December 31, 2022 Docket No. 52-050

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of the technical report, “US460 NuScale Power Module Seismic Analysis,” TR-121515, Revision 0

REFERENCES:

1. NuScale letter to NRC, “NuScale Power, LLC Submittal of Planned Standard Design Approval Application Content,” dated February 24, 2020 (ML20055E565)
2. NuScale letter to NRC, “NuScale Power, LLC Requests the NRC staff to conduct a pre-application readiness assessment of the draft, ‘NuScale Standard Design Approval Application (SDAA),’” dated May 25, 2022 (ML22145A460)
3. NRC letter to NuScale, “Preapplication Readiness Assessment Report of the NuScale Power, LLC Standard Design Approval Draft Application,” Office of Nuclear Reactor Regulation dated November 15, 2022 (ML22305A518)
4. NuScale letter to NRC, “NuScale Power, LLC Staged Submittal of Planned Standard Design Approval Application,” dated November 21, 2022 (ML22325A349)

NuScale Power, LLC (NuScale) is pleased to submit the technical report, “US460 NuScale Power Module Seismic Analysis,” TR-121515, Revision 0. This report supports Chapter 3 of the Standard Design Approval Application, “Design of Structures, Systems, Components and Equipment,” Revision 0. Chapter 3 supports Part 2, “Final Safety Analysis Report,” (FSAR) of the NuScale Standard Design Approval Application (SDAA), as described in Reference 1. NuScale submits the report in accordance with requirements of 10 CFR 52 Subpart E, Standard Design Approvals. As described in Reference 4, the enclosure is part of a staged SDAA submittal. NuScale requests NRC review, approval, and granting of standard design approval for the US460 standard plant design.

From July 25, 2022 to October 26, 2022, the NRC performed a pre-application readiness assessment of available portions of the draft NuScale FSAR to determine the FSAR’s readiness for submittal and for subsequent review by NRC staff (References 2 and 3). The US460 NuScale Power Module Seismic Analysis technical report was not available for NRC readiness assessment review.

Enclosure 1 contains the technical report, “US460 NuScale Power Module Seismic Analysis,” TR-121515-P, Revision 0, proprietary version. NuScale requests that the proprietary version (Enclosure 1) be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. Enclosure 3 pertains to the information proprietary to NuScale, denoted by double braces (i.e., “{{ }}”). Enclosure 4 pertains to the information proprietary to Framatome

Inc. (formerly AREVA Inc.), denoted by brackets (i.e., "[ ]"). Enclosure 2 contains the nonproprietary version.

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

If you have any questions, please contact Mark Shaver at 541-360-0630 or at mshaver@nuscalepower.com.

I declare under penalty of perjury that the foregoing is true and correct. Executed on December 31, 2022.

Sincerely,

Carrie Fosaaen
Senior Director, Regulatory Affairs
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Distribution: Brian Smith, NRC
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David Drucker, NRC

Enclosure 1: "US460 NuScale Power Module Seismic Analysis," TR-121515-P, Revision 0," (proprietary)
Enclosure 2: "US460 NuScale Power Module Seismic Analysis," TR-121515-NP, Revision 0," (nonproprietary)
Enclosure 3: Affidavit of Carrie Fosaaen AF-132101
Enclosure 4: Affidavit of Morris Byram, Framatome Inc.

Enclosure 1: "US460 NuScale Power Module Seismic Analysis," TR-121515-P, Revision 0 (proprietary)

Enclosure 2: "US460 NuScale Power Module Seismic Analysis," TR-121515-NP, Revision 0 (nonproprietary)

Licensing Technical Report

US460 NuScale Power Module Seismic Analysis

December 2022

Revision 0

Docket: 52-050

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Department of Energy Acknowledgement and Disclaimer

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Abstract

This report describes the methodologies and structural models used to analyze the dynamic structural response from seismic loads acting on the US460 NuScale Power Module (NPM). In addition, the report provides the dynamic analysis methodology and presents analysis results. The NPM detailed dynamic model couples with the dynamic model of the Reactor Building (RXB) to consider effects of fluid-structure interaction due to pool water found between the NPM and pool floor and walls. The performance of the dynamic analysis yields loads, in-structure response spectra, and in-structure time histories, which are the basis for the mechanical design of Seismic Category I structures, systems, and components that comprise or are supported by the NPM.

This report supports Final Safety Analysis Report Section 3.7, “Seismic Design,” for the NuScale US460 Standard Design.

Executive Summary

Seismic analysis of the US460 NuScale Power Module (NPM) and its structures, systems, and components (SSC) requires a complete system model to represent the dynamic coupling of the reactor pressure vessel (RPV), containment vessel (CNV), reactor internals and core support, reactor core, surrounding pool water, and SSC supported by the NPM. NuScale performed a dynamic analysis of the NPM system using time history dynamic analysis methods and a three-dimensional (3D) ANSYS finite element model.

The ANSYS computer code analyzes the RXB system model for soil-structure interaction (SSI) in the frequency domain. Results from the RXB seismic system analysis include in-structure time histories at each NPM support location and the pool walls and floor surrounding the NPM. In-structure response spectra (ISRS) are also calculated. The RXB is analyzed for a number of SSI analysis cases.

A detailed time-history dynamic analysis of three-dimensional models of the NPM is performed using ANSYS. The NPM models provide in-structure time histories or response spectra for qualification of NPM components, equipment supported by the NPM, and in-structure time histories for seismic qualification of fuel assemblies.

1.0 Introduction

1.1 Purpose

This report describes methodologies and structural models used for seismic analyses of the NuScale Power Module (NPM) and presents analysis results. In-structure responses determined by using the methodologies and models are inputs for the dynamic response analysis of subsystems and components supported by the NPM. Loads and displacement time histories determined using these models are used in conjunction with other loads to design the containment vessel (CNV), reactor pressure vessel (RPV), core support, and internal structures.

Seismic analysis of the NPM and supported structures, systems, and components (SSC) requires a complete system model to represent the dynamic coupling of the RPV, the CNV, reactor internals and core support, the reactor core, surrounding pool water, and supported SSC. The dynamic analysis of the complete model uses time history dynamic analysis methods and a three-dimensional (3D) ANSYS finite element model.

1.2 Scope

The SSC in the scope of this report are those that comprise the NPM, which is the self-contained nuclear steam supply system in the NuScale Power Plant. The NPM is comprised of a reactor core, a pressurizer (PZR), and two steam generators (SGs) integrated within an RPV and housed in a compact steel CNV. Other components integral to the NPM are the fuel assemblies, reactor vessel internals (RVI), control rod drive mechanisms (CRDMs), piping, valves, and instrumentation and controls.

