NuScaleDCRaisPEm Resource

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Sent: Friday, August 25, 2017 2:56 PM
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Subject: Request for Additional Information No. 202, RAI 8911 (3.9.2)
Attachments: Request for Additional Information No. 202 (eRAI No. 8911).pdf

Attached please find NRC staff's request for additional information concerning review of the NuScale Design Certification Application.

Please submit your technically correct and complete response within 60 days of the date of this RAI to the NRC Document Control Desk.

If you have any questions, please contact me.

Thank you.

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301-415-0546

Hearing Identifier: NuScale_SMR_DC_RAI_Public
Email Number: 226

Mail Envelope Properties (5772bca2fc16411687bb8883a1a5ebc3)

Subject: Request for Additional Information No. 202, RAI 8911 (3.9.2)
Sent Date: 8/25/2017 2:56:05 PM
Received Date: 8/25/2017 2:56:12 PM
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Post Office: R4PWMSMRS03.nrc.gov

Files	Size	Date & Time
MESSAGE	556	8/25/2017 2:56:12 PM
Request for Additional Information No. 202 (eRAI No. 8911).pdf	356657	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Request for Additional Information No. 202 (eRAI No. 8911)

Issue Date: 08/25/2017
Application Title: NuScale Standard Design Certification - 52-048
Operating Company: NuScale Power, LLC
Docket No. 52-048
Review Section: 03.09.02 - Dynamic Testing and Analysis of Systems Structures and Components
Application Section: 3.9.2

QUESTIONS

03.09.02-18

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, "NuScale Power Module Seismic Analysis" describes the methodologies and structural models that are used to analyze the dynamic structural response due to seismic loads acting on the NuScale Power Module (NPM). The description is insufficient for staff to reach a safety finding. Specifically, the report does not provide the seismic and LOCA stress results. Please provide the seismic analysis details and stress results under Service Level D condition for the following reactor internals components. Include the requested information in the NPM Seismic Report or in separate reports.

- core support assembly (core barrel, lower core plate, reflector, upper core plate, upper core support)
- lower riser assembly
- upper riser assembly (upper riser, upper riser hanger support)
- control rod assembly guide tube, control rod assembly guide tube support, control rod assembly card, control rod drive shaft, and control rod drive shaft support
- steam generator tubes and tube supports
- control rod assembly guide tubes

The component analysis should include a brief description of the component structure modelling, input motion (time history or in-structure response spectrum), major assumptions, acceptance criteria under Service Level D condition including stress and deflection limits, fluid modelling, mass distribution, damping values, gap considerations, dominant modes and frequencies, and seismic and LOCA stress results and ASME B&PV Code Section III stress evaluation under Service Level D condition.

03.09.02-19

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.0 states that three 3D ANSYS finite element models of the NuScale power modules (NPM) are developed. During normal operation, one of 12 NPMs is being refueled. Provide justification for not including in the seismic analysis for the scenarios in which the NPM is on the containment flange tool, reactor flange tool, in the dry dock, or in transit. Without addressing

these scenarios, the staff cannot reach a safety finding. Include the requested information in the NPM Seismic Report.

03.09.02-20

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. In TR-0916-51502-P, Rev. 0, subsection 3.1.5, the applicant states that seismic analyses are performed by applying displacement time histories obtained from the Reactor Building soil structural interaction analysis to the NuScale power module (NPM) support locations and acceleration time histories to the reactor pool fluid surfaces in contact with the reactor pool floor and walls in the detailed 3D ANSYS Full Pool Model. In the detailed 3D ANSYS Full Pool Model, only one of the twelve NPMs is modeled. To account for the effect of NPMs that are not explicitly modeled, the containment vessel centerline acceleration time histories are applied to the surfaces of the fluid that would be in contact with the “missing” NPMs. Multiple seismic analyses are performed for each model. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Explain why displacement time histories are used for the boundary conditions of the NPM support locations (NPM skirt support and lugs) and not for the RP fluid surfaces in contact with the RP floor, walls, and the missing NPMs.
2. Explain what the multiple seismic analyses for each model are.

Include the requested information in the NPM Seismic Report.

03.09.02-21

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1 states that the NPM seismic model is created from five submodels: containment vessel and NPM pool bay, reactor pressure vessel, lower reactor vessel internals (RVI), upper RVI, and control rod drive mechanisms (CRDMs). Four of these submodels (not including the CRDMs submodels were created in ANSYS. All five submodels are combined into a single model. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Does “submodel” mean “substructure” in ANSYS modelling technique?
2. Which computer code is used for CRDMs submodel?
3. Explain in detail how the five submodels are combined into a single ANSYS model.
4. Is master node of ANSYS substructuring technique used in combining submodels into a single master model? If so, describe the criteria in selection of the master nodes in the submodels and the main model.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-22

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1.1.3 states that the pool is assigned acoustic material properties. The description is insufficient for staff to reach a safety finding. Provide a complete list of the assigned acoustic material properties of the pool water. Include the requested information in the NPM Seismic Report.

