RAIO-0818-61383

August 13, 2018

Docket: PROJ0769

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 9555 (eRAI No. 9555) on the NuScale Topical Report, "NuScale Applicability of AREVA Method for the Evaluation of Fuel Assembly Structural Response to Externally Applied Forces," TR-0716-50351, Revision 0

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 9555 (eRAI No. 9555)," dated June 15, 2018
2. NuScale Topical Report, "NuScale Applicability of AREVA Method for the Evaluation of Fuel Assembly Structural Response to Externally Applied Forces," TR-0716-50351, Revision 0, dated September 2016

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

The Enclosures to this letter contain NuScale's response to the following RAI Question from NRC eRAI No. 9555:

- 04.02-7

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 9555 (eRAI No. 9555). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 3) pertains to the AREVA proprietary information to be withheld from the public. Framatome proprietary information is denoted by straight brackets (i.e., “[ ]”). Enclosure 2 is the nonproprietary version of the NuScale response.

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

If you have any questions on this response, please contact Paul Infanger at 541-452-7351 or at pinfanger@nuscalepower.com.

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8G9A
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9555, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9555, nonproprietary

Enclosure 3: Affidavit of Nathan E. Hottle

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Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9555, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9555, nonproprietary

Response to Request for Additional Information
Docket: PROJ0769

eRAI No.: 9555
Date of RAI Issue: 06/15/2018

NRC Question No.: 04.02-7

Title 10 of the Code of Federal Regulations, Part 50, Appendix A, General Design Criterion (GDC) 2, requires that SSCs important to safety are designed to withstand the effects of earthquakes without the loss of capability to perform their safety functions. The design bases for these SSCs shall reflect: (1) the severity of the historical reports, with sufficient margin to cover the limited accuracy, quantity, and time period for the accumulated data, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed. SRP Section 4.2 Appendix A (II)(1) provides review guidance regarding the review of inputs used to analyze the loads.

Topical report TR-0716-50351-P references the Framatome topical report ANP-10377P "PWR Fuel Assembly Structural Response to Externally Applied Dynamic Excitations" as the methodology for analyzing the NuScale fuel assembly structural response in the NuScale reactor and ensuring compliance with GDC 2. Any licensee referencing ANP-10377P must comply with the nine conditions and limitations listed in Section 5 of the staff's safety evaluation report for ANP-10337P. The staff needs additional information to determine if the NuScale design complies with these conditions and limitations.

1. Provide information to demonstrate that the grid behavior of the NuScale fuel assembly meets ANP-10337P limitation and condition numbers 1, 2 and 9
2. Topical report ANP-10337P limitations 4, 7, and 8 are related to the methods used to calculate fuel assembly component stresses in 3D nonlinear structural models based on deflections calculated in the dynamic models.
    1. Clarify how the limiting NuScale deflection cases were selected for evaluation in 3D structural models.
    2. ANP-10337P limitation and condition number 4 limits the use of time phasing for identification of the most limiting deflection stress states to applications that are similar to the current fleet of fuel assemblies and core designs. The NuScale design is outside the current range of operational experience, so unusual dynamic behavior and unusual deflection shapes are a concern to the staff. If time phasing was used for NuScale, describe how time phasing was used to find the most limiting fuel assembly component stress states. If time phasing was not used, confirm that limitation and condition number 7 was followed.

3. Confirm that the NuScale 3D load combination was performed consistent with ANP-10337P limitation and condition number 8.

3. Topical report ANP-10337P limitation number 4 also addresses strain energy in the horizontal dynamic model. It also restricts the application of the methodology to the current fleet of fuel and core designs, and the NuScale design is outside this limitation. Provide the following information necessary for the staff to review the strain energy in the horizontal dynamic model of the NuScale fuel assembly.
    1. Identify the maximum lateral deflection and strain energy calculated over the full set of design basis horizontal analyses.
    2. Provide force-deflection data from the lateral stiffness test described in 5.1.1 of TR-0816-51127-P, Revision 1. Provide force-deflection data that encompasses the maximum deflection calculated in the model, or as high of a deflection as was recorded in the lateral stiffness test.
    3. Compare the maximum lateral deflection and strain energy calculated in the horizontal dynamic finite element model to the supporting mechanical test data. Confirm that the calculated lateral deflection is within a range where model behavior agrees with test data, or justify the use of the model outside the range where it agrees with test data.

NuScale Response:

The response is organized along the three main categories in the RAI:

1. Grid behavior compatibility with ANP-10337PA ([3]).

2. Stress analysis method compatibility with ANP-10337PA.

3. Stress analysis model validation to test data.

1.1 RAI 9555 - GRID BEHAVIOR COMPATIBILITY WITH ANP-10337PA

<u>Question 1:</u> The NRC requests clarification on the NuScale grid design and conformance with Limitations and Conditions (L&C) # 1, 2, and 9.

