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

December 19, 2019

MEMORANDUM TO: Michael I. Dudek, Chief
New Reactor Licensing Branch
Division of New and Renewed Licenses
Office of Nuclear Reactor Regulation

FROM: Marieliz Vera, Project Manager ***/RA/***
New Reactor Licensing Branch
Division of New and Renewed Licenses
Office of Nuclear Reactor Regulation

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION REPORT OF THE REGULATORY FOLLOW-UP AUDIT PERFORMED BETWEEN MARCH 20, 2019, THROUGH OCTOBER 9, 2019, REGARDING EMERGENCY CORE COOLING SYSTEM VALVE DESIGN DEMONSTRATION TESTING AND FOLLOW-UP ITEMS NUSCALE POWER, LLC, STANDARD PLANT DESIGN CERTIFICATION

On January 6, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17013A229), NuScale Power, LLC (NuScale) submitted a design certification (DC) application, via a transmittal letter dated December 31, 2016, for a Small Modular Reactor to the U.S. Nuclear Regulatory Commission (NRC). The NRC staff started its detailed technical review of NuScale's DC application on March 15, 2017.

The NRC staff conducted an audit to review the design of the emergency core cooling system (ECCS) valves for the NuScale reactor, including the design demonstration testing and other follow-up items from the NRC staff's audit report "U.S. Nuclear Regulatory Commission staff report of regulatory audit of Failure Modes and Effects Analysis and other supporting documents for Emergency Core Cooling System Valves in the NuScale Power, LLC, design certification Application" dated August 14, 2018 (ADAMS Accession No. ML18219B634). The audit was initiated on March 20, 2019, and ran through October 9, 2019, in accordance with the audit plan in ADAMS (ML19067A143).

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The purpose of the audit was to: (1) gain a better understanding of the NuScale design; (2) verify 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. The audit was conducted in accordance with the NRC Office of New Reactors (NRO) Office Instruction NRO-REG-108, "Regulatory Audits."

The publicly available version of the audit report is enclosed with this memorandum.

Docket No. 52-048

Enclosure:
1. Audit Summary – (Non-Proprietary)
2. Audit Summary – (Proprietary)

cc: NuScale DC ListServ

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DATED: DECEMBER 19, 2019

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U.S. NUCLEAR REGULATORY COMMISSION

SUMMARY REPORT OF REGULATORY AUDIT OF EMERGENCY CORE COOLING

SYSTEM VALVE DESIGN DEMONSTRATION TESTING AND FOLLOW-UP ITEMS

NUSCALE POWER, LLC, STANDARD PLANT DESIGN CERTIFICATION

DOCKET NO. 52-048

I. INTRODUCTION AND BACKGROUND

On January 6, 2017, NuScale Power, LLC (NuScale) submitted a design certification application (DCA) with subsequent revisions (Reference 1) for a small modular reactor (SMR) to the U.S. Nuclear Regulatory Commission (NRC) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19241A315 for DCA Revision 3 submittal letter dated August 22, 2019). On March 23, 2017, the NRC accepted the DCA for docketing to initiate the NRC review of the NuScale SMR design (Reference 2).

NuScale DCA Part 2, Tier 2, Section 6.3, "Emergency Core Cooling System," describes the emergency core cooling system (ECCS) for the NuScale reactor. On June 2, 2017, the NRC staff prepared Request for Additional Information (RAI) 8820 to obtain information on the design of the ECCS valves to support the NRC review of the NuScale DCA. In its response to RAI 8820, dated August 1, 2017 (Reference 3), 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 audits of the design documentation would be the most efficient method to complete the review of the ECCS valves for the NuScale reactor.

In late 2017 and early 2018, the NRC staff conducted an initial audit of the NuScale documentation supporting the NuScale DCA regarding the design of the ECCS valves to be used in the NuScale SMR. On February 26, 2018, the NRC staff issued a report summarizing the results of the initial audit of the NuScale ECCS valve design (Reference 4).

In 2018, the NRC staff conducted an audit to review the Failure Modes and Effects Analysis (FMEA) and additional information at the valve vendor related to the design of the NuScale ECCS valves. On August 14, 2018, the NRC staff issued a report summarizing the results of the audit of the FMEA and other design documentation related to the ECCS valve (referred to herein as the FMEA audit report) (Reference 5).

On September 21, 2018, NuScale submitted a letter describing its plans to resolve the follow-up items specified in the FMEA audit report (Reference 6). On March 20, 2019, the NRC staff issued a plan for a regulatory audit of NuScale ECCS valve design demonstration testing and follow-up audit items (Reference 7). The NRC staff conducted this audit in accordance with the guidance provided in the Office of New Reactors (NRO)-REG-108, "Regulatory Audits" (Reference 8).

II. REGULATORY AUDIT BASIS

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Section 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 states the following specific 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, "Additional standards and provisions affecting class 103 licenses and certifications for commercial power," required by 10 CFR 52.47(c)(2) states the following:

> (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. [sic] 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 design documents for the ECCS valves described in the following portions of NuScale DCA Part 2, Tier 2:

- Section 3.9.6, “Functional Design, Qualification, and Inservice Testing Programs for Pumps, Valves, and Dynamic Restraints,”
- Section 5.2.2, “Overpressure Protection,” and
- Section 6.3, “Emergency Core Cooling System.”

III. NRC AUDIT TEAM

Thomas G. Scarbrough, Senior Mechanical Engineer (NRC), Audit Lead
Shanlai Lu, Senior Reactor Systems Engineer (NRC)
Ian Jung, Senior Reliability and Risk Analyst (NRC)
John Budzynski, Reactor Systems Engineer (NRC)
Clinton Ashley, Reactor Systems Engineer (NRC)
Alissa Neuhausen, Reliability and Risk Analyst (NRC)
Marieliz Vera, Project Manager (NRC)

IV. AUDIT PURPOSE

The purpose of this audit was to evaluate the ECCS Valve Design Demonstration Testing, including test plans, procurement requirements, set-up and performance specifications, procedures, acceptance criteria, quality assurance (QA) provisions and implementation, equipment and instrumentation descriptions, calibration information, and results and evaluation. The audit included review of the measured pressure transient history for potential water hammer. In addition, the NRC staff evaluated the resolution of the follow-up items in the FMEA audit report. Among the most significant remaining items for the demonstration of the safety features of the ECCS valves and their individual subcomponents to satisfy the NRC regulations were the following:

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

(2) assurance that the main valve will not partially or fully open prematurely;

(3) capability of the inadvertent actuation block (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 reactor pressure vessel (RPV) and containment vessel (CNV) has reduced sufficiently to the specified conditions;

(4) 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) assurance that the trip valve and line size, orifices, fittings, and installed configuration will 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) assurance that the trip valve and line size, orifices, fittings, and installed configuration will 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.

V. AUDIT PREPARATION

On March 20, 2019, the NRC staff issued an audit plan that identified the information needed for this audit. (See Reference 7.) The audit plan requested that documentation related to the design of the ECCS valves and the planned design demonstration testing be made available for review. NuScale made available specific design and testing documents related to the ECCS valves in the NuScale electronic reading room (eRR). NuScale arranged for specific documents to be made available at the Curtiss-Wright Target Rock facility in East Farmingdale, New York, for review during the NRC staff observation of the ECCS Valve Design Demonstration Testing.

VI. NUSCALE ECCS DESIGN

NuScale DCA Part 2, 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 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 [reactor coolant system] inventory is returned to the reactor vessel by natural circulation. This return path to the vessel ensures that the core remains covered. The ECCS passively transfers water from containment to the RPV. It also transfers heat from the RCS to the reactor pool passively through the CNV wall. Actuating the ECCS ensures that the core remains covered and that RCS temperature and pressure are reduced for all design-basis losses of coolant.

Based on the description in the NuScale DCA Part 2 and design documents, each ECCS valve consists of four distinct valve subcomponents connected by several feet of tubing that contains borated reactor coolant as follows:

1. 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 (with a small spring to hold the main valve open) when the main valve control chamber is vented to the CNV;

2. The 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;

3. The 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

4. The 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.

VII. AUDIT SCOPE

The primary scope of this audit was the NRC staff review of the planning, performance, and results of the ECCS Valve Design Demonstration Testing to evaluate compliance with 10 CFR 52.47 and 50.43(e). The audit scope included observation of a sample of the test runs for the ECCS Valve Design Demonstration Testing at the Target Rock facility. In addition, the audit scope included the NRC staff review of NuScale’s resolution of the follow-up items indicated in the FMEA audit report.

VIII. AUDIT PERFORMANCE

In late 2017 and early 2018, the NRC staff performed an initial audit of the NuScale ECCS valve design to determine whether 10 CFR 52.47(c)(2) and 10 CFR 50.43(e) have been satisfied, including the following activities:

1. 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 DCA.

2. 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.

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

4. Determine whether the 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.

5. 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.

6. 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.

7. 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 DCA.

8. Determine whether the qualification plans are sufficient to provide reasonable assurance that a holder of a combined license (COL) 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.

Based on the initial audit, the most significant remaining items for the demonstration of the safety features of the ECCS valves to satisfy the NRC regulations included 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.

From March 6, 2018, to May 22, 2018, the NRC staff conducted an audit of the FMEA and supporting documents for the design of the NuScale ECCS valves. As part of that audit, the staff conducted an onsite audit review at the Target Rock facility from May 14to18, 2018. During the onsite portion of the FMEA audit, the staff reviewed numerous reports, calculations, analyses, and drawings related to the ECCS valve design, and conducted discussions with

NuScale and Target Rock personnel. The onsite audit was conducted in conjunction with an NRC vendor inspection evaluating the design and test control, and other quality assurance activities, by Target Rock for the NuScale ECCS valves. NuScale had made available a report on its proof-of-concept (POC) testing of the ECCS valve design performed in 2015 by Target Rock. During the FMEA audit, the staff reviewed the adequacy of the POC testing to satisfy 10 CFR 52.47 and 10 CFR 50.43(e) for the NuScale DCA. Based on its review, the staff found that the POC testing did not include all of the appropriate performance requirements and conditions for the RVVs and RRVs to be used in the NuScale reactor. For example, the POC test report indicated that the testing was conducted with air and water that did not match the high temperature and pressure and borated water conditions of the NuScale RCS. In addition, the NRC vendor inspection performed during the onsite audit in May 2018 identified concerns regarding the validity and reliability of the POC test data. In particular, the calibration and traceability of the measurement and test equipment (M&TE) used for the POC testing needed to be verified for use of the POC test data. Further, the POC test equipment was not procured as safety-related components with specific internal dimension control and verification. Based on its review, the staff did not consider the POC testing to be sufficient to demonstrate the safety features of the ECCS valves for the actual valve design, configuration, and operating and design-basis conditions of the NuScale reactor. In the FMEA audit report dated August 14, 2018, the staff indicated the issues to be resolved to support the demonstration of the performance of the ECCS valves as part of the NuScale DCA.

The following is a summary of the items identified in the FMEA audit report to be resolved related to the design performance of the ECCS valves for the NuScale DCA:

1. The POC testing provided support for the initial conceptual design of ECCS valves but was not sufficient to demonstrate the design performance of the ECCS RVV and RRV valve systems for the NuScale reactor in accordance with 10 CFR 52.47(c) and 50.43(e).

2. Resolve the potential failure mode for the main valve disc to open only partially if the main valve control chamber loses sufficient pressure to initiate main disc opening upon initial opening of the trip valve at high RCS pressure as indicated in the FMEA audit report.

3. Resolve the issues regarding the justification for the passive component assumption for the IAB valve in the safety analysis as indicated in the FMEA audit report.

4. Resolve the remaining FMEA questions as indicated in the FMEA audit report.

5. Resolve staff comments on NuScale and Target Rock reports as indicated in the FMEA audit report.

6. Resolve remaining follow-up items from the initial ECCS valve audit as indicated in the FMEA audit report.

Based on the FMEA audit, the NRC staff concluded that NuScale had 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 had not demonstrated the capability and reliability of the ECCS valves to perform their safety functions to support the NuScale DCA. In the FMEA audit report, the NRC staff provided a list of the remaining items to be addressed regarding the demonstration of the design of the ECCS valves.

In a letter dated September 21, 2018, NuScale submitted its plans to resolve the findings described in the FMEA audit report. Most significantly, NuScale specified that ECCS Valve Design Demonstration Testing would be performed using ECCS valve subcomponents similar to its 2015 Proof-of-Concept Testing. In early 2019, the NRC staff discussed the testing plan with NuScale with subsequent adjustments of the plan to provide an acceptable demonstration of the design of ECCS valve function to satisfy 10 CFR 52.47 and 10 CFR 50.43(e) to support the NuScale DCA.

On March 20, 2019, the NRC staff issued an audit plan to review the NuScale performance of the ECCS Valve Design Demonstration Testing. During this audit, the staff reviewed the information made available by NuScale in the eRR, and at Target Rock, regarding the ECCS Valve Design Demonstration Testing, including test plans, procurement requirements, set-up and performance specifications, procedures, acceptance criteria, QA provisions and implementation, equipment and instrumentation descriptions, calibration information, and results and evaluation. As part of this audit, the staff also evaluated the resolution of the follow-up items specified in the FMEA audit report.

