NuScale Power™

RAIO-0618-60277

June 04, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 407 (eRAI No. 9468) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 407 (eRAI No. 9468)," dated April 03, 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 Enclosure to this letter contains NuScale's response to the following RAI Question from NRC eRAI No. 9468:

- 21.0-2

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

If you have any questions on this response, please contact Steven Mirsky at 240-833-3001 or at smirsky@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9468

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9468

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

eRAI No.: 9468
Date of RAI Issue: 04/03/2018

NRC Question No.: 21.0-2

General Design Criterion (GDC) 5, "Sharing of structures, systems and components," requires structures, systems, and components important to safety not be shared unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.

GDC 10, "Reactor design," requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

DSRS 15.0 states, "The reviewer evaluates licensees' claims that individual AOOs [Anticipated Operational Occurences] and postulated accidents, including IEs [Infrequent Events], are limiting or nonlimiting, or bounded by other AOOs, IEs and postulated accidents, with particular attention to the bases used for comparison."

FSAR Tier 2, Section 21.2.3 states Table 21-2, "Shared System Interactions (Mechanical Systems)," identifies and evaluates shared systems that have the potential for an adverse system interaction or an undesirable multi-module interaction. In several locations, Table 21-2 states that an event is evaluated [considered, included, or captured] in the "safety analysis." Typically, the staff would interpret this as the safety analysis for design basis events located in Chapter 15 of the FSAR. However, the staff could not verify most of these statements. For example, Table 21-2 states, "A [Module Heatup System] MHS heat exchanger tube rupture or loss of the auxiliary boiler system (ABS) steam may result in an addition of cooler water to the reactor coolant system (RCS). This is a single-module event that is evaluated in the safety analysis." The staff reviewed FSAR Chapter 15 and Section 9.3.4, but could not find a discussion regarding the impact a MHS heat exchanger tube rupture would have on the RCS.

Therefore, the applicant is requested to substantiate statements made in Table 21-2 when referring to multi-module events that are evaluated as part of the safety analysis. The applicant is requested to revise the FSAR as necessary to include the absent evaluation or reference to a specific section in the FSAR where such an evaluation of the event already exists.

NuScale Response:

Based on eRAI 9468 and a clarification call with NRC, the following shared systems described in Table 21-2 require additional substantiation that they are evaluated in the safety analysis. The FSAR has been revised as necessary to include the additional evaluation language or FSAR section reference where an event evaluation already exists.

- Module heatup
- Reactor component cooling water
- Circulating water
- Site cooling water
- Nitrogen distribution
- Demineralized water
- Instrument air

As an interfacing system with the chemical and volume control system (CVCS), a malfunction in the module heatup system (MHS) resulting in loss of heat addition could result in injection of colder fluid through the CVCS injection lines to the reactor coolant system (RCS). Injection of colder fluid through the CVCS injection lines, particularly during startup, could lead to decreased reactor coolant system flow due to the natural circulation forces of the NuScale reactor design. An MHS malfunction could cause a reactivity transient if the colder fluid reaches the core. The CVCS is isolated from the RCS by the module protection system on low low reactor coolant system flow, limiting the amount of cold water injection that could possibly occur. Therefore, considering the capacity of the NuScale Power Module (NPM) CVCS, a reactivity change due to MHS malfunction is judged a non-limiting reactivity event compared to the spectrum of reactivity events analyzed as presented in the FSAR Section 15.4.

Note that for consistency with section 15.4.4 of the Standard Review Plan, Section 15.4.4 of the FSAR discusses startup of an inactive loop or recirculation loop at an incorrect temperature; however, this event is not applicable to NuScale because the NuScale design does not have multiple coolant loops or means in the design to introduce a substantial amount of cold water similar to an inactive loop startup.

A decrease in RCS inventory that could be caused by a tube failure in the MHS is bounded by the safety analysis for CVCS line breaks outside the containment vessel as presented in the FSAR Section 15.6. Both the diameter of the CVCS line and its much closer proximity to the reactor coolant system result in a larger decrease in RCS inventory than an MHS tube failure.