For convenience these three L&Cs to ANP-10337PA ([3]) are reproduced below:

L&C #1 imposes requirements on the tested behavior of grids in order to be compliant with the ANP-10337PA ([3] methodology.

1. Dynamic grid crush tests, must be conducted in accordance with Section 6.1.2.1of ANP-10337P (as amended by RAI 16), and spacer grid behavior must satisfy the requirements in

the TR, the key elements of which are:

a. ***[***

]

b. ***[***

]

c. ***[***

]

L&C #2 imposes requirements on the maximum allowable deformation of spacer grids:

2. For fuel assembly designs where spacer grid applied loads are limited based on allowable grid permanent deformation (as opposed to buckling), the following limits from Table 4-1 of the TR apply:

a. For all OBE analyses, allowable spacer grid deformation is limited to design tolerances and ***[*** ***]****.*

b. For SSE, LOCA, and combined SSE+LOCA analyses, ***[***

]

L&C #9 places a restriction over the range of applicability of **[**

]

9. ***[***

]*.*

Response:

The NuScale grid design is the W-17 HTP ([2], Section 2.0), which is exactly the same grid design used in ANP-10337PA ([3]) to formulate all the grid behavior requirements. Further, this is the same grid used in the Fuel Assembly described and analyzed in the Sample Problem (Appendix B) of ANP-10337PA ([3]). As such, the NuScale spacer grids are fully compatible with the ANP-10337PA requirements and linear visco-elastic grid element validity limits. Therefore the NuScale design meets the requirements of L&C 1, 2, and 9. The fuel technical report ([1]), Table 4-7 indicates positive margin to the peak grid impact loads confirming that the plastic deformation of less than 1 mm is met for the NuScale design.

1.2 *RAI 9555 - STRESS ANALYSIS METHOD COMPATIBILITY WITH ANP-10337PA*

<u>Question 2.1:</u> Clarify how the limiting NuScale deflection cases were selected for evaluation in 3D structural models.

Response:

The selection process uses time-phasing and follows the process outlined in Section 8.1.2 of ANP-10337PA ([3]):

- For each time history **[** **]** and the maximum values are reported

- The maximum **[** **]**

- Given that the calculated stresses do not take into account the core location, a Level C service limit is imposed as allowable.

<u>Question 2.2:</u> The NRC requests further information to determine implementation of time phasing in view of L&C #4. If time phasing was used for NuScale, describe how time phasing was used to find the most limiting fuel assembly component stress states. If time phasing was not used, confirm that L&C # 7 was followed.

For convenience L&C #4 is reproduced below:

4. This methodology is limited to applications that are similar to the current operating fleet of PWR reactor and fuel designs. The core geometry should be comparable to the current fleet, in terms of dimensions, dimension tolerances, fuel assembly row lengths, and the gaps between fuel assemblies. Fuel designs should be comparable to the current fleet,in terms of materials, geometry, and dynamic behavior.

Response:

The time phasing process used for the NuScale analysis conforms to Section 8 of ANP-10337PA ([3]). In more detail:

- For each time history, **[** **]** at each specific core location.

- The X and Z deflections at each core location, **[**

  ] due to numerical noise.

- The deformed configurations in the X and Z direction are then used **[**

  ]

- In conclusion, the NuScale maximum **[** **]** deflections are determined via time-phasing at each core location. However, only the overall maximum cases for each simulated event, independent of core location, were retained for detailed analysis with the 3-D model. As such, the margin reporting was performed using Level C limits and therefore, L&C #7 is not a concern. L&C #7 requires that: *"As indicated in ANP-10337P when orthogonal deflections from separate core locations are artificially superimposed to calculate component stresses, the component stresses must be compared against the design criteria associated with control rod positions."*

The rest of the discussion for this question addresses the similarity between the NuScale fuel assembly and the current range of operational experience, which makes the use of time-phased deflection selection acceptable. To this end, the relevant NuScale core and fuel assembly design parameters are compared with the corresponding core and fuel assembly design parameters used in the Sample Problem in Appendix B of ANP-10337PA ([3]). This comparison is summarized in Table 1-1. The parameters listed in this table are relevant for a comparison of the amount of strain the slender components in the two assemblies can be subjected to, given that strain is a geometric scale invariant, by virtue of its definition as deflection divided by length. A mechanical structure under an imposed displacement will experience the same strain as a half-scale of this structure under half the imposed displacement. The direct consequence of this observation is that two fuel assemblies will experience the same strains if they have the same cross-sectional properties, and the length ratio and the deflection ratio in the same mode are the same. Based on this the total geometrically available gap space in the core for a Mode 1 and a Mode 3 deflection has been calculated.

