April 11, 2019

Docket No. 52-048

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

SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 386 (eRAI No. 9316) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 386 (eRAI No. 9316)," dated March 13, 2018

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. 9316:

- 03.09.02-54

Enclosure 1 is the proprietary version of the NuScale Response to NRC RAI No. 386 (eRAI No. 9316). NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The proprietary enclosures have been deemed to contain Export Controlled Information. This information must be protected from disclosure per the requirements of 10 CFR § 810. The enclosed affidavit (Enclosure 3) supports this request. 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 Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

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

Distribution: Gregory Cranston, NRC, OWFN-8H12
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9316, proprietary

Enclosure 2: NuScale Response to NRC Request for Additional Information eRAI No. 9316, nonproprietary

Enclosure 3: Affidavit of Zackary W. Rad, AF-0419-65183

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9316, proprietary

Enclosure 2:

NuScale Response to NRC Request for Additional Information eRAI No. 9316, nonproprietary

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

eRAI No.: 9316
Date of RAI Issue: 03/13/2018

NRC Question No.: 03.09.02-54

Provide the detailed information on acoustic resonance (AR) assessments to the CVAP report as originally requested in RAI 8884, Question 03.09.02-7, particularly on the decay heat removal system (DHRS) standby modes. Given that strong acoustic resonances excited by second order shear layer flow instabilities have been observed in the main steam lines of boiler water reactors (BWRs) it has been common practice for licensees requesting Extended Power Uprates (EPUs) or those proposing new plant designs to confirm that first and second order shear layer instabilities do not lock-on to sidebranch acoustic modes and damage valves or generate acoustic loads which could damage other components including reactor internals. Other evidence of the ability of 2nd order instabilities to excite acoustic resonances are available in Ziada and Lafon, “Flow-excited acoustic resonance excitation mechanism, design guidelines, and counter-measures,” Applied Mechanics Reviews, Vol. 66, Jan 2014. Expand the NuScale AR assessments, particularly in the DHRS, to include second order instabilities. Also, given the small margin against AR at the primary shear layer modes, explain in detail how AR will be assessed and, if necessary, mitigated during initial startup or other testing. Without the information, the staff cannot reach a reasonable assurance finding on the structural integrity of the reactor internals components to withstand the adverse effects of vibration.

Add the information to the comprehensive vibration assessment (CVAP) report TR-0716-50439.

NuScale Response:

A description of the analysis methodology for acoustic resonance assessments is provided in Section 3.2.4 of NuScale Comprehensive Vibration Assessment Program (CVAP) Technical Report, TR-0716-50439.

The scope of flow induced vibration (FIV) screening for acoustic resonance (AR) of NuScale power module (NPM) components has been expanded to include the piping sections outside of containment between the containment isolation valves and the NPM disconnect flanges, and additional regions inside containment. The locations added to the scope are listed below:

- Containment system (CNTS) main steam (MS) drain valve branches
- Steam generating system (SGS) pressure relief valve branches
- CNTS chemical and volume control (CVC) drain valve branches
- CNTS feedwater (FW) drain valve branches
- Main steam isolation valve (MSIV) upstream and downstream bypass lines
- Reactor coolant system (RCS) injection to the reactor recirculation valve (RRV) and reactor vent valve (RVV) reset lines

These regions have closed side branches with single phase occluded flow and therefore have been evaluated for AR. TR-0716-50439 has been revised to include the results of the AR evaluations for these regions.

For regions that screen for AR, an acoustic frequency of the closed side-branch cavity is calculated. Using this, a Strouhal number is determined for when the acoustic frequency aligns with the vortex shedding frequency. Figure 17 in Reference 1 (Ziada and Lafon) shows a design chart of critical Strouhal numbers at the onset of resonance for closed side-branches. This design chart depicts a relationship between design parameters, including approach flow conditions and geometry of pipe arrangement, and the critical Strouhal number coinciding with onset of first order shear layer instabilities. This relationship was used to calculate critical Strouhal numbers with NuScale parameters, as reported in TR-0716-50439, Section 3.2.4. Although the previous methodology compared NuScale Strouhal numbers to the maximum limit of the critical Strouhal number range, from 0.35 to 0.62, a geometry-dependent critical Strouhal number provides a more accurate means of evaluating the onset of AR, since AR is highly dependent on local flow conditions.

In addition to the effects of approach flow conditions and cavity to main pipe diameter ratios, experiments have shown that the critical Strouhal number is impacted by the shape of the upstream edge of the cavity. Figure 8 of Reference 2 (Omer et al.) shows the velocity at which acoustic pressures begin to increase due to resonance onset, which occurs at higher velocities for a rounded edge entrance than for a sharp edge. A ratio of the critical velocities for a sharp edge versus rounded edge entrance is obtained to characterize this delay of resonance onset. Although most fittings, such as tees, will have rounded edges, not all of the fillet radii of these fittings have been defined as this point in the NuScale design. For the NuScale piping regions where the fillet radius for a cavity entrance is known, the critical Strouhal number is multiplied by this ratio. These locations are the branches of the CNTS MS drain valves, the tees connecting the CNTS steam piping and decay heat removal system (DHRS) steam lines, and the MSIV upstream and downstream bypass lines.

All locations analyzed have positive margin to the onset of AR at the most limiting operating condition for first order shear layer modes. An evaluation of second order shear layer instabilities has also been performed, where the calculated Strouhal numbers for each region are compared to two times the critical Strouhal numbers determined utilizing the methodology of Reference 1 (Ziada and Lafon). The results of this evaluation have been added to Section 3.2.4 of TR-0716-50439. Because the component Strouhal numbers are minimized by analyzing maximum flow conditions for each region, positive margin to a second order shear layer mode indicates that the region would not be exposed to an onset of AR at an intermediate flow condition. However, the locations with less than 100% margin to the onset of AR at maximum design flow conditions for the first order shear layer mode excitation are predicted to experience second order shear layer modes at lower flow rate conditions. These locations are the branches of the CNTS MS drain valves, the tees connecting the CNTS steam piping and DHRS steam lines, and the MSIV upstream and downstream bypass lines. These locations will be tested in order to detect any acoustic excitation and resulting pressure amplifications or vibrations. The relevant reactor power levels at which second order shear layer instabilities could be present at these locations are between 15% and 20% for the CNTS steam piping to DHRS steam line, between 25% and 30% for the CNTS MS drain valve branches, and between 60% and 65% for the MSIV upstream and downstream bypass lines.

Section 5.2.1 of the NuScale Comprehensive Vibration Assessment Program Measurement and Inspection Plan Technical Report, TR-0918-60894, provides the plan for vibration testing of the DHRS steam line tees during initial startup testing. The test requirements state that the test gradually increases the system flow rate, such that the DHRS side branch is exposed to a range of partial-power steam flow rates in order to detect any acoustic excitation by a higher order shear layer mode. When the flow velocity is ramped up from a low value, a given resonance mode can be excited by a higher-order shear mode before it is excited by the first order shear mode. The shear-layer excitation is expected to be the strongest at the first shear layer mode, where the most severe pressure pulsations are developed. The test procedure also requires minimum hold times at each flow rate for sufficient data collection and confirmation that vibration levels are acceptable before increasing to the full 100 percent power conditions.

The AR testing design scope will be expanded to include consideration of the MSIV bypass lines and the CNTS MS drain valve branches in the next revision to the CVAP Measurement and Inspection Plan Technical Report, TR-0918-60894. This will include providing the locations of additional vibration sensors required for initial startup testing of the steam lines.

References

1: Ziada, S & Lafon, Philippe. Flow-Excited Acoustic Resonance Excitation Mechanism, Design Guidelines, and Counter Measures. Applied Mechanics Reviews, Vol. 66, Jan 2014.