From June 3 to 6, 2019, and on July 17, 2019, the NRO staff conducted an onsite portion of the audit at the Target Rock facility to observe the NuScale ECCS Valve Design Demonstration Testing and to review the supporting documentation. The NuScale ECCS Valve Design Demonstration Testing includes a 2-inch globe valve (similar to the current-designed RRV main valve), an IAB valve (a stand-alone valve consistent with the current design), a trip valve, and a reset valve with connecting hydraulic tubing that bounds the installation planned for a NuScale reactor module. NuScale stated that it would address in the final test report (FTR) the results of the RRV testing to demonstrate the design performance of the 5-inch RVV, including its low temperature overpressure protection (LTOP) function. The objectives of the NuScale ECCS Valve Design Demonstration Testing were:

- demonstration of main valve functionality at operating temperature and pressure fluid conditions (Main Valve Actuation Test Series);
- demonstration of IAB valve functionality at operating temperature and pressure fluid conditions (IAB Valve Functionality Test Series); and
- demonstration of IAB valve and trip line functionality at operating chemistry fluid conditions, including boric acid solution (Boric Acid Effects Test Series).

The initial plan for the three test series beginning in June 2019 was as follows:

Main Valve Actuation Test Series	**Test Runs**	**Initial Pressure (psig)**	**Initial Fluid Condition**
1	3	1000 ± 30	Saturated steam
2	3	1000 ± 30	100°F below saturated fluid (± 15°F)
3	3	1000 ± 30	70 °F (± 20°F)
4	3	500 ± 15	Saturated steam
5	3	500 ± 15	100°F below saturated fluid (± 15°F)
6	3	500 ± 15	70 °F (± 20°F)
7	3	30-40	Saturated steam
8	3	30-40	100°F below saturated fluid (± 15°F)
9	3	30-40	70 °F (± 20°F)

IAB Valve Functionality Test Series			
1	3	1850 ± 55.5	Saturated steam. Trip line ≥ 400°F
2	3	1850 ± 55.5	100°F below saturated liquid (± 15°F). Trip line ≥ 400°F
3	3	1850 ± 55.5	70°F (± 20°F). Trip line ≤ 100°F
4	3	1300 ± 39	Saturated steam. Trip line ≥ 400°F
5	3	1300 ± 39	100°F below saturated liquid (± 15°F). Trip line ≥ 400°F
6	3	1300 ± 39	70°F (± 20°F). Trip line ≤ 100°F
Boric Acid Effects Test Series			
1	3	1850 ± 55.5	Saturated liquid (pure water)
2	3	1000 ± 30	Saturated liquid (pure water)
3	3	30-40	Saturated liquid (pure water)
4	3	1850 ± 55.5	Saturated liquid (1.2-1.8% weight boric acid solution)
5	3	1000 ± 30	Saturated liquid (1.2-1.8% weight boric acid solution)
6	3	30-40	Saturated liquid (1.2-1.8% weight boric acid solution)

The onsite NRO audit team did not identify any concerns with the NuScale and Target Rock test documentation or other test program implementation activities related to the ECCS Valve Design Demonstration Testing. Concurrent with the NRO audit, NRR conducted a QA program implementation inspection on June 3 to 6, 2019, of NuScale's oversight of the ECCS Valve Design Demonstration Testing being performed by Target Rock. The NRR QA inspection team did not identify any findings of significance. The NRC issued the QA inspection report on the NuScale activities at Target Rock on July 18, 2019 (Reference 9).

During the June 2019 audit/inspection, the NRC staff observed a successful test run of IAB Valve Functionality Test #2 at initial conditions of 1850 pounds per square inch gauge (psig) with 100 degrees Fahrenheit (°F) subcooled (about 525 °F) pure water. Upon the trip valve opening during this test run, the IAB valve closed and sealed the main valve control chamber in a timely manner preventing the main valve from opening. When the supply pressure (simulating RCS pressure) was reduced in accordance with the test procedure, the IAB valve opened at a pressure within the specified range (about 1100 pounds per square inch differential (psid)), depressurized the main valve control chamber, and allowed the main valve to open. The staff reviewed the test data immediately following the test, conducted a walkdown of the test setup, and verified the test equipment calibration. Based on its review of the test data for pressure changes in the hydraulic tubing, the staff did not identify any concerns related to significant water hammer effects during operation of the ECCS valve system.

During the June 2019 audit/inspection, NuScale reported the following issues for the test runs then-completed to date:

1. failure of the IAB valve to close during a test run of IAB Valve Functionality Test #6 at 1300 psig and 70 °F pure water such that the main valve opened prematurely;

2. loss of data during a test run of IAB Valve Functionality Test #2 at 1850 psig with 100 °F subcooled pure water; and
3. failure of the main valve to open within test acceptance criteria during a test run of IAB Valve Functionality Test #2 at initial conditions of 1850 psig with 100 °F subcooled pure water.

NuScale prepared a Condition Report in response to each of these three issues in accordance with its QA program. NuScale initiated corrective action to address each issue. During the June 2019 audit/inspection, the staff did not identify any concerns with the NuScale QA activities in response to these issues.

With respect to the first test issue identified during the June 2019 audit/inspection, NuScale reported that the failure of the IAB valve to close during a test run of IAB Valve Functionality Test #6 at 1300 psig and 70 °F pure water resulted in the main valve opening immediately upon the trip valve opening, although the IAB valve should have blocked the main valve from opening based on the design information in the NuScale DCA Part 2, Tier 2, Section 6.3, that the IAB valve threshold is 1100 ± 100 psid. During the June 2019 audit/inspection, NuScale stated that it was evaluating possible options, such as reassessing the basis for the current threshold limits and modifying as appropriate, evaluating the test configuration against the design configuration to determine if a tighter threshold can be expected for the final design, or modifying the ECCS valve design to achieve a tighter window between the valve release and threshold pressures. This first test issue continues to be a design concern as discussed later in this paper.

In response to the second test issue identified during the June 2019 audit/inspection, NuScale reported the loss of data during a test run of IAB Valve Functionality Test #2 at 1850 psig with 100 °F subcooled pure water. This issue occurred following the test observed by the NRC staff. Immediately following the test, NuScale presented the performance data for the RRV valve system, including the trip valve, IAB valve, and main valve, directly from the test equipment to the NRC staff. The staff did not identify any concerns with the results obtained from the test valve performance data. NuScale subsequently repeated the test run to provide a complete data set.

In response to the third test issue identified during the June 2019 audit/inspection, NuScale reported that based on pressure measurements during a test run of IAB Valve Functionality Test #2 with initial conditions at 1850 psig with 100 °F subcooled pure water, the IAB valve closed upon trip valve opening as expected and later reopened at the appropriate pressure (about 1100 psid) when the supply pressure was reduced. However, the main valve did not open until the supply pressure was reduced to a much lower value than specified in the test acceptance criteria. Because of the significance of this test failure, NuScale initiated a test stand-down. Internal inspection of the main valve did not reveal any issues, but the IAB valve seating surface showed wear. During the June 2019 audit/inspection, Target Rock had not determined the cause of the main valve failure to open in accordance with the test acceptance criteria. As part of its response activities, Target Rock lapped the IAB valve seating surfaces and installed a more direct and larger exhaust line beyond the trip valve. At the end of the June 2019 audit/inspection, NuScale stated that it would continue to evaluate the cause of the main valve failing to open and would inform the staff of its evaluation results.

On June 17, 2019, the NRC staff held an audit meeting with NuScale at the NuScale Rockville office to discuss the three test issues identified during the June 2019 audit/inspection. With respect to the first test issue (IAB valve closing pressure), NuScale reported that Target Rock would conduct tests at incremental pressures above 1300 psig with 70 °F pure water to determine the precise pressure for the IAB valve to close and seal the main valve control chamber. NuScale stated that Target Rock would then use that specific pressure as the initial pressure for IAB Valve Functionality Tests #4, 5, and 6 in lieu of the then-current 1300 psig pressure criterion. NuScale reported that accident analyses and DCA information might need to be updated to reflect the corrected closing pressure for the IAB valve. With respect to the second test issue (loss of data), NuScale stated that the missing data involved failure to collect data over the full time range specified in the test procedure, rather than an actual loss of collected data. NuScale stated that no further data collection problems had occurred during the remaining tests. With respect to the third test issue (main valve failing to open), NuScale stated that Target Rock had determined that the orifice in the main valve that communicates supply pressure (RCS pressure) with the main valve control chamber needed to be reduced in size to avoid excessive pressure transfer into the control chamber that was preventing the main valve from opening at the proper supply pressure. NuScale reported that the main valve had been redesigned with the orifice in the main valve reduced from [ ] to reduce the pressure communication between the supply pressure and the main valve control chamber. The staff considers that such a design change to not be unusual based on testing of an FOAK valve. In response to this valve design change and test setup improvements, NuScale re-initiated the ECCS Valve Design Demonstration Testing. With this new valve design, NuScale reported that each of the three test runs had been successfully completed for IAB Valve Functionality Test #1 and Test #2 at 1850 psig with saturated steam and 100 °F subcooled pure water, respectively. During the June 17 meeting, NuScale discussed its plans to conduct the full Main Valve Actuation Test Series and full Boric Acid Effects Test Series and to complete the remaining IAB Valve Functionality Tests #3, #4, #5, and #6.

On July 17, 2019, NRO staff observed a sample test run of Boric Acid Effects (BAE) Test Series at the Target Rock facility for the ECCS Valve Design Demonstration Testing program. The purpose of the BAE testing was to provide reasonable assurance that the ECCS valve system will not be adversely impacted by the blowdown of borated reactor coolant through the IAB valve and hydraulic tubing in the ECCS valve system. The staff considered the observed BAE test run to successfully demonstrate the performance of the IAB valve and hydraulic tubing at high pressure and temperature borated fluid conditions. However, NuScale reported that previously during the pure water portion of the BAE testing, Target Rock had identified variations in the IAB valve performance such that the test acceptance criteria needed to be modified. NuScale made available the revised test specification for NRC staff review in the eRR. During the July 17 audit, NuScale also provided an update of the status of the first and third test issues identified during the June 2019 audit/inspection. Regarding the first test issue (IAB valve closing pressure), NuScale was continuing to evaluate the cause of the greater-than-assumed closing pressure, and possible options to resolve this test finding (such as IAB valve internal adjustments and/or accident analysis revisions). Regarding the third test issue (main valve not opening at the proper pressure), NuScale reported that this issue had been resolved by implementing the design change to reduce the size of the main valve orifice to allow the main valve control chamber to depressurize more promptly and allow the main valve to open in a timely manner.

During the July 17 audit, NuScale discussed a new test issue related to greater variation in the blowdown times for the BAE pure water tests than specified in the test acceptance criteria. At that time, NuScale was evaluating the appropriate response to the test variation. On July 22, 2019, NuScale prepared Condition Report CR-0719-66385 to justify a change in BAE test acceptance criteria in light of the variation in blowdown times during the pure water test runs. All of the tests were reported to have supported the design limit of 10 seconds, but the variations in time were larger than the 20% difference specified in the original acceptance criteria. As a result, NuScale adjusted the BAE test acceptance criteria to define the blowdown time to 40% of the initial pressure to resolve the variability issue. NuScale closed CR-0719-66385 on July 25, 2019.

On July 30, 2019, the NRC staff held an audit telephone conference with NuScale to discuss the status of the ECCS Valve Design Demonstration Testing. During the telephone conference, NuScale reported that the Main Valve Actuation Test Series, IAB Valve Functionality Test Series, and the BAE Test Series had been completed. As part of the response to the test results, NuScale had modified the design of the main valve control chamber orifice as discussed on June 17. In addition, NuScale had modified the requirements for Tests #4, 5, and 6 in the IAB Valve Functionality Test Series from 1300 psig to about 1500 psig to ensure that the IAB valve closed promptly to prevent the main valve from opening. NuScale stated that the tests indicated that the IAB valve will close at high pressure (1850 psig) and then re-open at an appropriate pressure (about 1100 psig) when supply pressure is reduced. However, NuScale stated that the tests revealed that an open IAB valve will not close unless the supply pressure is at least 1500 psig. NuScale discussed design adjustments attempting to reduce the IAB valve closing pressure to be consistent with the design information in NuScale DCA Part 2, Tier 2, Section 6.3, that the IAB valve threshold is 1100 ± 100 psid. For example, NuScale described shim adjustments in the IAB valve and reduction of the port size between the IAB valve inlet and the main valve control chamber outlet. NuScale indicated that these design adjustments were intended to lower the IAB valve pressure operating band such that the IAB valve closing pressure would approach the design information in the DCA. No definitive test results were available at that time.

On August 7, 2019, the staff and NuScale conducted an audit telephone conferenceto discuss the completion of the ECCS Valve Design Demonstration Testing and resolution of the testing issues. NuScale provided the status of the condition reports initiated in response to the ECCS Valve Design Demonstration Testing. NuScale also discussed its activities to resolve the follow-up items from the FMEA audit.