Section 15.1.6 of the FSAR discusses the safety analysis for reactor component cooling water system pipe breaks inside the containment vessel. The prior discussion of MHS malfunctions covers analysis for failed-open RCCWS flow control valve on the CVCS non-regenerative heat exchanger's secondary side.

The principal function of the circulating water system (CWS) is to remove heat from the condensate and feedwater system and to reject that heat to the environment. Since the CWS provides cooling water to the condensate and feedwater system, a malfunction in the CWS could result in a decrease in feedwater temperature or a loss of feedwater. An increase in feedwater temperature is not typically considered in the design basis spectrum. The reduced heat removal from the secondary side due to these types of conditions is bounded by consideration of loss of feedwater events. The FSAR discusses the safety analysis that evaluates events that could be caused by a loss of circulating water in Section 15.1 and Section 15.2. Specifically, Section 15.1.1 addresses a decrease in feedwater temperature, Section 15.2.3 addresses a loss of condenser vacuum, and Section 15.2.7 addresses a loss of feedwater.

The site cooling water system (SCWS) provides cooling water to plant auxiliary systems, ultimately transferring waste heat to the normal heat sink cooling towers. The SCWS performs no safety functions; however, as a system applicable to the site, failure of the SCWS would affect multiple modules. The effect of a failure in the SCWS that affects an interfacing system and would result in a design basis initiating event would be captured in the consideration of the specific interfacing system. Loss or component failures in the SCWS that affect interfacing systems do not result in identification of a new Chapter 15 design basis event.

The SCWS interfaces with:

- chiller condensers
- instrument air compressor coolers
- reactor pool, spent fuel pool, and reactor component cooling water heat exchangers
- condenser air removal heat exchangers
- turbine generator heat exchangers (generator, lube oil and governor)
- main steam sample coolers
- condensate and feedwater sample coolers
- process sampling system chillers
- auxiliary boiler blowdown coolers

The nitrogen distribution system (NDS) provides pressure-regulated supplies of nitrogen gas needed for cooling, purging, diluting, inerting, and pressurizing plant components and systems. The NDS supplies nitrogen to the liquid radioactive waste system degasifiers, the containment evacuation system, and the gaseous radioactive waste system charcoal guard beds and absorber tanks. The NDS supplies the chemical and volume control system with nitrogen to pressurize the reactor pressure vessel during startup and shutdown operations. The main steam system is supplied with nitrogen during refueling or when a NPM is in shutdown.

Failure of the NDS itself does not result in a design basis event. Failure of the NDS that impacts a nonsafety system and results in an event is captured by consideration of failure of the other system.

- Failure of the gaseous radioactive waste system is addressed in FSAR Section 11.3.2.
- Failure of the liquid radioactive waste system is addressed in FSAR Section 11.2.
- Failure of the chemical and volume control system is addressed in FSAR Section 9.3.4.
- Failure in the containment evacuation system is addressed in FSAR Section 9.3.6.
- Failure in the main steam system is addressed in FSAR Section 10.3.

For the demineralized water system, Section 15.4.6 of the FSAR addresses an inadvertent decrease in boron concentration in the reactor coolant system (RCS). Boron dilution causes an increase in reactivity, and the plant response to the event is similar to an uncontrolled control rod assembly withdrawal, which is presented in FSAR Section 15.4.1 and Section 15.4.2. The limiting CVCS dilution source considered in this analysis is the demineralized water system supply through the CVCS makeup pumps. To preclude the the boron addition system (BAS) supply to the CVCS makeup pumps from being a dilution source for the RCS or the refeuling pool, the boron concentration of BAS supply is verified to be within specification.

For design basis events, the primary effect of a loss of instrument air is on the secondary system (main steam, feedwater, and turbine generator). Instrument air system failure could result in secondary main steam isolation valve and feedwater regulating valve closure, resulting in unnecessary reactor trip. Feedwater regulation valves include their own air accumulators with the valves so that they will not immediately close on loss of instrument air; however, the backup main steam isolation valves are expected to close on loss of instrument air.