2: Omer, A., Arafa, N., Mohany, A., & Hassan, M. (2016). The effect of upstream edge geometry on the acoustic resonance excitation in shallow rectangular cavities. International Journal of Aeroacoustics, 15(3), pp. 253-275.

Impact on DCA:

The CVAP Technical Report TR-0716-50439 has been revised as described in the response above and as shown in the markup provided with this response.

1.2 Abbreviations

Table 1-1 Abbreviations

Term	Definition
AR	acoustic resonance
ASME	American Society of Mechanical Engineers
CFD	computational fluid dynamics
CNTS	containment system
CNV	containment vessel
CRA	control rod assembly
CRAGT	control rod assembly guide tube
CRD	control rod drive
CVAP	Comprehensive Vibration Assessment Program
CVCS	chemical and volume control system
DHRS	decay heat removal system
FEI	fluid elastic instability
F/G	flutter/gallop
FIV	flow-induced vibration
FW	feedwater
ICIGT	in-core instrument guide tube
LFI	leakage flow instability
MS	main steam
MSIV	main steam isolation valve
NPM	NuScale Power Module
PSD	power spectral density
PWR	pressurized water reactor
RCS	reactor coolant system
RG	Regulatory Guide
RMS	root mean square
RPV	reactor pressure vessel
RRV	reactor recirculation valve
RVI	reactor vessel internals
RVV	reactor vent valve
RXC	reactor core
SG	steam generator
SGS	steam generator system
TB	turbulent buffeting

The following subsections discuss in more detail the components that are screened for FIV and the components that are found to be susceptible to FIV based on the screening criteria. Components that are classified as susceptible to FIV require analysis, measurement, and inspection to meet the intent of the CVAP. Flow-induced vibration mechanisms and screening criteria, which are derived from References 8.1.3 and 8.1.4, are summarized in Table 2-3.

Table 2-2 NuScale Power Module components screened for susceptibility to flow induced vibration mechanisms

NPM Region or Category	Component	Section Number
Components exposed to secondary coolant flow	Steam piping, nozzle, MSIVs, MSIV upstream and downstream bypass lines, CNTS MS drain valve branch	2.3.1.1
	SG steam plenum Note 1	2.3.1.2
	DHRS steam piping	2.3.1.3
	DHRS condensate piping	2.3.1.3
	Helical SG tubing Note 1	2.3.1.4
	SG tube inlet flow restrictors	2.3.1.5
	SGS pressure relief valve branch, CNTS FW drain valve branch	2.3.1.6
SG tube supports exposed to primary coolant flow	SG tube support bars	2.3.2.1
	SG lower tube support cantilevers	2.3.2.2
Upper riser assembly exposed to primary coolant flow	Upper riser section	2.3.3.1
	Riser section slip joint	2.3.3.2
	In-core instrument guide tube (ICIGT)	2.3.3.3, 2.3.8
	Control rod drive (CRD) shaft	2.3.3.4, 2.3.8
	CRD shaft support	2.3.3.5
	Upper riser hanger brace	2.3.3.6
	CRD shaft sleeve	2.3.8
Lower riser assembly exposed to primary coolant flow	Lower riser section	2.3.4.1
	Control rod assembly guide tube (CRAGT) assembly	2.3.4.2, 2.3.8
	CRAGT support plate	2.3.4.3
	Upper core plate	2.3.4.4
Core support assembly exposed to primary coolant flow	Core barrel	2.3.5.1
	Upper support block	2.3.5.2
	Core support block	2.3.5.3
	Belleville spring	2.3.5.4
	Reflector block	2.3.5.5
	Lower core plate	2.3.5.6
	Fuel pin interface	2.3.5.7
Other RVI exposed to primary coolant flow	Pressurizer spray RVI	2.3.6.1
	Chemical and volume control system (CVCS) injection RVI	2.3.6.2
	Flow diverter	2.3.6.3

NPM Region or Category	Component	Section Number
	Thermowells Note 2	2.3.6.4
	Component and instrument ports	2.3.6.5
Primary coolant piping	RCS Injection to reactor vent valve (RVV) and reactor recirculation valve (RRV) reset lines	2.3.7.1
	CNTS CVC drain valve branches	2.3.7.2

Notes to Table 2-2:

1. Component is exposed to primary and secondary coolant flow.
2. Thermowells also evaluated in NPM piping exposed to secondary coolant flow.

Table 2-3 Flow-induced vibration screening criteria

Phenomenon	Screening Criteria
Fluid elastic instability (FEI)	• array of cylinders (minimum one row), i.e., geometry • array pitch/diameter < 2.0; array must sufficiently confine fluid to allow feedback between adjacent cylinders
Vortex shedding (VS)	• bluff body (or edge of a cavity in line with flow) , i.e., geometry • subject to cross-flow • absence of downstream structures to disrupt vortices
Turbulent buffeting (TB)	• subject to turbulent flow (axial, cross-flow or combination) • component interface that is in load path of one or more components subject to turbulent flow
Acoustic resonance (AR)	• suitable geometry to generate an AR, typically a hollow or cavity • single phase environment within hollow/cavity
Leakage flow instability (LFI)	~~• narrow annular flow path exists, i.e., geometry~~ ~~• flexible structure in annulus, bounded by fixed surface~~ ~~• annular flow path is diverging (restriction at inlet to annulus) or parallel~~ ~~• flow conditions to generate sufficient flow velocity and pressure differential through annular flow path~~ Conditions 1 and 2 are met: 1. narrow annular flow path exists, i.e., geometry 2. flexible structure in annulus, bounded by fixed surface AND either Condition 3 or Condition 4 is satisfied: 3. flow conditions to generate sufficient flow velocity and pressure differential through annular flow path 4. annular flow velocity greater than the critical flow velocity for LFI (see Section 2.3.8)

Galloping/flutter	• non-circular cross section, i.e., geometry • aspect ratio (length/width) in prevailing direction of flow is less than 4.0 (for tall rectangular structure) and less than 2.0 (for low, long rectangular structure)

2.3.1 Components Exposed to Secondary Flow

The components exposed to secondary flow are contained in the SGS and DHRS. The SGS transfers heat from the reactor coolant to produce superheated steam, while providing a leak-tight pressure boundary between the primary reactor coolant and the secondary-side coolant. Additionally, the SGS removes residual and decay heat from the RXC in conjunction with the DHRS following DHRS actuation.

The SGS consists of two independent, but intertwined, SGs. Each SG has a pair of feedwater plenums and a pair of steam plenums. The SGs are once-through helical coils with primary-side reactor coolant outside the tubes and secondary-side fluid inside the tubes. On the secondary side, preheated feedwater enters the SGS feedwater piping from the SGS feedwater lines and then enters the SGs through the feedwater supply nozzles and feed plenums. Feedwater flows up the helical tubes where it is heated, boiled, superheated, and exits the SGs through the steam plenums and main steam supply nozzles to the SGS steam lines. The SGS steam piping then supplies steam to the CNTS steam lines. The components exposed to secondary-side flow that screen for FIV are identified in the following subsections.

2.3.1.1 Steam Piping, Plenum Exit Nozzle, ~~and~~ Main Steam Isolation Valve, MSIV Upstream and Downstream Bypass Lines, CNTS MS Drain Valve Branch

The SGS piping includes the steam piping inside containment (see Figure 2-4). The SGS steam lines initiate at the steam supply nozzle safe ends on the steam plenums and terminate inside the CNV at the CNV penetration nozzle safe ends. Outside the CNV, the steam lines are termed CNTS steam piping through the MSIV to the NPM disconnect flange. The CNTS steam lines have three regions of side branches that are closed during normal operation: the tees to the DHRS steam lines, connections upstream and downstream of the MSIV body to the bypass MSIV, and branch lines to the CNTS MS drain valves.~~are connected to the DHRS.~~

These components meet the screening criteria for AR. Vortices can potentially form off the leading edges of transitions within these components. Similar shedding could potentially occur due to shedding off the main steam valve bodies. When shedding frequencies become close or equal to the acoustic frequencies of the downstream piping and valve or nozzle bodies, AR can occur. No other FIV phenomena are credible for these regions.

