description of the grade-level slab at elevation (EL) 100'-0".
- Table 3.8.4-10 provides the material properties of the concrete used.
- Appendix 3B.3.1 provides the structural material requirements of the CRB.

- Section 3.8.4.1.2 provides a description of the CRB with respect to its design category.
- Figures 1.2-24 and 1.2-26 show the CRB layout at the grade-level and elevation views.
- Table 3.8.4-1 defines the concrete design load combinations.

### 3.5.1.3.3 Bounding Turbine Missile Properties

Analyses are performed for three different turbine missiles: a 32.6 pound turbine blade traveling at 1241 mph, a 52.5 pound turbine blade with a fragment of the rotor traveling at 1183 mph, and half of the last stage of the turbine rotor traveling at 476 mph. The turbine rotor is determined to be the most limiting case for the NuScale design. This is based on evaluating the maximum penetration distance for the three postulated missiles and comparing the kinetic energy of the three missiles.

The bounding turbine missile is defined as half of the last stage portion of the turbine rotor with the blades attached. It is a semicircular steel section that has a 24 inch radius, weighs 3568 pounds, and travels at 476 mph (based on a 190 percent destructive overspeed of a 3600 rpm turbine). The weight is determined by summing the weight of the semicircular steel rotor portion and 15 turbine blades. The speed is determined by first calculating the distance from the center of the rotor to the centroid of half the rotor with the blades attached, and then multiplying that value by the rotational velocity (and increasing it to 190 percent overspeed).

Section 10.2.2 and Table 10.2-1 provide details regarding the type of turbine used in the analysis.

### 3.5.1.3.4 Methodology

NuScale assessed the structure of the RXB and CRB for the effects of turbine missiles. The assessment consists of two focus areas: local and global.

The local turbine missile barrier assessment evaluates penetration, perforation, and scabbing of the barriers.

The global turbine missile barrier analysis evaluates the wall or slab panels of the RXB and CRB to assess the structural response and the ability of the wall or slab to perform its function of resisting design basis loads and transferring loads to adjacent structural elements.

The finite element analysis described in the sections that follow, demonstrates that the effects of the bounding turbine missile are local and the wall strain values from the bounding turbine missile are essentially zero at a distance, d, of the missile diameter away from where the impact is applied. As such, for the global assessment, a review of demand-to-capacity ratios from other design basis loads is performed to ensure that adequate margin is available for the bounding turbine missile when applied coincident with those other loads.

#### 3.5.1.3.4.1 Acceptance Criteria

Acceptance criteria for local damage:

1) Penetration

The acceptance criteria for turbine missile barriers as delineated in subsection II.1.A of SRP 3.5.3 suggests the use of empirical equations such as the modified National Defense Research Council (NDRC) formula and "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," by R.P. Kennedy (Reference 3.5-3). Although the methodologies referenced in these documents do not have definitive limits on size or mass, the research and tests that inform the methodology do not use missiles greater than 300 pounds or velocities greater than 500 feet per second. These methods were developed for a steel slug, a piece of steel pipe, and a wooden pole. These objects are relatively small and light when compared to a projectile the size of half of a turbine rotor. Additionally, the NRDC formula is limited with respect to penetration distance, particularly if the results of the penetration distance divided by the overall thickness are outside of certain values. When this occurs, the NDRC equation results become uncertain. As an alternative, NuScale utilizes a finite element analysis for predicting penetration distance in concrete, instead of the NDRC formula suggested in the acceptance criteria of SRP 3.5.3.

2) Perforation, Spalling, or Scabbing

Barrier thickness to protect from perforation, spalling, and scabbing are considered. The modified NDRC formula are used to determine the thickness necessary to prevent perforation and scabbing, based on the penetration thickness determined in the finite element analysis. Spalling is not a concern because it occurs on the face the missile impacts. The required thickness to protect against perforation and scabbing is increased by 20 percent as required by ACI 349-06 Appendix F. The required thickness is then compared to the available thickness of the wall or slab.

Acceptance criteria for global damage:

NuScale uses the finite element analysis described in the preceding paragraphs to assess the global effects of the bounding turbine missile. Following the missile impact, the wall or floor needs to serve its function of supporting the structure and transferring forces and moments to adjacent structural elements. To perform this assessment, the concrete and rebar strains are reviewed to determine the extent of damage. Results are then compared to the calculated demand-to-capacity ratios presented in Appendix 3B to confirm that the available margin in the wall or floor is adequate to ensure that each retains its structural integrity and remains capable of performing its safety-related function as described in Part 2 Tier 1, Section 3.11 (RXB) and Section 3.13 (CRB).

#### 3.5.1.3.4.2 Finite Element Analyses (FEA)

Concrete barriers require assessment to determine the wall thickness required to prevent barrier perforation and scabbing. First, the concrete barrier penetration depth is determined using FEA. NuScale uses the FEA approach because the penetration depth to missile diameter ratio is outside the limits of the empirical equations commonly used for barrier design.

The concrete barrier is modeled using concrete material performance provided through an ANACAP constitutive model. The concrete material properties are modeled to match the RXB or CRB. The compressive strength of concrete used in the analyses is the minimum specified design value. The concrete elastic modulus is calculated from the ACI relation, $E=57000\sqrt{fc'}$, and the tensile strength is calculated from the relation $ft=1.7*(fc')^{2/3}$, where fc' is the effective compressive strength of concrete. Note that these equations use English units (psi). In the analytical concrete material model, the uniaxial cracking strain is used, which is the tensile strength divided by the elastic modulus. The turbine missile is modeled in TeraGrande. The missile material properties, ASTM A470 CL4 (Table 10.2-1), are also modeled.

Using actual material properties and barrier and missile geometries, the maximum penetration depth is calculated using nonlinear FEA in TeraGrande. The velocity of the missile is determined by converting the rotational speed of the turbine to a linear velocity of the missile ejected from the turbine rotor. The rotational speed of the NuScale turbine is 3600 rpm and the radius of rotation is taken as the distance from the center of the rotor to the centroid of the missile. TeraGrande performs non-linear analysis factoring in strain hardening of the turbine missile, deformation of the missile, and degradation of the concrete through contact with the missile. The maximum penetration is the distance that the turbine missile penetrates into the concrete barrier before its motion is stopped by the barrier.

The wall section considered for each model is 20 ft by 20 ft. A 20 ft by 20 ft section size is used because it is large enough to eliminate any boundary condition effects from the impact of the rotor at the center of the target and serves to assess the global response of the wall to the turbine missile. The floor-to-floor height of the RXB is 26 feet, and an evaluation of the wall strain results of the 20 ft x 20 ft model show that at a distance of one missile diameter away from where the impact is applied, the wall strains approach zero. The above-grade floor-to-floor height of the CRB is 20 ft, which is the same as the height of the wall panel used in the FEA model, and the 20 ft width is shown to adequately capture the behavior of the wall and eliminate any boundary condition effects. The sides of the wall are fixed along all sides parallel to the impact direction. The concrete wall is meshed with 8-node continuum elements. Steel reinforcement is included in the walls and slab (for the CRB), and modeled one-to-one with the layout described in Appendix 3B. The placement of the missile impactor is positioned with the leading edge directly on the center of the target wall. Evaluations also place the rotor strike near the model edge and near a model corner. These evaluations confirm that the penetration depth is not sensitive to the strike location. The overspeed velocities are applied as initial conditions on the rotor during the assessment of the wall. No reduction in velocity is assumed between the location of the turbine and the wall. The rotor fragment is oriented to strike the wall such that it produces the maximum penetration, and is aligned perpendicular to the wall from the sharp edge of the rotor through the center of gravity of the rotor. This produces the largest principal strain and penetration depth as it minimizes the rotation of the rotor on impact with the concrete wall. In addition, investigation is performed with the orientation of the rotor at an alignment that minimizes the projected area of the rotor with the target.