The cross-sectional properties of the two assemblies are the same as shown in reference ([2]). Comparing the length ratio of the NuScale vs. generic ANP-10337PA fuel assemblies and the geometrically feasible displacement ratios, it is apparent that while the NuScale fuel assembly is 56.4% the length of the generic ANP-10337PA fuel assembly, it can experience proportionally lower deflections of only 44.4% in mode 1 and 40.5% in mode 3. This allows the extension, on a scale basis, of all considerations and acceptability measures from the generic fuel assembly of ANP-10337PA to the NuScale assembly. This observation substantiates the conclusion that the NuScale assembly is similar to the generic assembly in the approved methodology of ANP-

10337PA, and the time-phasing method is appropriate in this case. Furthermore, the margin calculations were performed using Level C stress limits and therefore, L&C #7 is fulfilled.

<u>Question 2.3:</u> Confirm that the NuScale 3-D load combination was performed consistent with ANP-10337P limitation and condition number 8.

For convenience L&C #8 is reproduced below:

L&C #8 to ANP-10337PA ([3]) requires that, in the case when **[**

]

8. In accordance with RG 1.92, the combination of loads for non-grid component evaluation should ideally be based on three orthogonal components (two horizontal and one vertical). ***[***

]*.*

Response:

The NuScale fuel assembly was analyzed using a load combination in three orthogonal directions and therefore, L&C #8 is not a concern.

Table 1-1 - NuScale vs. ANP-10337PA Sample Problem Fuel Assembly Comparison

Design	NuScale	ANP-10337PA Sample Problem
	Parameter Value	Parameter Value
Spacer Grid	W-17x17 HTP	W-17x17 HTP
Core Gaps	FA-FA: 1.68 mm FA-BP: 1.58 mm	FA-FA: 1.76 mm FA-BP: 1.65 mm
Fuel Assembly Length (between Nozzles)	2196 mm	3892 mm
Maximum Core Row Length	7	15
FA length ratio (NuScale/ANP-10337)	56.4%	N/A
Mode 1 full core gap ratio	44.4%	N/A
Mode 3 half core gap ratio	40.5%	N/A

1.3 RAI 9555 - STRESS ANALYSIS MODEL VALIDATION TO TEST DATA

<u>Question 3.1:</u> Identify the maximum lateral deflection and strain energy calculated over the full set of design basis horizontal analyses

Response:

In this document only the maximum deflection cases for the BOL (Table 1-2) and EOL (Table 1-3) condition are described. The maximum deflections are caused by **[**

]

The deflections in Table 1-2 and Table 1-3 are reported in the absolute coordinate system and must be processed to eliminate the rigid body modes (per RAI 18 of ANP-10337PA ([3]). For the purposes of this discussion it is sufficient to zero the deflections to the Bottom Nozzle displacement. This yields a conservative estimate of the maximum FA deflection of **[ ]** for the BOL case and **[ ]** for the EOL case. **[**

]

Table 1-2 - Maximum Lateral FA Deflection - BOL Seismic

[

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***Note for Table 1-2:* [**

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Table 1-3 - Maximum FA Lateral Deflection - EOL Seismic

[

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Note **for** ***Table 1-3*****: [**

]

<u>Question 3.2:</u> Provide force-deflection data from the lateral stiffness test described in 5.1.1 of TR-0816-51127-P, Revision 1. Provide force-deflection data that encompasses the maximum deflection calculated in the model, or as high of a deflection as was recorded in the lateral stiffness test.

Response:

In this response the test data for the BOL (Figure 1-1) and the EOL (Figure 1-2) condition are provided.

The BOL lateral stiffness test data extends up to **[**

] Similarly, the EOL test extends up to **[**

]

[

]

Figure 1-1 - BOL Lateral Stiffness Test Data and Model Benchmark

[

]

Figure 1-2 - EOL Lateral Stiffness Test Data and Model Benchmark

Question 3.3: Compare the maximum lateral deflection and strain energy calculated in the horizontal dynamic finite element model to the supporting mechanical test data. Confirm that the calculated lateral deflection is within a range where model behavior agrees with test data, or justify the use of the model outside the range where it agrees with test data.

Response:

As shown in Figure 1-1 and Figure 1-2, above, the tested deflection range is representative of the model deflection range and the model agrees reasonably well with the test data, including the non-linear behavior, **[**

]

2.0 IMPACT ON TECHNICAL REPORT:

There are no impacts to the technical report, TR-0816-51127, as a result of this response.

3.0 REFERENCES

1. NuScale, LLC, "NuFuel-HTP2 TMFuel and Control Rod Assembly Designs," TR-0816-51127-P, Rev. 1, January 2017

2. NuScale, LLC, "NuScale Applicability of AREVA Methods for the Evaluation of Fuel Assembly Structural Response to Externally Applied Forces," TR-0716-50351-P, Rev. 0, September 2016

3. AREVA NP, Inc., "PWR Fuel Assembly Structural Response to Externally Applied Dynamic Excitations," ANP-10337PA, Rev. 0, May 2018

4. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components," 2009 Revision with Addenda, New York

Impact on Topical Report:

Topical Report TR-0716-50351, NuScale Applicability of AREVA Method for the Evaluation of Fuel Assembly Structural Response to Externally Applied Forces, has been revised as described in the response above and as shown in the markup provided in this response.