On August 19, 2019, the NRC staff conducted a telephone conference with NuScale to discuss the status of the staff audit of the ECCS valve design. During the call, NuScale described:

(1) the completion of the ECCS Valve Design Demonstration Testing, test results, and resulting ECCS valve design changes;

(2) the impact of the test results and ECCS valve design changes on the accident and containment analyses; and

(3) the status of remaining ECCS valve design audit follow-up items.

NuScale stated that all testing activities for the ECCS Valve Design Demonstration Testing had been completed. NuScale reported that several design changes to the ECCS main valve and IAB valve are necessary based on the test results. These design changes included reduction of the main valve control chamber orifice to [ ] in diameter, reduction of the IAB valve port inlet to [ ] in diameter, and reduction in the shim size. Even with these valve design changes, NuScale indicated that the operating range of the IAB valve will be expanded from 1100 psid +/- 100 psid to 1100 psid +/- 200 psid. NuScale stated that several test runs at various fluid conditions to demonstrate the performance of the new ECCS valve system design had been repeated to supplement the original test plan. NuScale indicated that the FTR would describe the ECCS valve test results and the valve design changes. NuScale stated that it would update the DCA and modify the accident and containment analyses for the ECCS valve system to reflect the new opening and closing pressure range of the IAB valve.

In a letter dated August 21, 2019 (Reference 10), NuScale provided responses to several follow-up items specified in the FMEA audit report. The staff discusses its review of these responses in the enclosure to this audit report.

In a letter dated August 26, 2019 (Reference 11), NuScale provided its closure plan to address the impacts of the adjusted IAB valve operating pressure range. In the closure plan, NuScale proposed the schedule for the following action items: (1) DCA and Technical Report changes to reduce specific ranges to the IAB valve operating pressure ranges; (2) presentation of closure plan at a public meeting; (3) make draft FMEA revision available in eRR; (4) make draft FTR available in eRR; (5) make vendor calculations supporting resolution of IAB valve partial opening issue at vendor facility; (6) make revised Chapter 6 and 15 analyses available in eRR; and (7) submit DCA change packages reflecting revised analyses. The specific dates for these action items were considered proprietary by NuScale. Also on August 26, 2019, NuScale provided an e-mail with its initial plans to update the IAB valve operating pressure range in Chapter 6 to the DCA Part 2, Tier 2, and in the associated technical report.

On August 28, 2019, the staff held a public telephone conference with NuScale to provide an update on the completion of the ECCS Valve Design Demonstration Testing. During the telephone conference, NuScale summarized the results of the ECCS Valve Design Demonstration Testing. For example, NuScale indicated that the test results did not support the IAB valve operating pressure range then specified in the DCA at 1100 psid +/- 100 psid. NuScale stated that valve design changes had been implemented for the ECCS valve system, including reduction in the port sizes in the main valve and IAB valve and reduction of the IAB valve spring force by installing a smaller shim. NuScale reported that repeat tests for fluid conditions had been performed to supplement the original test plan for the ECCS Valve Design Demonstration Testing. NuScale stated the FTR would describe the ECCS Valve Design Demonstration Testing, the test results, and the valve design changes. During the closed portion of the telephone conference, NuScale reported that it was evaluating reliance on the IAB valve to close at high pressure conditions and then to re-open at approximately 950 psid in the accident analyses.

On September 5, 2019, the NRC staff held an audit telephone conference with NuScale to discuss the status of the NRC staff review of the ECCS Valve Design Demonstration Testing and its results. During the telephone conference, the staff indicated that a significant audit finding from the ECCS Valve Design Demonstration Testing is the importance of the inservice testing (IST) activities to verify that the IAB valves open and close at their intended differential pressure conditions. The staff discussed the IST requirements specified in the ASME OM Code for major equipment that relies on multiple subcomponents (referred to as skid-mounted equipment). Based on those discussions, NuScale plans to submit a request in accordance with 10 CFR 50.55a(z) to justify its planned IST activities for ECCS valves and their subcomponent valves (main valve, IAB valve, trip valve, and reset valve). The staff will track the update of the DCA to reflect appropriate NuScale IST activities for the ECCS valves as **Audit Follow-Up Item 1** from this audit.

During the September 5, 2019, telephone conference, the NRC staff noted that the DCA does not correctly describe the performance attributes of the ECCS valve system (particularly, the IAB valve engagement and release pressures) based on the results of the ECCS Valve Design Demonstration Testing. The staff also noted that DCA Technical Specifications refer to the "setpoint" of the IAB valve, although the operating characteristics of the IAB valve is based on the internal construction of the valve by the manufacturer rather than an external setpoint adjustment. NuScale plans to update the DCA to include the proper performance attributes in the various applicable sections. Subsequent to the September 5, 2019, telephone conference, NuScale placed a draft markup of the DCA to update the performance attributes of the IAB valve based on the ECCS Valve Design Demonstration Testing. In particular, NuScale plans to update the DCA to specify that (1) the threshold pressure for operation of the IAB valve to prevent spurious opening of the main valve is 1300 psid; (2) the IAB valve will prevent the main valve from opening for all reactor pressures 1300 psid and greater with respect to containment; (3) given an initial IAB block, the IAB valve will release at 950 psid ± 50 psi once the reactor pressure is reduced; and (4) the IAB valve will not prevent the main valve from opening for initial pressures of 900 psid and below. The staff considers this update to the performance attributes of the IAB valve for the DCA to be consistent with the results of the ECCS Valve Design Demonstration Testing. The staff will track the update to the DCA to reflect the proper performance attributes of the ECCS valve system as **Audit Follow-Up Item 2** for this audit.

During the September 5, 2019, telephone conference, the NRC staff noted that several design documents for the ECCS valves need to be updated to reflect the design changes to the ECCS valves and performance attributes in response to the results of the ECCS Valve Design Demonstration Testing. The potentially affected ECCS valve design documents include, for example, ASME Design Specification ED-B020-2140, ASME Design Report EQ-B020-6306, and the RVV, RRV, and IAB valve design drawings. NuScale stated that its change control process was underway to incorporate the design changes in the various ECCS valve design documents. NuScale stated that a specific time period has not been established for the completion of the document change control process. The staff will track the NuScale process to update of the specific ECCS valve design documents to reflect the design of the ECCS valve system (including the subcomponent valves) and performance attributes as a result of the ECCS Valve Design Demonstration Testing as **Audit Follow-Up Item 3** from this audit.

During a telephone conference on September 20, 2019, the NRC staff discussed the draft FTR with NuScale and Target Rock personnel. NuScale described the key test observations specified in the draft FTR. With respect to the identification of boron powder mentioned in the draft FTR, NuScale indicated that the boron powder had been found after the valves had been cooled to room temperature and disassembled such that a concern did not exist that boron would precipitate during valve operations. NuScale indicated that certain questions could be discussed with Target Rock personnel during the planned onsite audit on September 27, 2019.

During the telephone conference on September 20, 2019, the staff discussed the draft revision of the FMEA with NuScale personnel. The staff provided comments on the draft FMEA revision for consideration by NuScale. On September 23, 2019, NuScale provided the revised FMEA for NRC staff review in the eRR. The staff found that the revised FMEA addresses its comments discussed with NuScale during the previous FMEA audit, such as providing a lower threshold for the evaluation of potential failure modes and the comments on the draft revision to the FMEA. The staff findings for specific follow-up items for the FMEA report from the previous audit are described in the enclosure to this report. The staff has determined that the revised NuScale FMEA report has resolved its comments provided during the previous FMEA audit and during this audit.

On September 24, 2019, the staff reviewed at the NuScale Rockville office a sample of the diagnostic test data from the ECCS Valve Design Demonstration Testing. The staff found the sample of diagnostic data to be consistent with the summary provided in the FTR. The staff did not identify any concerns with the electronic presentation of the diagnostic data.

On September 25, 2019, NuScale made available the final FTR in its eRR. The final FTR provides additional test descriptions, specifies another key test observation, and describes the extrapolation of the RRV test results to the performance of the RVV. The FTR specifies that the ECCS Valve Design Demonstration Testing was intended to perform functional testing of a valve of similar geometry and configuration to the RRVs and RVVs. The two concepts of functionality specified in the FTR to be tested included (1) the ECCS valves operate as required over the range of operating conditions; and (2) the testing demonstrated that the presence of boric acid in the coolant at bounding concentrations did not adversely affect the valve's performance. The FTR describes the test facility, the performance of the initial valve tests and supplemental tests, the design changes to the main valve and IAB valve identified to be necessary based on the test results, the performance characteristics of the modified valve designs, and the conclusions and key observations (as indicated in a following paragraph) from the ECCS Valve Design Demonstration Testing. The FTR describes the failure of the main valve to open during specific tests when the main valve control chamber did not depressurize sufficiently to a specific pressure (approximately [ ]) to allow the main valve to open to perform its safety function. The FTR describes the subsequent design change to reduce the orifice size in the main valve disc to provide assurance that the main valve control chamber will depressurize sufficiently for the main valve to open. The FTR describes the failure of the IAB valve to block the opening of the main valve at the intended pressure of 1300 psig. The FTR describes the exploratory tests performed to determine the engagement pressure of the IAB valve (1525 psig). To adjust the performance of the ECCS valve system, the FTR describes the design changes as (1) reducing the IAB valve spring force by reducing the shim size, (2) reducing the control orifice between the IAB valve and main valve control chamber, and (3) reducing the inlet control orifice in the main valve disc. The FTR describes the supplemental testing to demonstrate the performance of the modified design of the ECCS valve system including Test #1 (Saturated Steam) at approximately 900 psig and Test #7 (Saturated Steam) at approximately 35 psig of the Main Valve Actuation Test Series, and Test #4 (Saturated Steam) at approximately 1275 psig and Test #5 (100°F Subcooled Liquid) at approximately 1275 psig of the IAB Valve Functionality Test Series.

The FTR describes specific design changes to the main valve and IAB valve found to be necessary based on the test results and the resulting effect on performance of the ECCS valve system. For example, the orifice in the main valve disc was reduced in size from the original [ ] in diameter to reduce the inflow rate into the main valve control chamber from the supply (RCS) source to provide assurance that the main valve control chamber pressure will be reduced to a sufficient level ([ ]) upon opening of the trip valve to allow the main valve to be opened by the supply (RCS) pressure. In addition, a [ ] flow control orifice was installed in the [ ] from the main valve control chamber to the IAB valve to allow the pressure to drop more rapidly within the IAB valve and reduce the IAB valve threshold pressure. Further, the shim for the IAB valve spring was reduced from [ ] to lower the IAB valve release and threshold pressures. Even with these design changes, the FTR reports that the original IAB valve performance range of 1000 to 1200 psid had to be modified to a new range of 900 to 1300 psid.

The FTR concludes that the test program was successful in demonstrating the functional performance of the ECCS valves at reactor operating conditions. The FTR also concludes that the boric acid solution did not have a significant impact on the valve performance. The FTR states that the testing provided feedback and insights for the QME-1 qualification testing. The key observations from the ECCS Valve Design Demonstration Testing specified in the FTR are (1) the ratio of the inflow and outflow for the main valve [ ] is critical to allow proper depressurization of the main valve control chamber; (2) the IAB valve threshold and release pressure is significantly impacted by fluid temperature; (3) the location and size of the minimum outflow area downstream of the main valve control chamber is critical to the IAB valve threshold pressure; and (4) dynamic performance limitations of the IAB valve do not allow the release and threshold pressure to be within a narrow pressure range such that the IAB valve pressure range was increase to 900-1300 psid to allow for satisfactory IAB valve performance under the range of fluid conditions tested. The FTR discusses the extrapolation of the RRV test results to evaluate the performance of the RVV to support the DCA review. The COL holder will perform qualification testing of both the RRV and RVV designs in accordance with ASME Standard QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," as accepted in Regulatory Guide (RG) 1.100 (Revision 3), "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants," to demonstrate the capability of the RRVs and RVVs to perform their safety functions under the applicable design-basis conditions.

On September 27, 2019, the staff conducted an onsite review of the calculations performed by Target Rock to evaluate the potential for the main valve of the ECCS valve system to remain in a partial open position when activated to open by its trip valve. The Target Rock calculations evaluate whether the inflow into the main valve control chamber through the main disc orifice from the RCS can exceed the outflow from the main valve control chamber through the IAB valve to the trip valve hydraulic line, such that the main valve might remain in a partially open position. Target Rock developed force balance spreadsheet calculations for the main valve disc using accepted industry formulas with 22 incremental time steps to determine the forces on the main disc and its motion for the full stroke ([ ]) for various temperature and fluid conditions. The Target Rock calculations indicate that the inflow into the main valve control chamber will be less than the outflow for all temperature and fluid conditions, although the amount that the inflow is less than the outflow will depend on the conditions. The Target Rock calculations predict that the net opening force on the main valve disc (and the acceleration of the opening motion of the disc) will continue to increase for each time step when the main valve begins to open. The calculations are consistent with the actual test data in predicting that the main valve disc will begin to open when the pressure in the main valve control chamber decreases to about [ ]

During the September 27, 2019, onsite review, Target Rock described its calculations of the stress and deflection of the main valve disc for both the RRV and RRV assuming a 1300 psi static load. In particular, Target Rock calculated the bending stress on the thinnest section of the main valve disc for both the RRV and RRV and demonstrated that the bending stress for each disc is significantly less than the allowable stress for the main valve disc material. In addition, the Target Rock calculations demonstrated that the maximum deflection for the main valve disc under the assumed worst-case conditions was extremely small for both the RRV and RVV.