#### 3.5.1.3.4.3 Final Required Barrier Thickness

Empirical equations endorsed by NUREG 0800 SRP 3.5.3 are used to determine the concrete barrier thickness to prevent perforation of the missile through the barrier and scabbing of concrete material off the back face of the wall. The modified NDRC equations are used.

Modified NDRC equations for perforation and scabbing are provided in Section 3.5.3.1.1.2 and Section 3.5.3.1.1.3, respectively. The penetration depth calculated from the FEA is used as input x. The missile diameter is determined from the projected area of the missile on the concrete target. For the RXB, this occurs when the center of gravity of the missile is aligned with the target and results in an equivalent diameter of 22.58 inches. For the CRB, since the missile penetrates the wall and impacts the floor, this occurs when the flat face of the missile impacts the floor, resulting in an equivalent diameter of 27.1 inches. Based on ACI 349 F7.2.1 and F7.2.2, the results from the empirical equations for perforation and scabbing are increased by 20 percent to calculate the final required barrier thickness.

The extent of the finite element analyses is a 20 ft x 20 ft wall panel. As such, global damage of the walls is assessed in the same model. An evaluation of reinforcing yielding effects in the wall are evaluated to determine the wall's ability to retain its required capacity. The analysis results show reinforcement yielding is localized to the impact location, which is indicative of a local punching shear mechanism. Reinforcement away from the impact location is seen to be elastic at the end of the impact analyses. As a result, the global assessment focuses on reviewing the overall building results that include the other design basis loads presented in Appendix 3B to ensure that margin is available for the distribution of loads to adjacent elements following the missile perforation.

#### 3.5.1.3.4.4 Verification and Validation of Finite Element Analysis Software for Turbine Missiles

NuScale performed FEA of the concrete barriers to assess penetration effects of turbine missiles. The software used, TeraGrande Explicit Dynamics Version 2.0-13905, was audited through NuScale's quality assurance program for commercial-grade dedication in accordance with Regulatory Guide 1.231, “Acceptance of Commercial-Grade Design and Analysis Computer Programs

Used in Safety-Related Applications for Nuclear Power Plants," (Reference 3.5-10) and Electric Power Research Institute (EPRI) TR-1025243, "Plant Engineering: Guideline for the Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Nuclear Safety-Related Applications," (Reference 3.5-11).

To ensure that the FEA software produced penetration results similar to what would be expected of the NuScale turbine missiles, the TeraGrande software was verified and validated against data from EPRI NP-2745, "Full-Scale Missile Concrete Impact Experiments" for larger missiles (Reference 3.5-12). Table 3.5-2 provides the input parameters for the missiles analyzed. The diameter and shape of the turbine missile and the construction of the target used in the EPRI tests were similar to those of the bounding turbine missile and barriers in the NuScale design.

TeraGrande was validated to ensure the software penetration results represent test data published by EPRI for a larger missile. In the EPRI study, case 4 tested a full-scale turbine rotor fragment thrown at a heavily reinforced concrete wall (Table 3.5-2 shows the size and velocity of the missile). This study published results that the 4630 pound turbine rotor fragment penetrated the concrete wall by 25.6 inches and that a steel plate liner on the back face of the wall deformed by 1.77 inches. Parameters of the EPRI test case 4 were modeled using the same rotor missile and concrete wall properties and analyzed using TeraGrande. The FEA results show the rotor missile penetrates the concrete wall 29.6 inches and the steel plate liner on the back face of the wall deforms by 1.81 inches. The FEA results are 15.8 percent higher for penetration and only 2.3 percent higher for deformation of the liner plate. The EPRI test and TeraGrande FEA results demonstrate that the FEA software accurately predicts the penetration depth of a large turbine rotor missile.

#### 3.5.1.3.5 Results

The RXB is evaluated for both local and global effects of the bounding turbine missile using design basis concrete and rebar material properties. For the local effects, the FEA was used to determine the penetration depth of the bounding missile into the barrier. The FEA results show that the bounding turbine missile at 190 percent overspeed penetrates the 60 inch, reinforced concrete wall a maximum of 51.2 inches. That value, and the minimum projected area, are used as inputs in the NDRC equations to determine the minimum thickness to prevent perforation and scabbing. The results show that some perforation and scabbing occur. However, damage is contained within the gallery space opposite the reactor pool, at either the 100 ft or 125 ft elevations of the RXB. In the event that equipment in either of these rooms is rendered inoperable, the plant remains in a safe condition due to the redundancy of equipment in the other room. Given the physical separation of the redundant safety-related equipment in the NuScale design, no single turbine missile can prevent an essential system from performing its safety function. In addition, the majority of essential equipment that needs to be protected is located on top of the NPM. The NPM is located behind an additional five ft thick concrete reinforced barrier (i.e., the RXB "pool wall") as shown in Figure 3.5-2, and is unaffected by the postulated bounding turbine missile. For the global effects, the FEA of the RXB is used. A wall panel is modeled and evaluated for global effects of the bounding turbine missile to determine the overall response of the wall given the turbine missile impact. The maximum principal strains show that, while there is perforation of the wall around the area of the bounding turbine missile application, the overall wall remains intact and serves its function of resisting design basis loads. Specifically, the analysis results show reinforcement yielding is localized to the impact location, which is indicative of a local punching shear mechanism. The analysis also shows that damage is limited to the region where the missile hits, and extends approximately a distance of the missile diameter, d, away from that point. At this location, the principal strain caused by the impact is essentially zero, and as such, the stress in the wall from the missile impact is also zero. This means that the perforation in the wall is limited to a size of the 24 inch radius of the turbine missile. Given that the damage is confined to this local region, it is concluded that the turbine missile has a negligible effect on the overall response of the building. Reinforcement away from the impact location is seen to be elastic at the end of the impact analyses. As a result, the global assessment focuses on reviewing the overall building results that include the other design basis loads as presented in Appendix 3B. Table 3B-14 shows that the maximum element demand-to-capacity ratio for RXB wall reinforcement in any direction is 0.77 (most are below 0.5), which indicates available margin for these and other applicable loads. In other words, the FEA model shows that the wall reinforcing yields only near the point of missile impact, indicating that the stresses on the wall beyond the point of impact are minimal and within the margin of the wall capacity. These analyses, local and global, demonstrate that, while there is perforation from the bounding turbine missile, the wall retains its overall required strength for design basis loads.

