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RAIO-1118-62468

November 05, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 42 (eRAI No. 8836) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 42 (eRAI No. 8836)," dated June 02, 2017

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

The Enclosure to this letter contains NuScale's response to the following RAI Questions from NRC eRAI No. 8836:

- 03.06.02-3
- 03.06.02-4
- 03.06.02-5
- 03.06.02-7

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

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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 8836

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 8836

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

eRAI No.: 8836

Date of RAI Issue: 06/02/2017

NRC Question No.: 03.06.02-3

NuScale FSAR Tier 2, Section 3.6.1.3, “Protection Methods,” states that as the piping analysis is finalized other protection methods (i.e., other than ISR) may be employed to protect against pipe whip and jet impingement. NuScale FSAR Tier 2, Section 3.6.1.3, “Protection Methods,” states that as the piping analysis is finalized other protection methods (i.e., other than ISR) may be employed to protect against pipe whip and jet impingement. The FSAR further states that these other protection methods may include equipment shields, barriers, and pipe whip restraints utilizing energy-absorbing structures. Moreover, it states that pipe whip and jet protection methods are developed when postulated breaks are identified that cannot utilize an ISR. However, the NRC staff found that the design criteria for the equipment shields, barriers, and pipe whip restraints utilizing energy-absorbing structures are not currently included in the FSAR Section 3.6. The applicant is requested to provide the information as described.

NuScale Response:

NuScale is no longer pursuing the ISR concept. Discussion of equipment shields, barriers, and pipe whip restraints is included in the Pipe Rupture Hazards Assessment (PRHA) Technical Report Rev. 0, which was submitted to the NRC by LO-0918-61827 dated October 3, 2018, and referenced by FSAR Section 3.6. The PRHA technical report TR-0818-61384, Section 3.5 specifically discusses criteria used to determine the suitability of equipment shields, barriers, and pipe whip restraints.

Criteria for the design of equipment shields, barriers, and pipe whip restraints has also been included in FSAR Section 3.6.2.3.

Impact on DCA:

The FSAR Tier 2, Section 3.6.2.3 has been revised as described in the response above and as shown in the markup provided in this response.

As discussed previously, methods employed in the NuScale design to address pipe ruptures vary by location and system.

RAI 03.06.02-6

- In the CNV, main steam and feedwater piping is designed to satisfy LBB. Reactor coolant system-connected intermediate piping locations are designed to satisfy criteria to avoid breaks, while terminal ends of RCS lines are analyzed for break effects.
- Above the NPM under the bioshield, breaks are excluded by identifying a design that satisfies criteria for break exclusion in the containment penetration areas or criteria to avoid breaks at the intermediate piping locations.
- In the RXB, the SSC requiring protection against rupture effects are generally separated in rooms not containing high- or moderate-energy piping, and bounding analysis is performed to ensure the structural integrity of the RXB itself.

RAI 03.06.02-6

The application of passive safety systems and the simplification of systems that remain eliminate both potential break locations and targets. Where breaks are postulated, the smaller-scale systems reduce the amount of energy available to drive blasts, pipe whip, and jet impingement. Short piping lengths, intervening obstacles, short jet reach, and hard targets resistant to damage lower the risk for interactions that could adversely affect the functionality of safety-related and essential SSC.

RAI 03.06.02-3

3.6.2.3.1 Restraints, Barriers, and Shields

RAI 03.06.02-3

Pipe whip restraints may be used to limit the motion of a broken pipe to prevent it from hitting an essential structure, system, or component. Protection for pipe whip and jet impingement is also available through barriers afforded by walls, floors, and other structures. Sufficiently large and robust SSC can also function as a pipe whip barrier or jet impingement shield.

RAI 03.06.02-3

3.6.2.3.1.1 Pipe Whip Restraints

RAI 03.06.02-3

Pipe whip restraints constrain movement of a broken pipe for purposes of preventing or limiting the severity of contact with essential SSC. Restraints installed only for purposes of controlled pipe whip are not ASME Code components; restraints that also serve a support function under normal or seismic conditions are designed to ASME criteria. The design criteria for pipe whip restraints are:

RAI 03.06.02-3

- Pipe whip restraints do not adversely affect structural margin of piping for other conditions.