03.09.02-23

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1.2.2 (Reactor Pressure Vessel boundary conditions) states that the male end of the lower lateral reactor pressure vessel (RPV) support is coupled to the female end on the containment vessel (CNV) in the horizontal directions only. This is done using the pilot nodes for the two mating surfaces of the RPV/CNV alignment feature. The RPV upper support segments are connected to the CNV ledges in the vertical and circumferential directions only. This is done using pilot nodes scoped to the slots of the RPV support and holes of the CNV ledges. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Explain in detail the methodology in creating the pilot nodes.
2. Describe the function and input for the pilot nodes. Are there any constraint equations associated with the pilot nodes? If so, explain the constrain equations.
3. Discuss how the boundary conditions of the reactor pressure vessel are derived.
4. Can the RVP upper support segments uplift from the CNV ledges?

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-24

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The Standard Review Plan (SRP) establishes criteria that the NRC considers acceptable to use in implementing the agency's regulations. SRP 3.9.2, Revision 3 states that the number of element is adequate when additional degrees of freedom do not result in more than a 10-percent increase in responses. TR-0916-51502-P, Rev. 0, Section 4.1.3.1 states that the lower RVI submodel geometry is based on the lower riser and core support drawings. The computer-aided design model used to generate the drawings was defeatured and

simplified in order to reduce the element count of the mesh. The lower RVI is meshed using 8-node solid shell elements and 8-node solid elements. The reflector is modeled as a separate part as is the rest of the lower RVI. This avoids requiring a conformal mesh between the two parts. A cutaway view of the lower RVI mesh is shown in Figure 4-5. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Provide a discussion of how the SRP provision regarding adequate number of element is addressed considering the reduced element count of the mesh.
2. List all the sub components that are modelled in the lower RVI submodel and the corresponding element types.
3. Explain the meaning of "defeatured" and what simplifications were made in creating the lower RVI submodel.
4. In Figure 4-5, indicating the location of the 8-node shell elements and 8-node solid elements by using two different colors and provide element type of the 8-node shell element and 8-node solid element.
5. Is the reflector modelled by 8-nodes shell elements or 8-node solid elements?
6. How are the upper and lower core plates modelled? Provide FE mesh figures for the upper and lower core plates with element and nodal numbers.
7. The upper part of the lower RVI submodel shown in Fig. 4-5 appears to be a complicated structure. Provide a detailed description of the structure and its modelling.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-25

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1.3.1 states that the lower RVI submodel has its mass adjusted in a similar manner as the vessels. The core support mass is the sum of the following three RVI components: the core support, surveillance capsules, and core entrance flow plate. The negative mass adjustment associated with the core support was incorporated by reducing the density of the reflector material. This subsection provides a detailed description on mass adjustment in the lower RVI submodel. However, it lacks the description on mass adjustment to account for the fluid within the lower RVI, and the staff cannot reach a safety finding. The applicant is requested to provide a detailed description on how the fluid mass within the lower RVI is accounted for in the mass adjustment of the lower RVI submodel. Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-26

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev.

0, Section 4.1.3.2 states that within the lower RVI submodel is a model to represent the fuel assemblies. The model uses properties provided directly by the fuel vendor. The fuel model is a single fuel assembly stick model that consists of beam and spring elements. To account for all 37 fuel assemblies, the stiffnesses of the beams and springs were multiplied by 37. Increasing the axial area of the beam elements by 37 also increases the mass by 37 for a total fuel mass. The combined mass and stiffness for a single fuel assembly is attached to the upper and lower core plates of the lower RVI submodel (fixed at the base and laterally/fully rotationally coupled on the top of the fuel assembly). The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Does the total mass include the fluid mass?
2. Does the spring element include only rotational spring? If yes, explain why only rotational spring is needed and translation spring is excluded.
3. Provide a FE mesh figure of the lower RVI model with the fuel assembly model attached and locations of the attachment.
4. Table 4-8 in section 4.1.3.2 depicts fuel beam element properties. Provide the formulas used in the calculations of the lower nozzle spring stiffness, fuel spring stiffness and upper nozzle spring stiffness. Provide key to the abbreviations BN, HMP, HTP1-4, and TN in Table 4-8?
5. Figure 4-6 in section 4.1.3.2 shows a simple sketch of the fuel assembly stick model with rotational springs attached. The applicant is requested to provide a figure of the full fuel assembly FE model with all the beams and spring elements. Also provide a sketch that uses traditional circle type legend to represent the rotational springs. If three rotational springs are needed for coupling in three directions, include all three springs in the sketch and provide detailed explanation of the sketch. The sketch should indicate the components and locations where the fuel assembly model is coupled to.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-27

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1.3.3 (Lower Reactor Internals Boundary Conditions) states that the four lower core plate tabs on the lower RVI are coupled to the four lower core support blocks of the RPV submodel in the horizontal direction. For the vertical boundary condition, four spring elements are added between the four lower core plate tabs and the four lower core support blocks. These springs represent the Belleville washers at this connection. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Describe what are the ANSYS elements used in the coupling of the four RVI lower core plates tabs to the four lower core support blocks of the RPV and how the couplings are achieved in two separated submodels.
2. What are the ANSYS elements used for representing the Belleville washers?
3. List the spring constant of the spring element and explain how it is determined.
4. Provide a FE mesh figure that shows the locations of the couplings between the lower RVI and the RPV and the spring elements.