1.0 Introduction

1.1 Purpose

This report demonstrates the applicability of *PWR Fuel Assembly Structural Response to Externally Applied Dynamic Excitations*, ANP-10337P (Reference 1), to the NuScale fuel assembly designed for use in the NuScale Power Module. The generic methodology described in ANP-10337P is used to evaluate the structural response of the NuScale fuel assembly to dynamic loads applied during seismic and loss-of-coolant accident (LOCA) events, consistent with the guidance in Standard Review Plan Section 4.2 Appendix A, *Evaluation of Fuel Assembly Structural Response to Externally Applied Forces*, NUREG-0800 (Reference 2).

NuScale Power, LLC is submitting this topical report for Nuclear Regulatory Commission (NRC) approval to apply the methodology described in ANP-10337P to the NuScale fuel assembly design. ~~Use of this applicability report is contingent upon NRC approval of ANP-10337P, currently under NRC review.~~

1.2 Scope

In order to demonstrate the applicability of ANP-10337P to the NuScale fuel assembly, this report:

- Provides an evaluation of each chapter of ANP-10337P with regard to NuScale applicability.
- Provides additional justification for areas of the methodology that require special consideration due to unique features of the NuScale fuel assembly.
- Summarizes selected elements of the NuScale fuel assembly modeling to enhance the applicability justification.

This report does not provide results of the full suite of characterization tests and the structural response analyses of the NuScale fuel. A summary of the application results are being submitted for review and approval as part of the NuScale Design Certification Application.

2.0 Background

ANP-10337P defines a generic methodology to evaluate the structural response of pressurized water reactor (PWR) fuel assembly designs subjected to dynamic loads under seismic and LOCA events. ~~ANP-10337P has been submitted for NRC review and approval.~~ This report demonstrates that this method is applicable to the NuScale fuel design.

To assist in the review of the applicability of the methodology, a brief summary of the NuScale fuel design is provided below.

Welded Fuel Assembly Structure

The NuScale 17x17 fuel assembly design is a reduced-height version of AREVA's 17x17 PWR fuel designs for Westinghouse-type reactors. The total, nominal height of the fuel assembly is 94 inches (not including hold-down springs). Due to the reduced height and the use of span lengths between spacer grids that are typical for operating PWR plants, the assembly has a total of five spacer grids. The HTP™ grids are welded to the guide tubes, while the HMP™ grid is captured by rings welded to the guide tubes. The design includes features as described in the following subsections.

Fuel Rod with Alloy M5® Fuel Rod Cladding

The fuel rod design features M5® cladding. The seamless M5® cladding encapsulates ceramic UO_2 pellets that are cylindrically shaped with a spherical dish at each end. The fuel rod has an internal spring system that axially restricts the position of the fuel stack within the rod, preventing the formation of gaps during shipping and handling while allowing for the expansion of the fuel stack during operation. The lower end cap has a bullet-nose shape to provide a smooth flow transition in addition to facilitating insertion of the rods into the spacer grids during assembly. The upper end cap has a grippable shape that allows for the removal of the fuel rods from the fuel assembly if necessary, which is typical of AREVA fuel for operating PWR plants.

The nominal density of the pellets is 96 percent theoretical density with a possible enrichment up to 4.95 weight percent ^{235}U.

Zircaloy-4 HTP™ upper and intermediate spacer grids

The four HTP™ spacer grids that occupy the top four grid positions are formed from interlocking strips that are welded at all intersections and welded to the side plates. Each grid strip includes a pair of strips welded back-to-back to produce flow channels. The design creates a flow path that is slanted at its outlet, thus causing a vortex flow pattern under normal PWR operating conditions. The spacer grid design creates line contacts with the fuel rod, which provide resistance to grid-to-rod fretting relative to traditional point-contact spacer grid designs. The HTP™ grids on the NuScale design are identical to those used on AREVA's 17x17 PWR product.

design is identical to the grid cited in the sample problem for ANP-10337P, this potential limitation on the applicability of the methodology is satisfied.

In summary, the NuScale design is consistent with the general conditions defined in Chapter 2 of ANP-10337P. Therefore, the range of applicability defined in this chapter encompasses the NuScale design. The differences in assembly length and number of spacer grids are addressed in Section 3.3 of this report. Compliance to the requirement defined in Section 2.2 of ANP-10337P is demonstrated in Section 4.0 and Appendix A.

Chapter 3 Regulatory Requirements

Chapter 3 reviews the regulatory requirements that are relevant to this methodology. These requirements include Appendix A (GDC 2, 27, and 35) and Appendix S of 10 CFR Part 50 and 10 CFR 50.46. In addition, this chapter reviews the NRC guidance from the Standard Review Plan Section 4.2 that pertains to these requirements (primarily Appendix A).