RAI 03.06.02-3

  - Restraint design does not restrict thermal expansion and contraction.

RAI 03.06.02-3

  - The restraint design either: a) does not carry loads during normal operation or seismic events or b) the structural analysis includes a conservative load combination.

RAI 03.06.02-3

- Pipe whip restraints are located as close to the axis of the reaction thrust force as practicable. Pipe whip restraints are generally located so that a plastic hinge does not form in the pipe. If, due to physical limitations, pipe whip restraints are located so that a plastic hinge can form, the consequences of the whipping pipe and the jet impingement effect are further investigated. Lateral guides are provided where necessary to predict and control pipe motion. For further details, see the Pipe Rupture Hazards Analysis technical report TR-0818-61384.

RAI 03.06.02-3

- Generally, pipe whip restraints are designed and located with sufficient clearances between the pipe and the restraint, such that they do not interact and cause additional piping stresses. A design hot position gap is provided that allows maximum predicted thermal, seismic, and seismic anchor movement displacements to occur without interaction.

RAI 03.06.02-3

  - Exception to this general criterion may occur when a pipe support and restraint are incorporated into the same structural steel frame, or when a zero design gap is required. In these cases, the pipe whip restraint is included in the piping analysis and designed to the requirements of pipe support structures for all loads except pipe break, and designed to the requirements of pipe whip restraints when pipe break loads are included.

RAI 03.06.02-3

- In general, the pipe whip restraints do not prevent access required to conduct inservice inspection examination of piping welds. When the location of the restraint makes the piping welds inaccessible for in-service inspection, a portion of the restraint is designed to be removable to provide accessibility.

RAI 03.06.02-3

- Analysis of pipe whip restraints

RAI 03.06.02-3

  - Is either dynamic or conservative static.

RAI 03.06.02-3

  - Static analysis includes

RAI 03.06.02-3

    - dynamic load factor of 2.0

RAI 03.06.02-3

    - potential increase by a factor of 1.1 in loading due to rebound.

RAI 03.06.02-3

- Loading combination includes dead weight, seismic, and the jet thrust reaction force

RAI 03.06.02-3

- The criteria for analysis and design of pipe whip restraints for postulated pipe break effects are consistent with the guidelines in ANSI/ANS 58.2-1988.

RAI 03.06.02-3

- Design is based on energy absorption principles by considering the elastic-plastic, strain-hardening behavior of the materials used.

RAI 03.06.02-3

- Non-energy absorbing portions of the pipe whip restraints are designed to the requirements of AISC N690 Code.

RAI 03.06.02-3

- Except in cases where calculations are performed to determine if a plastic hinge is formed, the energy absorbed by the ruptured pipe is assumed to be zero. That is, the thrust force developed goes directly into moving the broken pipe and is not reduced by the force required to bend the pipe.

RAI 03.06.02-3

- In that a HELB is an accident (i.e., infrequent) event, pipe whip restraints are single use: allowed to deform provided the whipping pipe is fully restrained throughout the blowdown. Where structural members of a restraint are designed for elastic response, a dynamic increase factor is used.

RAI 03.06.02-3

- Allowable strain in a pipe whip restraint is dependent on the type of restraint.

RAI 03.06.02-3

  - Stainless steel U-bar – this one-dimensional restraint consists of one or more U-shaped, upset-threaded rods or strips of stainless steel looped around the pipe but not in contact with the pipe. This allows unimpeded pipe motion during seismic and thermal movement of the pipe. At rupture, the pipe moves against the U-bars, absorbing the kinetic energy of pipe motion by yielding plastically.

RAI 03.06.02-3

  - Structural steel – this two-dimensional restraint is a stainless steel frame encircling the pipe that does not restrict pipe motion for normal operation or earthquakes. Should a rupture occur, the pipe motion brings it into contact with the frame, absorbing the kinetic energy of the pipe by deforming plastically.

RAI 03.06.02-3

  - Crushable material – if used, the allowable energy absorption of the material is 80 percent of its capacity based on dynamic testing performed at equivalent temperatures and at loading rates of ±50 percent of that determined by analysis.

RAI 03.06.02-3

Note that a wall penetration may also serve as a two-dimensional pipe whip restraint, provided the wall has sufficient strength to resist the pipe load.

