UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 26, 2018

MEMORANDUM TO: Samuel S. Lee, Chief
Licensing Branch 1
Division of New Reactor Licensing
Office of New Reactors

FROM: Marieliz Vera Amadiz, Project Manager ***/RA/***
Licensing Branch 1
Division of New Reactor Licensing
Office of New Reactors

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REPORT OF INITIAL REGULATORY AUDIT FOR EMERGENCY CORE COOLING SYSTEM VALVES IN NUSCALE POWER, LLC, DESIGN CERTIFICATION APPLICATION

On January 6, 2017, NuScale Power, LLC (NuScale) submitted a design certification (DC) application for a small modular reactor (SMR) to the U.S. Nuclear Regulatory Commission (NRC) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17013A229). In a letter dated March 23, 2017, the NRC accepted for docketing the DC application for the SMR design submitted by NuScale (ADAMS Accession No. ML17074A087).

The NRC staff has conducted an initial audit of the design of the emergency core cooling system (ECCS) valves described in the NuScale DC application, Final Safety Analysis Report (FSAR), Section 6.3, "Emergency Core Cooling System." The audit was conducted from November 28, 2017, to January 17, 2018, in accordance with the audit plan (ADAMS Accession No. ML17325B037).

The purpose of the audit was to: (1) gain a better understanding of the NuScale design; (2) verify FSAR information; (3) identify information that may require docketing to support the basis of the licensing or regulatory decision; and (4) review related documentation and non-docketed information to evaluate conformance with regulatory guidance and compliance with NRC regulations.

The NRC staff conducted the audit via access to NuScale's electronic reading room and telephone conferences with the applicant. The audit was conducted in accordance with the NRC Office of New Reactors (NRO) Office Instruction, NRO-REG-108, "Regulatory Audits" (ADAMS Accession No. ML081910260).

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The audit report, audit attendee list, and follow-up item list are enclosed with this memorandum.

Docket No. 52-048

Enclosures:
1. Audit Report
2. List of Audit Attendees
3. Follow-Up Items List

cc: NuScale DC ListServ

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION STAFF REPORT OF INITIAL REGULATORY AUDIT FOR EMERGENCY CORE COOLING SYSTEM VALVES IN NUSCALE POWER, LLC DESIGN CERTIFICATION APPLICATION
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NUSCALE POWER, LLC

SUMMARY REPORT OF INITIAL AUDIT REGARDING

EMERGENCY CORE COOLING SYSTEM VALVES IN NUSCALE DESIGN

INTRODUCTION AND BACKGROUND

In a letter dated March 23, 2017, the NRC accepted for docketing the NuScale Power, LLC (NuScale) Standard Plant Design Certification (DC) Application for a small modular reactor (SMR) design (Reference 1).

The NRC staff determined that efficiency gains would be realized by auditing the documents supporting the NuScale SMR design presented in the NuScale Final Safety Analysis Report (FSAR), in lieu of multiple requests for additional information (RAIs) for the applicant to submit design documents. The purpose of this audit was to allow the NRC technical staff to understand the design of the emergency core cooling system (ECCS) valves in the NuScale reactor to support preparation of the NRC safety evaluation.

In this report, the NRC staff summarizes the results of the initial audit of the design of the ECCS valves in the NuScale reactor. As discussed herein, the staff plans to conduct a future audit to review the follow-up items related to the demonstration of the safety features of the ECCS valves identified during this initial audit.

REGULATORY AUDIT BASES

The audit basis was to determine that the design of the NuScale ECCS valves satisfies the regulatory requirements for demonstrating the safety features of the NuScale reactor. The audit basis also was to confirm that the ECCS valve design is consistent with the assumptions for the performance of those valves in the NuScale DC application.

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Section 52.47, "Contents of Applications; Technical Information," states the following:

> *The application must contain a level of design information sufficient to enable the Commission to judge the applicant's proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted. The information submitted for a design certification must include performance requirements and design information sufficiently detailed to permit the preparation of acceptance and inspection requirements by the NRC, and procurement specifications and construction and installation specifications by an applicant. The Commission will require, before design certification, that information normally contained in certain procurement specifications and construction and installation specifications be completed and available for audit if*

the information is necessary for the Commission to make its safety determination.