During the September 27, 2019, onsite review, the staff discussed with NuScale and Target Rock the performance of the main valve disc if the IAB valve closes late such that the pressure in the main valve control chamber falls to [ ] of the reactor pressure before the IAB valve blocks further release of main valve control chamber pressure. Under that scenario, Target Rock indicated that the forces on the main valve disc would fully open the main valve if the disc begins to open. If the main valve disc did not leave its seat, the main valve would remain closed for that scenario.

During the September 27, 2019, onsite review, the staff discussed specific aspects of the FTR and FMEA with Target Rock personnel. For example, Target Rock indicated that a minor pressure relationship might exist with the stroke time of the main valve. The staff also discussed with Target Rock the long operating times for water conditions during the IAB Valve Functionality Tests to determine applicability to actual valve operating conditions. In the final FMEA, Target Rock indicated that the potential failure modes related to the hex nut and set screw of the Trip/Reset Valves (TRVs) and Trip Valves (TVs) were changed to an acceptable category because the failure would result in these valves moving to their open safety position. The staff did not identify any concerns with the additional information provided by Target Rock during the September 27, 2019, onsite review.

As part of this audit, the staff reviewed the extrapolation of the performance of the RRV during the ECCS Valve Design Demonstration Testing to predicted RVV performance as described in the FTR. For example, the FTR includes a calculation of the discharge volume (including the main valve control chamber, IAB valve, and connecting hydraulic tubing) for the RRV test setup. The FTR then indicates that the discharge volume is calculated to be [ ] for a similar setup for the RVV. This discharge volume increase is predicted to result in only a [ ] in stroke time for the RVV under saturated steam conditions compared to the maximum RRV stroke time of [ ] during the testing program. The FTR determines that this predicted RVV stroke time of [ ] will satisfy the 10-second stroke time requirement in the design specification. The FTR specifies that the seat area to piston area ratio for the main valve is similar for both the RRV and RVV, which predicts similar main valve performance. The FTR also notes that the several test runs during ECCS Valve Design Demonstration Testing were conducted under steam conditions that are representative of the RVV operating conditions. The FTR predicts that the RVV will operate in a similar manner to the RRV based on the small percentage increase in discharge volume for an RVV setup, the similarity of the seat area to piston area ratio of the main valve for both the RRV and RVV, and the stroke time for the RRV being well within the design specification requirement during the testing.

With respect to the resolution of the other follow-up items from the NRC audit of the ECCS valve FMEA and supporting documents, the NRC staff reviewed the completion of the follow-up items listed in the FMEA audit report and the resolution plans specified in the NuScale letter dated September 21, 2018. The staff evaluated the documents made available in the eRR, such as the FTR for the ECCS Valve Design Demonstration Testing, revised FMEA report, and related design documents. The audit findings for the specific follow-up items from the previous FMEA audit are provided in the enclosure to this audit report.

On October 9, 2019, the NRC staff conducted an exit meeting by telephone conference with NuScale to discuss the results of this audit for the review of the ECCS valve system, including the ECCS Valve Design Demonstration Testing, FMEA, design documents, and follow-up items from the previous audit. During the exit telephone conference, the staff summarized the performance and results of this audit, the follow-up items described in this audit report, and the next steps for the completion of the staff review of the ECCS valve system for the NuScale DCA. The staff stated that the FMEA had been acceptably updated to incorporate its comments provided during this audit and the previous audit. The staff stated that the FTR acceptably describes the ECCS Valve Design Demonstration Testing but requested that NuScale discuss the extrapolation of the test results for the RRV to demonstrate the performance of the RVV to satisfy 10 CFR 50.43(e) in support of the NuScale DCA. During the exit telephone conference, NuScale reported that the RRV tests of 70 °F and 525 °F each with pressures of 35, 500, and 1000 psig in the Main Valve Actuation Test Series encompassed the required performance range for the LTOP function of the RVV from 193 °F and 380 pounds per square inch absolute (psia) to 318 °F and 850 psia as specified in DCA Part 2, Tier 2, Table 5.2-10, “LTOP Pressure Setpoint as Function of Cold Temperature.” In addition, NuScale stated that the performance requirements for the RVV include the same stroke-time requirements for the RRV as demonstrated in the ECCS Valve Design Demonstration Testing.

During the exit telephone conference on October 9, 2019, the staff described the three follow-up items from this audit. With respect to **Audit Follow-Up Item 1**, NuScale discussed its plan to submit a request to apply an alternative to the ASME OM Code for IST of the IAB valve as a subcomponent of the ECCS valve system. As feedback to NuScale during the exit telephone conference, the staff suggested that NuScale address its preservice testing (PST) plans for the IAB valves as part of its request and consider whether the request involves an alternative that provides an acceptable level of quality and safety under 10 CFR 50.55a(z) or involves relief from an ASME OM Code requirement that NuScale considers impractical under 10 CFR 50.55a(f)(5) and (6). With respect to **Audit Follow-Up Item 2**, NuScale stated that the next revision to the DCA will update the performance requirements for the IAB valve that were outlined in an eRR document. With respect to **Audit Follow-Up Item 3**, NuScale stated that it would prepare an engineering change notice to specify that the applicable ECCS valve design documents will be updated as necessary to reflect the significant design features and performance requirements of the main valve and IAB valve determined from ECCS Valve Design Demonstration Testing. At the conclusion of the exit telephone conference, NuScale stated that it would submit a letter describing its plans to close-out the follow-up items in response to this audit.

A summary of the results of the staff audit review of the ECCS valve system is provided in the following paragraphs.

A. ECCS Valve Design Demonstration Testing

The NRC staff reviewed the FTR for the ECCS Valve Design Demonstration Testing. The FTR specifies that the ECCS Valve Design Demonstration Testing was intended to perform functional testing of a valve of similar geometry and configuration to the RRVs and RVVs. The two concepts of functionality specified in the FTR to be tested included (1) the ECCS valves operate as required over the range of operating conditions; and (2) the testing demonstrated that the presence of boric acid in the coolant at bounding concentrations did not adversely affect the valve’s performance. The FTR concludes that the test program was successful in demonstrating the functional performance of the ECCS valves at reactor operating conditions. The FTR also concludes that the boric acid solution did not have a significant impact on the valve performance. The FTR indicates that the testing provided feedback and insights for the QME-1 qualification testing. The key observations from the ECCS Valve Design Demonstration Testing specified in the FTR are (1) the ratio of the inflow and outflow for the main valve control chamber is critical to allow proper depressurization of the main valve control chamber; (2) the IAB valve threshold and release pressure is significantly impacted by fluid temperature; (3) the location and size of the minimum outflow area downstream of the main valve control chamber is critical to the IAB valve threshold pressure; and (4) dynamic performance limitations of the IAB valve do not allow the release and threshold pressure to be within a narrow pressure range such that the IAB valve pressure range was increase to 900-1300 psid to allow for satisfactory IAB valve performance under the range of fluid conditions tested. Based on the NRC staff review of the FTR and the discussions with NuScale on October 9, 2019, the staff finds that the FTR adequately demonstrates the performance of the RVV based on the RRV test results to support the DCA review. A COL holder will complete qualification testing of both the RRV and RVV designs in accordance with ASME Standard QME-1-2007 as accepted in RG 1.100

(Revision 3) to demonstrate the capability of the RRVs and RVVs to perform their safety functions under the applicable design-basis conditions.

Based on its review, the NRC staff finds that the ECCS Valve Design Demonstration Testing is sufficient to demonstrate the design features of the ECCS valve system to satisfy 10 CFR 52.47(c)(2) and 50.43(e), provided the following audit follow-up items from the testing program are resolved.

> **Audit Follow-Up Item 1**: NuScale will update the description of the IST program for the ECCS valves (including the subcomponent valves) in the DCA, including the planned request to depart from the ASME OM Code requirements for the IAB valve testing, to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.
>
> **Audit Follow-Up Item 2**: NuScale will update the DCA provisions for the ECCS valve performance (such as the IAB valve performance attributes) to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.
>
> **Audit Follow-Up Item 3**: NuScale will update the applicable ECCS valve design documents to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.

On October 24, 2019 (Reference 12), NuScale submitted a letter with the status of its actions to address these audit follow-up items. Upon resolution of the audit follow-up items, the staff will determine whether the ECCS Valve Design Demonstration Testing performed by NuScale satisfies the regulatory requirements in 10 CFR 52.47(c)(2) and 50.43(e) for the demonstration of the performance of the safety features of the NuScale ECCS valve system to support the NRC review of the NuScale DCA. Following completion of the NuScale DCA review, a COL holder will address the lessons learned from the ECCS Valve Design Demonstration Testing in developing the ASME QME-1 qualification testing program for the ECCS valve system (including its subcomponent valves).

B. Partial Open ECCS Valve Failure Mode

The NRC staff reviewed the Target Rock calculations related to the potential for partial opening of the main valve in the ECCS valve system. During the May 2018 onsite audit review, the staff reviewed the preliminary Target Rock calculations that predicted that the main valve would not remain partially open during operation of the ECCS valve system. On September 27, 2019, the staff conducted an onsite audit review of the finalized Target Rock calculations of the potential for the main valve to remain partially open in a stable position during operation of the ECCS valve system. Based on its onsite review and discussions with NuScale and Target Rock, the staff finds that NuScale has demonstrated that there is no credible potential for the main valve in the ECCS valve system to remain in a partially open position during its opening stroke from either fluid flow forces or mechanical loading.

C. IAB Valve Passive Component Assumption

On December 14, 2018, NuScale submitted a letter describing its position with respect to application of the single failure criterion to the IAB valve in its accident analyses. In Commission Paper SECY-19-0036 (April 11, 2019), “Application of the Single Failure Criterion to NuScale Power LLC’s Inadvertent Actuation Block Valves,” the NRC staff requested that the Commission provide guidance on the appropriate approach to address the single failure criterion with respect to the IAB valve in the NuScale accident analyses. On July 2, 2019, the Commission issued a Staff Requirements Memorandum (SRM) for SECY-19-0036 directing that the NRC staff should review Chapter 15, “Transient and Accident Analyses,” of the NuScale DCA without assuming a single active failure of the IAB valve to close. Based on the Commission direction in SRM-SECY-19-0036, the applicability of the single failure criterion to the IAB valve for the NuScale accident analyses is closed for this audit.

D. ECCS Valve Subcomponent Level FMEA

During this follow-up audit, the NRC staff found that the NuScale FMEA has been revised to apply recent FMEA guidance available for a wide-range of general industrial applications. This new guidance uses an updated FMEA approach rather than the Risk Priority Number (RPN) method used previously. The revised NuScale FMEA indicates that Target Rock applied the concepts of new FMEA guidance to develop Severity (S), Occurrence (O), and Detection (D) rankings for the design and performance of the ECCS valves. Target Rock then combined the Severity and Occurrence rankings to achieve an overall SO Risk Ranking with consideration of the D ranking to determine those postulated ECCS valve failures that are unacceptable such that mitigation features by design changes or testing/monitoring programs will be applied. The revised NuScale FMEA describes the evaluation of two specific failure modes: (1) potential partial open failures of the main valve; and (2) potential adverse effects from boric acid crystallization on the ECCS valve fluid flow in the internal valves and hydraulic lines. Overall, the revised NuScale FMEA report identified 36 potential failures that could severely affect the safety function of the ECCS valves. For the unique design features of the ECCS valves, the revised NuScale FMEA report indicates that the primary mitigating factors are (1) design analyses, (2) POC testing in 2015, and (3) DCA testing in 2019. The revised NuScale FMEA also states that the NuScale ECCS valve prototypes are required to undergo qualification testing (ASME QME-1) to assure all required performance parameters are met in the required process and environment conditions. The revised NuScale FMEA report also references the IST program to monitor for potential degradation in the ECCS valve performance. The staff determined that the revised FMEA addresses its comments discussed with NuScale during the previous FMEA audit, such as providing a lower threshold for the evaluation of potential failure modes, and the comments on the draft revision to the FMEA. The staff review of the specific follow-up items on the FMEA report from the previous audit is described in the enclosure to this report. The staff finds that the revised NuScale FMEA report has resolved its comments provided during the previous FMEA audit and during this audit.