The control building is also evaluated for local and global effects of the bounding turbine missile using design basis concrete and rebar material properties. Similar to the local analysis of the RXB, a finite element analysis of the CRB is performed. In the analysis, the missile is impacted on the three ft thick reinforced concrete CRB exterior wall (see Figure 3.5-3). As determined by the FEA, the missile at 190 percent overspeed penetrates the CRB exterior wall with a hole that is roughly the size of the missile, and exits with a residual velocity of 223 mph. This residual velocity is then applied at a 15 degree angle to the floor of the CRB and a maximum of 2.9 inches of penetration occurs on the grade-level slab of the building. The angle is determined by conservatively doubling the angle of a direct line from the top of the turbine to the grade-level slab of the building. The thickness to prevent perforation is 10.83 inches and thickness to prevent scabbing is 25.64 inches, both of which are less than the 36 inch thickness of the floor. Therefore, no perforation or scabbing occurs. In general, the missile applies a glancing blow to the floor. Since the safety-related equipment and the main control room are below the grade-level slab, the CRB structure adequately protects against the postulated bounding turbine missile. Similar to the reactor building, the control building finite element analysis is used for the global assessment. The maximum principal strains show that, while the bounding turbine missile penetrates the exterior wall of the CRB, the strain effects are localized to the region of the wall and floor slab where the missile impacts, and they remain intact. Similar to the reactor building, the extent of damage caused by the turbine missile is limited to the size of the missile, and a distance, d, away from the point of impact. The hole in the wall developed from the missile penetration is the size of the 24 inch radius. In addition, as shown in Table 3B-33 and Table 3B-47, the element demand-to-capacity ratio for the exterior wall and grade-level slab, respectively, of the CRB are presented. The maximum demand-to-capacities of the reinforcement in any direction (including shear) are 0.78 (most are below 0.4) and 0.84, demonstrating available margin to these and other applicable loads. In summary, the FEA model shows that the slab reinforcing yields only near the point of missile impact, indicating that the stresses on the slab beyond the point of impact are minimal and within the margin of the slab capacity. The analyses show that the CRB wall and slab adequately retain their structural function so as not to compromise the function of safety-related equipment and the main control room.

Evaluation of shock effects from turbine missiles are not explicitly mentioned by SRP 3.5.3 or RG 1.115, but are also considered for turbine missiles. When a missile strikes a barrier, shock is transmitted starting from the center of the initial impact along a structural pathway that may affect essential equipment. The buildings are robust with respect to vibrations, specifically slabs, and anchored equipment are designed to withstand the effects of the in-structure response spectra provided in Section 3.7.2 and will remain functional after the accelerations that are a part of a safe-shutdown earthquake. This provides confidence that the design will also be adequate for shock accelerations that result from a turbine missile impact. In the RXB, systems susceptible to direct missile strike effects are protected from shock accelerations by physical separation; specifically, redundant equipment is separated by different floor elevations and north/south plan dimensions, such that the one train of redundant equipment could be rendered inoperable and the duplicate equipment in a separate room remains available to perform the safety function. System functionality is maintained given this redundancy. In the CRB, safety-related equipment is mounted on the floor of the main control room (or below), and not affected by an impact at the grade-level slab. Given the separation of redundant equipment, shock effects from a turbine missile cannot prevent a system from performing its safety function.

~~RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2~~

~~The turbine generator building layout in relation to the overall site layout is shown on Figure 1.2-2. The turbine generator rotor shafts are physically oriented such that the RXB, CRB, and RWB are within the turbine trajectory hazard, thereby making the turbines unfavorably oriented with respect to the NPMs, as defined by RG 1.115, Revision 2. Appendix A of RG 1.115, Rev. 2 identifies SSC requiring protection from turbine missiles. The SSC that require protection from turbine missiles (high-trajectory and low-trajectory turbine rotor and blade fragments) are located in either the RXB or the CRB. The SSC located in the RXB and below grade in the CRB are classified as A1 or A2 (per Section 3.2) and are considered essential SSC as defined in Appendix A of RG 1.115. Table 3.2-1 provides a complete listing of these SSC.~~

~~Section 10.2.2 and Table 10.2-1 provide details regarding the type of turbine to be used in the NuScale design. Using the design and material specifications that appear in Section 10.2.2 and Table 10.2-1, the turbine missiles selected for evaluation included:~~

- ~~A turbine blade weighing 32.6 lbs with an equivalent diameter of 1.41 inches, and a velocity of 1150 ft/s.~~

- ~~A turbine blade with a rotor fragment weighing 52.6 lbs with a rotor width of 4.5 inches, and a velocity of 1461 ft/s.~~
- ~~Half of the last stage of the turbine rotor weighing 3079 lbs that is 48 inches in diameter by 12 inches wide, and a velocity of 512 ft/s.~~

RAI 03.05.03-4, RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

COL Item 3.5-1: A COL applicant that references the NuScale Power Plant design certification will demonstrate that the site-specific turbine missile parameters are bounded by the ~~DC~~design certification analysis, or provide a missile analysis using the site-specific turbine generator parameters to demonstrate that barriers adequately protect essential ~~SSC~~structures, systems, and components from turbine missiles. Parameters to verify are limiting turbine missile spectrum (rotor and blade material properties); turbine rotor design, geometry and number of blades; final design of the reactor building exterior wall; final design of the control building exterior wall and grade-level slab; and location of the turbines with respect to the reactor building and control building.

RAI 03.05.01.03-1, RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

COL Item 3.5-2: A COL applicant that references the NuScale Power Plant design certification will address the effect of turbine missiles from nearby or co-located facilities.

#### 3.5.1.3.6 Regulatory Guide 1.115 Appendix A Essential Systems

Regulatory Guide 1.115, Appendix A states that SSC considered for protection from postulated turbine missiles may be limited to the SSC listed in the Appendix and the effect of physical separation of redundant or alternative systems may also be considered. The regulatory guide refers to the Appendix A list of SSC as "essential" SSC. Some Appendix A SSC do not exist in NuScale's design, others perform no safety-related function, and each is designed to fail to its safe position.

For the NuScale design, essential SSC are classified as A1 and A2 in Table 3.2-1 and are located in either the CRB or the RXB.

Protection of essential SSC from the postulated bounding turbine missile is achieved as follows:

- Essential SSC in the CRB are located below grade and are protected by the CRB exterior wall and grade-level slab.
- Essential SSC within the RXB are protected from missile penetration by the RXB exterior wall. There is some perforation and scabbing. However, given the physical separation of the redundant safety-related equipment, there is no missile that can prevent an essential system from performing its function. Essential SSC listed in Table 3.5-3 and located in the RXB can be grouped into three areas: those located behind the pool wall, those located below grade, and those located generally within the building.

**3.5.1.3.6.1 Reactor Coolant Pressure Boundary**

The reactor coolant pressure boundary is located within the RXB behind the exterior wall and behind the pool wall and is adequately protected against the effects of turbine missiles.

**3.5.1.3.6.2 Main Steam and Feedwater Systems**

The portions of the main steam and main feedwater systems, up to and including the main steam isolation valves, secondary main steam isolation valves and feedwater isolation valves, are located within the RXB behind the exterior wall and behind the pool wall and are adequately protected against the effects of turbine missiles.

**3.5.1.3.6.3 The Reactor Core**

The reactor core is located within the RXB behind the exterior wall and behind the pool wall and is adequately protected against the effects of turbine missiles.

**3.5.1.3.6.4 Safe Shutdown and Cooling**

Systems required for attaining safe shutdown are located in the RXB and are protected through redundancy and separation such that the ability of these systems to perform their safety-related functions is not affected by the effects of turbine missiles. There are no SSC required for attaining safe shutdown located outside the RXB.

Systems required for removing residual heat are located in the RXB and are protected through redundancy and separation such that the ability of these systems to perform their safety-related functions is not affected by the effects of turbine missiles. There are no SSC required for removing residual heat located outside the RXB.

The combined capacity of the reactor pool and spent fuel pool (ultimate heat sink) provide the required design basis cooling for spent fuel. As described in Table 1.9-3, the ultimate heat sink is a supply and source for spent fuel cooling for accident conditions. The reactor pool and spent fuel pool are located in the RXB behind the exterior wall and behind the pool wall and are adequately protected against the effects of turbine missiles.

The containment system main steam isolation valves and the nonsafety-related secondary main steam isolation valves are located in the RXB behind the pool wall and are adequately protected against the effects of turbine missiles.

There are no systems required for supplying makeup water for the primary system to achieve safe shutdown.