Paragraph (c) in 10 CFR 52.47 specifies the following requirements for applications that differ from the light-water reactor designs that have been licensed to date:

> *(c) This paragraph applies, according to its provisions, to particular applications:*
>
> > *(1) An application for certification of a nuclear power reactor design that is an evolutionary change from light-water reactor designs of plants that have been licensed and in commercial operation before April 18, 1989, must provide an essentially complete nuclear power plant design except for site-specific elements such as the service water intake structure and the ultimate heat sink;*
> >
> > *(2) An application for certification of a nuclear power reactor design that differs significantly from the light-water reactor designs described in paragraph (c)(1) of this section or uses simplified, inherent, passive, or other innovative means to accomplish its safety functions must provide an essentially complete nuclear power reactor design except for site-specific elements such as the service water intake structure and the ultimate heat sink, and must meet the requirements of 10 CFR 50.43(e); and*
> >
> > *(3) An application for certification of a modular nuclear power reactor design must describe and analyze the possible operating configurations of the reactor modules with common systems, interface requirements, and system interactions. The final safety analysis must also account for differences among the configurations, including any restrictions that will be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating.*

Paragraph (e) in 10 CFR 50.43 required by 10 CFR 52.47(c)(2) specifies the following requirements:

> *(e) Applications for a design certification, combined license, manufacturing license, or operating license that propose nuclear reactor designs which differ significantly from light-water reactor designs that were licensed before 1997, or use simplified, inherent, passive, or other innovative means to accomplish their safety functions, will be approved only if:*
>
> *(1) (i) The performance of each safety feature of the design has been demonstrated through either analysis, appropriate test programs, experience, or a combination thereof;*
>
> *(ii) Interdependent effects among the safety features of the design are acceptable, as demonstrated by analysis, appropriate test programs, experience, or a combination thereof; and*
>
> *(iii) Sufficient data exist on the safety features of the design to assess the analytical tools used for safety analyses over a sufficient range of normal*

operating conditions, transient conditions, and specified accident sequences, including equilibrium core conditions; or

(2) There has been acceptable testing of a prototype plant over a sufficient range of normal operating conditions, transient conditions, and specified accident sequences, including equilibrium core conditions. If a prototype plant is used to comply with the testing requirements, then the NRC may impose additional requirements on siting, safety features, or operational conditions for the prototype plant to protect the public and the plant staff from the possible consequences of accidents during the testing period.

The NRC staff reviewed the available design documents for the ECCS valves described in the NuScale FSAR Tier 2:

- Section 3.9.6, "Functional Design, Qualification, and Inservice Testing Programs for Pumps, Valves, and Dynamic Restraints," and

- Section 6.3, "Emergency Core Cooling System."

The NRC staff conducted this audit in accordance with the guidance provided in the Office of New Reactors (NRO)-REG-108, "Regulatory Audits" (Reference 2).

NRC AUDIT TEAM

Thomas G. Scarbrough, Senior Mechanical Engineer (NRC), Audit Lead
John Budzynski, Reactor Systems Engineer (NRC)
Clinton Ashley, Reactor Systems Engineer (NRC)
Luis Betancourt, Electronics Engineer (NRC)
Marieliz Vera Amadiz, Project Manager (NRC)

AUDIT PREPARATION

The NRC staff issued a detailed audit plan (Reference 3) that identified the information needed for the audit. The audit plan requested that documentation related to the design of the ECCS valves in the NuScale reactor be provided for review. NuScale made available specific design documents related to the ECCS valves in the NuScale electronic reading room (eRR).

DOCUMENTS MADE AVAILABLE BY NUSCALE FOR THE AUDIT

Below is a list of the design documents related to the ECCS valves made available in the NuScale eRR:

1. NuScale Report ER-B020-3817 (Revision A, December 18, 2015), "Proof of Concept Test Report for Emergency Core Cooling (ECC) System Valves."