E. Other ECCS Design Documents and Previous Audit Items

The NRC staff reviewed several design documents as part of its audit of the ECCS valve design. For example, the staff reviewed NuScale Report ER-B020-6289, “ECCS Valve Description,” NuScale Report ER-B020-6052, “ECCS RVV Diffuser Report,” NuScale Report ER-B020-6117, “ECCS Valve Qualification Plan,” and NuScale Preliminary ASME Design Reports. In the enclosure to this audit report, the staff describes its review of these documents and the resolution of the follow-up items from previous FMEA audit. During this follow-up audit, the staff focused on the information necessary for the NRC to make a safety finding on the DCA for the NuScale reactor design. Prior to plant construction, the NuScale DCA specifies that the ECCS valves will be qualified in accordance with ASME Standard QME-1-2007 as accepted in RG 1.100 (Revision 3). The NRC will evaluate the specific details of the qualification plan for the ECCS valves during its review of a COL application for a NuScale nuclear power plant. As indicated in the FTR for the ECCS Valve Design Demonstration Testing, a COL holder will address the lessons learned from the ECCS Valve Design Demonstration Testing to demonstrate that ECCS valves will perform their safety functions. The staff considers these lessons learned will be addressed in an updated Qualification Plan to include, for example, the small internal clearances for manufacturing tolerances, fluid flashing effects, boric acid effects, and allowable fluid particulate size.

VIII. CONCLUSIONS

In this report, the NRC staff describes its audit review of the NuScale ECCS Valve Design Demonstration Testing and the follow-up items from the FMEA audit to evaluate compliance with the regulatory requirements in 10 CFR 52.47(c)(2) and 50.43(e) for the demonstration of the performance of the safety features of the NuScale ECCS valve system to support the NRC review of the NuScale DCA. This report indicates the remaining follow-up items to be resolved to complete the staff review of the design of the ECCS valve system for the NuScale DCA. Based on its audit review, the staff concludes that the lessons learned from the ECCS Valve Design Demonstration Testing need to be addressed in developing the ASME QME-1 qualification program and the IST program for the ECCS valve system. In addition, the staff found that the ECCS performance attributes specified in the NuScale DCA were not consistent with the results of the ECCS Valve Design Demonstration Testing. In response to the ECCS Valve Design Demonstration Testing, the NuScale will update the DCA provisions for the IST program description for the ECCS valve system (including the subcomponent valves) and the ECCS valve performance attributes to reflect the lessons learned from the ECCS Valve Design Demonstration Testing. In addition, the NuScale will update applicable ECCS valve design documents to reflect the modifications to the design and performance characteristics of the ECCS valve system based on the results of the ECCS Valve Design Demonstration Testing. As indicated in the FTR, a COL holder will address the lessons learned from the ECCS Valve Design Demonstration Testing in developing the ASME QME-1 qualification testing program for both the RRV and RVV design of the ECCS valve system (including its subcomponent valves). Upon resolution of the follow-up items indicated in this audit report, the staff will determine whether the ECCS Valve Design Demonstration Testing performed by NuScale satisfies the regulatory requirements in 10 CFR 52.47(c)(2) and 50.43(e) for the demonstration of the performance of the safety features of the NuScale ECCS valve system to support the NRC review of the NuScale DCA.

IX. DOCUMENTS REVIEWED

<u>NuScale Documents</u>

NuScale DCA, Part 2, 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,” Revision 3.

NuScale Design Specification EQ-B020-2140, “ASME Design Specification for Emergency Core Cooling System Valves,” Revision 3, February 14, 2018, with ECN-B020-6969, “Update Loads and Qualification Requirements for DCA Review,” Revision 0, May 29, 2019.

NuScale Report ER-B020-3817, “Proof of Concept Test Report for Emergency Core Cooling (ECC) System Valves,” Revision B, July 30, 2018.

NuScale Report ER-B020-6052, “ECCS RVV Diffuser Report,” Revision 1, July 15, 2019.

NuScale Report ER-B020-6113, “ECCS Valve Subcomponent Level FMEA,” Revision 0, January 26, 2018.

NuScale Report ER-B020-6113, “ECCS Valve Subcomponent Level FMEA,” Revision 1, September 20, 2019.

NuScale Report ER-B020-6117, “ECCS Qualification Plan,” Revision 1, July 18, 2019.

NuScale Report ER-B020-6230, “Preliminary ASME Design Report for RRV,” Revision 0, March 29, 2018.

NuScale Report ER-B020-6289, “ECCS Valve Description,” Revision 1, July 18, 2019.

NuScale Report, ER-B020-6306, “Preliminary ASME Design Report for RVV,” Revision 0, March 29, 2018.

NuScale Report ER-B020-6307, “Preliminary ASME Design Report for Pilot Valves,” Revision 0, March 29, 2018.

NuScale Report FTR-B020-7262, “ECCS Valve DCA Demonstration Test Final Test Report,” Revision 0, September 25, 2019, forwarding Target Rock TRP No. 10107, “Final Test Report NuScale Emergency Core Cooling System Valve DCA Demonstration Testing,” September 24, 2019, with appendices TRP No. 10103, “Test Procedure and Plan, NuScale Emergency Core Cooling System Valve DCA Demonstration Testing,” Revision C, September 17, 2019, and TRP No. 10104, “As-Built and Dimensional Inspection Report, NuScale Emergency Core Cooling System Valve DCA Demonstration Testing,” Revision A, September 18, 2019.

NuScale Draft Audit Plan Miscellaneous Follow-up Item Closure, May 16, 2019.

NuScale Draft ECCS FMEA Report 7-29-2019 Responses, August 1, 2019.

NuScale Milestone Test Review Checklist, April 9, 2019.

NuScale Statement of Work SW-1018-62176, “ECCS Valve DCA Demonstration Statement of Work,” Revision 3, May 20, 2019; and Revision 6, August 23, 2019.

NuScale Task Order 25, Revision 0, SW-1018-62176, Revision 0, February 5, 2019.

NuScale Task Order 25, Revision 1, SW-1018-62176, Revision 1, March 20, 2019.

NuScale Task Order 25, Revision 3, SW-1018-62176, Revision 3, May 22, 2019.

NuScale Presentation, Entrance Meeting – NRC Inspection and Audit ECCS Valve Demonstration Test, June 3-7, 2019.

NuScale Test Specification TSD-B020-6749, “NuScale ECCS Valve DCA Demonstration Test Specification,” Revision 1, March 12, 2019, Revision 2, April 30, 2019; Revision 3, July 17, 2019; Revision 4, July 30, 2019; and Revision 5, August 22, 2019.

NuScale SDR-0319-7142, “Project Execution Plan for NuScale ECCS Valve DCA Demonstration Testing,” Revision 1, May 23, 2019, with TRP 10099, Revision A, May 21, 2019.

NuScale SDR-0319-7143, “Project Specific Quality Plan for NuScale ECCS Valve DCA Demonstration Testing,” Revision 1, May 23, 2019, with TRP 10100, Revision A, May 21, 2019.

NuScale SDR-0419-7206, “ECCS Valve Demonstration Test Program Test Requirements Compliance Matrix,” Revision 2, May 28, 2019, with TRP 10101, Revision A, May 21, 2019.

NuScale Report SDR-0519-7256, “Test Design Report for NuScale ECCS Valve DCA Demonstration Testing,” Revision 3, May 29, 2019, with TRP 10102, Revision C, May 24, 2019.

NuScale Test Procedure SDR-0519-7257, “Test Procedure and Plan, NuScale Emergency Core Cooling System Valve DCA Demonstration Testing,” Revision 2, May 29, 2019, with TRP 10103, Revision B, May 24, 2019.

NuScale Report SDR-0519-7260, “As-Built and Dimensional Inspection Report, NuScale Emergency Core Cooling System Valve DCA Demonstration Testing,” Revision 0, May 28, 2019, with TRP 10104, May 23, 2019.

NuScale Report SDR-0519-7261, “ECCS Valve DCA Demonstration Test Equipment Error and Accuracy Report,” Revision 0, May 29, 2019, with TRP 10105, May 24, 2019.

NuScale TRR-0519-65243, “ECCS Valve DCA Demonstration Testing,” Revision 0, May 30, 2019.

Policy and Procedures

NuScale Licensing Topical Report NP-TR-1010-859-NP, “NuScale Topical Report: Quality Assurance Plan Description for the NuScale Power Plant,” Revision 4, April 17, 2017.

Target Rock QMP-1010, “Inspection and Testing,” Revision H, October 1, 2013.

Target Rock QMP-1011, “Control of Inspection, Measuring, and Test Equipment,” Revision K, September 12, 2018.

Target Rock QMP-1023, “Energy Products Nuclear Quality Assurance Manual, Edition 10,” Revision 2, November 8, 2018.

NuScale EP-1103-2992, “Test Control,” Revision 10, November 26, 2018.

Valve Drawings

NuScale Engineering Drawing (ED)-B020-2617, “Reactor Vent Valve Drawing,” Revision 1, dated March 29, 2018, forwarding Target Rock Drawing No. ECCS-RVV-001, “Reactor Vent Valve (RVV) Assembly, Pilot Operated, Fail Open, On/Off, NPS 5 Class 2500, Flanged,” Revision 2, dated September 15, 2017.

NuScale ED-B020-2650, “Reactor Recirculation Valve Drawing,” Revision 1, dated March 29, 2018, forwarding Target Rock Drawing No. ECCS-RRV-001, “Reactor Recirculation Valve (RRV) Assembly, Pilot Operated, Fail Open, On/Off, NPS 2 Class 2500, Flanged,” Revision 2, dated September 15, 2017.

NuScale ED-B020-5679, “Inadvertent Actuation Block Drawing,” Revision 1, dated March 29, 2018, forwarding Target Rock Drawing No. ECCS-IAB-001, “IAB Valve Assembly,” Revision 2, dated September 15, 2017.

NuScale ED-B020-2651, “Trip and Reset Valves Drawing,” Revision 1, dated March 29, 2018, forwarding Target Rock Drawing No. ECCS-TRV-001, “Trip/Reset Valve (TRV) Assembly, On/Off, NPS 3 Schedule 160 BW Connection,” Revision 2, dated September 15, 2017.

NuScale ED-B020-5690, “Single Trip Valve Drawing,” Revision 1, dated March 29, 2018, forwarding Target Rock Drawing No. ECCS-TV-001, “Trip Valve (TV) Assembly, On/Off, NPS 3 Schedule 160 BW Connection,” Revision 2, dated September 15, 2017.

Target Rock Reports and Calculations (in addition to those listed above)

Target Rock Report No. 9967, “NuScale ECCS RVV Diffuser Report,” Revision B, April 30, 2019.

Target Rock Report No. 10013, “System Description and Summary Report for Detail Design of the Emergency Core Cooling (ECC) System Valves,” Revision A, dated March 9, 2018 (draft update).

Target Rock Calculation “Inflow-Outflow Analysis and Opening Analysis Calculations for ECCS,” September 26, 2019.

Target Rock Calculation “Bending Stress Calculation: RRV Main Disc Pressure Side-Load Analysis,” September 26, 2019.

Target Rock Calculation “Bending Stress Calculation: RVV Main Disc Pressure Side-Load Analysis,” September 26, 2019.

<u>Nonconformance and Corrective Action Reports</u>

NuScale Condition Report CR-0619-65832, “Anomaly during 1300 psi ECCS testing,” dated June 4, 2019.

NuScale Condition Report CR-0619-65857, “Anomalous Test Run of ECCS Main Valve,” dated June 5, 2019.

NuScale Condition Report CR-0619-65860, “Loss of Test Data,” dated June 5, 2019.

NuScale Condition Report CR-0719-66385, “Change to Boric Acid Test Acceptance Criteria in ECCS Valve DCA Demonstration Test,” dated July 22, 2019.

XI. PARTICIPATING NUSCALE AND TARGET ROCK PERSONNEL

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Steve Pauly
Greg Sanh
Scott Schoeps
William Velkoff
James White

XII. REFERENCES

1. NuScale Standard Plant Design Certification Application, Revision 3, ADAMS Accession No. ML19241A315, August 22, 2019.

2. NRC Letter, "NuScale Power, LLC – Acceptance of an Application for Standard Design Certification of a Small Modular Reactor," ADAMS Accession No. ML17074A087, March 23, 2017.

3. NuScale Letter, "NuScale Power, LLC Response to NRC Request for Additional Information No. 47 (eRAI No. 8820) on the NuScale Design Certification Application," ADAMS Accession No. ML17213A540, August 1, 2017.

4. NRC Report of Initial Regulatory Audit for Emergency Core Cooling System Valves in NuScale Power, LLC, Design Certification Application, ADAMS Accession No. ML18052A079, February 26, 2018.

5. NRC Report of Regulatory Audit of Failure Modes and Effects Analysis and Other Supporting Documents of Emergency Core Cooling System Valves in the NuScale Power, LLC, Design Certification Application, ADAMS Accession No. ML18219B634, August 14, 2018.

6. NuScale Letter, "NuScale Power, LLC Submittal of Resolution Plans and Classification for ECCS Valve FMEA Audit Follow-Up Items," ADAMS Accession No. ML18264A312, September 21, 2018.