The NPM seismic analysis provides time histories of core support motions that use seismic input for fuel qualification. This report also includes interface between the NPM and the Reactor Building (RXB) (lug and skirt reaction forces). The methodologies for seismic qualification of the fuel itself are provided in TR-117605, “NuFuel-HTP2 Fuel and Control Rod Assembly Designs.”

The NPM model obtains seismic input from the RXB soil-structure interaction (SSI) analysis results. The Final Safety Analysis Report, Section 3.7.2, addresses methodologies used for the RXB soil-structure interaction analysis; however, this report includes a brief discussion as background information.

The seismic analysis methodology described in this report applies to the NPM and the SSCs supported by the NPM, and includes the CNV, top support structure (TSS) and piping outside containment, piping inside containment, RPV, upper RVI (URVI), LRVI, CRDM, and CRDM support structure.

This report includes the methodology for building the model, performance of static analysis for model validation, and modal and transient analysis of the integrated system.

Because details of the geometry and mesh refinements are insufficient for representing local stress distributions and stress concentrations, this report does not consider stress analysis models.

Software used for performing NPM seismic anlayses conforms with the requirements for computer software as per the NuScale Quality Assurance Program Description (QAPD).

1.3 Abbreviations and Definitions

Table 1-1 Abbreviations

Term	Definition
BOL	beginning of life
CAD	computer aided design
CNV	containment vessel
CRDM	control rod drive mechanism
CRDS	control rod drive system
CSDRS	certified seismic design response spectra
DHRS	decay heat removal system
FSI	fluid-structure interaction
FW	feedwater
ISRS	in-structure response spectra
LCP	lower core plate
LRVI	lower reactor vessel internals
MS	main steam
NPM	NuScale Power Module
NRC	U.S. Nuclear Regulatory Commission
PZR	pressurizer
RCS	reactor coolant system
RPV	reactor pressure vessel
RVI	reactor vessel internals
RXB	Reactor Building
RXP	reactor pool
SG	steam generator
SSC	structures, systems, and components
SSI	soil-structure interaction
TSS	top support structure
UCP	upper core plate
URVI	upper reactor vessel internals
3D	three-dimensional

2.0 Background

This US460 NPM seismic analysis technical report supports the NRC review of the NuScale US460 Standard Design by providing information necessary to conclude the design complies with General Design Criterion 2 and 10 CFR 50, Appendix S. These regulatory requirements, in part, state that SSC are designed to withstand effects of earthquakes without loss of capability to perform their safety functions.

2.1 Layout of the NuScale Power Module and Reactor Building

The RXB is an embedded structure located above and below grade. The RXB houses the NPMs, systems, and components required for plant operation and shutdown. The RXB is a rectangular configuration approximately 230 ft long and 155 ft wide, with a height approximately 81 ft above nominal plant grade level. The bottom of the RXB foundation is approximately 83 ft below grade except for the areas under the elevator pit and the refueling pool, which are approximately 92 ft below grade.

Each NPM is located in the common reactor pool (RXP) within its own three-walled bay with the open side toward the center of the pool. The bays are two rows, with three bays per row, along the north and south walls of the RXP. A central channel between the bays allows for movement of the NPMs between the bays and the refueling pool. The RXP is one of three safety-related pools that comprise the ultimate heat sink (UHS), a volume of borated water that consists of the combined water volume of the RXP, refueling pool, and spent fuel pool (SFP). The UHS is located below grade in the RXB.

2.2 Load Path for Core Support

The upper and lower core plates provide vertical and horizontal support for the reactor core. The core barrel and lower RPV support the core plates. The load transfers from the lower core plate (LCP) and core barrel to the RPV through four core support mounting brackets, located on the interior of the RPV bottom head.

The potential contact of peripheral fuel assemblies with the reflector resists horizontal displacements of the core. The reflector load, supported by the core support, is transferred through the core support blocks.

For horizontal seismic loads acting upon the LCP, the primary load path from the RPV to the RXB is through the RPV/CNV alignment feature located between the bottom of the RPV and the CNV. The horizontal load in this load path transfers to the pool floor primarily through the CNV skirt. Horizontal loads from the UCP and the LCP carry through the CNV skirt, with a secondary load path through the supports of the RPV and CNV support lugs. The CNV support lugs provide horizontal restraint.

Vertical loads from the core transfer from the core support and lower RPV upward to the connection of the upper RPV and CNV. The load transfers downward from the upper RPV and CNV to the CNV support skirt. To allow free vertical thermal expansion of the RPV and internals, no vertical load transfers through the alignment feature at the bottom of the RPV.

2.3 Regulatory Requirements

NuScale developed seismic analysis methods in accordance with guidance below:

- U.S. Nuclear Regulatory Commission, “Standard Review Plan for Review of Safety Analysis Reports for Nuclear Power Plants,” NUREG-0800
    - DSRS 3.7.2, U.S. Nuclear Regulatory Commission, "Design-Specific Review Standard for NuScale SMR Design, Section 3.7.2, Seismic System Analysis, Revision 0, June 2016
    - Section 3.7.1, “Seismic Design Parameters,” Revision 4, December 2014
    - Section 3.7.2, “Seismic System Analysis,” Revision 4, September 2013
    - Section 3.9.2,” Dynamic Testing and Analysis Of Systems, Structures, and Components,” Revision 3, March 2007
- DC/COL-ISG-017, “Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses”
- DC/COL-ISG-01, “Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications”

3.0 Analytical Methodology

This section describes ANSYS mechanical models. Figure 3-1 details this workflow.

Figure 3-1 Full Pool NuScale Power Module Model Schematic in ANSYS

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}}2(a),(c)

The full pool model contains six NPMs, pool water, and wall/basemat structure as shown in Figure 3-2. The modules are arranged such that M1, M2, and M3 are at the north location, and M4, M5, and M6 are at the south location.

Figure 3-2 Full-Pool NuScale Power Module Model Assembly

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}}2(a),(c)

The NPM model uses SOLID elements, SHELL elements, BEAM elements, and acoustic FLUID elements (for the RXP water), mass elements, contact/target elements, and spring elements. Figure 3-3 shows key components of one NPM.

Piping and valves (except for the MS and FW piping and valves), manways, instruments, PZR heaters, and other small internal components such as bolts are not explicitly modeled. These minor features do not affect the gross structural behavior of the model and removing them allows simplified meshing techniques. The piping that is not modeled is relatively flexible when compared to the vessels, and it does not drive the response of the CNV or RPV.

The PZR liquid level is assumed to be 60 percent for the NPM seismic model. Low and high level analytical limits that constrain the PZR water level are 35 percent and 80 percent, respectively; 60 percent falls within this range. The only effect this value has on the model is water mass in the PZR region. The change in water mass across the range of PZR levels has a small effect on the dynamic response of the NPM model.

The details of the model creation for the TSS, CNV, RPV, piping inside containment, LRVI, URVI, and CRDM are described below.