2. NuScale Drawing Document NP12-00-B020-M-GA-2617 (Revision 0, October 20, 2017), "Reactor Vent Valve Drawing."

3. NuScale Drawing Document NP12-00-B020-M-GA-2650 (Revision 0, October 20, 2017), "Reactor Recirculation Valve Drawing."

4. NuScale Drawing Document NP12-00-B020-M-GA-2651 (Revision 0, October 20, 2017), "Trip and Reset Valves Drawing."

5. NuScale Drawing Document NP12-00-B020-M-GA-5679 (Revision 0, October 20, 2017), "Inadvertent Actuation Block Drawing."

6. NuScale Drawing Document NP12-00-B020-A-GA-5690 (Revision 0, October 20, 2017), "Single Trip Valve Drawing."

NUSCALE ECCS DESIGN

NuScale FSAR Tier 2, Section 6.3, provides the following description of the ECCS for the NuScale reactor design:

> *The emergency core cooling system (ECCS) provides core cooling during and after anticipated operational occurrences (AOOs) and postulated accidents, including loss-of-coolant accidents (LOCAs). The ECCS is an important NuScale Power Plant safety system in its safety-related response to LOCAs and as a component of both the reactor coolant and containment vessel (CNV) pressure boundaries. In conjunction with the containment heat removal function of containment, the ECCS provides core decay heat removal in the event of a loss of coolant that exceeds makeup capability.*
>
> *The ECCS consists of three reactor vent valves (RVVs) mounted on the upper head of the reactor pressure vessel (RPV), two reactor recirculation valves (RRVs) mounted on the side of the RPV, and associated actuators located on the upper CNV as shown in Figure 6.3-1. All five valves are closed during normal plant operation and open to actuate the system during applicable accident conditions. The RVVs vent steam from the RPV into the CNV, where the steam condenses and liquid condensate collects in the bottom of the containment. The RRVs allow the accumulated coolant to reenter the RPV for recirculation and cooling of the reactor core. Placement of the RRV penetrations on the side of the RPV is such that when the system is actuated, the coolant level in the RPV is maintained above the core and the fuel remains covered. The cooling function of the ECCS is entirely passive, with heat conducted through the CNV wall to the reactor pool.*
>
> *After actuation, the ECCS is a passive system that does not include long lengths of piping or holding tanks. The system is made up of the valves described above, which allow recirculation of the reactor coolant between the RPV and the CNV. The valves are maintained in the closed position during normal plant operation and receive an actuation signal upon predetermined event conditions (initiated by low RPV level or high containment level) to depressurize the RPV and allow flow of reactor coolant between the CNV and the RPV.*
>
> *Reactor coolant inventory released during a LOCA event is collected and retained within the CNV which precludes the requirement to provide the makeup capacity necessary to replace coolant inventory lost to the core cooling function. The ECCS does not provide replacement or addition of inventory from an external source and does not provide a reactivity control function.*

Facility design relies on passive design provisions that ensure sufficient coolant inventory is retained in the module to maintain the core covered and cooled. Makeup (addition) of reactor coolant inventory is not necessary or relied upon to protect against breaks. Reactor coolant inventory released from the reactor vessel during an in-containment unisolatable LOCA is collected and maintained within the CNV. After the ECCS valves open, the collected RCS inventory is returned to the reactor vessel by natural circulation. This return path to the vessel ensures that the core remains covered. The coolant inventory maintained in the reactor coolant system (RCS), assuming minimum allowed pressurizer (PZR) level, is adequate to provide sufficient coolant level in the CNV during a postulated design basis LOCA and maintain the reactor core covered. This is further discussed in Section 6.2.2.