Since instrument air also supports the containment evacuation system, loss of instrument air could also result in a loss of containment vacuum. Loss of containment vacuum will result in an increase of heat removal from the primary system compared to normal operation.

Instrument air supports the CVCS; therefore, loss of instrument air could affect normal pressurizer spray control, recirculation, or makeup/letdown operation. The operation of these normal, nonsafety control systems is considered as part of evaluating design basis events.

Considering the effect of the loss of instrument air on the main steam, feedwater, containment evacuation system, and CVCS, loss of instrument air is bounded by analysis of a turbine trip event, which results in a rapid decrease in steam flow and decrease in heat removal from the primary system, because:

- Loss of instrument air will not cause the containment isolation valves to automatically close.
- Loss of instrument air will cause closure of the backup non-safety main steam isolation valves and possibly valves in the turbine generator system.
- Loss of instrument air will not cause immediate closure of the feedwater regulating valves due to local air accumulators on those valves.
- Loss of instrument air may cause loss of containment vacuum due to closure of valves in the containment evacuation systems. However, increase in heat removal from the primary side due to loss of containment vacuum is assumed to be insignificant compared

to the decrease in heat removal from decreased steam flow.

Loss of instrument air on other systems does not cause significant direct impact on the module that is not already accounted for by considering the availability of normal non-safety controls (such as pressurizer spray availability through the chemical and volume control system).

Section 15.2 of the FSAR contains the safety analysis for a turbine trip event.

Impact on DCA:

FSAR Table 21-2 has been revised as described in the response above and as shown in the markup provided in this response.

RAI 21.0-2

Table 21-2: Shared System Interactions (Mechanical Systems)

Shared System	NPMs Supported	System Interactions
Module heatup system (MHS)	Two independent subsystems each supporting 6 NPMs	The MHS supports one NPM at a time via an interface with the module-specific CVCS during startup and shutdown operations (if necessary) to heat the reactor coolant. The MHS design eliminates the possibility of boron dilution via inter-system leakage by providing double isolation valves with drains and pressure monitoring between the isolation valves. The instrument air supply to these valves can be removed via administrative controls to prevent a spurious or inadvertent opening. ~~A MHS heat exchanger tube rupture or loss of the auxiliary boiler system (ABS) steam may result in an addition of cooler water to the reactor coolant system (RCS). This is a single-module event that is evaluated in the safety analysis. An MHS component failure does not adversely affect safety-related NPM functions.~~ As an interfacing system with the chemical and volume control system (CVCS), a malfunction in the module heatup system (MHS) resulting in loss of heat addition could result in injection of colder fluid through the CVCS injection lines to the reactor coolant system. Injection of colder fluid through the CVCS injection lines, particularly during startup, could lead to decreased reactor coolant system flow due to the natural circulation forces of the NuScale reactor design. An MHS malfunction could cause a reactivity transient if the colder fluid reaches the core. The CVCS is isolated from the RCS by the module protection system on low low reactor coolant system flow, limiting the amount of cold water injection that could possibly occur. Therefore, considering the capacity of the NPM CVCS, a reactivity change due to MHS malfunction is judged a non-limiting reactivity event compared to the spectrum of reactivity events analyzed as presented in the FSAR Section 15.4. Note that for consistency with Section 15.4.4 of the Standard Review Plan, Section 15.4.4 of the FSAR discusses startup of an inactive loop or recirculation loop at an incorrect temperature; however, this event is not applicable to NuScale because the NuScale design does not have multiple coolant loops or means in the design to introduce a substantial amount of cold water similar to an inactive loop startup. A decrease in RCS inventory that could be caused by a tube failure in the MHS is bounded by the safety analysis for CVCS line breaks outside the containment vessel as presented in the FSAR Section 15.6. The MHS does not involve a unique NPM operating configuration. The design of the MHS and the CVCS reactor startup mode ensures that the reactor operates within the RCS stability map during reactor startup. A loss of both MHS heat exchangers would delay NPM startups until repairs could be made, but would not affect NPM operating configurations.
Boron addition system (BAS)	12	The BAS supplies borated water to each NPM via an interface with the module-specific CVCS. The BAS is designed to prevent a boron dilution event via plant control system (PCS) mode logic during tank transfers and batch tank manual isolation valves. BAS operation does not result in a new DBE. Administrative controls are used to control boron concentrations. A BAS component failure does not adversely affect safety-related NPM functions. As described in Section 9.3.4, the BAS sizing is conservatively based on a 12-NPM shutdown event. The BAS is designed such that the loss or outage of a single major component does not result in a significant loss of plant capacity, and a failure of a single BAS component does not prevent continued operation of up to 12 NPMs. In the unlikely event of a total failure of the BAS, failure to deliver borated water to the CVCS may result in a controlled reactor shutdown if the condition persists in the long term. If the BAS design features and administrative controls that prevent dilution fail, a failure of the CVCS that results in the BAS and demineralized water system (DWS) combining valve spuriously repositioning to the DWS bounds the BAS dilution.