5. Are there any nonlinear effects such as gaps exist in the boundary conditions? If so, address them and explain how the nonlinear effects are considered in the analysis.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-28

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 4.1.3.3 (Lower Reactor Internals Boundary Conditions) states that the upper support blocks of the lower RVI are connected to the inner walls of the core region of the RPV submodel. This is done using a no-separation contact between the four pairs of mating surfaces. Likewise, the reflector is connected to the inner surface of the core support barrel using a no-separation contact. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Describe the meaning of no-separation contact. Does it allow sliding between the mating surfaces? If so, what are the friction coefficients and how are they determined?
2. Which ANSYS elements are used for representing the no-separation contact condition? Describe the element and input data of the element. If the element represents a one-way compression-only one-way spring, describe the spring constant and how it is determined.
3. Indicating in Figure 4-5 where the no-separation contact surfaces are located.
4. What are the areas of the mating surfaces for the lower RVI and the reflector? Are the actual areas considered in the model?
5. Provide finite element mesh figures that show the locations of the no-separation contact.
6. Are there any nonlinear effects such as gaps exist in the boundary conditions. If so, address them and explain how the nonlinear effects are considered in the analysis.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-29

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The Standard Review Plan (SRP) establishes criteria that the NRC considers acceptable to use in implementing the agency’s regulations. SRP 3.9.2 states that the number of element is adequate when additional degrees of freedom do not result in more than a 10-percent increase in responses. TR-0916-51502-P, Rev. 0, Section 4.1.4.1 states that the upper RVI submodel geometry is based on the upper riser drawings. The computer-aided design model used to generate the drawings was defeatured and simplified in order to reduce the element count of the mesh. A cutaway view of the upper RVI submodel mesh is shown in

Figure 4-7. The upper RVI is meshed using 8-node solid shell elements and 8-node solid elements.

The solid shell elements are used at any shell section where there is one element through the thickness. The solid elements are used at intersection regions of shells and where there is more than one element through the thickness. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Provide a discussion of how the SRP provision regarding the adequate number of elements is addressed considering the reduced element count of the mesh.
2. Provide a cutaway view of upper RVI before defeature and simplification and provide detailed description of the major components in the upper RVI including their dimensions and wall thickness.
3. Provide a detailed description of the upper RVI submodel mesh in Figure 4-7.
4. Explain any major components that are not included in the upper RVI submodel and provide justifications.
5. Provide a FE mesh figure of the Upper RVI that shows the locations of the 8-node shell elements and the 8-node solid elements.
6. The FE mesh in Fig. 4-7 appears to have beam elements. Are there any beam elements and spring elements in the upper RVI submodel?

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-30

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The Standard Review Plan (SRP) establishes criteria that the NRC considers acceptable to use in implementing the agency's regulations. SRP 3.9.2 states that the number of element is adequate when additional degrees of freedom do not result in more than a 10-percent increase in responses. For boundaries conditions of the Upper RVI submodel, TR-0916-51502-P, Rev. 0, Section 4.1.4.2 states" the following:

> The cone of the upper RVI is coupled to the cone of the lower RVI submodel in the horizontal directions only.
>
> Eight rectangular contact surfaces on the upper RVI are coupled to the tips of the lower radial cantilever SG supports RPV submodel by coupling the eight pairs of pilot nodes in the radial direction only. Each pair of pilot nodes was created at the same location to avoid an inaccurate constraint.
>
> Radial coupling is provided between the upper riser and the RPV using constraint equations. These represent the radial load transfer that occurs due to the stack-up of SG tube supports between the upper riser and RPV. The load transfer occurs along the height of the SG at the 8 support locations around the circumference.
>
> The upper riser ring hole locations on the upper RVI are coupled to pin locations on the baffle plate of the RPV submodel. This is done by coupling the translational degrees of freedom on the eight pairs of pilot nodes.