7. NRC Plan for Regulatory Audit of NuScale Power, LLC, Emergency Core Cooling System Valve Design Demonstration Testing and Follow-Up Items, ADAMS Accession No. ML19067A143, March 20, 2019.

8. NRO-REG-108, "Regulatory Audits," ADAMS Accession No. ML081910260, April 2, 2009.

9. NRC Vendor Inspection Report of NuScale Power LLC No. 05200048/2019-203, ADAMS Accession No. ML19197A241, July 18, 2019.

10. NuScale Letter, "NuScale Power, LLC Submittal of Responses to ECCS Valve FMEA Audit Follow-Up Items," ADAMS Accession No. ML19233A203, August 21, 2019.

11. NuScale Letter, "NuScale Power, LLC Submittal NuScale's Proposed Closure Plan to Address Impacts of the Adjusted IAB Operations Range," ADAMS Accession No. ML19238A309, August 26, 2019.

12. NuScale Letter, "NuScale Power, LLC Submittal of ECCS Valve FMEA Audit Supplemental Items," ADAMS Accession No. ML19297H199, October 24, 2019.

U.S. NUCLEAR REGULATORY COMMISSION
SUMMARY REPORT OF REGULATORY AUDIT OF EMERGENCY CORE COOLING SYSTEM VALVE DESIGN DEMONSTRATION TESTING AND FOLLOW-UP ITEMS
NUSCALE POWER, LLC, STANDARD PLANT DESIGN CERTIFICATION

Resolution of Follow-Up Items from NRC Staff Audit of NuScale ECCS Valve Design

In a report dated August 14, 2018, the NRC staff described the follow-up items from its audit of the Failure Modes and Effects Analysis (FMEA) and other supporting information for the NuScale Emergency Core Cooling System (ECCS) valves. In a letter dated September 21, 2018, NuScale described its plans to resolve each of the follow-up items in the FMEA audit report and specified a tracking number for each item. In the paragraphs below, the staff discusses the findings from the audit of the NuScale ECCS Valve Design Demonstration Testing and the resolution of the follow-up items in the FMEA audit report, including the tracking numbers used by NuScale.

A. NuScale Report ER-B0202-3817, "Proof of Concept Test Report for Emergency Core Cooling (ECC) System Valves," Revision A, dated December 18, 2015

1. The proof-of-concept (POC) test report identifies 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 inadvertent actuation block (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; and (d) the effect on valve performance from the differences between test facilities and the reactor pressure vessel (RPV) will need to be assessed. NuScale should address these key aspects identified in the POC test report to demonstrate the safety features of the ECCS valves and their valve subcomponents. [Item 1]

2. NuScale should address the following items for application of the POC test results to the final design of the reactor vent valve (RVV) and reactor recirculation valve (RRV) for the ECCS valves:

a. Applicability of the POC test fluid conditions to the reactor fluid conditions for temperature, pressure, and borated water. [Item 2]

b. Applicability of the POC test valve size and tubing length, routing, and volume to the final ECCS valve system design to support the assumptions for IAB valve performance and validate IAB valve calculations. [Item 3]

c. Adequacy of the POC test results to support the passive component assumption for the IAB valve in the safety analysis. [Item 4]

d. Reliability of the POC test data for traceability and calibration of the pressure transducers and main disc position linear variable differential transformer (LVDT) used in the POC testing. [Item 5]

e. Applicability of the internal dimensions of the valves used in POC testing to the final RRV design. For example, the following information for the POC test equipment should be compared to the final ECCS valve design: (1) main valve and IAB valve internal dimensions and clearances; (2) internal volumes (main valve control chamber, IAB valve above and below bellows, and tubing); (3) main valve and IAB valve spring sizes, constants, and preloads; (4) valve seat sizes (main valve, IAB valve, trip valve, and reset valve); (5) main valve orifice and filter; (6) main valve and trip valve elevation difference and tubing routing; and (7) line flow restrictions (e.g., adapters, fittings, and line internal dimensions). [Item 6]

f. Applicability of the POC testing of a 2-inch valve (similar to the RRV) to the performance of the 5-inch RVV for reactor fluid conditions and applicable accident scenarios, including low temperature overpressure protection (LTOP). [Item 7]

3. NuScale should describe its plans to resolve the safety questions regarding the design demonstration testing of the ECCS valves to support the design certification application (DCA). [Item 8]

<u>Follow-Up Audit Finding</u>

In the letter dated September 21, 2018, NuScale described its plans to conduct ECCS Valve Design Demonstration Testing to satisfy the requirements in 10 CFR 50.47(c)(2) and 10 CFR 50.43(e). As part of this follow-up audit, the NRC staff reviewed the test plans, procedures, and results from the ECCS Valve Design Demonstration Testing. Based on the test results, NuScale identified several design changes that were necessary to the main valve and IAB valve of the ECCS valve system. The ECCS Valve Design Demonstration Testing addresses Follow-Up Items 1 through 9 as tracked in the NuScale September 21, 2018, letter, with the exception of Item 4, which is addressed below as part of the passive function issue for the IAB valve.

The NRC staff reviewed the Final Test Report (FTR) for the ECCS Valve Design Demonstration Testing made available in the NuScale eRR. The FTR specifies that the ECCS Valve Design Demonstration Testing was intended to perform functional testing of a valve of similar geometry and configuration to the RRVs and RVVs. The two concepts of functionality specified in the FTR to be tested included (1) the ECCS valves operate as required over the range of operating conditions; and (2) the testing demonstrated that the presence of boric acid in the coolant at bounding concentrations did not adversely affect the valve's performance. The FTR describes specific design changes to the main valve and IAB valve found to be necessary based on the test results. For example, the orifice in the main valve disc was reduced in size from the original [ ] in diameter to reduce the inflow rate into the main valve control chamber from the supply (reactor coolant system (RCS)) source to provide assurance that the main valve control chamber pressure will be reduced to a sufficient level ([ ]) upon opening of the trip valve to allow the main valve to be opened by the supply (RCS) pressure. In addition, a [ ] control orifice was installed in the . [ ] flow path from the main valve control chamber to the IAB valve to allow the pressure to drop more rapidly within the IAB valve and reduce the IAB valve threshold pressure. Further, the shim for the IAB valve spring was reduced from [ ] to lower the IAB valve release and threshold pressures. Even with these design changes, the FTR reports that the original IAB valve performance range of 1000 to 1200 pounds per square inch (psid) had to be modified to a new range of 900 to 1300 psid. The FTR concludes that the test program was successful in demonstrating the functional performance of the ECCS valves at reactor operating conditions. The FTR also concludes that the boric acid solution did not have a significant impact on the valve performance. The FTR indicates that the testing provided feedback and insights for the QME-1 qualification testing. The key observations from the ECCS Valve Design Demonstration Testing specified in the FTR are (1) the ratio of the inflow and outflow for the main valve control chamber is critical to allow proper depressurization of the main valve control chamber; (2) the IAB valve threshold and release pressure is significantly impacted by fluid temperature; (3) the location and size of the minimum outflow area downstream of the main valve control chamber is critical to the IAB valve threshold pressure; and (4) dynamic performance limitations of the IAB valve do not allow the release and threshold pressure to be within a narrow pressure range such that the IAB valve pressure range was increase to 900-1300 psid to allow for satisfactory IAB valve performance under the range of fluid conditions tested. The FTR adequately demonstrates the performance of the RVV based on the RRV test results to support the DCA review. The COL holder will complete qualification testing of both the RRV and RVV designs in accordance with ASME Standard QME-1-2007 as accepted in RG 1.100 (Revision 3) to demonstrate the capability of the RRVs and RVVs to perform their safety functions under the applicable design-basis conditions.

Based on its review, the staff considers the ECCS Valve Design Demonstration Testing to be sufficient to demonstrate the design features of the ECCS valve system to satisfy 10 CFR 52.47(c)(2) and 50.43(e), provided the following follow-up items from the testing program are resolved.

As **Audit Follow-Up Item 1**, NuScale will update the description of the IST program for the ECCS valves (including the subcomponent valves) in the DCA to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.

As **Audit Follow-Up Item 2**, NuScale will update the DCA provisions for the ECCS valve performance (such as the IAB valve pressure range) to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.

As **Audit Follow-Up Item 3**, NuScale will update the applicable ECCS valve design documents to reflect the lessons learned from the ECCS Valve Design Demonstration Testing.

Upon resolution of the follow-up items from this audit, the staff will determine whether the ECCS Valve Design Demonstration Testing performed by NuScale satisfies 10 CFR 52.47(c)(2) and 50.43(e) for the NRC review of the ECCS valve system described in the NuScale DCA. Following completion of the NuScale DCA review, a COL holder will address the lessons learned from the ECCS Valve Design Demonstration Testing in developing the ASME QME-1 qualification testing program for the ECCS valve system (including its subcomponent valves).

B. Partial Open ECCS Valve Failure Mode

1. NuScale should address the following technical aspects in resolving the safety questions regarding a partially open failure mode for an ECCS valve:

a. The main valve needs to be demonstrated to not be subject to tilting that could cause binding during valve actuation by the opening flow for the RVV and RRV, including diffuser turbulent flow for the RVV. [Item 9]

b. The pressure drop in the main valve control chamber upon operation of the IAB valve needs to be evaluated to demonstrate that the main valve will not open prematurely. [Item 10]

c. The preliminary calculations of the performance of the main valve upon partially opening need to be completed and verified with justification by analysis or testing as necessary, including demonstrating that the main valve will fully close or fully open in a timely manner in the event of a partial open condition. [Item 11]

d. The verification activities being performed by NuScale and Target Rock to demonstrate that a partial open failure mode of the ECCS valve is not credible need to be finalized as quality assurance products that are available for NRC staff review. [Item 12]

2. NuScale should describe its plans to resolve the safety questions regarding the potential partial open failure mode for the main valve of the ECCS valves to support the DCA. [Item 13]

Follow-Up Audit Finding

NuScale indicated that the Target Rock calculations addressing the potential partial open failure mode of the main valve of the ECCS valve system is available for NRC staff audit review at the Target Rock facility. The Target Rock calculations address Follow-Up Items 9 through 13 as tracked in the NuScale September 21, 2018, letter. On September 27, 2019, the staff conducted an onsite audit review of the finalized Target Rock calculations of the potential for the main valve to remain partially open in a stable position during operation of the ECCS valve system. Based on its onsite review and discussions with NuScale and Target Rock, the staff considers that NuScale has demonstrated that there is no credible potential for the main valve in the ECCS valve system to remain in a partially open position during its opening stroke from either fluid flow forces or mechanical loading. Based on its review, the staff considers Items 9 through 13 resolved and closed for this audit.

C. IAB Valve Passive Component Assumption

1. NuScale should justify its assumption that the guidance in Commission Paper SECY-94-084 (March 28, 1994), “Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs,” for categorizing a check valve in a new reactor as a passive component with respect to the single failure criterion is applicable to the spring-operated IAB valve in the NuScale reactor or identify alternative treatment for applying single failure to the IAB.

2. NuScale should address the following technical aspects in resolving the safety questions regarding its assumption that the IAB valve may be categorized as a passive component with respect to the single failure criterion or appropriately consider single failure for the IAB in the accident analysis:

a. The IAB valve has a different design from the pilot for the main steam safety relief valve (MSSRV), such that the MSSRV failure rate has not been demonstrated as applicable to the IAB valve without significant operating or testing experience. [Item 14]

b. The IAB valve has multiple operating positions of initially open, close, and re-open in performing its safety functions while the NuScale response to RAI 8815 only evaluates a failure to close in calculating the assumed failure rate for the IAB valve. [Item 15]

c. The low demand frequency assumed in the NuScale response to RAI 8815 to convert the failure rate of the IAB valve per demand to failure rate per year has not been justified in calculating the failure rate of the IAB valve to satisfy the Commission paper guidance for passive components. [Item 16]

3. NuScale should describe the plans to justify its consideration of the IAB valve similar to a passive component with respect to the single failure criterion to support the DCA. [Item 17]

Follow-Up Audit Finding

On December 14, 2018, NuScale submitted a letter describing its position with respect to application of the single failure criterion to the IAB valve in its accident analyses. In Commission Paper SECY-19-0036 (April 11, 2019), "Application of the Single Failure Criterion to NuScale Power LLC's Inadvertent Actuation Block Valves," the NRC staff requested that the Commission provide guidance on the appropriate approach to address the single failure criterion with respect to the IAB valve in the NuScale accident analyses. On July 2, 2019, the Commission issued a Staff Requirements Memorandum (SRM) for SECY-19-0036 directing that the NRC staff should review Chapter 15, "Transient and Accident Analyses," of the NuScale DCA without assuming a single active failure of the IAB valve to close. Based on the Commission direction in SRM-SECY-19-0036, Items 14 through 17 are closed for this audit.