Figure 3-3 Key Components of a Single NuScale Power Module Seismic Model

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}}2(a),(c)

3.1 NuScale Power Module Main Components

3.1.1 Containment Vessel

The upper CNV is primarily made of SA-336, F6NM. The lower CNV is primarily made of SA-965, FXM-19. The RPV support ledges are SB-168, Alloy 690. The elastic modulus of the CNV is taken at 100 degrees F. The geometry of the CNV is simplified to remove some large features such as manways and openings, as well as the closure bolt assembly, for which mass adjustment is performed. The removal of such features can affect the local stiffness of the CNV; however, it is assumed that the effect on global stiffness is negligible. The 2017 ASME Boiler & Pressure Vessel Code, Section II (Reference 6.1.1) further describes steel material properties.

Figure 3-4 shows the main components and meshing of the CNV. Lower order SOLID elements are used throughout the CNV with the exception of the lugs and ledges (SHELL elements are used). The lugs and ledges are geometrically inserted into the

CNV body such that SOLID and SHELL elements share the same nodes to allow for moment transfer, as shown in Figure 3-4. An applied distributed mass to the upper CNV flange, to account for the un-modeled mass of the CNV closure bolt assembly and vessel penetrations under the water line, bring the total mass of the model to within 2 percent of the target mass, as shown in Table 3-1.

Table 3-1 Containment Vessel Mass Comparison

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}}2(a),(c)

[1] This target mass is calculated inclusive of bolting in the models. Differences in density for bolting in the target mass calculation have a negligible impact on the overall mass of the upper CNV. Likewise, smaller valves and the CNV flange guide studs have masses on the order of several hundred pounds and are justifiably neglected completely in this comparison.

[2] Includes {{ }}2(a),(c) distributed mass applied to the upper CNV flange shell.

Figure 3-4 Containment Vessel Meshing

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}}2(a),(c)

3.1.2 Piping Inside Containment

BEAM elements are used to mesh the pipes, as shown in Figure 3-5. MASS elements are applied at the locations of the two FW thermal relief valves.

Piping and safe-ends in this submodel are assigned material properties of SA-312, TP304 SMLS, which is equivalent to SA-182, F304 and SA-403 WP304 SMLS. Density adjustments are shown in Section 3.1.2.1. The elastic modulus of the MS piping is taken at 560 degrees F and the elastic modulus of the FW piping is taken at 250 degrees F.

Figure 3-5 Top Support Structure and Piping Meshing

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}}2(a),(c)

3.1.2.1 Piping Inside Containment Mass Correction

Table 3-2 shows the mass correction for this submodel in terms of density adjustments and applied point masses. The "modeled mass before density adjustment" and "modeled mass after density adjustment" in Table 3-2 are calculated.

The "actual mass" column is the calculated mass based on the volume of the parts, the density of the material specified in the TSS bill of material, and the best estimate of the fluid mass contained in the piping.

Table 3-2 Density Adjustments Applied to the Piping Inside Containment Submodel

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}}2(a),(c)

Table 3-3 shows the point masses that are added to the piping inside containment submodel to represent the FW thermal relief valves and associated hardware (flanges and bolting).

Table 3-3 Point Masses Applied to the Piping Inside Containment Submodel

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}}2(a),(c)

3.1.3 Top Support Structure and Piping Outside Containment

The CNV top support structure assembly is the basis for the geometry. Engineering drawings are the bases for the MSIVs, FWIVs, MS piping, and FW piping geometry.

The chemical and volume control system injection and discharge line geometry, the PZR spray piping, reactor component cooling water (RCCW) supply and return piping, containment evacuation piping, RPV high point degasification piping, and containment flood and drain system (CFDS) piping are not explicitly modeled. Instead, the geometry from the references above is used to calculate the associated masses, and they are accounted for as described in Section 3.1.3.1.

The CAD model used to generate the drawings is defeatured and simplified to reduce the element count of the mesh. The submodel of the TSS reduces the complicated actual design shown in Figure 3-7 to an ANSYS BEAM element model of the load-bearing frame and significant piping shown in Figure 3-8. Piping on top of the CNV and TSS are rigidly constrained to the top of the CNV and hence its mass is appropriately includes. For each module, one remote point is at the CG of the pipes and one at the top of its corresponding CNV. The remote points are rigidly connected in all directions, with the CNV being the master.

Piping on top of the CNV is rigidly constrained to the top of the CNV and its mass is accounted for in the analysis. For each module, one remote point is created at the CG of the pipes and one is created at the top of its corresponding CNV. The remote points are rigidly connected both in all directions, with the CNV being the master. Outside piping constraint remote points are shown in Figure 3-6.

Figure 3-6 Outside Piping Constraint

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}}2(a),(c)

Figure 3-7 NuScale Power Module Top Support Structure, Piping, and Cables on the Containment Vessel Top Head

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Figure 3-8 NuScale Top Support Structure ANSYS Model - Materials and Masses

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}}2(a),(c)

Materials are assigned to the explicitly-modeled components per the bill of material of the associated drawings. The elastic moduli of the TSS frame materials is taken at 70 degrees F. The elastic modulus of the MS piping is taken at 560 degrees F and the elastic modulus of the FW piping is taken at 250 degrees F. Densities are taken at the as-built temperature of 70 degrees F and adjusted as necessary per Section 3.1.3.1. Line bodies representing isolation valves are assigned high elastic moduli to represent the behavior of the stiff valves.

3.1.3.1 Top Support Structure and Piping Outside Containment Mass Correction

Table 3-6 and Table 3-7 show the mass correction for the TSS for density adjustments and applied point masses, respectively. The "modeled mass before

density adjustment" and "modeled mass after density adjustment" in Table 4-6 are calculated.

The "actual mass" column is the calculated mass based on the volume of the parts and the density of the material specified in the TSS bill of material.

The density of the members of the load-bearing frame are adjusted to match the actual calculated mass. Additionally, the adjusted density of the top of the TSS structural frame (cross members and support ring in Figure 3-8), accounts for missing masses of un-modeled components (including smaller piping lines, cabling, cable trays, piping supports, and platform grating).

The mass of the lifting lugs that connect to the TSS to the Reactor Building crane and the mass of the base plates that connect the TSS to the CNV top head are included as MASS elements.

MASS elements representing the valves are applied at the centers of gravity. Note that the BEAM elements representing the valves themselves are low density and are effectively massless.

MASS21 elements are used to represent the ball joints present in the MS and FW piping. The DHRS branch piping off of the MS lines include MASS elements representing half of the piping mass between the MS line connection and the first DHRS piping support. The DHRS branches off the main steam line, which leads down the side of the CNV to the DHRS valves, and assumes liquid water is contained at 100 degrees F during normal operation.