Based on the description in the NuScale FSAR and design documents, each ECCS valve consists of 4 distinct valve subcomponents connected by several feet of tubing that contains borated reactor coolant as follows:

a) the main valve of the RVV that opens to allow steam in the RPV to be released to the CNV (and the main valve of the RRV that opens to allow coolant in the CNV to enter the RPV) by reactor pressure (and a small spring force) when the main valve control chamber is vented to the CNV;

b) a solenoid-operated trip valve located outside the CNV in the cooling pool that is normally closed and is de-energized to open to vent borated reactor coolant from the main valve control chamber to the CNV;

c) a solenoid-operated reset valve located outside the CNV in the cooling pool that is normally closed and is energized to open to pressurize the main valve control chamber with borated reactor coolant sufficient to initially close the main valve against its small spring force; and

d) an inadvertent block (IAB) valve which is normally open but promptly closes (by the differential pressure between the RPV and CNV against a large spring force when the trip valve initially opens) to prevent the main valve control chamber from being vented to the CNV (and to keep the main valve fully closed) until the differential pressure between the RPV and CNV is reduced sufficiently to allow the spring to open the IAB valve and vent the main valve control chamber to allow the main valve to open.

ECCS VALVE AUDIT PERFORMANCE

Based on the review of the description of the ECCS valves provided in NuScale FSAR Tier 2, Section 6.3, the NRC staff prepared RAI 8820, dated June 2, 2017, to obtain information on the design of the ECCS valves to be installed in the NuScale reactor to support the NRC review of the NuScale DC application. In its response to RAI 8820, dated August 1, 2017 (ADAMS Accession No. ML17213A540), NuScale provided information on the design of the ECCS valves and the schedule for completing activities to support the design of those valves. The NRC staff determined that an audit of the design documentation for the ECCS valves would be the most efficient method to complete the review of the design of the ECCS valves in the NuScale reactor.

The NRC staff performed the initial audit of the NuScale ECCS valve design to determine that 10 CFR 52.47(c)(2) and 10 CFR 50.43(e) have been satisfied, including the following:

a. Determine whether the ECCS design drawings and other design documents support the first-of-a-kind (FOAK) valve design as reasonable to perform the safety functions specified in the NuScale design certification application.

b. Determine whether the ECCS valves (and the valve subcomponents) will perform their safety functions in a timely manner over their full range of operational conditions.

c. Determine whether the ECCS valves will not inadvertently open when the differential pressure between the RPV and CNV exceeds the specified conditions.

d. Determine whether the Failure Modes and Effects Analysis (FMEA) for the ECCS valve design addresses potential failure mechanisms to provide reasonable assurance that the valve design analysis and testing will demonstrate the capability and reliability of the ECCS valves.

e. Determine whether the IAB valve in the ECCS valve can be assumed to be a passive device with a reliability consistent with the Commission policy on passive components with respect to the single failure criterion.

f. Determine whether the ECCS valve will reliably fully open during operation of the main valve and pressure release from the main chamber through the IAB valve.

g. Determine whether the plans for valve design testing will demonstrate the capability and reliability of the ECCS valve to support the assumptions in the NuScale DC application.

h. Determine whether the qualification plans are sufficient to provide reasonable assurance that a holder of a combined license for the NuScale design will demonstrate the qualification of the ECCS valves to perform their safety functions over the full range of operational conditions up through design-basis conditions.

In conducting this initial audit, the NRC staff reviewed the documents related to the design of the NuScale ECCS valves that were made available in the eRR. The NRC staff conducted telephone conferences with NuScale personnel to discuss those documents and the design of the ECCS valves. The staff provided comments to the NuScale personnel on the ECCS valve design during those telephone conferences.

CONCLUSIONS

Based on this initial audit, the NRC staff concludes that NuScale has not provided sufficient information necessary to demonstrate the safety features of the ECCS valves as required by 10 CFR 52.47(c)(2) and 10 CFR 50.43(e). In particular, NuScale has not demonstrated the capability and reliability of the ECCS valves to perform their safety functions to support the NuScale DC application. For example, NuScale was not able to make available the FMEA for the ECCS valves originally planned to be completed in December 2017. In an enclosure to this report, the NRC staff provides a list of follow-up items to be addressed during a future audit of the design of the ECCS valves.