D. NuScale Report ER-B020-6113 (Revision 0, dated January 26, 2018), "ECCS Valve Subcomponent Level FMEA"

General

1. An FMEA is performed to identify potential failure modes of a new component design and to enable the design process to avoid the significant failure modes of the component. An FMEA prioritizes the significance of the potential failure modes by calculating a Risk Priority Number (RPN) for each failure mode by the multiplication of assigned Severity, Occurrence, and Detection rating numbers. Based on the FMEA results, the potential failure modes with the highest priority RPNs are specified for corrective action as part of the design process or other activities to address those significant failure modes. NuScale Report ER-B020-6113 (Revision 0, dated January 26, 2018), "ECCS Valve Subcomponent Level FMEA," forwarded the FMEA of the NuScale ECCS valves performed by Target Rock. The FMEA for the NuScale ECCS valves indicated an RPN of 200 as the significance level for potential failure modes without justifying the RPN methodology.

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated for the basis of the cut-off level of significance and what further actions are needed for items above the cut-off. During this follow-up audit, the NRC staff found that the NuScale FMEA has been revised to apply the most recent FMEA guidance available for a wide-range of general industrial applications. This new guidance uses an updated FMEA approach rather than the Risk Priority Number (RPN) method used previously. The revised NuScale FMEA indicates that Target Rock applied the concepts of new FMEA guidance to develop Severity (S), Occurrence (O), and Detection (D) rankings for the design and performance of the ECCS valves. Target Rock then combined the Severity and Occurrence rankings to achieve an overall SO Risk Ranking with consideration of the D ranking to determine those postulated ECCS valve failures that are unacceptable such that mitigation features by design changes or testing/monitoring programs will be applied. The revised NuScale FMEA describes the evaluation of two specific failure modes: (1) potential partial open failures of the main valve; and (2) potential adverse effects from boric acid crystallization on the ECCS valve fluid flow in the internal valves and hydraulic lines. Overall, the revised NuScale FMEA report identified 36 potential failures that could severely affect the safety function of the ECCS valves. For the unique design features of the ECCS valves, the revised NuScale FMEA report indicates that the primary mitigating factors are (1) design analyses, (2) POC testing in 2015, and (3) DCA testing in 2019. The revised NuScale FMEA also states that the NuScale ECCS valve prototypes are required to undergo qualification testing (ASME QME-1) to assure all required performance parameters are met in the required process and environment conditions. The revised NuScale FMEA report also references the IST program to monitor for potential degradation in the ECCS valve performance. Based on the revision of the NuScale FMEA report, the staff considers Item 18 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

2. The FMEA report describing the categorization of potential failure modes of the ECCS valves and their four valve subcomponents identifies the IAB valve bellows assembly and the potential for debris to damage operational clearances as the most significant risk items in that their RPNs are calculated to be 200 or above. The FMEA report states that partial open failures were considered for the ECCS main valve. The FMEA indicates that several components in the main valve body were postulated as a risk of causing a partial open failure if they are damaged or entrained with debris. Other components outside of the main valve (such as the IAB valve, hydraulic line, and trip valve) were said to have postulated failures that could cause inadvertent opening of the main valve. The FMEA report concludes that no credible component failures were identified that would cause inadvertent opening or failure of the main valve to a partial open state. The FMEA report also notes that boric acid crystallization is a phenomenon that might affect the function of the valve system. The FMEA does not include plans to address these failure modes as part of the design process. [Item 19]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. As discussed for Item 18 above, the revised NuScale FMEA report addresses potential failure modes, including potential partial opening of the main valve and potential adverse effects of boric acid crystallization in the ECCS fluid lines. Therefore, the staff considers Item 19 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

3. In addition to the failure modes indicated in the FMEA report conclusions, the FMEA report identifies several failure modes that approach the RPN significance level of 200 (such as in Table 6-7). Minor uncertainty adjustments to the assignment of Severity, Occurrence, and Detection rating numbers for several failure modes would cause the RPN for those failure modes to approach or exceed the RPN significance level. An FMEA is intended to identify the significant failure modes for corrective action as part of the design process or other activities to avoid those failure modes. [Item 20]

Follow-Up Audit Findings: In its September 21, 2018, letter, NuScale indicated that the FMEA will be updated to address this item. As discussed for Item 18 above, the revised NuScale FMEA report applies updated FMEA guidance to identify potential failure modes of the ECCS valves. Therefore, the staff considers Item 20 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

4. The FMEA should identify the applicable mitigating factors to support the assigned Severity, Occurrence, and Detection rating numbers used in calculating the RPN for each failure mode. [Item 21]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA will be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. Therefore, the staff considers Item 21 to be resolved and closed for this audit.

5. Several failure modes, such as 6-1-8, 6-3-2, 6-6-28, 6-6-52, 6-6-53, 6-7-4, 6-7-10, 6-8-4a, 6-8-10, 6-8-14, 6-8-19, and 6-8-20, in the FMEA tables specify inservice or routine testing as part of the mitigating factors for those failure modes. The basis for these mitigating factors was not clear in the FMEA. [Item 22]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA will be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. Therefore, the staff considers Item 22 to be resolved and closed for this audit.

6. FMEA Table 5-1 (Severity), Table 5-2 (Occurrence), and Table 5-3 (Detection) assign rating numbers of 1 to 10 for potential failure modes. Comments on the specific tables are as follows:

Table 5-1, Severity (S)

a. Table 5-1 assigns a Severity rating number of 5 for inadvertent/spurious opening of the main valve. [Item 23]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel clarified that inadvertent opening of the main valve was considered a mid-range 5 severity because it does not directly challenge the reactor fuel. Based on this clarification, the staff considers Item 23 to be resolved and closed.

b. Table 5-1 assigns a Severity rating number of 5 for failure of the IAB function. [Item 24]

Follow-Up Audit Finding: During the previous audit, NuScale stated that the FMEA would be revised to clarify the severity rankings for the appropriate functions of the IAB valve. In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff found that the revised Table 5-1 in the NuScale FMEA report clarifies the failure of the IAB to close as a low severity ranking and the failure of the IAB valve to open as a critical severity ranking. Based on this clarification of the NuScale FMEA report, the staff considers Item 24 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

c. Table 5-1 assigns a Severity rating number of 6 for slow opening (est > 10 s, to 60 s) of the main valve. [Item 25]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel clarified that slow opening of the main valve was not a severe event because of the slow progression of core uncovery. Based on this clarification, the staff considers Item 25 to be resolved and closed.

Table 5-2, Occurrence (O)

a. Table 5-2 assigns Occurrence levels (and their rating numbers) as Not Credible (1), Remote (2 or 3), Moderate (4, 5, or 6), High (7 or 8), and Very High (9 or 10). However, the examples do not differentiate between these multiple rating numbers. [Item 26]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff found that the revised Table 5-2 in the NuScale FMEA report clarifies the Occurrence rankings and their examples. Based on this clarification of the NuScale FMEA report, the staff considers Item 26 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

b. Table 5-2 defines the Remote Occurrence level as failures that may have been reported in relevant developmental testing, but not in service, with examples of bolt breakage or broken wires. [Item 27]

Follow-Up Audit Finding: During the FMEA audit discussions, Target Rock personnel clarified that the operating experience with solenoid valves was applied in assigning the Remote Occurrence level to specific potential failure modes. Based on this clarification, the staff considers Item 27 to be resolved and closed.

c. Table 5-2 does not discuss potential failures related to the loss of power to the trip and reset valves. [Item 28]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale indicates that a loss of power to the ECCS trip solenoid valves has the same effect as a Module Protection System (MPS) actuation. Based on this information, the NRC staff considers Item 28 to be resolved and closed.

Table 5-3, Detection (D)

a. Table 5-3 assigns Detection levels (and their rating numbers) as Monitored (1), Detectable (2 or 3), Potential (4, 5, or 6), Late (7 or 8), and None (9 or 10). However, the examples do not differentiate between these multiple rating numbers. [Item 29]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff found that the revised Table 5-3 in the NuScale FMEA report clarifies the Detection rankings and their examples. Based on this clarification of the NuScale FMEA report, the staff considers Item 29 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

b. Table 5-3 assigns Detection rating numbers of 4 through 8 based on inservice inspection (ISI), IST and/or PST. If ISI and IST are only conducted during refueling outages every 2 years, ISI and IST will only detect some performance aspects prior to failure. Similarly, PST is only conducted prior to placing the valve in service. [Item 30]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff found that the revised Table 5-3 in the NuScale FMEA report clarifies the applicability of

PST, IST, and ISI in the examples for specific Detection rankings. Based on this clarification of the NuScale FMEA report, the staff considers Item 30 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

7. NuScale indicated that some design aspects of the safety features of the ECCS valves are planned to be addressed during qualification testing by the combined license (COL) holder. These include, for example, (1) the impact of flashing of the reactor coolant in the four valve subcomponents of the ECCS valves, (2) the establishment of the proper shim at the factory to provide assurance that the IAB spring will close and then re-open at the proper differential pressure between the reactor coolant system and containment vessel, and (3) the impact of boric acid on the four valve subcomponents of the ECCS valves. Design proof-of-performance testing by a DC applicant and component qualification testing by a COL holder are two separate activities. Specifically, design testing required by 10 CFR 52.47(c)(2) and 50.43(e) involves testing sufficient to demonstrate that a new design feature, which in this case is a new valve design, can perform its safety functions. Such testing may include a repetitive series of tests of an initially proposed valve design with modifications made to the valve design based on multiple test results until the necessary performance has been successfully demonstrated. In contrast to design testing, qualification testing involves testing to verify that the valves as procured for installation in the facility are capable of performing their specific safety functions as indicated in the DCA Part 2. Qualification testing does not generate design information at the DCA level of detail needed for design certification; rather, qualification testing is a special treatment activity under 10 CFR Part 50, Appendix B, Criterion III, "Design Control," and the requirements of the ASME *Boiler and Pressure Vessel Code* (BPV Code), Section III, among other NRC requirements for the design, manufacture, and installation of certain systems and components in a particular nuclear power plant. Qualification testing is not intended to provide proof-of-performance for new safety features or develop a first-of-a-kind prototype valve. Valve failure during qualification testing would result in an extent-of-condition evaluation of the design control process to identify the root cause of the failure and appropriate corrective action to resolve the specific valve failure and the discrepancy in the design control process. Such failure would not normally indicate that the high-level valve design was inadequate (thus requiring modification of the certified design by rulemaking); rather, failure during qualification testing normally indicates that the particular valve, as procured in accordance with its design specification, did not perform as designed (e.g., the valve did not meet its design specification or included a latent manufacturing flaw). [Item 31]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the importance of determining those design aspects to be verified for the NuScale DCA and those performance aspects that can be addressed as part of qualification activities by the COL holder. In its September 21, 2018, letter, NuScale stated that the ECCS Valve Design Demonstration Testing would be performed to support the NuScale DCA and that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff found that the NuScale FMEA report had been updated to reference the ECCS Valve Design Demonstration Testing and to clarify the applicable references to the subsequent qualification of the ECCS valves. Based on this clarification of the NuScale FMEA report, the staff considers Item 31 to be resolved and closed for this audit of the ECCS valve design documentation in support of the NuScale DCA review.

Potential Failure Modes and Reliability Not Addressed in FMEA

1. The FMEA report does not include an evaluation of the timeliness of the IAB valve function to initially close against a large spring force to isolate the main valve control chamber and then open at the appropriate differential pressure between the RPV and CNV to provide for the proper operation of the main disc of each ECCS valve. [Item 32]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock the importance of the IAB valve to close promptly to avoid inadvertent opening of the main valve disc at high reactor pressure, and then to re-open at the proper pressure conditions to allow the main valve control chamber to depressurize such that the main valve disc will open to allow natural circulation to begin for reactor core cooling. Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 32 to be resolved and closed for this audit.

2. The FMEA report does not include an evaluation of the sizing of the IAB valve seat, trip valve, and the connecting tubing to provide for the depressurization of the main valve control chamber in a timely manner. [Item 33]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the importance of the sizing of the IAB valve seat, trip valve, and the connecting tubing to provide for the depressurization of the main valve control chamber in a timely manner. Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 33 to be resolved and closed for this audit.

3. The FMEA report does not include an evaluation of the potential for boric acid precipitation and crystallization, as well as flashing of reactor coolant, to impact the performance of the ECCS valve and its subcomponents, with consideration of the small clearances of the tubing and valve seats. [Item 34]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the potential for boric acid precipitation and crystallization, as well as flashing of the reactor coolant, to impact the performance of the ECCS valve and its subcomponents. Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 34 to be resolved and closed for this audit.

4. The FMEA report does not address the potential failure mode related to borated liquid reactor coolant in the control chamber of the main valve and its effect on the operation and position of the main valve disc upon opening of the trip valve when a pressure drop occurs in the main valve control chamber prior to the IAB valve closing. [Item 35]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the potential failure mode related to borated liquid reactor coolant in the control chamber of the main valve and its effect on the operation and position of the main valve disc upon opening of the trip valve when a pressure drop occurs in the main valve control chamber prior to the IAB valve closing. Target Rock personnel prepared preliminary calculations that predicted that the main valve might fully open or might re-close following a partial opening depending on the specific reactor conditions. NuScale and Target Rock personnel do not believe that the main valve disc could stabilize in a partial open condition. As discussed regarding Items 9 through 13, the NRC staff reviewed the potential for partial opening of the main valve based on Target Rock calculations. Based on its review of the Target Rock calculations addressing Items 9 through 13, the staff considers Item 35 resolved and closed for this audit.