Table 3-4 provides the feedwater (FW) and MS pressures, temperatures, and densities.

Table 3-4 Water and Steam Densities

	Temp (°F)	Pressure (psia)	Density (lbm/in^3)
Feedwater	250	543	0.0341
Main Steam	537	475	0.00052

The assumed mass of the MS and FW flanges and ball joints are per Table 3-5 Assumed Flange Masses, including Hardware, for use as point masses applied at their respective locations on the explicitly modeled piping outside containment.

Table 3-5 Assumed Flange Masses, Including Hardware

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}}2(a),(c)

Table 3-6 Top Support Structure and Piping Outside Containment Density Adjustments

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Table 3-7 Point Masses Applied to the Top Support Structure and Piping Outside Containment Submodel

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}}2(a),(c)

3.1.4 Reactor Pressure Vessel

The CAD model used to generate the drawings is defeatured and simplified to reduce the element count of the mesh; specifically, by merging the cladding with the base metal and removing features that do not significantly affect the structural behavior. Figure 3-9 shows the RPV geometry and mesh.

Four-node SHELL elements and SOLID elements are used to mesh the RPV and multipoint constraint (MPC) connections between the SHELL and the SOLID elements are used to account for moment transfer, and to achieve a shell-to-solid connection.

Figure 3-9 Reactor Pressure Vessel

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}}2(a),(c)

The RPV material properties are SA-508 Grade 3 Class 2 steel, except for the upper RPV support, which is SB-166, Alloy 690; and the lower RPV, which is SA-965, FXM-19. The elastic modulus values are at the approximate average RCS temperature of 550 degrees F. The material density is at the as-built temperature of 70 degrees F. Table 3-8 shows the mass comparison between the model and masses calculated using RPV geometry. Also included in the comparison are components not modeled.

Table 3-8 Reactor Pressure Vessel Mass Comparison

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}}2(a),(c)

3.1.5 Lower Reactor Vessel Internals

Figure 3-10 shows the LRVI. The upper and lower core plates, lower riser section, core barrel, and CRAGT support plate are meshed using SHELL elements. The reflector blocks are replaced by a distributed mass of {{ }}2(a),(c), scoped to both the top face of the LCP and the inside face of the core barrel. Table 3-9 shows the mass comparison between the model and masses calculated using LRVI geometry.

Table 3-9 Lower Reactor Vessel Internals Mass Comparison (excluding fuel assemblies)

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}}2(a),(c)

Figure 3-10 Lower Reactor Vessel Internal

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}}2(a),(c)

3.1.6 Upper Reactor Vessel Internal

Figure 3-11 shows the URVI. The bellows shown are explicitly modeled. Modeling the bellows with its actual geometry directly accounts for axial and lateral stiffness. The SHELL elements represent the URVI assembly including the hanger plates and hanger connectors.

The control rod drive system (CRDS) supports are modeled using SHELL elements for the lower support and BEAM elements for the other supports as shown in Figure 3-12. Conformal meshing is used between the CRDS and the URVI shell.

The URVI are assigned material properties of Type 304 stainless steel. The elastic modulus is taken at the approximate average RCS temperature of 550 degrees F. The material density is taken at the as-built temperature of 70 degrees F. The material property values come from ASME Boiler and Pressure Vessel Code, Section II

(Reference 6.1.1). Table 3-10 shows the mass comparison between the model and masses calculated using released geometry.

Table 3-10 Upper Reactor Vessel Internals Mass Comparison

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}}2(a),(c)

Figure 3-11 Upper Reactor Vessel Internals and Bellows

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}}2(a),(c)

Figure 3-12 Control Rod Drive Shaft Supports

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}}2(a),(c)

3.1.7 Control Rod Drive Mechanism and Control Rod Drive Mechanism Support Structures

The CRDM support structure and CRDM support frame are modeled entirely using BEAM and SHELL elements with a conformal mesh. The CRDM assembly is replaced by a point mass {{ }}2(a),(c) located at the center of gravity of the assembly and attached to the top of the RPV.

Figure 3-13 shows the CRDM assembly modeled as a lumped mass of 56,804 lbm and attached to the top of the RPV. Pads at the upper and lower supports, modeled as SHELL elements, connect to the bottom of the CNV top head and the top of the RPV top head using multi-point constraint bonded contacts. The elastic modulus of the CRDM support structure is taken at 300 degrees F.

Figure 3-13 Control Rod Drive Mechanism Support Structure and Control Rod Drive Mechanism Support Frame

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}}2(a),(c)

3.1.8 Fuel Assembly

Located within the LRVI is a model to represent the fuel assemblies. The beginning of life (BOL) wet model is used. The fuel model is made of beam, spring, and point mass elements. The diagram of a single fuel assembly beam model is shown in Figure 3-14; Table 3-11 lists the values (Reference 6.1.2).

To account for the 37 fuel assemblies in one combined single beam model, the stiffness of the beams and springs, the density of the BEAM elements, and the displaced water mass and holddown preload are multiplied by 37. The holddown spring is modeled between node #7 and #9 in the vertical direction, and node #9 is vertically coupled to the UCP remote point. The fuel assembly is fully modeled in WB while using a command object to adjust beam properties.

Table 3-11 Fuel BEAM Element Properties (Beginning of Life)

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[	]
[	]

}}2(a),(c)

Table 3-11 Fuel BEAM Element Properties (Beginning of Life) (Continued)

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}}2(a),(c)

Figure 3-14 Fuel Beam Model

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}}2(a),(c)

3.1.9 Pool Bay and Walls Model

This section describes the model of the pool bay and surrounding walls. The RXP temperature is 100 degrees F. The RXP bays are approximately 20 ft wide by 20 ft long by 100 ft tall with a normal RXP water depth of approximately 53 ft, which corresponds to an elevation of approximately 6 ft below grade.

FLUID acoustic elements are used to mesh the pool water. The surrounding walls and basemat are modeled using SOLID SHELL elements with one element across the thickness. Figure 3-15 depicts this geometry and meshing.

Figure 3-15 Pool Bay and Walls Geometry and Mesh

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}}2(a),(c)

3.1.10 Fritz Elements for Hydrodynamic Masses

The fluid mass contained in the annular volume between the RPV and RVI shells is modeled by dynamic fluid coupling elements (Fritz elements) which represent a dynamic coupling between two points of a structure. The Fritz elements are applied to seven vertical segments separated at six elevations. At each segment, remote points

are created at the annulus of the RVI and RPV, respectively; these two remote points are then connected to create a Fritz element.

The contained volumes defined by the RPV inner diameter and displaced volumes defined by the RVI outer diameter are used to calculate the radius of the outer cylinder (R2) and the radius of the inner cylinder (R1) in an equivalent manner, for each Fritz elements, with the length of each segment. The formulation is:

$$V = \pi R^2 L \rightarrow R = \sqrt{\frac{V}{\pi L}}$$

Where V is the volume in cubic inches, R is the radius in inches and L is the span length in inches. Table 3-12 lists the volumes and elevations.