There are no support systems required for supporting the above functions.

#### 3.5.1.3.6.5 Spent Fuel Pool

The spent fuel storage pool is located within the RXB behind the exterior wall and behind the pool wall and is adequately protected against the effects of turbine missiles.

#### 3.5.1.3.6.6 Reactivity Control Systems

As identified in Table 1.9-3, the control rod drive system is the safety-related means of reactivity control for the NuScale design. The control rod drive mechanisms, which de-energize on a loss of power (fail safe), are located in the RXB behind the exterior wall and behind the pool wall and are adequately protected against the effects of turbine missiles.

#### 3.5.1.3.6.7 Control Room

The control room, including equipment needed to maintain the control room within safe habitability limits for personnel and within safe environmental limits for protected equipment, are located within the CRB and below grade and are adequately protected against the effects of turbine missiles.

#### 3.5.1.3.6.8 Gaseous Radwaste Treatment System

Portions of the gaseous radwaste treatment system (GRWS) are located in the RXB and in the radiological waste building (RWB).

The GRWS components located in the RWB and portions of the RXB are susceptible to the effects of turbine missiles. However, should a portion of the GRWS located in either of these buildings fail due to the effects of a turbine missile, the potential radioactive release does not exceed off-site exposures greater than 25 percent of the applicable guideline exposures in 10 CFR 52.47(a)(2)(iv) (equivalent to the guideline exposures of 10 CFR 50.34(a)(1)). Such a release is bounded by the failure of the GRWS postulated in Section 11.3.3.1 and the related doses presented in Table 11.3-9.

#### 3.5.1.3.6.9 Monitoring and Actuating Systems

The neutron monitoring system (NMS) and the module protection system (MPS) are the systems required for monitoring, actuating, and operating protected portions of the systems listed in Items 4, 6, and 7 of Appendix A of Regulatory Guide 1.115. Item 13 is not applicable to the NuScale design.

Portions of the MPS are located in the RXB and the CRB. The RXB houses the NMS equipment.

The NMS and MPS components in the RXB are located behind the pool wall or below grade and are protected through redundancy and separation such that the ability of these systems to perform their safety-related functions is not affected by the effects of turbine missiles.

The portions of the MPS located within the CRB are located below grade and are adequately protected against the effects of turbine missiles.

#### 3.5.1.3.6.10 Electric and Mechanical Devices and Circuitry

Electric and mechanical devices and circuitry between the process sensors and the input terminals of the actuator systems involved in generating signals relied on for initiating actions for:

- attaining safe shutdown are located in the RXB. These systems are adequately protected through redundancy and separation such that the ability to perform their safety-related functions is not affected by the effects of turbine missiles.
- removing residual heat are located in the RXB. These systems are adequately protected through redundancy and separation such that the ability to perform their safety-related functions is not affected by the effects of turbine missiles.
- initiating spent fuel cooling. There is no process sensor or actuation system that initiates spent fuel pool cooling. Spent fuel pool cooling system initiation is an operator task. The spent fuel cooling system is nonsafety-related and not risk-significant. The pool volume provides cooling as previously described.
- mitigating the consequences of a credible missile-induced high energy line break are located in the RXB and are adequately protected through redundancy and separation such that the ability to perform their safety-related functions is not affected by the effects of turbine missiles.
- providing make-up water to the reactor coolant system. There are no process sensors or actuation system that initiates make-up water to the reactor coolant system. As described in Section 3.1.4.4, the chemical and volume control system provides reactor coolant make-up during normal operation for small leaks in the reactor coolant pressure boundary, but is not relied upon during a design basis event.

Electric and mechanical devices and circuitry between the process sensors and the input terminals of the actuator systems involved in generating signals that are relied on for reactivity control are located in the RXB and the CRB. Those portions located in:

- The RXB are adequately protected through redundancy and separation such that the ability to perform their safety-related functions is not affected by the effects of turbine missiles.
- The CRB are located below the grade-level slab of the CRB and are adequately protected against the effects of turbine missiles.

There are no electric and mechanical devices and circuitry between the process sensors and the input terminals of the actuator systems involved in generating signals that initiate protective actions from the control room. These components are located in the RXB behind the pool wall under the bioshield or below grade.

The requirement to protect electric and mechanical devices and circuitry between the process sensors and the input terminals of the actuator systems involved in generating signals that initiate protective actions by protected portions of the Class 1E electric systems and auxiliary systems for the on-site electric power supplies that provide the emergency electric power needed for the functioning of plant features, is not applicable to the NuScale design. NuScale does not have a Class 1E electric system or any other emergency electric power necessary for the functioning of essential SSC.

### 3.5.1.3.6.11 Long-term Core Cooling

Emergency core cooling system equipment and other systems required to provide long-term core cooling (i.e., containment and the ultimate heat sink) after a loss-of-coolant accident are contained within the RXB behind the exterior wall and behind the pool wall and are adequately protected against the effects of turbine missiles.

Individual fuel assemblies in the NPM or in the spent fuel pool are located within the RXB behind the exterior wall and behind the pool wall and are adequately protected against the effects of turbine missiles.

### 3.5.1.3.6.12 Containment and Structures

The primary reactor containment is located within the RXB behind the exterior wall and behind the pool wall and is adequately protected against the effects of turbine missiles.

Damage to a protected item is considered unacceptable if the damage is such that the functionality of the system to which that item belongs is lost.

As described in Tier 1, Section 3.11.1, the RXB is a safety-related building. Protection of safety-related items located in the RXB is achieved through redundancy and separation such that the ability of these systems to perform their safety-related functions is not affected by the effects of turbine missiles.

As described in Tier 1, Section 3.13.1, the CRB is a safety-related building. The CRB exterior wall and grade-level slab serve as the barriers to protect safety-related SSC located within the CRB against the effects of turbine missiles.

The auxiliary building contains no essential SSC requiring protection from turbine missiles.

### 3.5.1.3.6.13 Electrical Systems

NuScale's design has no Class 1E electric systems or auxiliary systems for on-site electric power supplies that provide emergency electric power needed for the functioning of plant features included in Items 1 through 11 of Appendix A of Regulatory Guide 1.115.

#### 3.5.1.3.6.14 Other SSC

For the NuScale design, there are no SSC or portions of SSC not already identified in items 1 through 13 whose continued function, if lost, could reduce to an unacceptable safety level the functional capability of any plant features included in Items 1 through 13 of RG 1.115, Appendix A.

### 3.5.1.4 Missiles Generated by Tornadoes and Extreme Winds

Hurricane and tornado generated missiles are evaluated in the design of safety-related structures and risk-significant SSC outside those structures. The missiles used in the evaluation are assumed to be capable of striking in all directions and conform to the Region I missile spectrums presented in Table 2 of RG 1.76, Rev. 1, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" for tornado missiles and Table 1 and Table 2 of RG 1.221, Rev. 0, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," for hurricane missiles. These spectra are based on the design basis tornado and hurricane defined in Section 3.3.2 and represent probability of exceedance events of 1 x $10^{-7}$ per year for most potential sites.

The selected missiles include

- A massive high-kinetic-energy missile that deforms on impact, such as an automobile.

  The "automobile" missile is 16.4 feet by 6.6 feet by 4.3 feet with a weight of 4000 lbs. and a $C_D$A/m (drag coefficient x projected area/mass) of 0.0343 $ft^2$/lb.

  This missile has a horizontal velocity of 135 ft/s and a vertical velocity of 91 ft/s in a tornado; and corresponding velocities of 307 ft/s and 85 ft/s, respectively, in a hurricane.