Among the most significant remaining items for the demonstration of the safety features of the ECCS valves to satisfy the NRC regulations are the following:

(1) the capability of the main valve to open fully in a timely manner for design-basis conditions when required;

(2) the capability of the main valve to not partially or fully open prematurely;

(3) the capability of the IAB valve to close and seal the vent line in a timely manner at the initial opening of the trip valve to prevent the main valve from opening partially or fully until the differential pressure between the RPV and CNV has reduced sufficiently to the specified conditions;

(4) the capability of the IAB valve to open in a timely manner when the differential pressure between the RPV and CNV has reduced sufficiently to the specified conditions to allow the main valve to open fully to initiate emergency core cooling within the time specified in accident analyses;

(5) the capability of the trip valve and line size, orifices, fittings, and installed configuration to vent the trip line adequately in a timely manner to allow the differential pressure between the RPV and CNV to close and seal the IAB valve against the force of the IAB spring to prevent the main valve from opening partially or fully (with consideration of hot borated water flashing to steam and boron deposits) until the differential pressure between the RPV and CNV has reduced sufficiently to the specified conditions; and

(6) the capability of the trip valve and line size, fittings, and installed configuration to vent the trip line adequately in a timely manner after the IAB valve has opened to vent the main valve control chamber (with consideration of hot borated water flashing to steam and boron deposits) to allow the main valve to fully open within its stroke-time requirements.

The NRC staff will evaluate the follow-up items identified during this initial audit as part of a future audit.

<u>REFERENCES</u>

1. NRC Letter, “NuScale Power, LLC. – Acceptance of an Application for Standard Design Certification of a Small Modular Reactor,” dated March 23, 2017 (ADAMS Accession Number ML17074A087).

2. NRO-REG-108, “Regulatory Audits”, April 2, 2009 (ADAMS Accession No. ML081910260).

3. “Audit Plan for Regulatory Audit of NuScale Power, LLC; Design Documents for Emergency Core Cooling System Valves,” dated November 21, 2017 (ADAMS Accession No. ML17325B037).

4. NuScale Power, LLC Response to NRC Request for Additional Information No. 47 (eRAI No. 8820) on the NuScale Design Certification Application, dated June 2, 2017 (ADAMS Accession No. ML17213A540).

U.S. NUCLEAR REGULATORY COMMISSION

INITIAL REGULATORY AUDIT FOR THE EMERGENCY CORE COOLING SYSTEM VALVES

IN THE NUSCALE POWER, LLC DESIGN CERTIFICATION APPLICATION

LIST OF ATTENDEES

November 28, 2017 – January 17, 2018

U.S. Nuclear Regulatory Commission Staff Participants:

Thomas G. Scarbrough, Senior Mechanical Engineer
John Budzynski, Reactor Systems Engineer
Clinton Ashley, Reactor Systems Engineer
Luis Betancourt, Electronics Engineer
Marieliz Vera Amadiz, Project Manager

NuScale Power, LLC Participants:

Zack Houghton
Colin Sexton
Scott Harris
Greg Myers
Jennie Wike
Marty Bryan

U.S. NUCLEAR REGULATORY COMMISSION

INITIAL REGULATORY AUDIT FOR THE EMERGENCY CORE COOLING SYSTEM VALVES

IN THE NUSCALE POWER, LLC DESIGN CERTIFICATION APPLICATION

Follow-Up Items from Initial Regulatory Audit of NuScale Emergency Core Cooling System Valves

1. NuScale stated that the valve supplier (Curtiss-Wright Target Rock) has conducted calculations and analyses to support the design and performance of the Emergency Core Cooling System (ECCS) valves, including the main valve, inadvertent block (IAB) valve, trip valve, and reset valve. For example, NuScale stated that the Target Rock calculations and analyses include the following:

   a) sizing and flow capacity calculations for the ECCS main valve, including assumptions for set pressure, overpressure, temperature, flow rate, backpressure, flow coefficient (C_v), pressure drop ratio factor (X_T), and appropriate correction factors;

   b) force balance on the main disk during the stages of actuation;

   c) evaluation of the performance of the main valve with a control orifice and filter intended to allow the main chamber to achieve and maintain full reactor pressure condition during plant operation;

   d) evaluation of the temperature effects in the sizing of the four valve subcomponents of the ECCS valve from normal room temperature to the operating conditions of each subcomponent; and

   e) summary analysis report of the ECCS valve design.