The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Are there any nonlinear effects such as gaps existing in the couplings and connections of the CRDMs? If so, address them and explain how the nonlinear effects are considered in the analysis.
2. Explain in detail the physical connections between the upper RVI and the lower RVI. Provide figures to demonstrate the coupling. Explain how the couplings can be achieved in the models. Is the coupling in the horizontal direction only?
3. The Seismic Report has no information about modelling of the SG. Explain in detail of the physical connections between the upper RVI and SG supports. Provide figures to demonstrate coupling of the upper RVI with the lower radial cantilever SG supports RPV submodel. How far apart are the eight pairs of pilot nodes? Which NMP submodel contains the SG? Provide the FE model description that contains the SG.
4. Explain in detail the physical connections between the upper riser and the RPV. Where are the locations of radial coupling between the upper riser and the RPV? Provide sketches or figures to demonstrate the coupling. Provide the constraint equations and explain the reason not to use pilot node approach.
5. Explain in detail the physical connections between the upper RVI and the baffle plate of the RPV. Provide figures to demonstrate the coupling and locations of the pilot nodes.
6. Explain how nodes and elements are numbered in the upper RVI submodel, lower RVI submodel, and RPV submodel and how they are glued to a NPM full model.
7. It is confusing to use the term of submodel for upper RVI, lower RVI, and RPV. Submodel technique is generally used at regions with high stresses that need refined mesh. The displacement field calculated from a whole structure having a course mesh are used as input (boundary conditions) to the region of interest with refined mesh (i.e., submodel) to get the accurate highly-refined stress field. In the NPM modelling, it appears that all the submodels have course meshes and they are combined to a full NPM model. It is not consistent with the traditional submodelling technique. The deviations from the traditional submodelling technique should be explained at beginning of the NPM Seismic Report.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-31

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The Standard Review Plan (SRP) establishes criteria that the NRC considers acceptable to use in implementing the agency's regulations. The SRP 3.9.2 states that the applicant should consider any nonlinear effects in the analysis. In the CRDM Submodel, the applicant states in TR-0916-51502-P, Rev. 0, Section 4.1.5.1 that the CRDM is constrained to the RPV head by beam elements representing the CRDM nozzles. The nozzle elements share the two nodes through the thickness of the RPV head, and connect to the bottom of the CRDM. This couples the translational degrees of freedom, as well as rotation about the two horizontal axes. CRDM rotation about the vertical axis is constrained. The mid-heights of the CRDMs are coupled laterally to the CRDM support frame. The tops of the CRDMs

are coupled laterally to the inside of the CNV top head opening. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Explain the modeling of the CRDM support frame and coupling between the CRDM support frame and the RPV head.
2. Are there any nonlinear effects such as gaps exist in the couplings and connections of the CRDMs? If so, address them and explain how the nonlinear effects are considered in the analysis. Alternatively, provide technical justification for how GDC 4 is being met if nonlinear effects have not been considered in the analysis.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-32

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 4.1.8.2 states that half of the steam generator (SG) horizontal mass is applied to the riser, and the other half is applied to the inner surfaces of the RPV. The vertical mass is applied to the upper SG supports only to represent the floating vertical connection at the bottom cantilever interface. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Explain why there is no simplified SG submodel within the 3D NPM model.
2. Explain how the SG mass is distributed to the riser and RVP surfaces, by adjusting mass density of the shell elements or assigning mass elements at the nodes.
3. Discuss how the SG stiffness is considered in the NPM model.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-33

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 4.1.8.4 states that the mass of the control rod assemblies (CRA) is applied directionally. Half of the horizontal mass is applied to the CRA guide tube support plate, and the other half is applied to the upper core plate. The vertical mass is combined with the CRDS mass in the CRDM submodel. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Explain why half of the CRA horizontal mass is applied to the CRA guide tube support plate and the other half is applied to the upper core plate.

2. Are there any gaps between the CRA and the CRA guide tube support plate and the upper core plate. If so, provide a discussion of the gap sizes and how the gaps are modelled.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-34

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 4.1.8.5 states that fluid coupling between the two concentric cylinders of the RPV and the RVI is accounted for by a method called Fourier Nodes. The method creates a set of constraint equations connecting the inner and outer surfaces of the annulus at several elevations along the annulus (23 locations for this model). Only the first coupled mode (M=1, beam mode) between the RPV and RVI is considered because shell modes do not have a significant impact on the overall response of the NPM. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Provide mathematical terms of the beam-mode coupling mass matrices and the corresponding ANSYS element type.
2. Provide the procedure in setting up the Fourier nodes in the NPM model and a FE mesh figure showing the Fourier nodes.
3. Provide value of fluid density used in the mass matrix calculation.
4. Provide justifications that the shell modes of the RVI and RPV are not significant. In Figure 4-13 of EC-A023-3535, “RVI Turbulent Buffeting Degradation Evaluation,” Rev. 0, the plot of the first mode of the lower riser appears to be a shell mode (n=8). Does this mode have any significant impact on the overall response of the NPM?