  The automobile missile is considered capable of impact at all altitudes less than 30 ft above all grade levels within 1/2 mile of the plant structures.

- A rigid missile that tests penetration resistance, such as a six-inch diameter Schedule 40 pipe.

  The "pipe" missile is 6.625 inch diameter by 15 feet long with a weight of 287 lbs. and a $C_D$A/m of 0.0212 $ft^2$/lb.

  This missile has a horizontal velocity of 135 ft/s and a vertical velocity of 91 ft/s in a tornado; and corresponding velocities of 251 ft/s and 85 ft/s, respectively, in a hurricane.

- A one-inch diameter solid steel sphere to test the configuration of openings in protective barriers.

Missiles for Nuclear Power Plants" for protection of SSC from wind, tornado and hurricane missiles.

RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

~~The RXB and CRB have been credited to withstand turbine missiles.~~

RAI 03.05.02-02

COL Item 3.5-4: A COL Applicant that references the NuScale Power Plant design certification will evaluate site-specific hazards for external events that may produce more energetic missiles than the design basis missiles defined in ~~FSAR~~ Tier 2, Section 3.5.1.4.

## 3.5.3 Barrier Design Procedures

In the design, there are a limited number of potential internal missiles and a limited number of targets. If a missile/target combination is determined to be statistically significant (i.e., the product of ($P_1$), ($P_2$) and ($P_3$) is greater than $10^{-7}$ per year), barriers are installed.

Safety-related and risk-significant SSC are protected from missiles by ensuring the barriers have sufficient thickness to prevent penetration and spalling, perforation, and scabbing that could challenge the SSC. Missile barriers are designed to withstand local and overall effects of missile impact loadings. The barrier design procedures discussed below may be used for both internal and external missiles.

### 3.5.3.1 Local Damage Prediction

The prediction of local damage in the impact area depends on the basic material of construction of the structure or barrier (i.e., concrete, steel, or composite). The analysis approach for each basic type of material is presented separately. It is assumed that the missile impacts normal to the plane of the wall on a minimum impact area.

#### 3.5.3.1.1 Concrete Barriers

Concrete missile barriers are evaluated for the effects of missile impact resulting in penetration, perforation, and scabbing of the concrete using the Modified National Defense Research Committee (NDRC) formulas discussed in "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," (Reference 3.5-3) as described in the following paragraphs. Concrete barrier thicknesses calculated using the equations in this section for perforation and scabbing are increased by 20 percent. ~~The NDRC formulas were not used for determining penetration distance for the design basis turbine blade and blade with rotor fragment missiles. Instead, a finite element analysis was used because the Modified NDRC equations are based on the assumption that the missile and target are essentially non-deformable, which is not appropriate for a turbine blade which will deform. Using NDRC equations for deformable missiles over-predicts the penetration distance. After the penetration distance is determined with the finite element model, the Modified NDRC formulas are used to determine perforation and scabbing thicknesses.~~

RAI 03.05.03-1

Concrete thicknesses to preclude perforation or scabbing from the design basis hurricane and tornado pipe and sphere missiles have been calculated for the 5000 psi and 7000 psi concrete used for the RXB, CRB and RWB external walls and roof using the below equations. The design basis hurricane and tornado automobile missile is incapable of producing significant local damage; therefore, it is not considered. The same is true for the design basis turbine missile of half of the last stage of the turbine rotor. The wind and tornado missile results are tabulated in Table 3.5-1. The RXB has five foot thick outer walls and a four foot thick roof. The missile protected portions of the CRB have three foot thick exterior walls and roof, consisting of a concrete slab with a steel cover, and the RWB has exterior walls that are two feet thick above grade and has a one foot thick roof. The local results for the design basis turbine missile are presented in Table 3.5-2 through Table 3.5-4.

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Additional design characteristics of the RXB and the CRB are provided in Section 3B.2. The RWB exterior walls are 5000 psi concrete reinforced with a minimum of #8 reinforcing bars on 12-inch centers.

#### 3.5.3.1.1.1 Penetration and Spalling Equations

The depth of missile penetration, x, is calculated using the following formulas:

$$x = \left[4KNWd\left\langle\frac{V}{1000d}\right\rangle^{1.8}\right]^{0.5} \text{ for } \frac{x}{d} \le 2.0 \qquad \text{Eq. 3.5-1}$$

$$x = KNW\left(\frac{V}{1000d}\right)^{1.8} + d \text{ for } \frac{x}{d} \ge 2.0 \qquad \text{Eq. 3.5-2}$$

where,

x = penetration depth, in,

W = missile weight, lb,

d = effective missile diameter, in,

N = Missile shape factor:

- flat nosed bodies = 0.72,
- blunt nosed bodies = 0.84,
- average bullet nose (spherical end) = 1.00,
- very sharp nosed bodies = 1.14,

V = Velocity, ft/sec,

K = $180/(\sqrt{f'_c})$, and

$f'_c$ = concrete compressive strength (lb/in2).

#### 3.5.3.1.1.2 Perforation Equations

The relationship for perforation thickness, $t_p$ (inches), and penetration depth, x, is determined from the following formulas:

$$t_p/d = 3.19(x/d) - 0.718(x/d)^2 \text{ for } (x/d) < 1.35$$

$$t_p/d = 1.32 + 1.24(x/d) \text{ for } 1.35 \le (x/d) \le 13.5$$

#### 3.5.3.1.1.3 Scabbing Equations

The relationship for scabbing thickness, $t_s$ (inches), and penetration depth, x, is determined from the following formulas:

$$t_s/d = 7.91(x/d) - 5.06(x/d)^2 \text{ for } (x/d) < 0.65$$

$$t_s/d = 2.12 + 1.36(x/d) \text{ for } 0.65 \le (x/d) \le 11.7$$

### 3.5.3.1.2 Steel Barriers

RAI 03.05.03-2S1

There are no steel missile barriers used in the design.

### 3.5.3.1.3 Composite Barriers

The design does not use composite barriers.

## 3.5.3.2 Overall Damage Prediction

For predicting overall damage, a dynamic impulse load concentrated at the impact area is determined and applied as a forcing function to determine the structural response.

RAI 03.05.03-3

The forcing functions to determine the structural responses are derived using EPRI NP440, "Full Scale Tornado Missile Impact Tests," (Reference 3.5-9) for the triangular impulse formulation of the design basis steel pipe missile. BC-TOP-9A, Rev. 2, "Design of Structures for Missile Impact," (Reference 3.5-8) is used for the design basis automobile missile~~and design basis half of the last stage turbine rotor~~. The solid sphere missile is~~and turbine blades are~~ too small to affect the structural response of the

RXB and the CRB and wasweret not evaluated for itstheir contribution to overall structural response.

The automobile missile forcing functions are applied to the building models in selected locations using the horizontal impact loads since they are higher than the vertical loads. The results are addressed in Section 3.8.4.