   NuScale stated that the detailed design documentation is maintained at the valve supplier facility. The NRC staff plans to review the ECCS valve calculations and analyses at the valve supplier facility as part of its evaluation of the design of the ECCS valve and its subcomponents.

2. NuScale stated that the ECCS valve will be designed such that the main valve will move to its full open position in a timely manner upon actuation, and remain in the full open position throughout its required operation. The NRC staff will review the Failure Modes and Effects Analysis (FMEA) to evaluate the potential failure modes of the ECCS valve (including its four valve subcomponents) when made available by NuScale during a future audit.

3. NuScale Design Drawing NP12-00-B020-M-GA-2617, “Reactor Vent Valve Drawing,” identifies the Reactor Vent Valve (RVV) as Nominal Pipe Size (NPS) 5 with a 4.88-inch inlet diameter and a 4.625-inch discharge diameter. NuScale FSAR Tier 2, Section 6.3, “Emergency Core Cooling System,” specifies the RVV as a 6-inch valve. NuScale Design Drawing NP12-00-B020-M-GA-2650, “Reactor Recirculation Valve Drawing,” identifies the Reactor Recirculation Valve (RRV) as NPS 2 with a 2.25-inch inlet

diameter and a 2-inch discharge diameter. NuScale FSAR Tier 2, Section 6.3 specifies the RRV as a 4-inch valve. The NRC staff will evaluate the differences between the FSAR descriptions and design drawings for the RVVs and RRVs.

4. NuScale Design Drawings NP12-00-B020-M-GA-2617 and NP12-00-B020-M-GA-2650 specify a filter assembly installed in the orifice between the reactor coolant pressure and main valve control chamber for both the RVV and RRV, respectively. The NRC staff will evaluate the demonstration by NuScale that the filter assembly will not impact the capability of the RVV and RRV to perform their safety functions.

5. NuScale Design Drawing NP12-00-B020-M-GA-2617 indicates a diffuser assembly is installed near the discharge of the RVV. NuScale stated that the full assembly, including the diffuser, will undergo design testing to demonstrate the performance of the ECCS valves. The NRC staff will evaluate the design test setup, performance, and results for the potential impact of the diffuser assembly on the performance of the ECCS valves.

6. NuScale stated that the design of the IAB valve is consistent with the description in the response to the NRC Request for Additional Information (RAI) 8815 (Question 15-2) provided in the NuScale letter dated July 21, 2017 (ADAMS Accession No. ML17202V093). The RAI response states that the top of the rod is kept off the vent line seat by the pressure of the fluid in the control chamber and the vent line. However, the rod appears to be maintained in the open position by the IAB spring force. The rod will move against the vent line seat when the differential pressure between the reactor coolant system and the vent line is sufficient to overcome the IAB spring force. The NRC staff will review the final design of the IAB valve for consistency with the description in the RAI response.

7. NuScale stated that the ongoing detailed design evaluation of the IAB valve will provide reasonable assurance of the closure of the vent port in a timely manner to prevent the main valve chamber from losing pressure such that the main valve would open (fully or partially) prior to the differential pressure between the reactor pressure vessel (RPV) and containment vessel (CNV) being reduced to the specified value. The NRC staff will review the final design of the IAB valve for its performance characteristics during a future audit.

8. NuScale stated that the ongoing detailed design evaluation of the IAB valve will provide reasonable assurance of the sealing requirements for the vent port to prevent leakage from the main chamber prior to the differential pressure between the RPV and CNV being reduced to the assumed value for main valve opening. NuScale Drawing Document NP12-00-B020-M-GA-5679, “Inadvertent Actuation Block Drawing,” identifies the IAB valve assembly as a Category A valve in accordance with the inservice testing (IST) program requirements in the American Society of Mechanical Engineers (ASME) “Code for Operation and Maintenance of Nuclear Power Plants” (OM Code). NuScale stated that it will evaluate the IAB valve categorization in the NuScale IST Program to satisfy the ASME OM Code regarding leakage requirements. The NRC staff will review the final design of the ECCS valve (including the IAB valve) to support its IST categorization.