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-35

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 6.1.4 states that the vertical response of the simplified CNV beam model is captured by a set of tuned point masses and springs that comprise the primary vertical modes from the 3D model. Table 6-2 contains the numerical values of a set of three tuned mass and spring constant in the dry CNV model and a set of four tuned mass and spring constant in the wet CNV model. No modal information about the primary vertical modes from the 3D model is given; therefore, the staff cannot reach a safety finding. The applicant is requested to explain what are the frequencies, types of the mode, and the associated NPM components that are represented by the set of the four tuned springs shown in

Fig. 6-6 in the dry and wet CNV conditions. Which spring represents the fundamental dominant mode in the dry and wet conditions?

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-36

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 6.1.5 states that the beam elements of the simplified RPV beam model are assigned as massless. Masses are assigned by point mass elements. The mass include everything inside the RPV. Torsional mass moment of inertia is also assigned in the mass element. The values of the mass and torsional mass moment of inertia are determined from the 3D detailed RPV ANSYS model shown in Figure 6-9 by slicing the model horizontally and extracting the properties for each section. Table 6-3 shows the masses and torsional mass moments of inertia at each node of the simplified RPV beam model. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Add the legend for the colors in the Fig. 6-9.
2. Add a column in Table 6-3 that depicts the names of the NPM subcomponents that creates the torsional mass moment of inertia and provide a discussion of the subcomponents.
3. Table 4-4 contains the total RPV mass calculated from the 3D detailed RPV ANSYS model. The total RPV mass by adding all the nodal masses in Table 6-3 for the simplified RPV beam model is considerably higher than the total RPV mass of the 3D RPV model. Explain the discrepancy.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-37

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 6.2 states that certain modes that are visible in the harmonic response of the RPV 3D model are associated primarily with the RVI, the reactor coolant, or other subcomponents of the RPV. The responses associated with these modes are difficult to capture in the simplified RPV beam model that does not include a separate set of beams to explicitly model the components. Therefore, the response is alternatively captured by employing a set of tuned point masses and springs to model the three most significant missing modes in the simplified RPV beam model. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. List all the visible modes in the harmonic response of the RPV 3D model, their frequency, type of the mode, and the component associated with the mode. Explain what is the reactor coolant mode and its significance.
2. What are the three most significant missing modes that are captured in the simplified RPV beam model? List the three modes in sequence of significance.
3. SRP 3.9.2 states that a sufficient number of modes should be included in the dynamic analysis to ensure participation of all significant modes. The criterion for sufficiency is that the inclusion of additional modes does not result in more than a 10-percent increase in responses. Discuss how this SRP criterion is met. Alternatively, provide technical justification for how 10 CFR 52.47 is being met if using some other methodology other than discussed in SRP 3.9.2.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-38

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 7.2 states that from time history analyses of the NPM 3D model, time histories at locations of equipment supports within the NPM were calculated. Response spectra from the soil structure interaction (SSI) cases were then enveloped and broadened, according to ASCE 4-13 to give ISRS for use in design of the SSC supported within or directly on the NPM. NuScale FSAR Section 3.7.2.5 (Development of In-Structure Floor Response Spectra) states that development of ISRS follows the guidance in RG 1.122, Rev. 1, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components." The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. There are six 3D NPM seismic analysis runs. Each run will generate an ISRS in each direction at a given location. Explain how the six ISRS are enveloped at a given location for the design ISRS.
2. The use of ASCE 4-13 in the NPM ISRS generation is inconsistent with RG 1.122 which is utilized in the generation of the rest of ISRS within the RXB as stated in the NuScale FSAR Section 3.7.2.5. The major difference between the ASCE 4-13 and RG 1.122 is that ASCE 4-13 permits a 15% reduction in the narrow frequency peak amplitude if certain conditions are met. The 15% reduction of the narrow frequency peak amplitude is not consistent with RG 1.122 criteria. The use of 15% reduction of the narrow frequency peak amplitude may result in nonconservative seismic results. The applicant is requested to generate all design ISRS using the guidelines in RG 1.122 for seismic design of SSCs supported on the NPM or provide an alternative with justification.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-39

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 8.0 states that the detailed 3D NPM model is analyzed using the Certified Seismic Design Response Spectra (CSDRS) compatible Capitola time histories. Outputs of the analysis include in-structure response spectra (ISRS), time history data, relative displacements, and forces and moments within the NPM. Since the high frequency CSDRS (CSDRS-HF) compatible time histories (i.e., the Lucerne time histories) are not considered in the analysis, the applicant is requested to clarify whether the NPM seismic analysis outputs based on the Capitola time histories are applicable to the seismic design of the NPM that is located at hard rocks sites with the CSDRS-HF. Without the clarification, the staff cannot reach a safety finding.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-40

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 8.2, Table 8-1 depicts the modal analysis results of the 3D detailed single bay dry NPM model. The table contains six dominant natural frequencies and their effective mass in the E-W (X) direction (longitudinal direction of the reactor building), four dominant natural frequencies in the N-S (Z) direction (transverse direction of the reactor building) and three dominant natural frequencies in the Y direction (vertical). No discussion on the modal results is given; therefore, the staff cannot reach a safety finding. The applicant is requested to provide the following information:

