RAIO-0118-58176

January 15, 2018

Docket No. 52-048

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

SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 112 (eRAI No. 8983) on the NuScale Design Certification Application

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 112 (eRAI No. 8983)," dated July 30, 2017
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 112 (eRAI No.8983)," dated September 25, 2017

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

The Enclosure to this letter contains NuScale's supplemental response to the following RAI Question from NRC eRAI No. 8983:

- 03.05.03-2

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

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

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8G9A
Samuel Lee, NRC, OWFN-8G9A
Marieliz Vera, NRC, OWFN-8G9A

Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8983

Enclosure 1:

NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8983

Response to Request for Additional Information

eRAI No.: 8983
Date of RAI Issue: 07/30/2017

NRC Question No.: 03.05.03-2

10 CFR Part 50, Appendix A, GDC 2 requires, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as tornadoes and hurricanes without loss of capability to perform their safety functions. Also, 10 CFR Part 50, Appendix A, GDC 4 requires, in part, that SSCs important to safety shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures and from events and conditions outside the nuclear power unit.

a. In DCD Section 3.5.3.1.2 “Steel Barriers,” the applicant used the Stanford Formula and Ballistic Research Laboratory Formula to determine steel thickness for a steel barrier to prevent perforation of the missile through the barrier. Because ‘penetration’ and ‘perforation’ are both discussed in Section 3.5.3.1.2, the staff requests the applicant clarify the use of these terms throughout the section. For example, the sentence below the heading “Stanford Formula for Penetration” refers to the perforation of a steel plate. Similarly, under the heading “Ballistic Research laboratory Formula for Penetration,” tp is defined for perforation.
b. In DCD Section 3.5.3.1.2, the applicant showed the relationship between the critical kinetic energy required for perforation E and target plate thickness T in the Stanford Formulas, the staff requests the applicant to explain whether T is perforation thickness or designed plate thickness?
c. In DCD Section 3.5.3.1.1, the applicant described that concrete barrier thickness calculated using the equations in this section for perforation and scabbing are increased by 20%. The staff requests the applicant to provide how much calculated steel barrier thickness will be increased using the equations in DCD Section 3.5.3.1.2 for perforation.
d. In DCD Section 3.5.3.1.2, the staff identified apparent errors in the ranges provided for the Stanford Formula (e.g., “W/T” in the range “0.2

NuScale Response:

This response is a supplement to NuScale's original response to RAI 8983 Question 03.05.03-2. As discussed in a public meeting on November 29, 2017, the NRC requested that the 25% increase in steel target thickness, determined by the Standford Formula, be applied. After

further review by NuScale, it was determined that FSAR Tier 2, Section 3.5.3.1.2 will be deleted, as there are no steel missile barriers used in the NuScale design.

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

Several empirical equations have been developed to estimate the penetration of missiles through steel barriers. The Stanford Formula (Reference 3.5-4) is used to determine the minimum steel thickness for a barrier to prevent perforation of the missile through the barrier. The Ballistic Research Laboratory Formula (Reference 3.5-5) equations may also be used if the results are comparable to the Stanford Formula results or if they are validated by penetration testing.There are no steel missile barriers used in the design.

RAI 03.05.03-2, RAI 03.05.03-2S1

Stanford Formula for Penetration

RAI 03.05.03-2S1

The Stanford Formula calculates the energy, E, needed to perforate a steel plate of thickness, T.

RAI 03.05.03-2S1

$$\frac{E}{D} = \frac{S}{46{,}500}\left(16{,}000T^2 + 1{,}500\frac{W}{W_s}T\right)$$

RAI 03.05.03-2S1

where,

RAI 03.05.03-2S1

E = critical kinetic energy required for perforation, (ft-lb),

RAI 03.05.03-2S1

D = effective missile diameter, in.,

RAI 03.05.03-2S1

S = ultimate tensile strength of the target (steel), (psi),

RAI 03.05.03-2, RAI 03.05.03-2S1

T = Target plate thickness, in.,

RAI 03.05.03-2S1

W = length of square side between rigid supports, in., shall be no greater than 8D, and

RAI 03.05.03-2S1

W_s = length of standard window, 4 in.

RAI 03.05.03-2S1

The ultimate tensile strength (S) is directly reduced by the amount of bilateral tension stress already in the target. The Stanford equation is applicable within the following range of parameters:

RAI 03.05.03-2S1

~~$0.1 < T/D < 0.8$~~

RAI 03.05.03-2S1

~~$0.002 < T/L < 0.05$~~

RAI 03.05.03-2S1

~~$10 < L/D < 50$~~

RAI 03.05.03-2S1

~~$5 < W/D < 8$~~

RAI 03.05.03-2S1

~~$8 < W/T < 100$~~

RAI 03.05.03-2, RAI 03.05.03-2S1

~~$0.2 < W/T < 1.0$~~

RAI 03.05.03-2, RAI 03.05.03-2S1

~~$70 < V < 400$~~

RAI 03.05.03-2S1

~~where,~~

RAI 03.05.03-2S1

~~L = Missile length, in., and~~

RAI 03.05.03-2, RAI 03.05.03-2S1

~~V = impact velocity, ft/sec.~~

RAI 03.05.03-2, RAI 03.05.03-2S1

~~**Ballistic Research Laboratory Formula for Penetration**~~

RAI 03.05.03-2, RAI 03.05.03-2S1

~~The Ballistic Research Laboratory formula is used to calculate the thickness of steel plate that would be penetrated by a missile of known mass, velocity and equivalent diameter.~~

RAI 03.05.03-2S1

$$t_p = \frac{(E_k)^{2/3}}{672D}$$

RAI 03.05.03-2S1

~~where,~~

RAI 03.05.03-2S1

~~t_p = steel plate thickness for threshold of perforation, in.,~~

RAI 03.05.03-2S1

~~D = equivalent missile diameter, in.,~~

RAI 03.05.03-2S1

~~E_k = missile kinetic energy, foot-pounds~~

RAI 03.05.03-2S1

~~$E_k = M V^2 /2,$~~

RAI 03.05.03-2S1

~~where,~~

RAI 03.05.03-2S1

~~M = mass of the missile, lb-sec^2 /ft, and~~

RAI 03.05.03-2S1

~~V = impact velocity, ft/sec.~~

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. The solid sphere missile is too small to affect the structural response of the RXB and CRB and was not evaluated for its contribution to overall structural response.

The 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.

Design for impulsive and impactive loads is in accordance with ACI 349 "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary,"