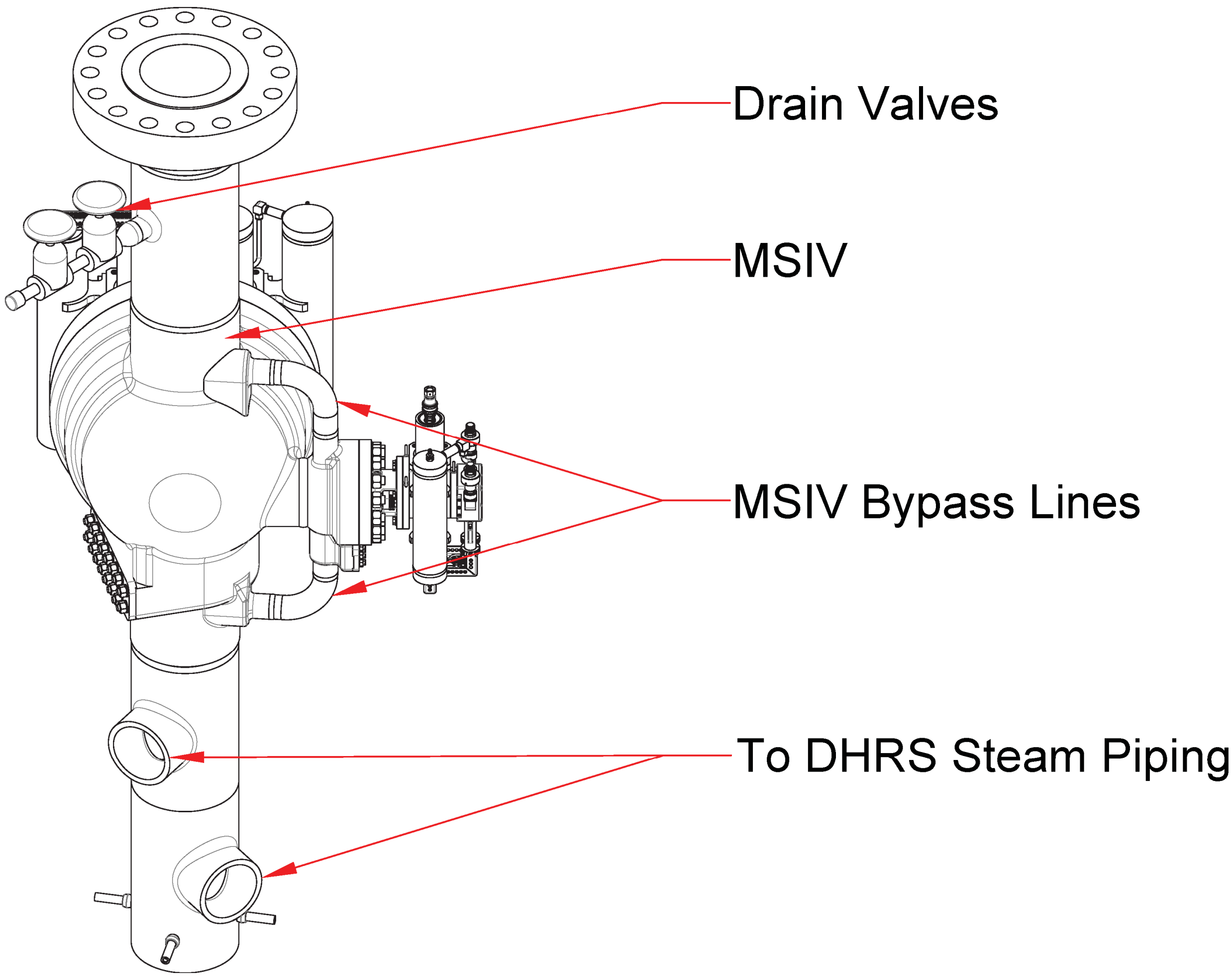

Figure 2-4 Steam piping downstream of steam nozzles

2.3.1.2 Steam Plenum

As shown in Figure 2-5, the SG steam plenums are located above the SG tube bundle and the pressurizer baffle plate. The plenum tube sheet region provides the termination point for the helical SG tubes and the plenum provides the flow path from the SG tubes to the steam nozzle located on the outside of the RPV.

2.3.1.6 SGS Pressure Relief Valve Branch and CNTS FW Drain Valve Branch

The SGS piping includes the feedwater piping inside containment. The SGS feedwater lines initiate inside the CNV at the CNV penetration nozzle safe ends and terminate at the feedwater supply nozzle safe ends on the feedwater plenums. A pressure relief valve is located on each of the two feedwater lines inside containment to provide thermal relief for the SGS.

The CNTS FW piping is located outside containment between the CNV penetration nozzle safe ends and the NPM disconnect flange. A drain valve is connected to each FW line.

The pressure relief valves and drain valves are connected to the main piping with a short branch of small diameter piping and weldolet. The fluid in these piping regions is single phase. The valves are normally closed, and the branch piping represents a flow occluded region connected to the main piping. Vortices may be generated as flow passes the discontinuity in the piping created by the branch. If the vortices generate an acoustic wave coincident with a structural mode, acoustic resonance could occur in the branch piping lines. No other FIV phenomena are credible for these regions.

2.3.2 Steam Generator Tube Supports

The SG steam and feedwater plenums are integral parts of the RPV. The SG helical tubing is provided with support bars and cantilever support members, which are welded to the RPV inner wall. In addition to considering these supports in the evaluation of the helical tubing for FIV, the supports themselves are assessed to ensure the designs are acceptable to prevent detrimental FIV.

2.3.2.1 Steam Generator Tube Support Bars

Tube support bars, shown in Figure 2-9 and Figure 2-10, span the full height of the helical tube bundle and are anchored at the attachment of the upper tube support bar to the bottom of the integral steam plenum. Based on their form (effectively a solid bar), the tube support bars are not subject to leakage flow or AR. Additionally, based on the confinement of the bars within the tube bundle, where the tortuous flow path creates turbulence, formation of coherent vortices will not occur. The axial alignment of the tube support bars provides an aspect ratio greater than 4.0 and an angle of attack of effectively 0.0 thus precluding galloping and flutter.

2.3.3.3 In-core Instrument Guide Tube

The ICIGTs extend from the upper RPV head to the top of the fuel assemblies. On the interior of the ICIGTs reside the in-core instruments which are routed through the pressure boundary at the RPV head and down into the core. The ICIGTs interface with the upper RPV head, pressurizer baffle plate, upper riser hanger ring, CRD shaft supports, lower riser assembly ICIGT support, and the upper core plate~~, and the in-core instruments~~. Each ICIGT is divided into three regions: tube sections within the pressurizer, upper riser, and lower riser. Each tube section is welded to at least one support location which fixes tube translation and rotation. ~~These~~The remainder of the ICIGT support interfaces provide lateral support while allowing small vertical displacements to accommodate differential thermal expansion movement.