1. For each mode, identify the NPM component associateed to that mode, type of the mode, percentage of the modal mass to the total mass and the total mass.
2. List all the modes up to 50 Hz in three directions from the NPM modal analysis. Provide the dominant modes of the CNV, RPV, lower RVI, upper RVI, CRDM, upper and lower core plate, core barrel, and SG.
3. In the N-S direction, mode 3 is the dominant mode with the highest effective mass. Provide an explanation why mode 3 is the dominant mode instead of the typical mode 1.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-41

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Section 8.2, Table 8-2 depicts the modal analysis results of the 3D detailed single bay wet NPM model. The table contains six dominant natural

frequencies and their effective mass in the E-W (X) direction (longitudinal direction of the reactor building), three dominant natural frequencies in the N-S (Z) direction (transverse direction of the reactor building) and four dominant natural frequencies in the vertical direction. No discussion on the model results is given; therefore, the staff cannot reach a safety finding. The applicant is requested to provide the following information:

1. For each mode, identify the NPM component associated to that mode, type of the mode, percentage of the modal mass to the total mass. Also provide the total mass for all the modes.
2. Mode 1 in the E-W direction is the fuel assembly first mode (see Table 4-9). The fuel model is attached to the upper and lower core plates of the lower RVI submodel which is part of the 3D detailed NPM model. This mode should be present in the modal analysis of the dry and wet 3D NPM models in both the E-W and N-S directions. Explain the reasons why this fuel assembly mode is missing in the dry NPM modal analysis results in Table 8-1 and the N-S direction of the wet NPM modal analysis results in Table 8-2.
3. List all the modes up to 50 Hz in the three directions from the NPM modal analysis. What are the dominant modes of the CNV, RPV, lower RVI, upper RVI, CRDM, upper and lower core plates, core barrel, and SG.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-42

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Sections 8.4.2.3 and 8.4.2.4 state that maximum seismic forces and moments are generated for 22 component sections within the NPM components, including various elevations of the RPV, CNV, and RVI. The upper and lower risers and core barrel in the 3D NPM model are modelled by 16 shell elements in the circumferential direction. The description is insufficient for staff to reach a safety finding. Explain how the maximum forces and moments in a cross section are determined from the 16 shell elements. Also explain how the maximum forces and moments in a cross section are determined from the six NPM seismic analysis runs. Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-43

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Section 8.4.3 states that maximum uplift displacements of the NPM were calculated for each of the six analysis runs. The maximum uplift occurred in the run representing the Capitola time history, soil type 7, with cracked RXB concrete, on the NPM in operating bay 6 with a nominal

stiffness. As stated in Section 8.0, for the cracked RXB concrete case, two NPM stiffness were considered. Section 7.4 of the report states that uncertainty in the input and assumptions used in the finite element models of the NPM is accounted for by considering multiple analyses using ±30 percent variations of the stiffness properties of the model. Therefore, in calculation of the maximum NPM uplift, the NRC staff considers that the case of 130% of the NPM stiffness for the cracked RXB concrete case should be considered. Increasing the NPM stiffness may bring the NPM dominant frequency closer to the cracked RXB frequency. The results of 77% NPM stiffness could be non-conservative. The applicant is requested to provide the maximum NPM uplift in the cracked RXB concrete case with an adjustment of +30 percent variation of the NPM stiffness (i.e., 130% NPM stiffness). Alternatively, provide justification for not performing a cracked RXB concrete case with 130% of the NPM stiffness.

Include the requested information in the NPM Seismic Report or in separate reports.

03.09.02-44

10 CFR 52.47 requires the design certification applicant to include a description and analysis of the structures, systems, and components (SSCs) sufficient to permit understanding of the system designs. TR-0916-51502-P, Rev. 0, Appendix B presents the representative ISRS plots in the three directions of the CNV lugs, CNV top head, RPV top head, lower core plate, upper core plate, and steam generator top and bottom sections. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Provide a discussion of the mode and frequency associated with the two spectral peaks in the vertical ISRS of the lower and upper core plates shown in Figure B-18 and B-21, respectively. Explain why the frequency of the first peak (at about 5.5 Hz) is not included in Table 8-2 entitled “Model Analysis Results for the Single Bay Wet NPM model”. Table 8-2 shows that the lowest vertical NPM mode much higher than 5.5 Hz.
2. Identify the mode and frequency associated of the spectral peaks in the East-West and North-South ISRS of the lower core plate. In Fig. B-17 (N-S ISRS of lower core plate), there is a noticeable spectral peak ay frequency about 70 Hz. Provide a discussion of this mode and include this mode in Table 8-2.
3. Provide a discussion of the mode and frequency associated with the two spectral peaks in the vertical ISRS of the top and lower sections of the steam generator shown in Figure B-24 and B-27, respectively. Explain which peak is associated with the steam generator.
4. Provide a discussion of the mode and frequency associated with the two spectral peaks in the East-West (X) and North-South (Z) ISRS of the top and lower sections of the steam generator shown in Figure B-22, B-23, B-25 and B-26, respectively. Explain which peak is associated with the steam generator. Explain why the north-south ISRS at the bottom steam generator section (Fig. B-26) has much higher spectral peaks than those at the top steam generator section in Fig. B-23 (e.g., for 5% damp ISRS, 18g vs. 6g).