The requirements of Appendices A (GDC 2, 27, and 35), and S of 10 CFR Part 50, 10 CFR 50.46 are directly applicable to the NuScale design. The guidance of SRP Section 4.2 Appendix A is directly applicable and is implemented in ANP-10337P. ~~The discussion of 10 CFR Part 50 Appendix S is applicable with the following minor clarification:~~

- ~~10 CFR 52.47(a)(2)(iv) specifies the requirements for offsite radiological consequence analyses, including exposure limits, for design certification applicants, as opposed to 10 CFR Part 100, 10 CFR 50.34, and 10 CFR 50.67 as stated in ANP-10337P. However, the conclusion that fuel rod failures are permitted during postulated accidents and must be accounted for in the dose analysis remains applicable. This minor clarification does not affect the applicability of the method.~~

The same regulatory requirements identified in ANP-10337P Chapter 3 are applicable to the NuScale Power Module; therefore, this chapter is applicable to the NuScale design.

Chapter 4 Acceptance Criteria

Chapter 4 establishes the appropriate selection of acceptance criteria in order to satisfy the regulatory requirements specified in Chapter 3. In general, this chapter establishes criteria to evaluate spacer grid impact loads and allowable stresses for non-grid components.

Like the regulatory requirements in Chapter 3, these criteria are generic to PWR fuel. The NuScale fuel design uses the same components and structure as the PWR designs presented in Chapter 2 of ANP-10337P; therefore, the criteria defined in this chapter can be applied to the NuScale design to demonstrate compliance to the regulatory requirements with the following minor clarification:

- Section 4.2.2 of ANP-10337P justifies excluding the evaluation of hold-down springs for accident condition loads based on specific designs of fuel assemblies and reactor core internals. The justification for Westinghouse designs applies to the NuScale

~~Two~~One item~~s~~ from Chapter 6 is~~are~~ potentially affected by the application to NuScale fuel.

- ~~Section 6.1.1.2 states that the objective of the forced vibration tests is to obtain at least the first five natural frequencies. In the case of the NuScale design, due to the shorter length and the presence of only three intermediate spacer grids, it is not necessary, nor practical, to obtain characteristics beyond the first three frequencies and mode shapes. [~~

  ~~] This difference is addressed in Section 3.3.~~
- Section 6.1.3 presents damping values to be used in the horizontal model. As noted in the review of Chapter 5, the contribution of axial coolant flow to the fuel assembly damping is expected to be much less than for other operating PWRs. As a result, the damping definition provided in Section 6.1.3 of ANP-10337P is not applicable to NuScale. This difference is addressed in Section 3.3.3~~3.3~~.

Chapter 6 of ANP-10337P is applicable to the NuScale fuel design with the exception of ~~(1) the request to experimentally characterize fuel assembly up to the first five natural frequencies, and (2)~~ the definition of damping values presented in Section 6.1.3. ~~Both of these~~This item~~s~~ is~~are~~ addressed in Section 3.3.

Chapter 7 Seismic and LOCA Analysis

Chapter 7 defines the process of applying appropriate forcing functions representing seismic or LOCA events to the models described in Chapter 5. Chapter 7 also defines the method of accounting for the combined effect of seismic and LOCA loads. In the horizontal analysis, the model calculates the time-varying displacements and impact forces for assemblies across the core. The results of this analysis are also used for calculating the resulting loads and stresses in the assembly. Similarly, the vertical model calculates a time-varying response from the fuel assembly that is used to evaluate the loading on fuel assembly components.

It was demonstrated above that the development of design-specific models and boundary conditions in accordance with ANP-10337P is applicable to the NuScale design. The process to apply these models to determine the fuel assembly structural response to seismic and LOCA events is design independent. Therefore, this chapter is applicable to the NuScale fuel design.

Chapter 8 Non-Grid Component Strength Evaluation Methodology

Chapter 8 defines the process of performing the structural component stress analysis using the loads and deflections generated by the seismic and LOCA analyses described in Chapter 7. Like the modeling approach addressed in Chapters 5 and 6, the analysis approach in Chapter 8 is applicable to NuScale fuel because the fuel design uses the

~~*Appendix E: Methodology for Evaluating the Effect of Grid Deformation on ECCS Coolability Analyses*~~

~~Appendix E presents the methodology for evaluating the effects of grid deformation on post-LOCA emergency core cooling system coolability analyses. The method presented here is based on a simple convective heat exchange across the fuel rod and it accounts for small reductions in the area of the flow channel.~~

~~This appendix is applicable to the NuScale fuel design.~~

Appendix ~~F~~E: Justification for the Use of Level C Stress Limits to Ensure Guide Tube Functionality

Appendix ~~F~~E provides the basis for the acceptability of using Level C stress limits to ensure guide tube functionality (i.e., control rod insertability) following a seismic or LOCA event. The discussion and data presented in Appendix ~~F~~E are generic to any guide tube geometry. The characterization of guide tube stress states and the definition of the Level C service limit in relation to guide tube geometry are generic. Furthermore, the testing discussed in Appendix ~~F~~E is performed on guide tubes of the same cross-sectional geometry as the NuScale design.