Table 3-12 Fritz Elements for Contained Fluid

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}}2(a),(c)

For calculation of the annular volumes, the reduced volumes of the SG region of the annulus are adjusted for the volume taken up by the SG. The SG secondary fluid volume is {{ }}2(a),(c). The total mass for the SG tubes and supports is {{ }}2(a),(c). Using a density of 0.29 lbm/in^3 at 70 degrees F, the total volume for the SG tubes and supports is {{ }}2(a),(c). Therefore, the total volume of the SG secondary fluid and the SG tubes and supports is {{ }}2(a),(c). For the calculation of Fritz elements, the distributed volume is proportional to the span length in Element 3 through Element 7.

3.2 Model Connections

3.2.1 Reactor Pressure Vessel to Containment Vessel Connections

3.2.1.1 Lower Seismic Restraint

The male cylindrical end of the RPV is concentric with the female end of the CNV with a radial gap of 0.125 in. as shown in Figure 3-16. A nonlinear gap connection represents the radial gap between the two bumpers.

Figure 3-16 Reactor Pressure Vessel_Containment Vessel Lower Seismic Constraint

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}}2(a),(c)

3.2.1.2 Ledge Supports

The RPV upper support segments are connected to the CNV ledges using rigid beam connections as shown in Figure 3-17.

Figure 3-17 Reactor Pressure Vessel_Containment Vessel Ledge Connection

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}}2(a),(c)

3.2.2 Top Support Structure to Containment Vessel Connections

The TSS pad is modeled as SHELL elements while the CNV top head is modeled using SOLID elements. A bonded connection in all directions is used.

3.2.3 Piping to Containment Vessel Connections

The FW and MS piping, modeled using BEAM elements, penetrate the CNV top head as shown in Figure 3-18. A bonded connection in all directions is used.

Figure 3-18 Main Steam and Feedwater to Containment Vessel Bonded Connection

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}}2(a),(c)

3.2.4 Feedwater Safe-ends to Decay Heat Removal System Connections

The FW, modeled using BEAM elements, is connected to the CNV shell using bonded contact. This connection is depicted in Figure 3-19. The DHRS valve, condenser, and piping masses are assumed to have a negligible effect on the global behavior of the CNV.

Figure 3-19 Feedwater to Decay Heat Removal System Bonded Connection

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}}2(a),(c)

3.2.5 Reactor Pressure Vessel to Piping Interfaces

The RPV piping can be split into a primary loop and a secondary loop. The primary loop includes RCS piping, and the secondary loop includes FW piping and MS piping. The secondary loop is shown in Figure 3-20.

Figure 3-20 Piping to Steam Generator Access and Plenum Connections

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}}2(a),(c)

3.2.6 Lugs to Corbel Connections

Remote points are generated for the CNV lateral lugs. Remote points are also generated for the corbels. The CNV lateral lugs are loaded or constrained only in the horizontal shear directions; therefore, constraint equations are created accordingly. The north-south lugs are constrained in the X direction, while the east-west lugs are constrained in the Y direction as shown in Figure 3-21.

Figure 3-21 Lugs/Corbels Constraint Equations

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}}2(a),(c)

3.2.7 Containment Vessel to Bay Pool Connection

Fluid-structure interaction between the CNV and the bay pool water is accounted for by assigning acoustic properties to the pool. Interfacing surfaces between the CNV and pool account for FSI.

The FSI and contact are applied to the three sides of the bay pool that interface with the walls and to the bottom surface that interfaces with the floor.

When the sloshing effect is not simulated, the top surface of the bay pool is assigned an acoustic pressure of 0 psi because this is the zero pressure surface.

3.2.8 Containment Vessel Skirt to Basemat Connection

The connection between the CNV and basemat is unconstrainted in the vertical direction. Passive seismic supports are added such that the skirt is laterally constrained while it is free to move in the vertical direction. Two perpendicular spring elements are used to simulate that behavior; one element is along the X direction while the other is along the Y direction, as shown in Figure 3-22.

Figure 3-22 Passive Seismic Supports

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}}2(a),(c)

3.2.9 Reactor Pressure Vessel to Upper Riser Hanger

The upper riser hanger is supported by threaded fasteners through the integral steam plenum baffle plate. This connection is modeled with a standard bonded contact as shown in Figure 3-23.

Figure 3-23 Reactor Pressure Vessel to Upper Riser Hanger

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}}2(a),(c)

3.2.10 Lower Riser to Core Barrel Assembly

The four LCP tabs on the LRVI are bonded to the four lower core support blocks of the RPV.

The upper support blocks of the LRVI are not connected to the inner walls of the core region of the RPV submodel. As confirmed in Section 5.7, the gap between the blocks and the RPV inner wall is always open in cold or hot conditions and during a seismic event. The top face of the LRVI is bonded to the bottom face of the URVI.

3.2.11 Upper Reactor Vessel Internal to Reactor Pressure Vessel

To represent the radial connection provided by the SG tube supports between the URVI shell and the RPV shell, radial couplings are created at eight circumferential locations at the support bars, and at six elevations (48 locations). The radial coupling is achieved by creating rigid springs between the URVI and the RPV as shown in Figure 3-11.

3.2.12 Fuel Assembly to Lower Core Plate and Upper Core Plate

The combined single beam model of fuel assembly (Section 3.1.8) is attached to the LCP of the LRVI submodel through a remote point scoped to the lower core plate. At the top end of the beam model, the top node in Figure 3-14 is coupled to the UCP for the lateral and all rotational degrees through a remote point scoped to the selected UCP.

3.3 Model Boundary Conditions (Acceleration Time Histories)

Acceleration time histories are applied to the wall and the base as shown in Figure 3-24. Time histories of 20 seconds are applied. This duration is acceptable because the main earthquake motion occurs in the first 20 seconds. 75 percent of the earthquake energy for all directions of all seeds used in this analysis occur before 20 seconds. The time when the energy is 75 percent is around 16 seconds. The normalized Arias intensity is greater than 95 percent at 20 seconds. Time history inputs are developed using harmonic results. NuScale used four different soil input signals (Soil 7, Soil 7SS, Soil 9, and Soil 11). Section 3.3.1 through Section 3.3.4 describe steps for developing the time histories.

Figure 3-24 Applied Acceleration at the Walls and the Base

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}}2(a),(c)

3.3.1 Store Transfer Functions for Each Frequency

In this step, transfer functions are generated from the files produced in the harmonic analysis. An .rst file exists for each frequency, for each direction, and for each soil type. The outputs from this step are transfer functions for a single frequency and all nodes for which time histories are produced for a given direction.