~~On the interior of the ICIGTs reside the in-core instruments that are routed through the pressure boundary at the RPV head and down into the core. The clearance between the ICIGT and the CRD shaft support is negligible compared to the riser flow area. Additionally, due to the very low pressure differential across the supports, it is not credible that significant flow through this annulus will develop to create leakage flow instability.~~

~~During steady state operation, there is negligible pressure difference between the riser outlet and the pressurizer. Due to the momentum of the flow as it exits the riser, it is possible that some flow will pass through the annular flow regions between the ICIGT and CRD shaft and the pressurizer baffle plate. This flow is expected to be very low, based on the low driving force.~~

The geometry of the ICIGTs is constructed in a manner that they are not susceptible to FEI, acoustic resonance, gallop, or flutter. Although small gaps exist between the ICIGTs and ~~the~~CRD shaft supports and the lower ICIGT support, ~~the pressure drop and flow in these gaps~~screening evaluations show that the gap velocity is negligible ~~under all operating conditions~~compared to the critical velocity for leakage flow instability; therefore, LFI is not credible (Section 2.3.8). The ICIGTs are exposed to turbulent flow and are susceptible to TB. Above the upper riser section and below the pressurizer baffle plate, the ICIGTs are subject to crossflow; therefore, VS is also applicable for this component.

2.3.3.4 Control Rod Drive Shaft

The CRD shafts pass through the CRD shaft supports as they are routed to the fuel assemblies. The CRD shaft support openings are one of the CRD shaft alignment features and the clearance between the two components is small. Similar to the ICIGT, although the clearance between the component and support is small, the ~~pressure drop and~~gap velocity ~~are~~is sufficiently low compared to the critical velocity that LFI is not credible (Section 2.3.8). The CRD shafts also pass through the pressurizer baffle plate. During steady state operation, there is negligible pressure difference between the riser outlet and the pressurizer. Due to the momentum of the flow as it exits the riser, it is possible that some flow passes through the annular flow regions between the CRD shaft and the pressurizer baffle plate. This flow is expected to be very low, based on the low driving force. Leakage flow instability screening for the CRD shaft interface with the pressurizer baffle plate and upper riser hanger ring has determined that the interface is not susceptible to LFI, as shown in Section 2.3.8.

Above the uppermost CRD shaft support, the fluid changes direction as it turns to the SG tube region. The CRD shaft becomes a bluff body with respect to the flow direction and is susceptible to VS in this region. Using the screening criteria, this interface is not susceptible to the FIV phenomena other than VS and TB.

2.3.3.5 Control Rod Drive Shaft Support

The CRD shaft support is attached to the upper riser section and is normal to the flow direction, as shown in Figure 2-15. As the primary fluid moves around the support beams, VS and TB may occur. Using the screening criteria, this component is not susceptible to the other FIV mechanisms.

the valve is open (See Figure 2-25). The valve disc is not in direct cross flow, and downstream structures (the valve 90 degree turn) are present to disrupt any potential vortices generated by the valve internals. The valve body is designed for reaction loads of valve discharge and seismic loads, and is therefore thick-walled relative to schedule 160 piping. It is not a bounding component for turbulent buffeting analysis (Section 3.2.3). Due to the geometry in the ECCS valves, no FIV mechanisms are credible for through-valve flow.

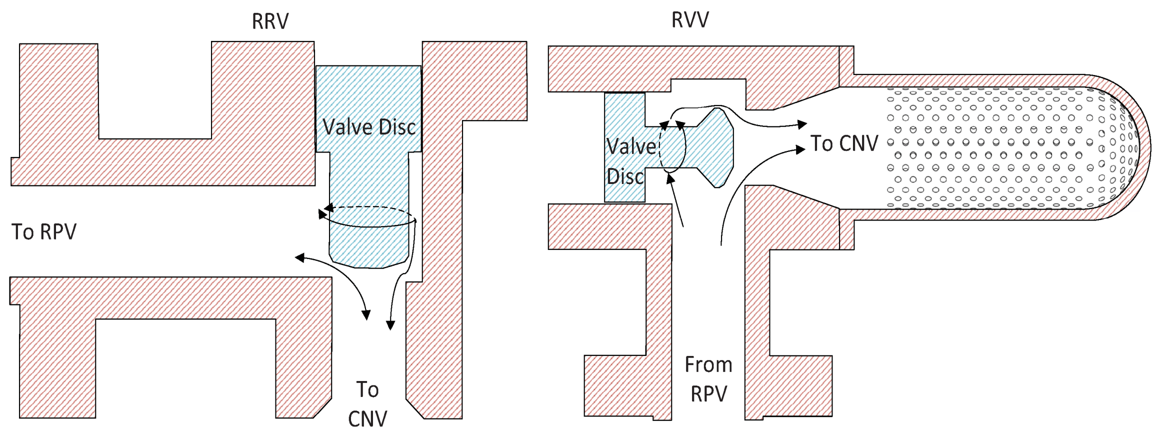

Figure 2-25 ECCS Valve Internal Flow Diagram

2.3.7 Primary Coolant Piping

2.3.7.1 RCS Injection to RVV and RRV Reset Lines

Inside containment, the RCS injection line contains two tee locations that connect to the emergency core cooling system reset valves. During normal operation, there is no flow in the valve reset lines. One tee connection is provided in the upper region of the injection line and one is provided in the lower portion of the injection line. Vortices could form at the tee locations, and the small diameter lines leading to the reset valves represents a flow occluded region. Therefore, these tee locations are susceptible to acoustic resonance. Due to the flow conditions and geometry in these regions, no FIV mechanisms other than AR are credible for these locations.

2.3.7.2 CNTS CVC Drain Valves

Each of the CNTS CVC piping lines: injection, discharge, pressurizer spray, and RPV high point degasification, contain short branch connections to a small diameter drain valve. These drain valves are closed during normal operation, and the short branch represents a flow occluded region. Therefore, these tee locations are susceptible to acoustic resonance. Due to the flow conditions and geometry in these regions, no FIV mechanisms other than AR are credible for these locations.

Table 3-1 NuScale Power Module components and their susceptibility to flow-induced vibration mechanisms

NPM Component Category	Component	FEI	VS	TB	AR	LFI	F/G
Components exposed to secondary side flow	Steam piping, nozzle, MSIVs, MSIV upstream and downstream bypass lines, CNTS MS drain valve branches	-	-	-	▲	-	-
	SG steam plenum Note 1	-	-	-	▲	-	-
	DHRS steam piping	-	-	-	▲	-	-
	DHRS condensate piping	-	-	-	▲	-	-
	SGS pressure relief valve branch and CNTS FW drain valve branches	-	-	-	▲	-	-
	Helical SG tubing Note 1	▲	▲	▲	-	-	-
	SG tube inlet flow restrictors	-	-	▲	-	▲	-
SG tube supports	SG tube support bars	-	-	▲	-	-	-
	SG lower tube support cantilevers	-	▲	▲	-	-	▲
Upper riser assembly	Upper riser section	-	-	▲	-	-	-
	Riser section slip joint	-	-	▲	-		-
	ICIGT	-	▲	▲	-		-
	CRD shaft	-	▲	▲	-		-
	CRD shaft support	-	▲	▲	-	-	-
	CRDS shaft sleeve	-	▲	▲	-	-	-
	Hanger brace	-	▲	▲	-	-	-
Other RVI	Pressurizer spray RVI	-	-	▲	-	-	-
	CVCS injection RVI	-	▲	▲	-	-	-
	RRV port	-	-	-	▲	-	-
	Thermowells Note 2	-	▲	▲	-	-	-
	Instrument ports	-	-	-	▲	-	-
	Flow diverter	-	-	▲	-	-	-
Core support assembly	Core barrel	-	-	▲	-	-	-
	Upper support block	-	▲	▲	-	-	-
	Fuel pin interface	-	-	▲	-	-	-
	Core support block	-	▲	▲	-	-	-
	Reflector	-	-	▲	-	-	-
	Belleville spring	-	-	▲	-	-	-
	Lower core plate	-	▲	▲	-	-	-
Lower riser assembly	Lower riser section	-	-	▲	-	-	-
	CRAGT support plate	-	▲	▲	-	-	-

NPM Component Category	Component	FEI	VS	TB	AR	LFI	F/G
	CRAGT assembly	-	▲	▲	-	-	-
	Upper core plate	-	▲	▲	-	-	-
Primary coolant piping	RCS injection to RVV/RRV reset lines	-	-	-	▲	-	-
	CNTS CVC drain valve branches	-	-	-	▲	-	-

Note(s) for Table 3-1:

1. Component is exposed to primary and secondary coolant flow.
2. Thermowells also evaluated in NPM piping exposed to secondary coolant flow.