Table 21-2: Shared System Interactions (Mechanical Systems) (Continued)

Shared System	NPMs Supported	System Interactions
Containment flooding and drain system (CFDS)	Two independent subsystems each supporting 6 NPMs	The CFDS subsystems are only operated after shutdown and prior to startup of a single NPM at a time. The NPM interface is via a nozzle in the CNV through containment isolation valves. There are three normally closed valves in series between the CFDS pumps and an NPM's containment. These include two containment isolation valves and a CFDS module isolation valve. The sequence necessary to inadvertently flood a containment of an operating NPM requires multiple spurious failures, starting of a CFDS pump, and operator errors, and is not considered an initiating event for containment flooding. A CFDS component failure does not adversely affect safety-related NPM functions. The CFDS can provide water to the CNV for cooling during a beyond design basis event as described in Section 9.3.6.
Reactor component cooling water system (RCCWS)	Two independent subsystems each supporting 6 NPMs	Each RCCWS supports up to 6 NPMs at a time. The system interface with the NPM is via control rod drive mechanism (CRDM) cooling within the NPM and via system piping routed in the CNV. The RCCWS is designed such that no single failure can cause the loss of RCCWS heat removal from more than one NPM. A leak in an RCCWS cooler, heat exchanger, condenser, or tank can be isolated locally. This could cause the shutdown of an individual NPM depending on the component failure, but it would not require the shutdown of multiple NPMs. In the event a NPM is shut down for maintenance or refueling, the RCCWS will continue to operate under normal conditions for the other five NPMs with the isolation valves closed to the CRDMs for the shutdown NPM. An RCCWS component failure does not adversely affect safety-related NPM functions. The RCCWS has no piping in the CNV. The RCCWS supplies RCCW to CVCS piping that then conducts RCCW to the CRDM piping. ~~RCCWS p~~Pipe breaks inside the containment that could release RCCW are isolated on high-containment pressure, but could result in a design basis loss of containment vacuum or containment flooding event and are included as a single-module event in the safety analysis. The ~~RCCWS~~ pipe break resulting in a release of RCCW does not result in an emergency core cooling system actuation from a high CNV water level. Section 15.1.6 of the FSAR discusses the safety analysis for RCCWS pipe breaks inside the containment vessel. A failed-open RCCWS flow control valve on the CVCS non-regenerative heat exchanger secondary side may result in introduction of cooler CVCS water to the NPM primary system~~, which is a single module event that is considered in the safety analysis,~~ but does not result in a new DBE. In addition, Section 15.5.1 of the FSAR addresses cold water injection through the CVCS, focusing on pressurization related to the increased inventory. A loss of RCCWS to the CVCS nonregenerative heat exchanger adds negative reactivity and is not a DBE. A total failure of a RCCW subsystem would eventually result in a manual shutdown of up to six NPMs due to rising CRDM temperatures, which are indicated in the control room, but does not prevent safety-related NPM functions and does not result in a design basis event.