~~The weights and velocity of an automobile missile and half of the last stage rotor are similar. Equating the turbine rotor to an equivalent static force resulted in the following:~~

~~For the RXB, the flexural demand to capacity ratio (DCR) is 0.18, shear DCR is 0.16, and wall deflection is 0.02 inches.~~

~~For the CRB, the flexural DCR is 0.81, shear DCR is 1.46, and deflection is 0.25 inches. All values are based on the exterior wall only. It is observed that the CRB exterior wall is not sufficient to prevent a shear failure that results from the impact of a turbine rotor missile. However, the penetration opening that could be developed is smaller than the size of a personnel door and after impact the normal operating loads will redistribute to the redundant structural members adjacent to the impact location to prevent further damage. In addition, it is anticipated that the exterior wall will suffice to reduce the velocity by a significant margin. The remaining turbine missile will then be contained by the three-foot-thick concrete grade-level floor; this conclusion is determined by inspection due to the significant loss of energy in the missile, and the fact that the strike will occur at not less than a 45 degree angle (which has a substantial influence on the penetration depth). The combination of the exterior wall and grade-level floor serve adequately to protect essential SSCs, which are located below grade in the CRB.~~

~~Finite element analyses of the automobile missile has shown to have an insignificant effect on the global response of either structure. Given the similarity of the turbine missile to the automobile missile, the analysis is considered valid for evaluating the effect from the turbine missile. The base reactions, joint displacements, and deformed shape of both the RXB and CRB support this conclusion.~~

Design for impulsive and impactive loads is in accordance with ACI 349 "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary," (Reference 3.5-6) for concrete structures and AISC N690 "Specification for Safety-Related Steel Structures for Nuclear Facilities," (Reference 3.5-7) for steel structures except for the modifications listed below.

Stress and strain limits for the missile impact equivalent static load comply with applicable codes and RG 1.142, Rev. 2 "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," and the limits on ductility of steel structures are given as noted below.

**Concrete**

3.5-6 American Concrete Institute, "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary," ACI 349-06, Farmington Hills, MI.

RAI 03.05.03-3

3.5-7 American Institute of Steel Construction, "Specification for Safety-Related Steel Structures for Nuclear Facilities," AISC N690, 2012, Chicago, IL.

3.5-8 Bechtel Power Corporation, "Design of Structures for Missile Impact," BC-TOP-9A, Rev. 2, San Francisco, CA, September 1974.

3.5-9 Electric Power Research Institute, "Full Scale Tornado Missile Impact Tests," EPRI NP440, Palo Alto, CA July 1977.

3.5-10 U.S. Nuclear Regulatory Commission, "Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Safety-Related Applications for Nuclear Power Plants," Regulatory Guide 1.231, Rev. 0, January 2017.

3.5-11 Electric Power Research Institute, "Plant Engineering: Guideline for the Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Nuclear Safety-Related Applications," EPRI Report TR-1025243, Rev. 1, December 2013.

3.5-12 Electric Power Research Institute, "Full-Scale Missile Concrete Impact Experiments," EPRI Report NP-2745, February 1983.

**Table 3.5-2: Comparison of Test Case Missiles and NuScale Missiles Summary of Barrier Thickness for Turbine Missile Penetration**

| OverspeedMissile Type | Velocity (mph)Mass | Penetration (inch)Velocity | Required Barrier Thickness (inch) |
|---|---|---|---|
| 120%EPRI NP-2745 Test Case | 7474630 pounds | 17.0257 mph | 20.4 |
| 140%NuScale Turbine Rotor Missile | 8723568 pounds | 21.5476 mph (includes 190% overspeed) | 25.8 |
| 160% | 996 | 24.0 | 28.8 |
| 180% | 1121 | 26.0 | 31.2 |
| 190% | 1183 | 25.5 | 30.6 |
| 200% | 1245 | 26.0 | 31.2 |
| 210% | 1308 | 28.5 | 34.2 |
| 220% | 1370 | 28.5 | 34.2 |

**Table 3.5-3: Reactor Building Essential SSC Locations**

**~~Summary of Barrier Thickness for Turbine Missile Perforation~~**

| ~~Overspeed~~ | ~~x Penetration FEA results (inch)~~ | ~~d* Missile Diameter (inch)~~ | ~~x/d*~~ | ~~$t_p$ (inch)~~ | ~~Required Barrier Thickness~~ |
|---|---|---|---|---|---|
| ~~120%~~ | ~~17.0~~ | ~~1.41~~ | ~~12.1~~ | ~~22.9~~ | ~~27.5~~ |
| | | ~~3~~ | ~~5.7~~ | ~~25.~~ | ~~30.3~~ |
| ~~140%~~ | ~~21.5~~ | ~~1.41~~ | ~~15.2~~ | ~~28.5~~ | ~~34.2~~ |
| | | ~~3~~ | ~~7.2~~ | ~~30.6~~ | ~~36.7~~ |
| ~~160%~~ | ~~24.0~~ | ~~1.41~~ | ~~17.0~~ | ~~31.6~~ | ~~37.9~~ |
| | | ~~3~~ | ~~8.0~~ | ~~33.7~~ | ~~40.5~~ |
| ~~180%~~ | ~~26.0~~ | ~~1.41~~ | ~~18.4~~ | ~~34.1~~ | ~~40.9~~ |
| | | ~~3~~ | ~~8.7~~ | ~~36.2~~ | ~~43.4~~ |
| ~~190%~~ | ~~25.5~~ | ~~1.41~~ | ~~18.1~~ | ~~33.5~~ | ~~40.2~~ |
| | | ~~3~~ | ~~8.5~~ | ~~35.6~~ | ~~42.7~~ |
| ~~200%~~ | ~~26.0~~ | ~~1.41~~ | ~~18.4~~ | ~~34.1~~ | ~~40.9~~ |
| | | ~~3~~ | ~~8.7~~ | ~~36.2~~ | ~~43.4~~ |
| ~~210%~~ | ~~28.5~~ | ~~1.41~~ | ~~20.2~~ | ~~37.2~~ | ~~44.6~~ |
| | | ~~3~~ | ~~9.5~~ | ~~39.3~~ | ~~47.2~~ |
| ~~220%~~ | ~~28.5~~ | ~~1.41~~ | ~~20.2~~ | ~~37.2~~ | ~~44.6~~ |
| | | ~~3~~ | ~~9.5~~ | ~~39.3~~ | ~~47.2~~ |

~~d* = conservative equivalent diameter used in perforation and scabbing equations~~

| Essential SSC, or portions thereof, located inside the RXB BEHIND THE POOL WALL | Essential SSC, or portions thereof, located inside the RXB BELOW GRADE (NOT behind the pool wall) | Essential SSC, and portions thereof, located inside the RXB NOT protected by the pool wall NOT below grade |
|---|---|---|
| CNTS, Containment System<br>• CVC Injection & Discharge Nozzles<br>• CVC PZR Spray Nozzle<br>• CVC PZR Spray CIV<br>• CVC RPV High Point Degasification Nozzle<br>• CVC RPV High Point Degasification CIV<br>• RVV & RRV Trip/Reset # 1 & 2 Nozzles<br>• RVV Trip 1 & 2/Reset #3 Nozzles<br>• CVC Injection & Discharge CIVs<br>• CNV Fasteners<br>• CNV Seismic Shear Lug<br>• CNV CRDM Support Frame<br>• Containment Pressure Transducer (Narrow Range)<br>• Containment Water Level Sensors (Radar Transceiver)<br>• SG 1 & 2 Steam Temperature Sensors (RTD)<br>• CIV Close and Open Position Indication<br>• FWS, Supply to SGs and DHR HXs FWIV | | CNTS, Containment System<br>• Hydraulic skid |
| SGS, Steam Generator System<br>• SG tubes<br>• Integral steam plenums<br>• Integral steam plenum caps<br>• Feedwater plenums access ports<br>• SG tube supports<br>• Upper and lower SG supports<br>• Steam piping inside containment<br>• Feedwater piping inside containment<br>• Feedwater supply nozzles<br>• Main steam supply nozzles<br>• Thermal relief valves<br>• Feedwater plenum access port covers<br>• Steam plenum access ports<br>• Steam plenum access port covers<br>• Flow restrictors | | |
| RXC, Reactor Core System<br>• Fuel assembly (RXF)<br>• Fuel Assembly Guide Tube | | |
| CRDS, Control Rod Drive System<br>• Control Rod Drive Shafts<br>• Control Rod Drive Latch Mechanism<br>• CRDM Pressure Boundary (Latch Housing, Rod Travel Housing, Rod Travel Housing Plug) | | |
| CRA, Control Rod Assembly<br>• All components | | |