RAI 03.06.02-3

- Material properties are consistent with applicable code values, with strain-rate stress limits 10 percent above code or specification values, consistent with NRC guidance (SRP 3.6.2).

RAI 03.06.02-3

3.6.2.3.1.2 Pipe Whip Barriers

RAI 03.06.02-3

Standard Review Plan 3.6.2 identifies that an unrestrained, whipping pipe need not be assumed to cause ruptures or through-wall cracks in pipes of equal or larger NPS with equal or greater wall thickness. By extrapolation, a structure, system, or component made of metal of equivalent or better yield strength, equal or larger diameter, and equal or greater wall thickness does not only not leak or crack but also obstructs further travel of the whipping pipe, protecting SSC farther away from being struck.

RAI 03.06.02-3

3.6.2.3.1.3 Jet Impingement Shields

RAI 03.06.02-3

NRC guidance does not have specific criteria for judging suitability of an SSC as a jet shield. Regarding impingement effects, if the following criteria are met, then the SSC is judged capable of serving as a shield:

RAI 03.06.02-3

- The diameter and wall thickness of the shield meet the criteria for a pipe whip barrier with a size equal or greater than that of the broken pipe.

RAI 03.06.02-3

- The barrier is of sufficient area and positioned to subtend a solid angle from the pipe break opening (considering potential pipe whip) that covers the essential SSC to be protected.

RAI 03.06.02-3

- The barrier is solid (without openings) to the extent that no direct line of sight exists from the break opening to the essential SSC. This criterion allows for some indirect passage of spray through an opening, but environmental qualification for pressurization and flooding demonstrates functionality. The possibility of pipe whip affecting the location of the pipe break exit must be considered.

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

eRAI No.: 8836
Date of RAI Issue: 06/02/2017

NRC Question No.: 03.06.02-4

NuScale FSAR Tier 2, Section 3.6.2.1.3, “Pipe Breaks in the Reactor Building (outside the Reactor Pool Bay),” states that as fluid jets have the potential to impact SSC further away than pipe whip, a conservative approach is to evaluate ruptures of high- or moderate-energy piping located within 25 pipe diameters of the target SSC and refers to Appendix A of SRP 3.6.2, Revision 3 Draft. NuScale FSAR Tier 2, Section 3.6.2.1.3, “Pipe Breaks in the Reactor Building (outside the Reactor Pool Bay),” states that as fluid jets have the potential to impact SSC further away than pipe whip, a conservative approach is to evaluate ruptures of high- or moderate-energy piping located within 25 pipe diameters of the target SSC and refers to Appendix A of SRP 3.6.2, Revision 3 Draft. However, it should be noted that the 25 pipe diameters identified in Appendix A of SRP 3.6.2 is to describe that tests in a German test facility showed that significant damage from the dynamic effects of steam jets can occur as far as 25 pipe diameters from a postulated high-energy pipe rupture. It should be noted that as described in FSAR Section 3.6.1.2, for moderate-energy pipe failure, only the environmental effects (e.g., flooding, spray wetting, increased temperature, pressure, and etc.,) are considered. Since the dynamic fluid jet is not a consideration for moderate-energy pipe failure, the applicant is to justify why it is a conservative approach by applying the 25 pipe diameters (for the dynamic fluid jet) to the evaluation of potential environmental impact for moderate- energy pipe failures.

NuScale Response:

NuScale performed an assessment of the jet impingement of pipe breaks for different thermodynamic conditions and different regions of the plant. The approach is described in the FSAR Section 3.6 and in the Pipe Rupture Hazards Assessment Technical Report TR-0818-61384, as submitted by LO-0918-61827 dated October 3, 2018.

The potential effects of jet impingement from high energy breaks were evaluated by considering three areas of the plant. Regulatory concern with adverse effects out to 25 piping diameters is primarily associated with stripping of piping insulation leading to potential sump blockage (i.e., GSI-191). This concern is not relevant to the NuScale design because:

1. In the containment vessel there is no thermal insulation,
2. In the reactor pool bay under the bioshield, only nonmechanistic ruptures of main steam and feedwater piping in the containment penetration area are postulated and evaluated, and
3. In the remainder of the reactor building there is no potential for stripped insulation to affect essential plant functions.