9. NuScale stated that the orientation of the trip and reset valves for the RVVs and RRVs might not match the orientation indicated in NuScale FSAR Tier 2, Figure 6.3-3, “Emergency Core Cooling System Valve and Actuator Hydraulic Schematic,” on page

6.3-27. NuScale stated that the actual design will have the reset valve on the top of the assembly, and the trip valve on the bottom of the assembly, to allow gravity to assist in the operation of each valve. The NRC staff will verify this orientation in final design drawings of the NuScale ECCS valves.

10. NuScale stated that the four ECCS valve subcomponents will not be designed to allow adjustments following installation. NuScale stated that shims will be installed in the ECCS valve to adjust its performance during pre-installation testing. NuScale Drawing Document NP12-00-B020-M-GA-5679 specifies that shims will be installed between the spring and disc to achieve the IAB threshold and IAB release pressures within the specification requirements. NP12-00-B020-M-GA-5679 specifies that the IAB threshold pressure will be set between 1100 and 1200 pounds per square inch differential (psid), and that the IAB release pressure will be set between 1000 and 1100 psid, at the factory. The NRC staff will review the design of the ECCS valves (including shims and their precision) to account for variations between pre-installation testing and normal operating conditions.

11. NuScale stated that only position indication of the main valve and trip/reset valves will be monitored to demonstrate the operational readiness of the ECCS valves. The NRC staff will review the design of the ECCS valves to provide reasonable assurance of operational readiness of the ECCS valves (including operation of the IAB valve).

12. NuScale stated that the trip/reset lines and control chamber of the ECCS main valve will be filled with borated water from the chemical volume and control system (CVCS) during initial setup prior to plant startup. When the trip valve is opened, hot borated water will flash to steam in the main control chamber, IAB valve, and trip line. The NRC staff will review the design of the ECCS valves to provide reasonable assurance that the flashing of hot borated water and boron deposits will not interfere with the reliability and timeliness of the operation of the NuScale ECCS valves.

13. The NRC staff reviewed NuScale Report ER-B020-3817 on proof-of-concept testing prepared by the valve supplier in 2015 and made available by NuScale during this initial audit. The test report stated that the testing demonstrated the viability of the ECCS valve design, and the expected operation of the disconnected pilot concept and the IAB feature, in this first-of-a-kind engineering (FOAKE) design for the ECCS valves. However, there were several significant differences between the configuration and conditions for the valves used in the proof-of-concept testing and the ECCS valves. Some of the differences are as follows:

    (a) The main valve used for the proof-of-concept testing was a 2-inch Y-pattern globe valve. The main valves for the NuScale RVVs are specified as 6-inch 90° globe valves and for the RRVs are specified as 4-inch 90° globe valves in NuScale FSAR Tier 2, Section 6.3, and associated design drawings.

    (b) The valve configuration used for the proof-of-concept testing included a main valve separate from the IAB valve. The IAB valve used for the proof-of-concept testing was indicated to be fully representative of the design of the IAB valve for the ECCS valves. In that test configuration, the high pressure to simulate the reactor coolant system entered the IAB valve directly below the IAB rod. NuScale Design Drawing NP12-00-B020-M-GA-5679 shows the IAB valve to be directly attached to the main valve with the reactor coolant system pressure to enter the IAB valve from the side to surround the rod bellows.

(c) The trip valve used for the proof-of-concept testing had a solenoid-operated valve (energize to open) with a 0.094” seat diameter for the water tests and a 3/8” manual ball valve for the air tests. The trip valve planned for the ECCS valves is a solenoid-operated valve (energize to close) with a 0.375” seat diameter.

(d) The trip line configuration used in the proof-of-concept testing provided a smaller elevation difference between the trip valve and IAB valve than will be present in the actual NuScale reactor. In addition, the fluid volume in the trip line configuration for the proof-of-concept testing was less than will be present in the actual NuScale installed configuration.