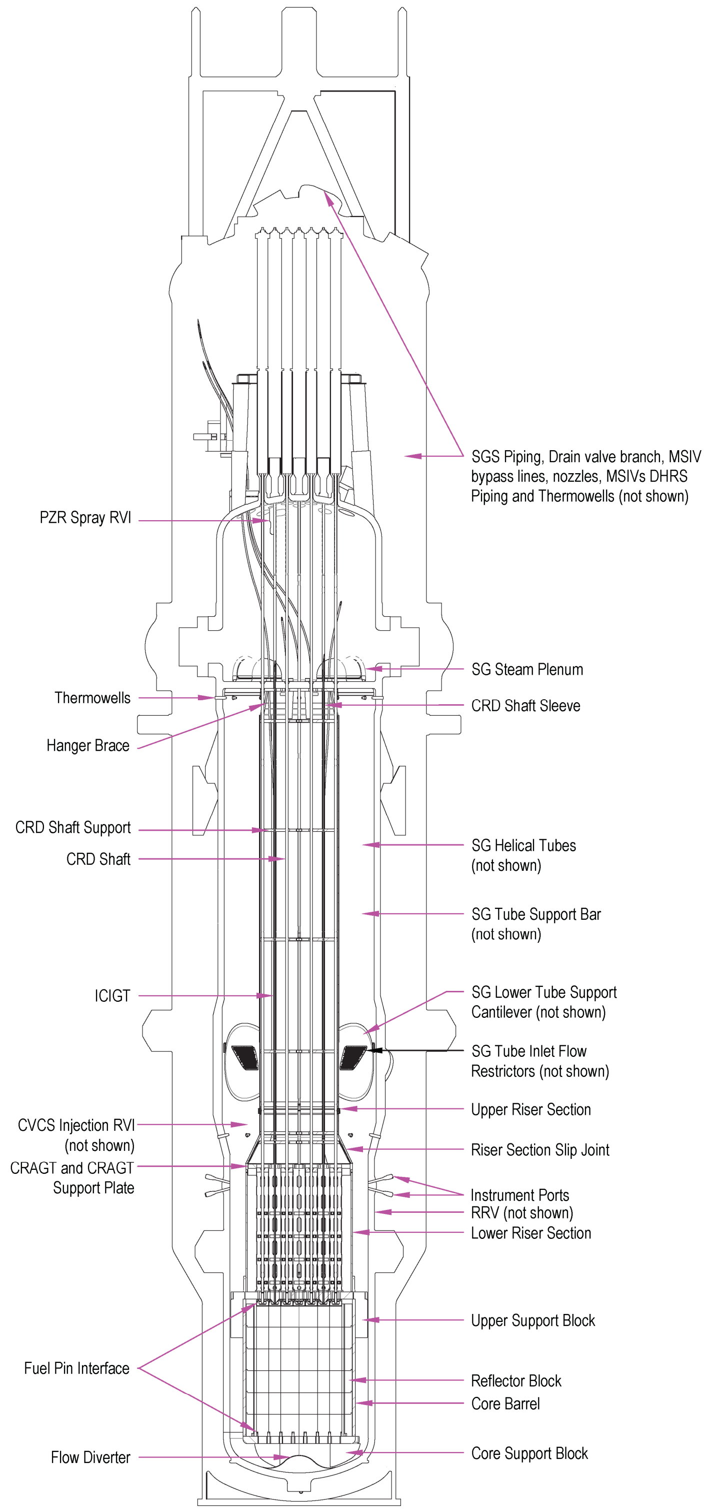

Figure 3-1 NuScale Power Module components and regions that meet flow-induced vibration screening criteria

Table 3-4 Flow conditions input summary

Analysis Category	Assumed Conditions	Analysis Method
FEI	Maximum design flow – average velocity	CFD Note 1
VS	Maximum design flow – average velocity	CFD Note 1
	Design flow at 102% – average velocity assuming low SG superheat performance	TH Note 4
AR	Maximum design flow – average velocity	CFD
	Design flow at 102% – average velocity assuming low SG superheat performance	TH Note 4
	Maximum CVCS flow – average velocity	TH Note 5
F/G	Maximum design flow – average velocity	CFD
LFI	None Note 2	None
TB	Maximum design flow – average or maximum velocity Note 3	CFD

Note(s) for Table 3-4:

1. For the VS and FEI analysis of the SG tubes, CFD flow rate is modified to represent velocity in the minimum flow area.
2. LFI confirmation is by prototype testing only for components that are screened as potentially susceptible to LFI.
3. Either average or maximum velocities are chosen for each component in TB analysis based on achieving the most bounding convective velocity for the purpose of impact and fatigue evaluations.
4. For the evaluation of AR and VS mechanisms for components exposed to secondary coolant flows, the TH flow is used. CFD analysis is not performed to characterize secondary side flow.
5. For the evaluation of AR mechanisms for components within piping exposed to primary coolant, the maximum CVCS flow is used.

Table 3-5 lists velocities used in the analyses of components subject to FIV~~representative average velocities based on CFD analysis at the maximum design flow~~. The analysis methods that produce these velocities~~categories and components that use the CFD results~~ are identified in Table 3-4, except as noted otherwise below.

~~Table 3-5 Maximum design flow velocities based on CFD~~

~~Flow Region~~	~~Average Velocity (in/s)~~
~~Around/Through CRAGTs~~	~~{{ }}2(b),(c),ECI~~
~~CRAGT Support~~	~~{{ }}2(b),(c),ECI~~
~~Bottom of Conic Riser Transition~~	~~{{ }}2(b),(c),ECI~~
~~CRD Shaft Support~~	~~{{ }}2(b),(c),ECI~~
~~Upper Riser~~	~~{{ }}2(b),(c),ECI~~
~~Flow Over the Top of the Upper Riser~~	~~{{ }}2(b),(c),ECI~~
~~Top of Conic Downcomer Transition~~	~~{{ }}2(b),(c),ECI~~

~~Bottom of Conic Downcomer Transition~~	~~{{ }}2(b),(c),ECI~~
~~Downcomer, around Core Barrel~~	~~{{ }}2(b),(c),ECI~~

Table 3-5 Velocities used in FIV analyses

Analysis Category	**Component**	**Velocity (in/s)**
FEI Note 1	Helical SG tubing	{{
VS Note 1	Helical SG tubing	
	SG tube support cantilever	
	RCS hot region thermowell	
	RCS cold region thermowell	
	CNTS steam thermowell	
	CNTS feedwater thermowell	
	Control rod drive shafts	
	CRD shaft support	
	Control rod assembly guide tubes	
	CRAGT support	
	Upper riser hanger brace	
	CVCS Injection RVI (in downcomer)	
	In-core instrument guide tubes	
AR Note 4, Note 5	DHRS steam line tee	
	DHRS condensate line tee	
	Reactor recirculation valve nozzle	
	Flowmeter port	
	FW drain valve	
	MS drain valves	
	MSIV upstream and downstream bypass lines,	
	SGS pressure relief valve	
	CNTS CVC drain valves: Injection line	
	CNTS CVC drain valves: Discharge line	
	CNTS CVC drain valves: Pressurizer Spray line	
	CNTS CVC drain valves: Degasification line	}}2(b),(c),ECI