Table 21-2: Shared System Interactions (Mechanical Systems) (Continued)

Shared System	NPMs Supported	System Interactions
Process sampling system (PSS)	12	The PSS is designed such that the system interfaces with multiple NPMs are limited. The sampling of individual NPM process fluid streams is module-specific. Each NPM is provided with its own PSS. Six primary sampling systems share a cooling water temperature control unit that supplies chilled water to their second-stage sample coolers. Secondary sampling systems have both module-specific and shared components. A containment sampling system used for collecting gas samples from the containment evacuation system is also provided for each NPM. As described in Section 9.3.2, the PSS is connected to the NPM via intervening systems and does not employ sample lines which penetrate the CNV or the reactor pressure vessel. There are no containment isolation valves or containment isolation functions included in the PSS. The shared components are due to common downstream equipment such as sample coolers and the ion chromatograph units. A component failure of this shared equipment does not affect plant operation or adversely affect safety-related NPM functions.
Circulating water system	Two subsystems each supporting 6 NPMs	A loss of circulating water results in a transient that would impact multiple NPMs, but does not adversely affect safety-related NPM functions. ~~The loss of~~A malfunction affecting the circulating water may result in a loss of condenser vacuum, loss of feedwater, or decrease in feedwater temperature and is evaluated in the safety analysis. The circulating water system interface with the condensate and feedwater system is the only interface relevant for the purpose of DBE identification. The ~~reduced~~change in heat removal from the secondary side due to these types of conditions is ~~bounded by consideration of loss of feedwater events~~considered in Section 15.1 and Section 15.2 in the FSAR. A total loss of circulating water would require that the 12 NPMs enter a shutdown state as process conditions would encroach on reactor trip setpoints.
Site cooling water system (SCWS)	12	The SCWS provides cooling water to auxiliary systems, interfacing with chiller condensers, instrument air compressor coolers, and heat exchangers for reactor pool cooling, spent fuel pool cooling, reactor component cooling water, condenser air removal, and turbine generators. In addition, the SCWS interfaces with main steam sample coolers, condensate and feedwater sample coolers, process sampling system chillers, and auxiliary boiler blowdown coolers. An SCWS failure is captured in the safety analysis by a failure in the interfacing system and does not result in a new DBE. The SCWS failure may affect the operation of multiple NPMs, but does not adversely affect safety-related NPM functions. A total loss of SCWS would affect cooling of auxiliary systems across multiple NPMs and would likely result in manual reactor trips due to loss of RCCWS and high CRDM temperatures.

Table 21-2: Shared System Interactions (Mechanical Systems) (Continued)

Shared System	NPMs Supported	System Interactions
Nitrogen distribution system (NDS)	12	The NDS provides pressure-regulated nitrogen supplies to various plant systems. An NDS failure is captured in the safety analysis by a failure in the interfacing system and does not result in a new DBE. Failure of the gaseous radioactive waste system is addressed in FSAR Section 11.3.2. Failure of the liquid radioactive waste system is addressed in FSAR Section 11.2. Failure of the chemical and volume control system is addressed in FSAR Section 9.3.4. Failure in the containment evacuation system is addressed in FSAR Section 9.3.6. Failure in the main steam system is addressed in FSAR Section 10.3. The NDS failure may affect the operation of multiple NPMs, but does not adversely affect safety-related NPM functions. A plant shutdown is not expected in the event of a total loss of the NDS. The operational impacts of a total loss of NDS are limited to the liquid radwaste and gaseous radwaste systems.
Demineralized water system (DWS)	12	The DWS provides makeup to various systems. ~~, and f~~Failures in the DWS are accounted for by considering failures in the DWS interface to the CVCS, which is a module-specific system. The DWS interfaces with the CVCS as a dilution source for boron concentration. A DWS failure does not adversely affect safety-related NPM functions. The DWS can be a dilution source to a single NPM via a spurious repositioning of a CVCS BAS and DWS combining valve to the DWS during makeup operation, which is evaluated in the safety analysis in FSAR Section 15.4.6. The design failure position of the combining valve is open to the BAS and closed to the DWS, which is the safe position. Boron dilution events are indicated by NPM power and reactivity instruments, and trigger closure of the CVCS demineralized water supply isolation valves if the safety setpoints are reached. There are two isolation valves in series in the DWS supply to each CVCS to satisfy single failure criteria. The valves are fail-closed air-operated valves. The DWS is not credited in a DBE, but may be used as an inventory makeup source via the CVCS. The DWS also provides plant support during abnormal conditions by providing additional makeup water to the spent fuel pool cooling system (SFPCS) to compensate for inventory loss and to the condenser for emergency fill. In the event of a total loss of DWS, a manual shutdown may be required due to loss of CVCS makeup if the failure persists in the long term.
Fire protection system and fire detection system	12	The fire systems are in a standby status during normal operation, and failures or inadvertent operation of these systems do not result in DBEs and do not adversely affect safety-related NPM functions. The fire hazard analysis includes an analysis of the protection of nuclear safety-related systems and components from inadvertent actuation and breaks in a fire protection system as described in Section 9A. Failures in these systems are subject to the requirements of the Fire Protection Program, which is described in Section 9.5 and is included in the administrative controls portion of the technical specifications.
Fuel handling equipment	12	Fuel handling accidents are described in Section 15.7.4. These accidents do not result in a DBE in operating NPMs and do not adversely affect safety-related NPM functions.