3.3.2 Reorganize Transfer Functions for Each Node

In this step, the output from the previous step is read and reorganized. Acceleration un-interpolated transfer functions (real and imaginary) are reorganized per node.

3.3.3 Interpolate and Convolve Transfer Functions with Input Motions

In this step, the un-interpolated transfer functions from the last step are interpolated using the SASSI method. After interpolation, the transfer functions are convolved with in-layer time histories. Finally, time history text files are written. The un-interpolated transfer functions from the previous step are interpolated and convolved with in-layer time histories. Outputs from this step are text files containing acceleration time histories for each node.

3.3.4 Create .sav Files

The final step is to read acceleration time histories from the last step for a given soil and write them to tables that can be read by ANSYS. The tables are generated by loading the text files produced in the previous step. The resulting acceleration time histories are saved in an ANSYS-compatible file.

4.0 Calculation Body

This section documents test runs for the seismic model. Test runs are done to ensure proper connectivity of the entire full-pool model and also accept inputs from the harmonic analysis.

4.1 Static Analysis

4.1.1 Deformation under Gravity Load

A static test run on a single module is performed to ensure proper connectivity within a single module. The module is fully constrained at the skirt. The end of the MS and FW piping(s) is also fully constrained. A gravity load is applied along the z axis as shown in Figure 4-1. Figure 4-2 shows the vertical displacement results (z axis) under static earth gravity. As expected, a minimum UZ occurs at the centroid of the TSS.

Figure 4-1 Static Analysis Test Case

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Figure 4-2 Displacement in the Vertical Direction under Static Gravity

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}}2(a),(c)

4.1.2 Deformation under Applied Lateral Load

Piping on top of the CNV is rigidly constrained to the top of the CNV and hence its mass is accounted for. A remote point is created at the CG of the pipes and a second point is created at the top of its corresponding CNV. The remote points are rigidly connected both in all directions, with the CNV being the master. A lateral load of 3E6 lbf is applied at the CNV remote point in the Y direction, as shown in Figure 4-3. Reaction force at the bottom of the CNV skirt is balanced at 3E6 lbf as shown in Figure 4-4.

Figure 4-3 Static Analysis under Lateral Load

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Figure 4-4 Reaction Force under Lateral Load F_Y = 3E6 lbf

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4.2 Modal Analysis

4.2.1 Modal Analysis Comparison

Table 4-1 compares the major modes of the NPM model developed in this report to the major modes of the simplified NPM. This check is performed to confirm that the two models would have similar interaction effects with the RXB, thereby justifying use of the simplified NPM in the double building model as an appropriate representation of NPM in that analysis. Because the major modes and mass participations in Table 4-1 are similar, the NPM model developed in this report is justified in using the double building model results as inputs at its cut boundaries. Section 3.2.11 describes development of the cut boundary inputs. The Final Safety Analysis Report, Section 3.7.2, describes the double building model.

> In order to directly compare the modal response of the two models, the code to combine the simplified NPM is modified not to use superelements.

Note that the modal results of the non-superelement model presented here and the superelement model used are identical, but a non-superelement model allows visualization of the major modes and the disposition of minor differences. Additionally, note that the FLUID elements representing the pool water are suppressed in both the simplified NPM and the NPM models to create an appropriate comparison of just the NPM.

4.2.2 Modal Analysis Constraints

In the modal analyses, the NPM lug displacements are constrained in the lateral directions, but are not restrained vertically. The CNV skirt displacements are constrained in all directions, and the piping outside containment is rigidly constrained to the CNV top head. The cylindrical gap between the RPV and CNV bumper is treated linearly by applying constraint equations in lateral directions.

4.2.3 Modal Analysis Results

Table 4-1 summarizes the major modes between the two models. Because the frequencies are similar and the mass participations sum to similar totals for each direction, the simplified NPM in the double building model is an appropriate representation of the NPM in that simulation. Figure 4-5, Figure 4-6, and Figure 4-7 show the major mode shapes of the two models for comparison.

Table 4-1 Modal Analysis Summary (Major Modes)

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}}2(a),(c)

Figure 4-5 Major Mode Shapes in X Direction for NuScale Power Module (Left) and the Simplified NuScale Power Module in the Double Building Model (Right)

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}}2(a),(c)

Note that piping and bellows in the NPM model are hidden and the scale is resized for a better comparison.

Figure 4-6 Major Mode Shapes in Y Direction for NuScale Power Module (Left) and the Simplified NuScale Power Module in the Double Building Model (Right)

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}}2(a),(c)

Note that piping in the NPM model is hidden and the scale is resized for a better comparison.

Figure 4-7 Major Mode Shapes in Z Direction for NPM (Left) and the Simplified NuScale Power Module in the Double Building Model (Right)

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}}2(a),(c)

Note that piping in the NPM model is hidden and the scale is resized for a better comparison.

4.3 Transient Analysis

A nonlinear transient analysis is performed on the full-pool model described in Section 3.0. An acceleration time history in X, Y, and Z, of a total time of 20 seconds, is applied at the base and walls around the pool. The “static acoustics” (cell H) in Figure 3-1 is converted to a transient analysis module. A constant time step size of 5 milliseconds is used. Rayleigh damping of an equivalent 4 percent damping is used for a frequency range {{ }}2(a),(c) resulting in a mass alpha damping of {{ }}2(a),(c) and a stiffness beta damping of {{ }}2(a),(c).

Nodes at the base and walls are subject to an acceleration input. A sample input at soils 7, 7SS, 9, and 11 at M1 to M6 is shown in Figure 4-8 to Figure 4-11.

Figure 4-8 Acceleration Time History at M1 to M6; Soil 7

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Figure 4-9 Acceleration Time History at M1 to M6; Soil 7SS

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Figure 4-10 Acceleration Time History at M1 to M6; Soil 9

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}}2(a),(c)

Figure 4-11 Acceleration Time History at M1 to M6; Soil 11

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}}2(a),(c)

5.0 Results and Conclusions

As indicated in Section 3.3, the NPM seismic analysis uses four different soil input signals.

Displacement and acceleration results are obtained. The acceleration results are then used for the ISRS calculation at 4 percent damping. Broadened ISRS with a ±15 percent frequency shift is calculated for the enveloping ISRS.

5.1 Core Plates Motions

The analysis generated NPM core plate acceleration time histories for the safe shutdown earthquake conditions for the four soils. Safe shutdown earthquake is the vibratory ground motion for which certain SSC must be designed to remain functional. Considering four soil types and six modules, 3 in north row and 3 in south row, there are 24 cases.

Figure 5-1 through Figure 5-8 show examples of time histories of acceleration of the LCP and UCP of soils 7, 7SS, 9, and 11 seismic transient loads. The application of a gravity load in the first 0.001 seconds resulted in an acceleration oscillation in the Z direction that is dampened and vanished well before the start of the seismic event (at around 0.75 seconds). Hence, the oscillation is removed from output accelerations used for ISRS calculations.