Analysis Category	Component	Velocity (in/s)
	CNTS CVC drain valves: Degasification line with N2	{{
	RCS Injection to RRV and RVV reset lines	
F/G [Note 1]	SG tube support cantilever	}}$^{2(b),(c),ECI}$
LFI	None, LFI confirmation is by prototype testing only for components that are screened as potentially susceptible to LFI.	
TB	Helical SG tubing, primary flow	{{
	Helical SG tubing, secondary flow (steam)	
	Helical SG tubing, secondary flow (liquid)	
	SG inlet flow restrictor	
	Core barrel	
	CRAGT inner diameter	
	CRAGT outer diameter	
	CRAGT support	
	CRD shaft	
	CRD shaft support	
	Flow diverter	
	Lower ICIGT	
	Upper ICIGT	
	Injection line, downcomer	
	Injection line, downcomer, interior	
	Lower core plate	
	Lower riser inner diameter	
	Lower riser outer diameter	
	Upper core plate	
	Upper riser inner diameter	
	Upper riser outer diameter	}}$^{2(b),(c),ECI}$

Notes for Table 3-5:

1. {{ }}$^{2(b),(c),ECI}$ margin is included in these values for transient velocity changes
2. Primary side gap velocity based on a minimum cross-sectional flow area
3. Component of this velocity perpendicular to the tubes is used in the analysis
4. {{ }}$^{2(b),(c),ECI}$ is added to these values in the analysis to account for transient velocity changes
5. Velocity is from TH analysis
6. Velocity is hand-calculated

Table 3-10 Turbulent buffeting results summary

Component	Contact Occurs?	Fatigue Margin (%) Note 1	Items to Verify	Verification Method and Testing Phase	Test
SG helical tubing	yes	{{ }}$^{2(b),(c),ECI}$	Frequencies mode shapes vibration amplitude	Separate effects	SG FIV (Section 4.1.2)
ICIGT	Yes	100	N/A	N/A	N/A
CRD shaft	Yes	100	N/A	N/A	N/A

Note(s) for Table 3-10:

1. Safety margin is reported based on the margin to the allowable fatigue usage based on the predicted fatigue usage due to vibration and/or impact.

3.2.4 Acoustic Resonance

Acoustic resonance is evaluated for the steam plenums and nozzles, main steam isolation valves, MSIV bypass lines, SGS piping, CNTS piping, DHRS piping, and at valve and instruments ports. It was determined that AR is not possible at the steam plenums and nozzles. The flow through these nozzles prevents the formation of shear waves and AR in these cavities. The MSIVs are an unlikely source of pressure fluctuations associated with AR because the MSIVs are directly mounted on the steam piping with no standpipe. The ~~only~~ locations that flow excitation due to AR may be possible are at the branch lines and cavities at the following locations:

- the closed side branches from the CNTS MS piping with connections to: ~~steam tee to the DHRS actuation valves~~
  - DHRS steam line and actuation valves
  - MS drain valves
  - Upstream line to bypass MSIV
  - Downstream line to bypass MSIV
- the closed side branches from the SGS feedwater piping with connections to: ~~tee to the DHRS condenser~~
  - DHRS condensate line to the DHRS condenser
  - pressure relief valves
- the closed side branches in the CNTS FW piping to the FW drain valves
- the closed side branches in the CNTS CVC piping to the CVC drain valves
- the closed side branches in the RCS injection line to the RRV and RVV reset lines
- RCS instrument and valve ports

Sources of AR developed inside the tubes due to density wave oscillation (DWO) is precluded by the design of the SG tube inlet orifices. If DWO were not precluded, DWO acoustic waves would not be expected to affect the steam plenum or piping because frequencies are less than 0.5 Hz, which is well below the component and piping AR frequencies.

Acoustic resonances due to the generation of shear waves at closed branch lines are evaluated with the following methodology. To determine if there is a concern for AR, the piping locations where this source of flow excitation is possible are identified and the Strouhal number is calculated for each location. ~~To determine the margin to AR, the calculated Strouhal number is compared to the range of Strouhal numbers that could lead to the onset of AR. A Strouhal number between 0.35 and 0.62 could lead to the onset of AR.~~ To determine the margin to AR, the calculated Strouhal number is compared to the critical Strouhal numbers that could lead to the onset of AR. As documented in Reference 8.1.19, Figure 17, experiments show that the critical Strouhal number at the onset of resonance is dependent on the local geometric parameters including the ratio of the branch and main pipe diameters (d/D) as well as the ratio of the nearest upstream flow disturbance to the main pipe diameter, (x/D). See Table 3-11 for NuScale critical Strouhal numbers.

Table 3-11 NuScale Critical Strouhal Numbers

Location of Component	x/D	d/D	Critical Strouhal Number
CNTS Steam Piping to DHRS Steam Line	{{		
DHRS Condensate Condenser to SGS FW Line			
Ultrasonic Flowmeter Cavity			
RRV Cavity			
CNTS MS Drain Valve Branch			
MSIV Upstream Bypass Line			
MSIV Downstream Bypass Line			
RCS injection line to RRV line			
RCS injection line to RVV line			
CNTS CVC Drain Valve Piping – Degasification line with N2			
SGS Pressure Relief Valve Branches			
CNTS FW Drain Valve Branch			}}2(b),(c),ECI

Note: Second order critical Strouhal numbers are determined by doubling the first order critical Strouhal number listed in this table.

A delay of onset to acoustic resonance occurs when the upstream edge of the cavity is rounded. Figure 8 in Reference 8.1.20 shows a delay in velocities when comparing the first order sharp edge acoustic pressure to the round edge acoustic pressure. There is a 105 m/s flow velocity at the sharp edge which is delayed to 135 m/s with a round edge with a radius of 25.4 mm, or 1 inch. Because of its relationship to velocity, this has an effect on the critical Strouhal number. It delays its onset by multiplying it by the ratio 105/135.

The Strouhal number for the DHRS steam and condensate lines provide approximately {{ }}[2(b),(c),ECI] and more than 100 percent margin, respectively to ~~the upper bound of the~~each region's first order critical Strouhal number ~~range~~ for susceptibility to AR. More than 100 percent margin is also demonstrated for the RRV cavity and instrument cavities in the RCS downcomer region, the CNTS CVC and FW drain valve branches, the SGS pressure relief valve branches, and the RRV and RVV reset line tees. The MSIV bypass lines have {{ }}[2(a),(c),ECI] margin and the CNTS MS drain valve branches have {{ }}[2(a),(c),ECI] margin.

The safety margin is determined by comparing the critical Strouhal number to a minimum component Strouhal number calculated at maximum flow conditions for each region. Positive margin to either the first or second order critical Strouhal number indicates that the region would not be exposed to an onset of AR at an intermediate flow condition. All locations have positive margin to first order shear layer mode excitation, however a few locations are predicted to experience second order shear layer mode excitation at lower flow rate conditions. These locations are the branches of the CNTS MS drain valves, the tees connecting the CNTS steam piping and DHRS steam lines, and the MSIV upstream and downstream bypass lines. These locations will be tested in order to detect any acoustic excitation and resulting pressure amplifications or vibrations. The relevant reactor power levels at which second order shear layer instabilities could be present at these locations are between 15% and 20% for the CNTS steam piping to DHRS steam line, between 25% and 30% for the CNTS MS drain valve branches, and between 60% and 65% for the MSIV upstream and downstream bypass lines. ~~Testing is required to confirm that AR does not occur in the DHRS steam piping.~~

Safety margin results for first order shear layer mode excitation~~Results~~ and testing information are summarized in Table 3-12~~Table 3-11~~. Results provided below show safety margin for the MSIV upstream bypass line which is slightly lower than for the downstream line.