This appendix is applicable to the NuScale fuel design.

3.2 Topical Report Restrictions

~~ANP-10337P is currently under review by the NRC. Thus, no additional restrictions have been imposed on its use.~~This section addresses the Limitations and Conditions (L&Cs) of ANP-10337P in the context of the application of this methodology to the NuScale Fuel Assembly design.

L&C #1 Discussion:

L&C #1 imposes requirements on the tested behavior of grids in order to be compliant with the ANP-10337P (Reference 1) methodology:

1. *Dynamic grid crush tests, must be conducted in accordance with Section 6.1.2.1 of ANP-10337P (as amended by RAI 16), and spacer grid behavior must satisfy the requirements in the TR, the key elements of which are:*
   - *a.* [ ]
   - *b.* [ ]
   - *c.* [ ]

[ ]

The acceptability of the NuScale grids under L&C #1 has been addressed in Reference 3.

L&C #2 Discussion:

L&C #2 imposes requirements on the maximum allowable deformation of spacer grids:

2. *For fuel assembly designs where spacer grid applied loads are limited based on allowable grid permanent deformation (as opposed to buckling), the following limits from Table 4-1 of the TR apply:*
    a. *For all OBE analyses, allowable spacer grid deformation is limited to design tolerances and [ ].*
    b. *For SSE, LOCA, and combined SSE+LOCA analyses, [ ]*

The acceptability of the NuScale grids under L&C #2 has been addressed in Reference 3.

L&C #3 Discussion:

L&C #3 imposes controls and quality requirements on the computer programs implementing the methodology of ANP-10337P (Reference 1):

3. *The modification or use of the codes CASAC and ANSYS (or other similar industry standard codes) are subject to the following limitations:*
    a. *CASAC computer code revisions, necessitated by errors discovered in the source code, needed to return the algorithms to those described in ANP-10337P (as updated by RAIs) are acceptable.*
    b. *Changes to CASAC numerical methods to improve code convergence or speed of convergence, transfer of the code to a different computing platform to facilitate utilization, addition of features that support effective code input/output, and changes to details below the level described in ANP-10337P would not be considered to constitute a departure from a method of evaluation in the safety analysis. Such changes may be used in licensing calculations without NRC staff review and approval. However, all code changes must be documented in an auditable manner to*

meet the quality assurance requirements of 10 CFR Part 50, Appendix B.

c. ANSYS or other industry standard codes may be used if they are documented in an auditable manner to meet the quality assurance requirements of 10 CFR Part 50, Appendix B, including the appropriate verification and validation for the intended application of the code.

The NuScale analyses use the same code versions employed in the analytical method demonstration in Appendix B of ANP-10337P. Therefore, L&C #3 is not a concern.

L&C #4 Discussion:

L&C #4 limits the un-restricted use of the ANP-10337P (Reference 1) methodology to fuel designs and applications consistent with the operating fleet. Markedly new designs have to be assessed:

4. *This methodology is limited to applications that are similar to the current operating fleet of PWR reactor and fuel designs. The core geometry should be comparable to the current fleet, in terms of dimensions, dimension tolerances, fuel assembly row lengths, and the gaps between fuel assemblies. Fuel designs should be comparable to the current fleet, in terms of materials, geometry, and dynamic behavior.*

L&C #4 has been addressed in Reference 3. While in absolute terms the NuScale fuel assembly is different from the operating fleet, this design has been demonstrated to be similar, on a scale basis to the generic fuel assembly of ANP-10337P (Reference 1). The available lateral deflections in core when scaled by fuel assembly lengths are smaller for NuScale than those for the generic assembly in ANP-10337P. This justifies the extension, on a scale basis, of all considerations and acceptability measures from the generic fuel assembly of ANP-10337P to the NuScale assembly. This observation substantiates the conclusion that the NuScale assembly is similar to the generic assembly in the approved methodology of ANP-10337P, and the time-phasing method is appropriate in this case.

L&C #5 Discussion:

L&C #5 limits the applicability of the lateral damping formulation to existing designs, and requires an applicability justification or a new formulation for new designs:

5. *ANP-10337P established generic fixed damping values intended to be used for all PWR designs. All applications of this methodology to new*

> *fuel assembly designs must consider the continued applicability of the fixed damping values of this methodology. If new materials, new geometry, or new design features of a new fuel assembly design may affect damping, additional testing and/or evaluation to determine appropriate damping values may be required.*

The NuScale fuel assembly is much shorter than the current fleet designs, and the lateral fuel assembly damping has been re-formulated to account for specific test results on short assemblies, the particulars of the axial flow, and the phenomena governing the dynamics of these designs. This formulation is addressed within this document in Appendix 2 and also in Reference 4 (Question 29611).

L&C #6 Discussion:

L&C #6 requests that the fuel rod assessment under faulted conditions be demonstrated.