| Essential SSC, or portions thereof, located inside the RXB BEHIND THE POOL WALL | Essential SSC, or portions thereof, located inside the RXB BELOW GRADE (NOT behind the pool wall) | Essential SSC, and portions thereof, located inside the RXB NOT protected by the pool wall NOT below grade |
|---|---|---|
| RCS, Reactor Coolant System<br>• All components (except as listed as B1 or B2 in Table 3.2-1)<br>• Reactor vessel internals (upper riser assembly (Note 7), lower riser assembly, core support assembly, flow diverter, and pressurizer spray nozzles)<br>• Reactor vessel internals upper riser bellows-lateral seismic restraining structure<br>• Wide Range RCS Pressure Elements<br>• Wide Range RCS Cold Leg Temperature Elements | | |
| | CVCS, Chemical and Volume Control System<br>• DWS Supply Isolation Valves | |
| ECCS, Emergency Core Cooling System<br>• Reactor Vent Valve (RVV)<br>• RVV Trip Valve<br>• Reactor Recirculation Valve (RRV)<br>• RRV Trip Valve<br>• Reset Valve<br>• Hydraulic lines | | |
| DHRS, Decay Heat Removal System<br>• SG Steam Pressure Instrumentation (4 per side)<br>• Actuation Valve (2 per side)<br>• Condenser (1 per side) | | |
| UHS, Ultimate Heat Sink<br>• UHS Pool (water only; also see RXB and RBCM below) | | |
| MPS, Module Protection System<br>• Under-the-Bioshield Temperature Sensors | MPS, Module Protection System<br>• All components (except as listed as B1 or B2 in Table 3.2-1) | |
| NMS, Neutron Monitoring System<br>• Excore Neutron Detectors | NMS, Neutron Monitoring System<br>• Excore Separation Group A/B/C/D - Power Isolation, Conversion and Monitoring Devices<br>• Excore Signal conditioning and processing equipment | |
| ICIS, In-Core Instrumentation System<br>• In-core instrument string sheath [Note: Provides none of the functions listed in Appendix A.] | | |
| | | RBCM, Reactor Building Components<br>• Over-Pressurization Vents (OPV) |

**Table 3.5-4: Not UsedSummary of Barrier Thickness for Turbine Missile Scabbing**

| Overspeed | x Penetration FEA results (inch) | d* Missile Diameter (inch) | x/d* | $t_p$ (inch) | Required Barrier Thickness (inch) |
|---|---|---|---|---|---|
| 120% | 17.0 | 1.41 | 12.1 | 26.1 | 31.3 |
| | | 3 | 5.7 | 29.5 | 35.4 |
| 140% | 21.5 | 1.41 | 15.2 | 32.2 | 38.7 |
| | | 3 | 7.2 | 35.6 | 42.7 |
| 160% | 24.0 | 1.41 | 17.0 | 35.6 | 42.8 |
| | | 3 | 8.0 | 39.0 | 46.8 |
| 180% | 26.0 | 1.41 | 18.4 | 38.3 | 46.0 |
| | | 3 | 8.7 | 41.7 | 50.1 |
| 190% | 25.5 | 1.41 | 18.1 | 37.7 | 45.2 |
| | | 3 | 8.5 | 41.0 | 49.2 |
| 200% | 26.0 | 1.41 | 18.4 | 38.3 | 46.0 |
| | | 3 | 8.7 | 41.7 | 50.1 |
| 210% | 28.5 | 1.41 | 20.2 | 41.7 | 50.1 |
| | | 3 | 9.5 | 45.1 | 54.1 |
| 220% | 28.5 | 1.41 | 20.2 | 41.7 | 50.1 |
| | | 3 | 9.5 | 45.1 | 54.1 |

d* = conservative equivalent diameter used in perforation and scabbing equations

**Figure 3.5-1: Plan View of Partial NuScale Plant Showing Turbine Missile Trajectory**

{{ Withheld - See Part 9 }}

**Figure 3.5-2: Section View of RXB and TGB Showing Turbine Missile Barriers**

{{ Withheld - See Part 9 }}

**Figure 3.5-3: Section View of CRB and TGB Showing Turbine Missile Barriers**

{{ Withheld - See Part 9 }}

#### 3.8.4.3.22 Other Loads

##### 3.8.4.3.22.1 Buoyant Force (B)

The buoyant force is the upward pressure exerted on the bottom of the foundation during a saturated condition. It is the equivalent weight of the water that would otherwise occupy the below grade volume of the structure. The buoyant force is equal to the volume of the building below grade multiplied by the density of water. See Section 3.8.5.3 for use of buoyant force with the RXB and the CRB structures.

##### 3.8.4.3.22.2 Construction Loads

Construction loads are loads from events and activities during construction. These loads will be developed in accordance with Standard SEI/ASCE 37-02, "Design Loads on Structures During Construction." Construction loads are not included when determining seismic loads.

##### 3.8.4.3.22.3 Operation with Less than 12 NuScale Power Modules

The NuScale design allows for operation with less than twelve NPMs. The building analysis was performed with all twelve NPMs in place. However, a study was performed as described in Section 3.7.2.9.1 to evaluate the dynamic effects of an earthquake when operating with less than twelve NPMs. That study concluded that the dynamic effects on the building with less than twelve modules installed would be similar to the dynamic effects when all twelve modules are in place.

No static analysis of operation with a reduced population of NPMs has been performed. Each NPM weights approximately 1,800 kips and displaces approximately 11,200 $ft^3$ of water. The mass of the displaced water is approximately 700 kips. Therefore the overall weight of the building decreases by about 1100 kips for each NPM not present. This decrease in weight is small compared to the overall weight of the building, which is approximately 600,000 kips (concrete + water + equipment).

#### 3.8.4.3.23 Turbine Missile Loads

Turbine missile loads are developed as described in Section 3.5.1.3. The bounding turbine missile is defined as half of the last stage portion of the turbine rotor with the blades attached. This is a semicircular steel section that has a 24 inch radius, weighs 3568 pounds, and travels at 476 mph (based on a 190 percent destructive overspeed of a 3600 rpm turbine).