Table 3-12 Acoustic resonance results summary

Component	Safety Margin	Items to Verify	Verification Method and Testing Phase	Test
DHRS steam piping	{{ }}2(b),(c),ECI	Vibration amplitude	Initial startup testing	Flow testing (Section 4.3)
MSIV bypass lines	{{ }}2(a),(c),ECI	Vibration amplitude	Initial startup testing	Flow testing (Section 4.3)
CNTS MS drain valve branch	{{ }}2(a),(c),ECI	Vibration amplitude	Initial startup testing	Flow testing (Section 4.3)

3.2.5 Leakage Flow Instability

~~Due to the sensitivity of LFI~~Leakage flow instability is sensitive to flow and geometry conditions.~~, there are no accepted analytical methods and acceptance criteria available to predict a critical velocity for the onset of LFI.~~ For NPM components that meet the screening criteria for LFI, testing is required to determine susceptibility to LFI.

The major parameters that have been shown to lead to LFI are large pressure differences across small annular gaps, component flexibility, and small diffusion angles. Due to the natural circulation design of the NPM, most regions are not susceptible to LFI because pressure differences across these interfaces, and thus gap velocities, are very small under all operating conditions. One exception to this is on the secondary coolant side at the entrance to the SG tubes, where a flow restrictor upstream of each SG tube is provided. The SG tube flow restrictor is designed to provide flow stability by restricting the volume of secondary side flow through the tube. The flow restriction is created by narrow annular gaps between the flow restrictor and the tube inner diameter. A separate effects test is performed to validate that LFI is not a concern for the SG tube flow restrictor, per Table 3-13~~Table 3-12~~.

Table 3-13 Leakage flow instability results summary

Component	Safety Margin	Items to Verify	Verification Method and Testing Phase	Test
SG tube inlet flow restrictors	Need to verify	Vibration amplitude	Separate effects testing	SG tube inlet flow restrictor test (Section 4.1.1)

3.2.6 Gallop and Flutter

The SG tube support cantilever is the only NPM structure that requires evaluation for flow excitation created by gallop and flutter.

Flow tests of rectangular cross sections have been performed to investigate the influence of the VS frequency and the response of the structure to torsional gallop considering both smooth and turbulent flow conditions. The results of the flow test summarized in Reference 8.1.5 are applicable to rectangular cross sections whose validate relevant input parameters because they can be quantitatively used to sufficiently validate predicted analytical margin.

For VS analysis of all components except the SG tubes and ICIGTs, the key input that requires validation is the fundamental frequency. For the SG tubes, the frequencies, mode shapes, and damping ratio are relevant inputs for both VS and FEI analyses that affect the predicted analytical margin and require validation. For the ICIGTs, the frequencies and mode shapes require validation, but since a conservatively low damping value is used (0.5%) validation of that input is not necessary. For components that undergo flow testing, the dynamic pressure measurement results can be used to demonstrate if there are spectral peaks in the PSD that could be attributed to vortex shedding, acoustic resonance, and leakage flow instability. Additionally, dynamic pressure fluctuations created by AR inside the piping system may be measured using strain gages mounted on the pipe wall to detect this source of flow excitation.

Because components susceptible to TB experience vibration when exposed to turbulent flow, it is possible to validate the TB analysis during natural circulation operating conditions. The analysis of the NPM components for TB currently considers PSDs that have been published in open literature and used by the industry. Based upon the computed response of the NPM components considering these FIV inputs, components with less than a 100 percent margin of safety are selected for instrumentation and testing to verify the FIV inputs and analysis results for TB.

Pre-test predictions for all prototype tests that have an associated design analysis methodology are performed to ensure that the overall experiment design, including test conditions, number and location of sensors, and sensor accuracy are sufficient to validate the analysis program. Pre-test predictions provide the expected test result ranges considering uncertainties due to operating conditions, manufacturing tolerances, instrument error, and other sources of experimental biases and uncertainties. Pre-test predictions demonstrate the range of acceptable experimental results that can be used to validate analysis inputs, results, and margins of safety. Post-test analysis verifies the results fall within the pre-test prediction acceptable range, and justifies technically relevant differences between the predicted and actual test results.

Section 2.2 of RG 1.20 suggests that steam, feedwater and condensate piping should be instrumented for vibration measurement during initial startup testing. With the exception of the DHRS steam piping, these components either do not screen for FIV or have been shown to have a margin of safety greater than 100 percent. Only components with less than 100 percent safety margin are tested in the prototype measurement program, consistent with the overall measurement program objectives of validating relevant analytical inputs, results, and margins of safety.

Table 4-1 summarizes the testing and inspections to be performed to verify the FIV analysis program for the prototype NPM. The testing scope addresses ~~five~~six components:

- DHRS steam piping: Testing to validate the AR safety margin is performed during initial startup testing. See Section 4.3 for additional details.

- CNTS steam piping: Testing to validate the AR safety margin is performed during initial startup testing for the MSIV bypass lines and CNTS MS drain valve branches. See Section 4.3 for additional details.

- SG helical tubing: Testing to validate the safety margin for fluid elastic instability, vortex shedding, and turbulent buffeting is performed as a separate effects test. See Section 4.1.2 for additional details.

- SG tube inlet flow restrictors: Testing to validate that LFI is precluded is performed in a separate effects test. See Section 4.1.1 for additional details.

- ICIGT: Testing to validate safety margin for VS is performed as a factory test. See Section 4.2 for additional details.

- CRD shaft: Testing to validate safety margin for VS is performed as a factory test. See Section 4.2 for additional details.

Note that flow testing to provide an assessment of the CRAGT fingers and rodlets is performed to demonstrate acceptable vibration performance of components that are part of the reactor core system and are not within the scope of the CVAP. Testing results will be reviewed to ensure vibration levels are acceptable for the CRAGT; however, detailed validation testing of the CRAGT is not required due to the predicted safety margins of greater than 100%.

Table 4-1 Analysis program verification testing and inspections

NPM Component Category	Component	Susceptible Mechanisms	Mechanisms with less than 100% Safety Margin	Prototype Testing		
				Separate Effects	Factory	Initial Startup
Components exposed to secondary side flow	SGS piping, nozzle, MSIVs, MSIV bypass lines, MS drain valve branches	AR	AR~~-~~	-	-	~~-~~CNTS steam piping testing
	SG steam plenum Note 2	AR	-	-	-	-
	DHRS steam piping	AR	AR	-	-	DHRS steam piping testing
	DHRS condensate piping	AR	-	-	-	-
	SGS pressure relief valve branches, FW drain valve branches	AR	-	-	-	-
	SG helical tubing Note 2	FEI, VS, TB	FEI, VS, TB	SG FIV testing	-	

NPM Component Category	Component	Susceptible Mechanisms	Mechanisms with less than 100% Safety Margin	Prototype Testing		
				Separate Effects	Factory	Initial Startup
	SG tube inlet flow restrictors	LFI, TB	LFI	SG flow restrictor FIV testing	-	-
SG tube supports	SG tube support bars	TB Note 1	-	-	-	-
	SG lower tube support cantilevers	VS, TB, F/G Note 1	-	-	-	-
Upper riser assembly	Upper riser section	TB	-	-	-	-
	Riser section slip joint	TB	-	-	-	-
	ICIGT	VS, TB Note 1	VS	-	CRD shaft and ICIGT in-air frequency testing	-
	CRD shaft	VS, TB Note 1	VS	-		-
	CRD shaft support	VS, TB	-	-	-	-
	CRD shaft sleeve	VS, TB	-	-	-	-
	Hanger brace	VS, TB	-	-	-	-
Other RVI	PZR spray RVI	TB	-	-	-	-
	CVCS injection RVI	VS, TB	-	-	-	-
	RRV port	AR	-	-	-	-
	Thermowells Note 3	VS, TB	-	-	-	-
	Instrument ports	AR	-	-	-	-
	Flow diverter	TB	-	-	-	-
Core support assembly	Core barrel	TB	-	-	-	-
	Upper support block	VS, TB	-	-	-	-
	Fuel pin interface	TB	-	-	-	-
	Core support block	VS, TB	-	-	-	-
	Reflector	TB	-	-	-	-
	Belleville spring	TB	-	-	-	-
	Lower core plate	VS, TB	-	-	-	-
Lower riser assembly	Lower riser section	TB	-	-	-	-
	CRAGT support plate	VS, TB	-	-	-	-
	CRAGT assembly	VS, TB	-	-	-	-
	Upper core plate	VS, TB	-	-	-	-
Primary coolant piping	RVV and RRV reset line tees	AR	-	-	-	-
	CNTS CVC drain	AR	-	-	-	-