Explain why the frequency of the second peak in the East-West ISRS at the top steam generator section (about 11 Hz shown in Fig. B-22) is different from the frequency of the second peak of the ISRS at the bottom of steam generator section (about 16 Hz shown in Fig. B-25). Provide a table and discussion of the dominant frequencies of the steam generator in the three directions and their mode shapes.

5. The NPM has two steam generators. Does the SG ISRS presented in Appendix B envelop both steam generators? If so, discuss the enveloping process.
6. One of spectral peak of the North-South ISRS of the CNV lugs (Figs. B-2, B-5, and B-8), containment vessel top head (Fig. B-11), and reactor vessel top head (Fig. B-14) occurs at frequency is about 7 Hz. This is inconsistent with Table 8-2 (Model Analysis Results for the Single Bay Wet NPM Model) which shows a different frequency for the lowest NPM mode in North-South direction. Explain the discrepancy.

Include the requested information in the NPM Seismic Report.

03.09.02-45

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. TR-0916-51502-P, Rev. 0, Appendix C, Table C-1 (Summary of NuScale Power Module Component Interfaces) states that the reflector blocks and lower core plate are stacked and restrained in the horizontal direction with alignment pins. The reflector blocks and lower core plate are not restrained in the vertical direction other than by gravity. Tolerances and deformation between the mating parts allow some sliding to take place between parts. On the interface between the upper riser and lower riser, Table C-1 states that the lower riser conical section seats within the upper riser conical section. There are tolerances between the two interfacing components allowing them to pitch slightly. The upper riser is not restrained in the vertical direction other than by gravity and compression of the bellows which keeps the interface closed. The description is insufficient for staff to reach a safety finding. The applicant is requested to provide the following information:

1. Figure B-18 (vertical ISRS at top of the lower core plate) indicates that the maximum vertical acceleration at top of the lower core plate is about 1.6 g (i.e., spectral acceleration at the high frequency end of the ISRS) that exceeds gravity acceleration. Provide a discussion on the possibility of uplift between the reflector blocks as well as between the reflector blocks and the lower core plate under the maximum vertical acceleration and their consequence.
2. Provide the vertical ISRS and the maximum vertical acceleration at the interface between the upper riser and the lower riser. Provide a discussion on the possibility of uplift of the upper riser from the lower riser under the maximum vertical acceleration and their consequence.

Include the requested information in the NPM Seismic Report.

03.09.02-46

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. Regulatory guides (RG) describe methods that the NRC considers acceptable to use in implementing the agency's regulations. RG 1.61 Rev.1 states that for steel structures with a combination of different connection types, use the lowest specified damping value, or as an alternative, use a "weighted average" damping value based on the number of each type present in the structure. TR-0916-51502-P, Rev. 0, Table C-3, "Summary of NuScale Power Module Damping Values" states that a 7 percent damping is assigned for the NPM sub-system seismic analysis of reactor vessel internals (RVI), reactor pressure vessel (RPV), and containment as well as 7 percent NPM system damping is assigned for NPM system seismic analysis. For the RVI, the applicant states that because the RVI joints allow for sliding at the interfaces developing of sliding friction forces, and these connections are analogous to bolted steel with bearing connections in RG 1.61. However, NuScale FSAR Rev. 0, Section 3.9.5.1 states that the upper support blocks of the core support assembly are welded to the core barrel. In addition, the lower core plate is welded to the bottom of the core barrel to support and align the bottom end of the fuel assemblies. RG 1.61 specifies a 4 percent SSE damping for welded steel.

For the containment, the applicant uses energy dissipation in the plastic deformation based on containment yielding stresses in faulted condition for justification of 7 percent SSE damping. The applicant calculated the dissipated energy in terms of NPM equivalent drop height and equivalent static acceleration and stated that the amount of dissipated energy in these two cases justifies the use of 7 percent damping. The NRC staff recognizes that yielding of steel would increases damping. However, the staff has concerns with the use of 7 percent damping for the containment. First, the containment yielding stress in faulted condition consists of combination of seismic and loss of coolant accident (LOCA) stresses. The LOCA stress should be excluded from the yielding stress because LOCA stress is a short-term transient type stress and peaks of seismic stress and LOCA stress may not occur at the same time. Second, in the calculations of NPM equivalent drop height and static acceleration, the applicant didn't provide a direct quantitative correlation between energy dissipation and damping values. The NRC staff used 6 percent damping to calculate the NPM equivalent static acceleration, the result only differs about 7.5 percent from that based on 7 percent damping. Therefore, the staff is not able determine whether the amount of energy dissipated in the containment plastic deformation could achieve 7 percent damping.