(e) The accumulator used for the proof-of-concept testing had significantly less volume for the main valve pressure than will be present in the NuScale RPV. The pressures applied in the proof-of-concept testing were not always consistent with the actual pressures for operation of the ECCS valve and its subcomponent valves. The proof-of-concept testing resulted in accumulator pressure reduction during the tests more significant than would occur during the actual ECCS valve operation. In addition, the proof-of-concept testing provided the trip line exhaust to atmospheric conditions rather than the CNV conditions.

The NRC staff will evaluate the design testing of the ECCS valves to demonstrate the safety features of the ECCS valves for the actual valve design, configuration, and operating and design-basis conditions.

14. The report of the proof-of-concept testing concluded that, overall, the test program was highly successful and proved that the proposed ECCS valve design can operate as designed. However, the test report identified several key aspects to be addressed during the detailed design and testing such as the following:

(a) Sizing of the trip valve is critical for the trip valve to adequately vent the trip line to allow operation of the main valve and to allow the IAB valve to immediately seat to prevent premature opening of the main valve.

(b) Sizing of the trip line, fittings, and orifice is critical to adequately vent the trip line.

(c) In that the proof-of-concept testing included only air and water tests, the effects of hot water, steam, and flashing will need to be assessed.

(d) The effect on valve performance from the differences between test facilities and the RPV will need to be assessed.

The NRC staff will evaluate the design testing of the ECCS valve (including its four valve subcomponents) to address the issues identified during the proof-of-concept testing and issues identified during the detailed design process and NRC staff audit findings.

15. In its response to RAI 8820, dated August 1, 2017 (ADAMS Accession No. ML17213A540), NuScale specified the schedule for the availability of ECCS valve design documents as follows: design drawings (October 2017), FMEA (December 2017), qualification plan (December 2017), test plans (May 2018), and initial tests and analyses (December 2019). NuScale was not able to make available the FMEA and

qualification plan for the ECCS valves for review during this audit. The NRC staff will review these documents supporting the design of the ECCS valves during a future audit.

16. In its response to RAI 8820, NuScale stated that the justification of the IAB valve as a passive mechanical component is provided in the response to RAI 15-2. The NRC staff reviewed the NuScale response to RAI 15-2 (dated July 21, 2017) and determined that the information is not sufficient to justify the IAB valve as a passive device consistent with the Commission policy. For example, Commission Paper SECY-77-439 (dated August 17, 1977), "Single Failure Criterion," specified that simple check valves could be considered passive components in the then-current operating plant designs. Commission Paper SECY-94-084 (dated March 28, 1994), "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs," indicated that check valves in new reactors with passive cooling systems might not be justified as passive components, because the driving head to open check valves in passive cooling systems might rely on gravity rather than pump flow. SECY-94-084 specified that a failure probability on the order of 1E-4 per year or less would be low enough to be considered a passive failure. Commission Paper SECY-05-138 (dated August 2, 2005), "Risk-Informed and Performance-Based Alternatives to the Single-Failure Criterion," described the NRC consideration of passive components in nuclear power plants. The NRC staff will review the design tests and analyses to justify the IAB valve as a passive component consistent with Commission policy during a future audit.

17. In its response to RAI 8820, NuScale stated that the ECCS valves will be designed in accordance with the ASME *Boiler and Pressure Vessel Code*, including capacity certification, with ASME design reports developed in accordance with combined license (COL) items. The NRC staff conducted a Phase 1 audit of the ECCS valve design specifications and provided comments to NuScale. NuScale stated that the Phase 1 audit comments have been addressed in the ECCS valve specifications and will be available for review in early 2018. The NRC staff will conduct a follow-up audit of the design specifications to verify that the comments have been addressed to support the design of the ECCS valves.

18. In its response to RAI 8820, NuScale summarized the proposed FSAR Tier 1 inspections, tests, analyses, and acceptance criteria (ITAAC) for the ECCS valves. The NRC staff is reviewing the ITAAC for the ECCS valves through a separate RAI process.