NPM Component Category	Component	Susceptible Mechanisms	Mechanisms with less than 100% Safety Margin	Prototype Testing		
				Separate Effects	Factory	Initial Startup
	valve branches					

Note(s) for Table 4-1:

1. Mechanism does not require verification due to predicted safety margin; however, test results will be available due to other required testing and will be used to validate inputs, methods and safety margin to the extent practical.
2. Component is exposed to primary and secondary coolant flow.
3. Thermowells are located in the RCS and in NPM piping exposed to secondary coolant flow.

4.1 Separate Effects Testing

Separate effects tests are planned for components that are judged to have the highest susceptibility to FIV based on the analysis program results. Performing separate effects testing, which is isolated full-scale mockup testing of the NPM components of interest, is advantageous because it provides the most accurate method to verify the FIV performance of these components before the prototype NPM is fabricated. This plan allows design changes prior to fabrication, if necessary. Separate effects testing for the SG tube inlet flow restrictor and SG tube bundle are performed. A summary of the testing scope and objectives are summarized in the following sections. The specific test details, such as operating conditions, test durations, instrument types and locations, applicable testing hold points, and pre-test predictions of the expected and allowable experimental results, considering bias errors and random uncertainties, will be provided in the CVAP Measurement Program Report.

4.1.1 Steam Generator Tube Inlet Flow Restrictor Test

This separate effects test provides an assessment of the vibration performance of the SG tube inlet flow restrictors. The test results are used to verify acceptable performance against LFI. Although verification for TB is not required because impact is not predicted to occur, the testing results may be used to verify TB analysis inputs and methods for this component, to the extent practical. This test is described further in Section 5.3 of the NuScale Comprehensive Vibration Assessment Program Measurement and Inspection Plan Technical Report (Reference 8.1.14).

~~Flow tests are performed at a range of flow rate conditions that cover limiting operating flow conditions. The tests are run at low temperature and pressure conditions. Corrections for these test conditions are performed analytically to demonstrate acceptable performance at full power operating conditions.~~

4.1.2 Steam Generator Flow Induced Vibration Test

The full-scale mockup of the SG tube bundle has five prototypic helical columns and supports. This separate effects test provides an assessment of the vibration performance of the SG tubes and tube supports to aid in demonstrating that FEI and VS are not active sources of flow excitation at the equivalent full-power normal operating conditions. The SG tube bundle testing may not achieve the TH conditions scope; however, the specific testing details required to validate the secondary-side PSD are not identified in this section and are provided in the measurement program technical report.

4.2 Lead Unit Factory Testing

During the factory testing phase, testing is performed to verify component natural frequencies. Due to the natural circulation design of the NPM, it is not possible to perform flow testing without using temporary systems to provide the required primary and secondary-flow conditions necessary to validate portions of the analysis program. Design and installation of temporary systems to achieve full-power flow conditions prior to initial startup testing is impractical. Because the NPM components are subjected to low velocities characteristic of natural circulation and there are large factors of safety for susceptible components, flow testing of NPM components is not performed prior to the initial startup test phase.

4.2.1 In-Air Component Frequency Testing

In-air frequency tests are performed on the prototype NPM to determine the natural frequencies of the CRD shaft and the frequencies and mode shapes of the ICIGT. These parameters require verification in order to justify the margin obtained in the VS analysis. Because damping is not used in VS analysis of the CRD shaft, a damping value less than 1% is used for the ICIGT, and hydrodynamic mass can be approximated analytically using accepted empirical correlations, it is acceptable to validate these parameters using in-air testing.

4.3 Lead Unit Initial Startup Testing

Initial startup testing is performed on the first NPM after the first fuel load. Due to the natural circulation design of the NPM, it is not possible to obtain the limiting TH conditions that are necessary to verify the FIV inputs and results until the NPM is operating near full-power conditions. Initial startup testing will be performed for a sufficient duration to ensure one million vibration cycles for the component with the lowest structural natural frequency. It is expected to take less than 2.5 days to obtain one million cycles of vibration. This is a conservative estimate because the lowest natural frequency of any component evaluated in the CVAP is approximately {{

}}2(b),(c),ECI.

The initial startup test will be performed with online vibration monitoring of the DHRS steam piping, MSIV bypass lines, and CNTS MS drain valve branches. During the initial startup power ascension, these areas will be monitored for indication of acoustic resonance due to excitation of a shear layer mode at any partial or full power flow rate. Testing of this piping section is performed in accordance with the requirements of Part 3 of ASME OM-2012, Division 2 (OM Standards). In the event that an unacceptable vibration response develops any time during initial startup testing, the test conditions will be adjusted to stop the vibration and the reason for the vibration anomaly will be investigated prior to continuing with the planned testing. Vibration amplitudes in the

DHRS steam lines, MSIV bypass lines, and CNTS MS drain valve branches are measured to confirm the AR analysis results.

8.1.14 NuScale Power, LLC, “NuScale Comprehensive Vibration Assessment Program Measurement and Inspection Plan Technical Report,” TR-0918-60894-P.

8.1.15 Inada, F., “A Study on Leakage Flow Induced Vibration From Engineering Viewpoint,” PVP2015-45944, ASME 2015 Pressure Vessels and Piping Conference Volume 4: Fluid-Structure Interaction, July 19–23, 2015, American Society of Mechanical Engineers, New York, NY, 2015.

8.1.16 Inada, F. and S. Hayama, “A Study on Leakage-Flow-Induced Vibrations. Part 1: Fluid-Dynamic Forces and Moments Acting on the Walls of a Narrow Tapered Passage,” Journal of Fluids and Structures, (1990): 4:395-412.

8.1.17 Inada, F. and S. Hayama, “A Study on Leakage-Flow-Induced Vibrations. Part 2: Stability Analysis and Experiments for Two-Degree-Of-Freedom Systems Combining Translational and Rotational Motions,” Journal of Fluids and Structures, (1990): 4:413-428.

8.1.18 Inada, F., “A Parameter Study of Leakage-Flow-Induced Vibrations,” Proceedings of the ASME 2009 Pressure Vessels and Piping Division Conference, July 26-30, 2009, American Society of Mechanical Engineers, New York, NY, 2009.

8.1.19 Ziada, S & Lafon, Philippe. Flow-Excited Acoustic Resonance Excitation Mechanism, Design Guidelines, and Counter Measures. Applied Mechanics Reviews, Vol. 66, Jan 2014.

8.1.20 Omer, A., Arafa, N., Mohany, A., & Hassan, M. (2016). The effect of upstream edge geometry on the acoustic resonance excitation in shallow rectangular cavities. International Journal of Aeroacoustics, 15(3), pp. 253–275.

Enclosure 3:

Affidavit of Zackary W. Rad, AF-0419-65183

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

1. I am the Director, 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 Request for Additional Information response reveals distinguishing aspects about the method by which NuScale develops its comprehensive vibration assessment program.

   NuScale has performed significant research and evaluation to develop a basis for this method 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 response to NRC Request for Additional Information No. 386, eRAI No. 9316. 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 April 11, 2019.

Zackary W. Rad