For the RPV, the applicant states that metal yielding in the nozzles increases damping and the RPV contains the steam generator (SG) with many sliding tube-to-support interfaces generating large frictional dissipative forces for justification of 7 percent damping. The NRC staff's concern is that steel/steel coefficient of friction is much smaller underwater than in dry condition because of the water film acting as a lubricant. For example, the coefficient of friction of cast iron brake material is 0.4 in dry condition and 0.2 in wet condition (Machinery's Handbook 19th edition and http://www.engineershandbook.com/Tables/frictioncoefficients.htm). The NRC staff questions the justifications for using 7 percent damping for RPV based on SG frictional dissipative forces and yielding of nozzles. In addition, provide the damping value for the SGs.

Based on the concerns mentioned above, follow the provision of RG. 1.61 Rev. 1 that uses the lowest specified damping value (i.e., 4% for welded steel) or provide a "weighted average" damping value based on the number of each type of connections in the RVI components, RPV, and containment. Recalculate the NPM system damping based on the weighted average of individual NPM components. Alternatively, provide testing data to justify the use of 7% damping for RVI, RPV, containment, and NPM system damping or add an ITAAC to measure the as-built RVI components, RPV, containment, and NuScale power module system damping.

Include the requested information in the NPM Seismic Report.

03.09.02-47

10 CFR 50, Appendix A, GDC 4 requires structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. The Standard Review Plan (SRP) establishes criteria that the NRC considers acceptable to use in implementing the agency's regulations. SRP 3.9.2, Rev. 3 states that initial piping startup testing should be performed in accordance with ASME OM-S/G-1990, "Standards and Guides For Operation of Nuclear Power Plants," Part 3, "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems." DCD Tier 2, Section 3.9.2.1.1.1 states that ASME Code Class 1, 2, and 3 piping systems that are part of the reactor module are included within the scope of the NuScale Comprehensive Vibration Assessment Program (CVAP). This section also states that comprehensive vibration testing of all ASME Class 1, 2, and 3 piping is not required.

DCD Tier 2, Section 3.9.2.1.1.2 states that for ASME Code Class 3 piping that is not part of the reactor module (there is no Code Class 1 or 2 piping which is not part of the reactor module) and other ASME B31.1 piping outside of containment which requires vibration testing, vibration test specifications are developed in accordance with ASME OM-S/G, Division 2 (OM Standards), Part 3.

The CVAP piping system vibration measurement as discussed in RG 1.20, Rev. 3 is related to monitoring piping systems to ensure that vibration of the piping systems will not cause adverse effects for the reactor internals components. RG 1.20 does not provide acceptance criteria for piping. The piping vibration testing and the acceptance criteria should follow ASME OM S/G Part 3 provisions. The NRC staff requests that the applicant revise the application to perform the vibration testing in accordance with ASME OM S/G Part 3 for all piping systems within the scope of Section 3.9.2.

03.09.02-48

10 CFR 52.47 requires design certification applicants to demonstrate how operating experience insights have been incorporated into the plant design. Operating experience indicates that acoustic resonance at closed branching piping can cause acoustic resonance which leads to excessive vibration that can damage piping system components. Minor changes in piping design such as the branch transition radius can cause adverse vibration in the piping system. The NRC staff requests that the applicant provide a discussion in DCD Tier 2, Section 3.9.2.1 the process that is used to design all ASME Code Class 1, 2, and 3 piping systems to avoid vibration phenomena such as acoustic resonance at pipe branches. Without the requested information, the staff cannot reach a safety finding.

03.09.02-49

10 CFR 50, Appendix A, GDC 2 requires systems, structures, and components important to safety be designed to withstand appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena including earthquake. DCD Tier 2, Rev. 0, Section 3.7.1, Table 3.7.1-6 contains SSE damping values for NPM dynamic analysis. Damping values for structural materials, piping systems, electrical distribution systems, and HVAC Duct Systems are presented. The damping values of these systems are consistent with the damping values specified in RG 1.61, Revision 1, except the damping value of the sloshing mode of metal atmospheric storage tanks. Table 3.7.1-6 specifies SSE damping value of 2% for the sloshing mode of metal atmospheric storage tank which is not consistent with the damping value of 0.5% for sloshing mode of metal atmospheric storage tank specified in RG. 1.61, Revision 1. The NRC staff requests that the applicant provide the justification for using a lower damping value, and update the DCD to include the justification. Without the requested information, the staff cannot reach a safety finding.