The design of the NuScale plant does not include unique features that cause concern for jets from moderate energy line breaks. Therefore, consistent with regulatory guidance, the NuScale FSAR Section 3.6 was revised to remove the statement regarding evaluation of jet impingement for moderate energy line breaks in the RXB. This revision was implemented by NuScale letter LO-0918-61757, Submittal of Revision to FSAR Section 3.6, "Protection Against Dynamic Effects Associated with Postulated Rupture of Piping," dated September 14, 2018.

Impact on DCA:

There are no impacts to the DCA as a result of this response.

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

eRAI No.: 8836
Date of RAI Issue: 06/02/2017

NRC Question No.: 03.06.02-5

NuScale FSAR Tier 2, Section 3.6.2.1.3 refers to Appendix A of SRP 3.6.2, Revision 3. In that referred Appendix A of the SRP 3.6.2, the NRC staff discusses some potential non-conservatism of the jet modeling described in ANSI/ANS 58.2- 1988 (also referred to as ANS 58.2). These potential non-conservatisms include the assessments of the dynamic blast wave effect, the jet plume expansion and zone of influence, distribution of the pressure within the jet plume, and jet dynamic loading including potential feedback amplification and resonance effects. The applicant is requested to address those issues when using ANS 58.2 methodology for assessing the dynamic effects resulting from postulated high-energy piping rupture.

NuScale Response:

NuScale performed an assessment of the dynamic effects of pipe breaks in different regions of the plant. Discussion of the methodology and results is included in the Pipe Rupture Hazards Assessment Technical Report TR-0818-61384, as submitted by LO-0918-61827 dated October 3, 2018, and is summarized in FSAR Section 3.6. The assessment is described briefly below.

Blast effects: Results are based on three-dimensional computational fluid dynamics analysis using ANSYS CFX. Verification and validation was performed using test problems.

1. In the CNV: Because only NPS 2 lines are postulated to break, the mass and energy release feeding the blast formation is small. Only the degasification line has a potential for forming a blast, because the other CVCS lines contain subcooled liquid. The magnitude of the blast wave pressures is low, as is the maximum force imposed on any component. In

addition, the load is of short duration, a few milliseconds. The shortness of the loading eliminates the need to consider it in load combinations.

2. In the NPM bay: blast effects are not applicable because only non-mechanistic breaks of main steam system (MSS) and feedwater system (FWS) lines and leakage cracks are postulated based on the design of piping in accordance with BTP 3-3 and BTP 3.4 B.A.(ii) and (iii).
3. In the RXB: breaks are postulated in MSS lines at three locations in a pipe gallery. Only MSS lines have a potential for forming a blast, because the other CVCS lines contain subcooled liquid. The maximum force on any component or structure is low. No damage occurs as a result of a postulated break, and the shortness of the loading eliminates the need to consider it in load combinations.

Jet impingement: The small diameter piping in the NuScale plant yields small impingement forces. Target SSCs potentially in the path of jets issuing from postulated breaks are assessed for the load imparted by the jet.

1. Liquid jets: Liquid jets are assumed to not expand and to not droop with distance. The only areas subject to liquid jets are in the RXB where CVCS low temperature, high pressure piping is present. There are no essential SSCs in these areas and the liquid jets have less potential to damage concrete structures than steam jets.
2. Two-phase jets: Two-phase jets are assessed using the methodology of NUREG/CR-2913. A bounding approach is taken by identifying criteria for jet formation, to avoid the need to analyze individual break locations in the CNV and RXB.
    a. In the CNV: Although the low operating pressure of the CNV is a variation from the experimental and analytical basis of NUREG/CR-2913, the low ambient pressure results in faster expansion of the jet, which is conservative when estimating loading. Only RCS-connected NPS 2 pipe breaks were evaluated (DHRS system pressure and temperature are lower at postulated break locations). Results from the NUREG/CR-2913 methodology show that the jet pressures at about 2 L/D are low enough to cause no damage to the hard components.
    b. Under the bioshield: As only non-mechanistic breaks of the MSS and FWS and leakage cracks are considered, jet impingement is not evaluated.
    c. In the RXB: For CVCS and FWS HELBs in the RXB, the generic approach of a zone of influence (ZOI), which includes everywhere in the subcompartment housing the piping, bounds breaks at any location determined once the pipe routing is finalized. Based on the discussion that follows for steam jets, CVCS and FWS pressure loading is not damaging.