### 3.8.4.4 Design and Analysis Procedures

RAI 03.08.04-26

RAI 03.08.04-12, RAI 03.08.04-13

## Table 3.8.4-1: Concrete Design Load Combinations

| Load Combinations[1] | Design Loads | | | | | | | | | | | | | | | | | | | | | ACI 349-06 Section (Equation) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | F | H | L | $L_r$ | $R_o$ | $R_a$ | $T_o{}^3$ | $T_a{}^3$ | R | S | $S_e$ | W | $W_t/W_h$ | $E_o$ | $E_{ss}$ | $C_{cr}$ | $P_a{}^3$ | $Y_j{}^2$ | $Y_m{}^2$ | $Y_r{}^2$ | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | |
| 1 | 1.4 | 1.4 | | | | 1.4 | | 1 | | | | | | | | | | | | | | 9.2.1 (9-1) |
| 2 | 1.2 | 1.2 | 1.6 | 1.6 | 0.5 | 1.2 | | 1.2 | | | | | | | | | 1.4 | | | | | 9.2.1 (9-2) |
| 3 | 1.2 | 1.2 | 1.6 | 1.6 | | 1.2 | | 1.2 | | | 0.5 | | | | | | 1.4 | | | | | |
| 4 | 1.2 | 1.2 | 1.6 | 1.6 | | 1.2 | | 1.2 | | 0.5 | | | | | | | 1.4 | | | | | |
| 5 | 1.2 | 1.2 | 0.8 | 0.8 | 1.6 | 1.2 | | | | | | | | | | | 1.4 | | | | | 9.2.1 (9-3) |
| 6 | 1.2 | 1.2 | 0.8 | 0.8 | | 1.2 | | | | | 1.6 | | | | | | 1.4 | | | | | |
| 7 | 1.2 | 1.2 | 0.8 | 0.8 | | 1.2 | | | | 1.6 | | | | | | | 1.4 | | | | | |
| 8 | 1.2 | 1.2 | 1.6 | 1.6 | | 1.2 | | | | | | | | | 1.6 | | | | | | | 9.2.1 (9-4) |
| 9 | 1.2 | 1.2 | 1.6 | 1.6 | | 1.2 | | | | | | | 1.6 | | | | | | | | | 9.2.1 (9-5) |
| 10 | 1 | 1 | 1 | 0.8 | | 1 | | 1 | | | | | | | | 1 | 1 | | | | | 9.2.1 (9-6) |
| 11 | 1 | 1 | 1 | 0.8 | | 1 | | 1 | | | | | | 1 | | | | | | | | 9.2.1 (9-7) |
| 12 | 1 | 1 | 1 | 0.8 | | | 1 | | 1 | | | | | | | | 1 | 1.2 | | | | 9.2.1 (9-8) |
| 13[4] | 1 | 1 | 1 | 0.8 | | | 1 | | 1 | | | | | | | 1 | | 1 | 1 | 1 | 1 | 9.2.1 (9-9) |
| 14 | 1 | 1 | 1 | 0.8 | | 1 | | 1 | | | | 1 | | | | | | | | | | - |

Notes:

1. The load combinations are also evaluated with 0.9D to assess the adverse effects of reduced dead load.
2. Design loads $Y_j$, $Y_m$, and $Y_r$, from load combination 13 will be re-evaluated per COL Item 3.6-2 and COL Item 3.6.3 for localized effects. Also see Section 3.8.4.3.19 and Section 3.8.4.3.20.
3. Design loads $T_0$, $T_a$, and $P_a$ in the RXB are per Section 3.8.4.3.8, Section 3.8.4.3.9, and Section 3.8.4.3.18.
4. Loading combination 13 is used to assess the effects of a turbine missile where the missile load is defined as $Y_m$.

Major system components are accessible for inspection and are available for testing during normal plant operations. The governor and overspeed protection system are tested and inspected as recommended by the manufacturer. The stop valve and control valves are exercised at a frequency recommended by the turbine vendor or valve manufacturer.

RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

### 10.2.3 Not Used

RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

COL Item 10.2-3: Not used.

### 10.2.4 Safety Evaluation

The TGS serves no safety-related functions, is not credited for mitigation of a design basis accident, and has no safe shutdown functions. General Design Criterion 2 was considered in the design of the TGS. The TGS system meets RG 1.29, in that the TGS is not located in areas that contain safety-related components and is not required to operate during or after an accident.

RAI 10.02-3, RAI 10.02.03-1, RAI 10.02.03-2

General Design Criterion 4 was considered in the design of the TGS. Appendix A of RG 1.115, Rev. 2 identifies SSC requiring protection from turbine missiles and defines those SSC as "essential." Essential SSC are protected from high-trajectory and low-trajectory turbine rotor and blade fragments by using barriers in combination with physical separation of redundant safety-related equipment. Section 3.5.1 describes how the protection of essential SSC is accomplished using barriers.

General Design Criterion 5 was considered in the design of the TGS. The components of the TGS are not shared among NPMs, so their failure does not impair the ability of other NPMs to perform their safety functions.

The requirements of 10 CFR 20.1101(b) was considered in the design of the TGS. Radiological considerations do not affect access to system components during normal conditions. Therefore, radiation shielding is not provided for the TGS and associated components. However, in the event of a primary to secondary system leak or steam generator tube failure, the steam could become contaminated. The Technical Specifications (Chapter 16) provide a maximum limit on secondary coolant activities. If a steam generator tube failure is detected, the secondary coolant is sampled and a radiation survey is completed for ALARA purposes before performing maintenance or modification work on the system. Access to the areas containing the system is restricted if required based on the survey results. The TGS provides for continuous monitoring for radioactivity in the effluent discharge.

Instrumentation is provided at the condenser air removal system discharge as described in Section 11.5. The TGS design satisfies 10 CFR 20.1406 requirements relating to minimization of contamination of the facility. Further discussion of the facility design features to protect against radioactive contamination is provided in Section 12.3.

## Table 10.2-1: Turbine Generator Design Parameters

| Component | Parameter | Value |
|---|---|---|
| Turbine | Rotor | • Single Turbine<br>• 10 stage condensing<br>• Uncontrolled extraction<br>• Integrally forged<br>• ASTM A470 CL-4 or equal |
| | Blades | ASTM A276 - A403 or equal |
| | RPM | 3600 rpm |
| Generator | Generator power output | 50MWe |
| | Apparent Power | Greater than 57,000 kVA |
| | Active Power | Greater than 48,000 kWe |
| | Power Factor | 0.85 p.f |
| | Phase/Frequency/Voltage | 3PH/60Hz/13.8kV |
| | Cooling Type | Air (TEWAC - Totally Enclosed Water to Air Cooling) |
| Lube Oil | Oil Type | ISO VG 32 |
| | Normal Power | 3/60/460 VAC |
| | Emergency Power | 250 VDC |
| Valves | Turbine control valves | Multiple standard globe valves, with internal spring and yoke |
| | Stop valve | One hydraulically operated positionable trip valve with throttling pilot for startup operation |

# Part 9 - Withheld Information

Part 9 of the NuScale Power, LLC Design Certification Application (DCA) identifies the location of security-related information within the Final Safety Analysis Report (FSAR).

NuScale requests the security-related information be withheld from public disclosure in accordance with 10 CFR 2.390(d)(1).

The following figures and tables contain security-related information and have been withheld:

RAI 09.02.07-4S1, RAI 09.02.07-5S1

| Figure or Table Number | Figure or Table Title |
|---|---|
| Fig. 1.2-4 | Layout of a Multi-Module NuScale Power Plant |
| Fig. 1.2-5 | Cutaway Illustration of 12 Module Configuration |
| Fig. 1.2-10 | Reactor Building 24'-0" Elevation |
| Fig. 1.2-11 | Reactor Building 35'-8" Elevation |
| Fig. 1.2-12 | Reactor Building 50'-0" Elevation |
| Fig. 1.2-13 | Reactor Building 62'-0" Elevation |
| Fig. 1.2-14 | Reactor Building 75'-0" Elevation |
| Fig. 1.2-15 | Reactor Building 86'-0" Elevation |
| Fig. 1.2-16 | Reactor Building 100'-0" Elevation |
| Fig. 1.2-17 | Reactor Building 126'-0" Elevation |
| Fig. 1.2-18 | Reactor Building 145'-6" Elevation |
| Fig. 1.2-19 | Reactor Building East and West Section View |
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| Fig. 1.2-23 | Control Building 76'-6" Elevation |
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| Fig. 1.2-25 | Control Building 120'-0" Elevation |
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| Table 9.4.2-5 | Reactor Building Areas with Air Change Rates Greater than 0.5 per Hour |
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| Fig. 12.3-1b | Reactor Building Radiation Zone Map - 35'-8" Elevation |