Table 21-2: Shared System Interactions (Mechanical Systems) (Continued)

Shared System	NPMs Supported	System Interactions
Instrument air system (IAS)	12	Local failures in the IAS that would affect a specific valve are not explicitly considered in the safety analysis as the effects of such failures are considered in the interfacing system. The loss of the IAS that could affect multiple valves is considered. These failures may result in multi-module events, but do not adversely affect safety-related NPM functions. Loss of instrument air will cause closure of the secondary main steam isolation valves and possibly valves in the turbine generator system. Loss of instrument air may cause loss of containment vacuum due to closure of valves in the containment evacuation systems. The IAS supports the CVCS, and loss of instrument air could affect normal pressurizer spray control, recirculation, or makeup and letdown operation. The operation of these normal, non-safety control systems is considered as part of evaluating DBEs. Loss of instrument air on other systems does not cause significant direct impact on an NPM that is not already accounted for by considering the availability of normal non-safety controls in the safety analysis. The loss of instrument air is bounded by the turbine trip in the safety analysis (discussed in FSAR Section 15.2) because the immediate effects of a loss of air result in the closure of the secondary main steam isolation valves. Loss of the IAS is bounded by the turbine trip event because: Loss of instrument air will not cause the containment isolation valves to automatically close. Loss of instrument air will cause closure of the backup nonsafety main steam isolation valves and possibly valves in the turbine generator system. Loss of instrument air will not cause immediate closure of the feedwater regulating valves due to local air accumulators on those valves. Loss of instrument air may cause loss of containment vacuum due to closure of valves in the containment evacuation systems. However, this increase in heat removal from the primary side due to loss of containment vacuum is assumed to be insignificant compared to the decrease in heat removal from decreased steam flow. A total loss of the IAS would lead to an automatic shutdown on the 12 NPMs when closure of the secondary main steam isolation valves results in a reactor trip.
Gaseous radioactive waste system (GRWS)	12	A GRWS system failure is considered by failures of the GRWS interfacing system that more directly impacts the RCS such as the containment evacuation system. A GRWS failure does not introduce a new DBE and does not adversely affect safety-related NPM functions. Section 11.3.2 includes a GRWS equipment malfunction analysis and an evaluation of the radiological consequences of GRWS failures.
Liquid radioactive waste system (LRWS)	12	A LRWS system failure is considered by failures of the LRWS interfacing system that more directly impacts the RCS, such as CVCS. A LRWS failure does not introduce a new DBE and does not adversely affect safety-related NPM functions. Section 11.2.2 includes an evaluation of the consequences of LRWS failures. A total loss of the LRWS would complicate letdown operations.
Auxiliary boiler system (ABS)	12	Failures in the ABS are accounted for by considering failures in the MHS interface (considered part of the CVCS for analysis purposes). An ABS failure does not result in a new DBE and does not affect safety-related NPM functions.