3. Steam Jets:
    a. In the CNV: expansion of the jet into the low pressure surroundings results in different behavior than usually experienced for HELBs. Wider jet spreading (a half-angle exceeding 60 degrees) occurs because the initially low air density of the CNV removes most of the resistance to jet expansion. The wider jet expands the ZOI but substantially reduces the pressure and the penetration length, since the mass and energy of the jet are widely dispersed.
        i. For circumferential breaks, it is assumed that any essential system or component is within the ZOI if it is located within the forward-facing hemisphere based on the original pipe orientation. Applying the break exit pressure over this ZOI is an overestimation of the possible jet impingement loading. Therefore, the jet pressure is assumed to decrease with distance proportional to the area of a jet that expands at a 30 degree half-angle to five pipe diameters, and then at 10 degrees beyond that. A half-angle of 30 degrees is less than identified in the ANS 58.2 Standard and in other jet analyses for expansion into surroundings at normal atmospheric pressure. Although the NRC has challenged the general applicability of the ANSI/ANS Standard 58.2 spreading model, a half angle of approximately 45 degrees or more is generally used. As the jet spreads more rapidly into the low density CNV atmosphere, a 30 degree assumption sufficiently bounds actual jet impingement pressures due to local variation within the jet.
    b. Under the bioshield: As noted previously, consideration of jets is not required.
    c. In the RXB: The distance between a break and a target SSC is not defined because RXB piping arrangements have not yet been finalized. To verify suitability of the design of the RXB, bounding HELB scenarios have been identified. The MSS lines are larger and contain more energy than any other potential jet sources in the RXB.

       Demonstrating passing performance for MSS breaks provides confidence that final HELB analysis results are satisfactory. Therefore, an evaluation approach is taken in which the jet impingement pressure is conservatively assumed to be the same as that at the break exit (i.e., no reduction for spreading with distance). For an MSS HELB, the break exit pressure is 500 psia.

       The MSS jet impingement pressure is about one-eighth of the minimum compressive strength of the concrete used for the RXB, is less damaging than the pipe whip impact, which is shown to be acceptable, and does not cause erosion of structural concrete.

Dynamic Amplification and Resonance of Impingement Jet: The phenomenon of dynamic amplification and resonance of a HELB jet impinging upon a target SSC is not applicable to the NuScale design, as demonstrated in FSAR Section 3.6.2.2.4.

Impact on DCA:

There are no impacts to the DCA as a result of this response.

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

eRAI No.: 8836

Date of RAI Issue: 06/02/2017

NRC Question No.: 03.06.02-7

NuScale FSAR Tier 2, Section 3.6.2.1.3, "Pipe Breaks in the Reactor Building outside the reactor Pool Bay," outlines the information which will be included in the summary of the NuScale pipe rupture hazards analysis for the balance-of-plant high- and moderate-energy pipe ruptures. However, it is not clear that the described pipe rupture hazards analysis report is also applicable to all other areas in the NuScale plant design (e.g., pipe breaks inside the containment vessel, pipe breaks in the reactor pool bay outside containment, etc.). The applicant is requested to clarify/identify if the information as outlined in FSAR Section 3.6.2.1.3 is also to be provided in the pipe rupture hazards analysis report for other areas of the plant design where breaks and/or cracks are assumed.

NuScale Response:

Discussion of high and moderate energy line break methodology and results for inside the containment vessel, under the bioshield, and in the reactor building is included in the Pipe Rupture Hazards Assessment Technical Report TR-0818-61384, submitted by NuScale letter LO-0918-61827 dated October 3, 2018, and is summarized by FSAR Section 3.6.

For balance of plant (BOP) piping outside of the reactor pool bay walls, the routing of piping and analysis of these areas, including the finalization of a BOP PRHA, is to be completed by the COL applicant as described in COL Items 3.6-1, 3.6-2 and 3.6-3.

Impact on DCA:

There are no impacts to the DCA as a result of this response.