Figure 5-1 Acceleration Time Histories for Soil 7 (Lower Core Plate)

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Figure 5-2 Acceleration Time Histories for Soil 7 (Upper Core Plate)

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Figure 5-3 Acceleration Time Histories for Soil 7SS (Lower Core Plate)

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Figure 5-4 Acceleration Time Histories for Soil 7SS (Upper Core Plate)

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Figure 5-5 Acceleration Time Histories for Soil 9 (Lower Core Plate)

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Figure 5-6 Acceleration Time Histories for Soil 9 (Upper Core Plate)

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Figure 5-7 Acceleration Time Histories for Soil 11 (Lower Core Plate)

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}}2(a),(c)

Figure 5-8 Acceleration Time Histories for Soil 11 (Upper Core Plate)

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}}2(a),(c)

5.2 In-Structure Response Spectra on Lower Reactor Vessel Internals

NuScale generated the ISRS from the seismic model acceleration results at 4 percent damping and broadened ISRS with a ±15 percent frequency shift calculated for the enveloping ISRS.

Locations on the LRVI are shown in Figure 5-9. NuScale extracted three locations on the LRVI: the CRAGT support plate (CRAGT), upper core plate, and LCP. Figure 5-10 through Figure 5-12 show the ISRS vs. frequency plots of the CRAGT support, LCP, and UCP in modules 1 through 6 in three directions.

Figure 5-9 Locations on Lower Reactor Vessel Internals

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Figure 5-10 CRAGT Support Plate AX, AY, and AZ In-Structure Response Spectra

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Figure 5-11 Upper Core Plate AX, AY, and AZ In-Structure Response Spectra

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Figure 5-12 Lower Core Plate AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

5.3 In-Structure Response Spectra on Upper Reactor Vessel Internals

NuScale generated the ISRS from the seismic model acceleration results at 4 percent damping, and broadened ISRS with a ±15 percent frequency shift calculated for the enveloping ISRS. Locations on the URVI are shown in Figure 5-13. NuScale extracted six locations on the URVI at a centroid location for each. The locations are at the CRDS supports and the hanger plate. The ISRS is shown in Figure 5-14 through Figure 5-19.

Figure 5-13 Locations on Upper Reactor Vessel Internals

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}}2(a),(c)

Figure 5-14 Control Rod Drive Shaft Support 1 AX, AY, and AZ In-Structure Response Spectra

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Figure 5-15 Control Rod Drive Shaft Support 2 AX, AY, and AZ In-Structure Response Spectra

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Figure 5-16 Control Rod Drive Shaft Support AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

Figure 5-17 Control Rod Drive Shaft Support 4 AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

Figure 5-18 Control Rod Drive Shaft Support 5 AX, AY, and AZ In-Structure Response Spectra (Y-Scale is at 25g)

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}}2(a),(c)

Figure 5-19 Hanger Plate AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

5.4 In-Structure Response Spectra on Containment Vessel

NuScale generated the ISRS from the seismic model acceleration results at 4 percent damping, and broadened ISRS with a ±15 percent frequency shift calculated for the enveloping ISRS. Locations on the CNV are shown in Figure 5-20. At the CNV skirt, NuScale chose two points (one on the east side of the CNV (Sk_E, Figure 5-31), and one on the north side (Sk_N, Figure 5-32), as shown in Figure 5-21). At the transition (CTr, Figure 3-24), flange (FLG, Figure 5-25), and ledges (Ldg, Figure 5-27), four points are used at 0, 90, 180, and 270 degrees, which would result in 96 ISRS curves. For example, the broadened ISRS would include such points as shown in Figure 5-23. The ISRS at the CNV bumper is shown in Figure 5-24. Section 3.2.1.1 addresses the connection between the CNV bumper and the RPV bumper. The containment vessel top head is shown in Figure 5-26. The ISRS for the lugs are shown in Figure 5-28 to Figure 5-30. East, west, and north lugs are extracted (directions are relative to each module as shown in Figure 5-22).

Figure 5-20 Locations on Containment Vessel

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Figure 5-21 Locations on Skirts

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Figure 5-22 East, West, and North Lugs on Module 1 to Module 6

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Figure 5-23 Containment Vessel Transition (CTr) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-24 Containment Vessel Bumper AX, AY, and AZ In-Structure Response Spectra

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Figure 5-25 Containment Vessel Flange (FLG) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-26 Containment Vessel Top Head (CTp) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-27 Containment Vessel Ledges for Reactor Pressure Vessel Support (Ldg) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-28 West Lug (Lg_W) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-29 East Lug (Lg_E) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-30 North Lug (Lg_N) AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

Figure 5-31 East Skirt (Sk_E) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-32 North Skirt (Sk_N) AX, AY, and AZ In-Structure Response Spectra

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5.5 In-Structure Response Spectra on Reactor Pressure Vessel and Control Rod Drive Mechanism Supports

NuScale generated the ISRS from the seismic model acceleration results at 4 percent damping, and broadened ISRS with a ±15 percent frequency shift calculated for the enveloping ISRS. Locations on the RPV are shown in Figure 5-33. Then NuScale extracted eight locations on the RVI at four points except for the RVI bumper and the RVI top head. The ISRS is shown in Figure 5-34 through Figure 5-40.

Figure 5-33 Locations on Reactor Pressure Vessel

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Figure 5-34 Control Rod Drive Mechanism Support Frame (UpSp) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-35 Control Rod Drive Mechanism Support Structure (DnSp) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-36 Reactor Pressure Vessel Top Head (RTp) AX, AY, and AZ In-Structure Response Spectra

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Figure 5-37 Main Steam Plenum AX, AY, and AZ In-Structure Response Spectra

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Figure 5-38 Feedwater Plenum AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

Figure 5-39 Reactor Pressure Vessel Flange AX, AY, and AZ In-Structure Response Spectra

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Figure 5-40 Reactor Pressure Vessel Bumper AX, AY, and AZ In-Structure Response Spectra

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}}2(a),(c)

5.6 Reaction Forces

Reaction forces are extracted at key locations on the NPM: at the skirts, east lugs, west lugs, and north lugs. Vertical reaction force Fz at the skirt is shown in Figure 5-41 through Figure 5-44. Lugs are constrained in the lateral direction (Section 3.2.6), and hence east and west lugs have reaction force in the Y direction while north lugs have reactions in X direction. Lug reaction forces are shown in Figure 5-45 through Figure 5-56. Note that the directions are relative to each module as shown in Figure 5-22.