6. *The ANP-10337P methodology includes the generation of fuel rod loads, but does not provide a means to demonstrate compliance for fuel rod performance under externally applied loads (to applicable acceptance criteria). Applications of this methodology must provide an acceptable demonstration of fuel rod performance.*

The fuel rod analysis is part of the component stress evaluation that was performed for the NuScale fuel design.

L&C #7 Discussion:

L&C #7 requires that when bounding stress analysis of the non-grid components is used, without regard to specific core location, the more stringent limits for control rod locations must be used:

7. *As indicated in ANP-10337P when orthogonal deflections from separate core locations are artificially superimposed to calculate component stresses, the component stresses must be compared against the design criteria associated with control rod positions.*

The margin calculations for the NuScale fuel assembly Guide Tubes were performed using Level C stress limits, which are applicable to control rod locations, therefore L&C #7 is fulfilled.

L&C #8 Discussion:

L&C #8 requires that, in the case when [

]:

8. *In accordance with RG 1.92, the combination of loads for non-grid component evaluation should ideally be based on three orthogonal components (two horizontal and one vertical). [*

].

The NuScale component stress analysis was performed using a 3-D load combination as discussed in Reference 3. Therefore, L&C #8 is not a concern.

L&C #9 Discussion:

L&C #9 places a restriction over the range of applicability of [ ]:

9. *[*

].

This point has been addressed in Reference 3. The NuScale grid design is the same as the grid in the generic fuel assembly used in the Sample Problem (Appendix B) of ANP-10337P (Reference 1). The limitation of L&C #9 has been met.

3.3 NuScale Design Differences and Requirements

To extend the applicability of ANP-10337P to include NuScale fuel, the following design differences are addressed:

- NuScale fuel assembly is shorter than typical PWR designs presented in Table 2-1 of ANP-10337P.
- The experimental characterization of the frequency response of the NuScale fuel design is limited to the first three natural frequencies, as opposed to the first five natural frequencies as requested in Section 6.1.1.2 of ANP-10337P.
- The contribution of axial coolant flow to the NuScale fuel assembly damping is expected to be much less than that for other operating PWRs, and thus, the damping values presented in Section 6.1.3 of ANP-10337P are not applicable to NuScale fuel.

3.3.1 Fuel Assembly Length and Number of Spacer Grids

Although not stated as defining a range of applicability, Table 2-1 of ANP-10337P illustrates typical PWR designs to which ANP-10337P can be expected to be applied. The NuScale fuel assembly is outside the range of parameters in Table 2-1 in terms of fuel assembly length (shorter) and number of grids (fewer).

- The shorter assembly length of the NuScale fuel design will result in unique dynamic properties of the fuel assembly (i.e., higher stiffness and higher natural frequencies). However, this difference in design is captured in the method defined in ANP-10337P because the method requires that fuel assembly models be built to match design-specific experimental dynamic characterization of the fuel design. The expected differences in the dynamic properties of the NuScale fuel assembly due to its shorter length are directly characterized through full-scale prototype testing and the models built to match this tested behavior had negligible error. The application of this method to NuScale with its shorter length is discussed in more detail in Section 4.0 and Appendix A.

- The designs in Table 2-1 of ANP-10337P have between five and nine intermediate spacer grids, whereas the NuScale fuel design has three intermediate spacer grids. The NuScale fuel assembly has a total of five spacer grids, but following the modeling architecture defined in Section 5.2.1 of ANP-10337P, the uppermost and lowermost end grids are not modeled explicitly [ ] As a result, the NuScale fuel assembly model will be represented as a single beam with three rotational nodes at the intermediate grid locations. With three non-fixed degrees of freedom, the model is only capable of accurately representing the fuel assembly response up to the third mode, consistent with the limitations of the experimental testing of the NuScale fuel assembly, in which it is only practical to characterize assembly frequencies up to the third mode (see Section 3.3.2 below). [ ] The application of this fuel assembly model, with three rotational nodes, is demonstrated in Section 4.0 and Appendix A of this report and shows negligible error to tested results. Additional studies have demonstrated that results from this modeling approach reflect an appropriate level of mass participation in the dynamic response.

Therefore, with regard to the shorter fuel assembly length and fewer spacer grids, ANP-10337P remains applicable to NuScale fuel without modifications.

3.3.2 ~~Frequency Response of the NuScale Fuel~~Deleted

~~Section 6.1.1.2 of ANP-10337P establishes a requirement that the dynamic characterization testing provides the first five frequencies and mode shapes of the fuel assembly. For the NuScale fuel assembly, because of its shorter length and increased lateral stiffness, it is only practical to characterize the first three natural frequencies. In general, because of the increased lateral stiffness of the NuScale fuel assembly, the higher mode frequencies have shifted beyond the range of interest for the dynamic events that are analyzed. [ ]~~

Therefore, with regard to the representation of the NuScale fuel, ANP-10337P remains applicable to NuScale fuel without modifications. This section is no longer needed.

3.3.3 Fuel Assembly Damping

Section 6.1.3 of ANP-10337P defines fuel assembly damping values that are generically applicable to standard PWR fuel designs. However, relative to a standard PWR, the NuScale design will operate with a shorter fuel assembly and reduced flow rates. For these reasons, the damping values defined in Section 6.1.3 of ANP-10337P are not applicable to the NuScale design.

Section 5.0 and Appendix B provide details regarding the establishment of NuScale-specific fuel assembly damping values. For the NuScale design, the maximum fuel assembly damping ratio values to be used for the analysis of seismic and LOCA events in place of those defined in Section 6.1.3 of ANP-10337P are defined in Table 3-1. These damping values do not credit the additional contribution of damping in flowing water.

Table 3-1. NuScale Fuel Assembly Damping Ratio Values

[ ]

4.0 NuScale Fuel Characterization

Two areas of fuel characterization are reviewed to provide an explicit demonstration of the application of ANP-10337P to NuScale fuel. These two items are reviewed in detail in Appendix A, but a summary is provided in this section.

- Section 2.2 of ANP-10337P requires an explicit demonstration of the applicability of grid impact modeling elements.
- Section 3.3 of this document notes that the NuScale fuel assembly is outside the range of typical PWR designs to which ANP-10337P is applied in terms of both overall fuel assembly length and the number of spacer grids. The application of the single fuel assembly model described in Section 5.2.1 of ANP-10337P to the NuScale design, with a shorter overall length and fewer spacer grids, is demonstrated.

4.1 Spacer Grid Behavior

Under lateral impacts over the range of application, Section 2.2 of ANP-10337P specifies that **[**

]

The NuScale fuel design utilizes the same 17x17 HTP™ spacer grid that is currently in use in operating plants. Thus, this behavior is well established for this existing grid design. Figure A.2-1 and Figure A.2-2 in Appendix A demonstrate **[**

]

4.2 Single Fuel Assembly Model

The applicability of the single fuel assembly model, as defined in Section 5.2.1 of ANP-10337P, to the NuScale fuel design is addressed in this section. This section shows the ability of a benchmarked fuel assembly model to replicate a frequency that characterizes test data from free and forced vibration testing.

The free vibration test is performed in order to characterize the primary, or first mode, natural frequency of the fuel assembly. The NuScale fuel assembly was tested over a range of deflections from **[** **]**

7.0 References

1. AREVA Inc., "PWR Fuel Assembly Structural Response to Externally Applied Dynamic Excitations," ANP-10337P Rev. 0, August 2015.
2. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Fuel System Design," NUREG-0800, Chapter 4, Section 4.2, Rev. 3, March 2007.
3. ANP-3712P-000, Framatome Responses to NRC RAI No. 9555 regarding NuScale Topical Report TR-0816-51127
4. ANP-3591P, Revision 0, AREVA Responses to NRC RAI 8736 (Questions 29611, 29613-29616) regarding TR-0716-50351, "NuScale Applicability of AREVA Method for the Evaluation of Fuel Assembly Structural Response to Externally Applied Forces"

Appendix A. Review of NuScale Fuel Characterization Test Data Applicability to ANP-10337P

A.1 Introduction

The purpose of this appendix is to provide a review of NuScale fuel characterization test data in order to demonstrate the behavior necessary to confirm the applicability of ANP-10337P. Specifically, Section 2.2 of ANP-10337P requires an explicit demonstration of the applicability of grid impact modeling elements. In addition, Section 3.3 of this report notes that the NuScale fuel assembly is outside the range of typical PWR designs to which ANP-10337P is applied in terms of both overall fuel assembly length and the number of spacer grids. This appendix also demonstrates the application of the single fuel assembly model described in Section 5.2.1 of ANP-10337P to the NuScale design, with a shorter overall length and fewer spacer grids.

A.2 Spacer Grid Behavior

Under lateral impacts over the range of application, Section 2.2 of ANP-10337P specifies that [

]

The NuScale fuel design utilizes the same 17x17 HTP™ spacer grid that is currently in use in operating plants. Thus, this behavior is well established for this existing grid design. The data to be reviewed here are generic and not specific to NuScale.

Figure A.2-1 and Figure A.2-2 demonstrate [

] Figure A.2-1 and Figure A.2-2 present this relationship for single grids, but they are representative of the same behavior seen over the total population of tested spacer grids. [

]

Enclosure 3:

Affidavit of Nathan E. Hottle

A F F I D A V I T

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Nathan E. Hottle. I am Manager, Product Licensing, for Framatome Inc. (Framatome) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the following document: "Response to NRC RAI 9555 Question 04.02-7" and associated topical report markups, referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome Inc. for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by Framatome and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by Framatome to determine whether information should be classified as proprietary:

(a) The information reveals details of Framatome's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for Framatome.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Framatome in product optimization or marketability.

(e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in this Document is considered proprietary for the reasons set forth in paragraphs 6(c) and 6(d) above.

7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 13

day of August, 2018.

Heidi Hamilton Elder
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 12/31/2022
Reg. # 7777873

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