Figure 5-41 Skirt Reaction Force (Fz) - Soil 7SS

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Figure 5-42 Skirt Reaction Force (Fz) - Soil 7SS

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Figure 5-43 Skirt Reaction Force (Fz) - Soil 9

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Figure 5-44 Skirt Reaction Force (Fz) - Soil 11

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Figure 5-45 East Lug Reaction Force (Fy) - Soil 7

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Figure 5-46 East Lug Reaction Force (Fy) - Soil 7SS

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Figure 5-47 East Lug Reaction Force (Fy) - Soil 9

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Figure 5-48 East Lug Reaction Force (Fy) - Soil 11

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Figure 5-49 West Lug Reaction Force (Fy) - Soil 7

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}}2(a),(c)

Figure 5-50 West Lug Reaction Force (Fy) - Soil 7SS

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}}2(a),(c)

Figure 5-51 West Lug Reaction Force (Fy) - Soil 9

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}}2(a),(c)

Figure 5-52 West Lug Reaction Force (Fy) - Soil 11

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}}2(a),(c)

Figure 5-53 North Lug Reaction Force (Fx) - Soil 7

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}}2(a),(c)

Figure 5-54 North Lug Reaction Force (Fx) - Soil 7SS

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}}2(a),(c)

Figure 5-55 North Lug Reaction Force (Fx) - Soil 9

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}}2(a),(c)

Figure 5-56 North Lug Reaction Force (Fx) - Soil 11

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}}2(a),(c)

5.7 Gap between Upper Support Blocks and Reactor Pressure Vessel

The upper support blocks of the LRVI are not connected to the inner walls of the core region of the RPV submodel. It is necessary to ensure that the gap between the blocks and the RPV inner wall is always open in the cold or hot conditions and during a seismic event, as stated in Section 3.2.10. The analysis plotted in relative radial displacement for east, west, north, and south blocks, as shown in Figure 5-57 through Figure 5-72. These figures show that the maximum relative displacement does not exceed {{ }}2(a),(c), which indicates the gap is always open because the gap is approximately {{ }}2(a),(c).

Figure 5-57 Radial Gap at East Support Block (Soil 7)

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}}2(a),(c)

Figure 5-58 Radial Gap at East Support Block (Soil 7SS)

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Figure 5-59 Radial Gap at East Support Block (Soil 9)

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}}2(a),(c)

Figure 5-60 Radial Gap at East Support Block (Soil 11)

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Figure 5-61 Radial Gap at West Support Block (Soil 7)

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}}2(a),(c)

Figure 5-62 Radial Gap at West Support Block (Soil 7SS)

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}}2(a),(c)

Figure 5-63 Radial Gap at West Support Block (Soil 9)

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}}2(a),(c)

Figure 5-64 Radial Gap at West Support Block (Soil 11)

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}}2(a),(c)

Figure 5-65 Radial Gap at South Support Block (Soil 7)

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}}2(a),(c)

Figure 5-66 Radial Gap at South Support Block (Soil 7SS)

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}}2(a),(c)

Figure 5-67 Radial Gap at South Support Block (Soil 9)

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}}2(a),(c)

Figure 5-68 Radial Gap at South Support Block (Soil 11)

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}}2(a),(c)

Figure 5-69 Radial Gap at North Support Block (Soil 7)

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}}2(a),(c)

Figure 5-70 Radial Gap at North Support Block (Soil 7SS)

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Figure 5-71 Radial Gap at North Support Block (Soil 9)

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}}2(a),(c)

Figure 5-72 Radial Gap at North Support Block (Soil 11)

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}}2(a),(c)

6.0 Conclusion

Because of the complexity of the NPM and its connected subsystems, the dynamic analysis of the NPM required a complete system model to represent the dynamic coupling of the RPV, the CNV, reactor internals and core support, the reactor core, surrounding pool water, and SSC supported by the NPM. NuScale performed dynamic analysis of the complete NPM system using time history dynamic analysis methods and a three-dimensional ANSYS finite element model. The detailed NPM system model includes acoustic elements to properly represent effects of FSI due to the pool water between the CNV and pool floor and walls.

To account for the dynamic coupling of the NPMs and the RXB system, the RXB system model uses a model of each of the NPMs. NuScale analyzed the complete RXB system model, with representation of the NPMs for SSI in the frequency domain. Results from the RXB seismic system analysis provide in-structure time histories at each NPM support location and the pool walls and floor surrounding the NPM.

In-structure response spectra are also calculated and representative ISRS plots presented.

The NPM dynamic analysis produced forces and moments, in-structure time histories, and ISRS to be used for qualification of the NPM components and supported equipment. Time histories are developed at the core support locations for seismic qualification of fuel assemblies.

6.1 References

6.1.1 ASME Boiler and Pressure Vessel Code, Section II, “Materials,” Part D Properties (Customary), 2017 Edition.

6.1.2 AREVA Fuels Doc. FS1-0025171, Rev. 3.0, “NuScale Lateral Faulted Analysis – Grid Impact Loads From Externally Applied Lateral Dynamic Excitations.”

Enclosure 3:

Affidavit of Carrie Fosaaen, AF-132101

NuScale Power, LLC

AFFIDAVIT of Carrie Fosaaen

I, Carrie Fosaaen, state as follows:

(1) I am the Senior Director of Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale

(2) I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:

(a) The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.

(b) The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.

(c) Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

(d) The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.

(e) The information requested to be withheld consists of patentable ideas.

(3) Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying report reveals distinguishing aspects about the design by which NuScale develops its Design of Structures, Systems, Components and Equipment.

NuScale has performed significant research and evaluation to develop a basis for this design and has invested significant resources, including the expenditure of a considerable sum of money.

The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

(4) The information sought to be withheld is in the enclosed report entitled Design of Structures, Systems, Components and Equipment. The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.

(5) The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC §

552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).

(6) Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:

(a) The information sought to be withheld is owned and has been held in confidence by NuScale.

(b) The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.

(c) The information is being transmitted to and received by the NRC in confidence.

(d) No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.

(e) Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on 12/31/2022.

Carrie Fosaaen

Enclosure 4:

Enclosure 4: Affidavit of Morris Byram, Framatome Inc.

A F F I D A V I T

1. My name is Morris Byram. I am Product Manager, Licensing & Regulatory Affairs 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 Document TR-121515-P, Revision 0, "US460 NuScale Power Module Seismic Analysis," within Enclosure 1 to the NuScale Power, LLC letter Number LO-131929 with subject "NuScale Power, LLC Submittal of the NuScale Standard Design Approval Application Part 2 – Final Safety Analysis Report, Chapter 3, 'Design of Structures, Systems, Components and Equipment,' Revision 0," and 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 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 paragraph 6(b) 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.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: (12/22/2022)

BYRAM Morris Digitally signed by BYRAM Morris Date: 2022.12.22 16:30:33 -08'00'

(NAME)

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Phone: 434-221-1082