5. The FMEA report does not include an evaluation of the performance of the main disc with a small orifice and filter between the liquid borated reactor coolant in the main valve control chamber and steam in the pressurizer to transmit pressure of the borated reactor coolant for the intended valve performance. [Item 36]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the performance of the main disc with a small orifice and filter between the liquid borated reactor coolant in the main valve control chamber and steam in the pressurizer to transmit pressure of the borated reactor coolant for the intended valve performance. Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 36 to be resolved and closed for this audit.

6. The FMEA report does not address the potential impact of the reverse flow from the diffuser upon actuation of the RVV. [Item 37]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale states that thrust reaction loads on the RVVs due to jet flow out of the valves upon ECCS actuation are specified and evaluated to ASME Service Level B limits as indicated in DCA Part 2, Tier 2, Table 3.9-11. NuScale indicates that the final ASME design reports for the ECCS valves will show that the valves withstand the reaction loads according to the Service Level B allowable stress and limits as indicated in DCA, Part 2, Tier 1, Table 2.1-4. NuScale also states that ASME QME-1 qualification testing requires qualification of the ECCS valve functions including valve stroke and capacity of the RVV (including the diffuser). Based on this information, the staff considers Item 37 to be resolved and closed for this audit.

7. The FMEA report does not address the recirculation flow requirement of the RRVs to perform their safety function to allow condensed reactor coolant to enter the RPV from the CNV with sufficient flow to cool the reactor core in a timely manner. [Item 38]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this audit, the staff found that the revised FMEA specifies that the valve capacity requirements (C_v and X_T) for the RRVs and RVVs will be validated during qualification testing, with NuScale clarifying that these requirements include RRV recirculation flow. Based on this information, the staff considers Item 38 to be resolved and closed for this audit.

8. The FMEA report addresses a potential tubing break but does not discuss other potential failure modes of the tubing, such as binding or crimping. [Item 39]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale states that an ITAAC (Tier 1, Table 2.1-4, No. 26) requires inspections to confirmed that the hydraulic lines are installed in accordance with their installation specifications. Based on this information, the NRC staff considers Item 39 to be resolved and closed.

9. NuScale assumes that the ECCS valve is a passive component with respect to the single failure criterion for such design aspects as IAB valve performance and partial opening of the main valve disc. Commission Paper SECY-94-084 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. The FMEA report does not address the reliability of the ECCS valve with respect to the passive component assumption. [Item 40]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with Target Rock and NuScale personnel the need to justify the assumption that the IAB valve is a passive component in the NuScale safety analysis. Based on the discussion above for Items 14 through 17, the staff considers Item 40 to be closed for this audit.

<u>Table 6-1, Functional FMEA, Trip/Reset Valves</u>

The comments on Table 6-1 have been incorporated into other comments provided in this audit report. A few specific comments are provided below:

1. Failure mode 6-1-1 relates to the potential spurious opening of the trip valve that would cause the main valve to open. The Occurrence rating number for this failure mode is specified as 2, which is indicated as remote in Table 5-2. [Item 41]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed with NuScale and Target Rock personnel the potential spurious opening of the trip valve. Target Rock personnel considered that the potential spurious opening of the trip valve from mechanical causes is remote based on operational experience with solenoid valves. Target Rock personnel indicated that electrical aspects were not addressed in the FMEA as outside the Target Rock scope. Based on NRC staff review of the NuScale accident analyses, the staff considers Item 41 to be closed and resolved for this audit.

2. Failure mode 6-1-2 relates to leakage of the trip valve that might cause the main valve to open. The mitigating factors refer to control room leak detection. NuScale indicated that the leakage detection referenced for this failure mode applies to general RPV leakage rather than specific trip valve leakage. NuScale indicated that procedures will provide for plant shutdown in response to significant RPV leakage. [Item 42]

Follow-Up Audit Finding: As part of this audit, the NRC staff reviewed NuScale Technical Specification 3.4.5, “RCS Operational Leakage,” in DCA Part 4, “Generic Technical Specifications,” (Revision 3) and its bases. Based on its review, the staff considers Item 42 to be closed for this audit.

3. Failure mode 6-1-4 relates to the potential failure of the trip valve to open. The mitigating factors are specified as redundant RVVs and RRVs, and opening of the main valve by spring force when the pressure differential between the RPV and CNV reaches a small differential pressure. [Item 43]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale states that in the safety analyses, there is no reliance on the low pressure ECCS main valve spring to actuate the valves to the open position. The safety function for which the main valve spring is credited is to hold the ECCS main valves in the open position after an actuation in which differential pressure is used to initially open the valves. After ECCS actuation when the pressure between the reactor vessel and containment approach near equilibrium, the spring ensures that the valve disc stays in the open position. With this information, the staff considers Item 43 to be resolved and closed.

4. Failure mode 6-1-7 relates to the potential rupture of the manifold providing the CNV boundary. The mitigating factors refer to hydrotesting in accordance with ASME Standard B16.34, “Valves – Flanged, Welded, and Welding End.” [Item 44]

Follow-Up Audit Finding: During the FMEA audit, Target Rock personnel indicated that the ASME BPV Code requirements for the ECCS valve will be satisfied, including the reference to ASME B16.34. Based on this clarification, the staff considers Item 44 to be resolved and closed for this audit.

5. Failure mode 6-1-8 relates to the failure of the gasket providing the CNV boundary. The FMEA states that there is no effect on the main valve. [Item 45]

Follow-Up Audit Finding: The NRC staff is reviewing the design aspect of the ECCS valve with respect to the gasket providing the CNV boundary as part of RAI 9315, Question 03.08.02-14. Therefore, the staff considers Item 45 to be closed for this audit.

Table 6-2, Functional FMEA, IAB Valve

The comments on Table 6-2 were incorporated into other comments provided in the FMEA audit report.

Table 6-3, Functional FMEA, Main Valves

The comments on Table 6-3 were incorporated into the other comments provided in the FMEA audit report.

Table 6-4, Functional FMEA, Consideration of Partial Open Valve Failure

The comments on Table 6-4 were incorporated into other comments provided in the FMEA audit report.

Table 6-5, Functional FMEA, Consideration of Valve Failure Caused by Boric Acid

The comments on Table 6-5 have been incorporated into other comments provided in this audit report. A few specific comments are provided below:

1. Table 6-5 lists potential failure modes caused by boric acid. NuScale should provide justification that the lessons learned from the Davis Besse RPV degradation, such as described in NRC NUREG/BR-0353 (Revision 1), “Davis-Besse Reactor Pressure Vessel Head Degradation,” or documents prepared by the Institute of Nuclear Power Operations (INPO), have been addressed in the design of the ECCS valves, such as related to materials in failure mode 6-5-1. [Item 46]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale stated that the ECCS valve (main valve, trip/reset valves, and IAB valve) reactor pressure retaining materials are stainless steel base materials and not subject to corrosion by boric acid solutions as indicated in DCA Part 2, Tier 2, Section 6.1.1.2 and Table 6.1-1. NuScale notes that the external surfaces for the ECCS valves are stainless steel based material except for the non-pressure bound solenoid enclosure of the trip/reset valves, which is nickel plated carbon steel to support performance of the magnet and coil solenoid assembly. NuScale indicates that the carbon steel portions of the NuScale reactor vessel and containment vessel shell have stainless steel cladding on both the internal and external surface. NuScale reports that the Davis Besse reactor vessel experience is not applicable to the NuScale reactor and containment vessels. Based on this information, the staff considers Item 46 to be resolved and closed for this audit.

2. Failure mode 6-5-13 relates to the main valve filter being blocked by boric acid precipitation and crystallization. The FMEA categorizes this potential failure mode as remote. [Item 47]

Follow-Up Audit Finding: In response to Items 47, 53, and 57 in its letter dated August 21, 2019, NuScale states that as a precaution, a filter is provided on the ECCS main valve disc to prevent foreign material from entering the main valve control chamber, trip line, and trip valves. NuScale reports that the filter performance does not affect the ability of the ECCS valves to actuate to the open position when demanded. NuScale indicates that a clogged filter would limit the amount of trip valve leakage that could be accommodated during plant operation. NuScale states that the filter surface area is many times greater than the flow area of the control orifice such that a significant amount of blockage can be accommodated before flow through the control orifice would be affected. NuScale indicates that fluid which interfaces with the ECCS valves is reactor coolant with chemistry controls as described in DCA Part 2, Tier 2, Section 5.2.3.2.1. NuScale states that the primary chemistry control program will be based on the EPRI Primary Water Chemistry Guidelines (COL Item 5.2-4). As clarified in the eRR, NuScale indicates that the main valve orifice filter will be a [ ] while the CVCS filters are [.] NuScale notes that the ECCS valve hydraulic lines will be discharged during each refueling outage. The ECCS valve hydraulic lines are then filled with CVCS supplied coolant during the startup process with provisions for further flushing once the ECCS valve is closed. NuScale states that its response dated February 8, 2018, to RAI 9189, Question 09.03.04-7, provides additional information on the fluid chemistry. Based on this information, the staff considers Item 47 to be resolved and closed for this audit.

<u>Table 6-6, Component FMEA, Actuator Valves - Trip/Reset Valve (TRV) and Trip Valve (TV)</u>

The comments on Table 6-6 were incorporated into other comments provided in the FMEA audit report.

<u>Table 6-7, Component FMEA, IAB Valve</u>

The comments on Table 6-7 were incorporated into other comments provided in the FMEA audit report. A few specific comments are provided below:

1. Failure modes 6-7-5, 6-7-6, 6-7-7, and 6-7-8 relate to potential failures of the IAB valve involving the bellows assembly, bellows retainer, bellows, and rod, respectively. The FMEA tables indicated that these high RPN significance failure modes would be mitigated by the availability of pressure under the rod that will operate the IAB valve. [Item 48]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. For example, these specific failure modes have been updated with respect to the IAB valve performance. Therefore, the staff considers Item 48 to be resolved and closed for this audit.

2. Failure mode 6-7-9 relates to the potential jamming of the IAB disc from wear or entrapped debris causing inadequate operation of the IAB valve and main valve. The FMEA does not specify the mitigating factors for this high RPN significant failure mode. [Item 49]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. For example, this specific failure mode has been updated with respect to IAB valve performance. Therefore, the staff considers Item 49 to be resolved and closed for this audit.

3. Failure mode 6-7-11 relates to the leakage of the IAB O-ring causing increased time to vent control pressure and actuate the main valve. The FMEA does not specify mitigating factors for this high RPN significant failure mode. [Item 50]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. For example, the revised FMEA report includes mitigating factors for the IAB valve O-ring performance. Therefore, the staff considers Item 50 to be resolved and closed for this audit.

4. Failure mode 6-7-19 relates to inadequacy of the shim washer that is used to adjust the set pressure of the IAB valve. The Severity, Occurrence, and Detection rating numbers are specified as 1 for this failure mode. [Item 51]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. For example, the revised FMEA report includes clarification regarding the performance of the shim washer in the IAB valve. Therefore, the staff considers Item 51 to be resolved and closed for this audit.

<u>Table 6-8, Component FMEA, Main Valves</u>

The comments on Table 6-8 were incorporated into other comments provided in the FMEA audit report. A few specific comments are provided below:

1. Failure mode 6-8-5 relates to the potential jamming from wear or entrapped debris of the sleeve that allows axial movement of the main disc. The mitigating factor specifies a proven design with controlled clearances for operability under design conditions. [Item 52]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the potential jamming of the main valve with NuScale and Target Rock personnel. As discussed regarding Items 9 through 13, the NRC staff reviewed the potential for partial opening of the main valve based on Target Rock calculations. Based on its review of the Target Rock calculations addressing Items 9 through 13, the staff considers Item 52 resolved and closed for this audit.

2. Failure mode 6-8-17 relates to the potential clogging of the filter assembly with debris that could cause inadvertent main valve opening. The FMEA specifies this failure mode as low significance. [Item 53]

Follow-Up Audit Finding: See Item 47 above for the discussion of the NuScale response to Items 47, 53, and 57 in its letter dated August 21, 2019. Based on this information, the staff considers Item 53 to be resolved and closed for this audit.

3. Failure mode 6-8-46 relates to the impact of the diffuser installed at the outlet of the RVVs. The FMEA assigns Severity, Occurrence, and Detection rating numbers of 1 for this failure mode. [Item 54]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this follow-up audit, the NRC staff reviewed the revised FMEA report with an updated FMEA approach. The staff finds that the FMEA report has been revised in an acceptable manner that is consistent with the discussions during the previous FMEA audit, lessons learned from the ECCS Valve Design Demonstration Testing, and recent Commission direction. For example, the revised FMEA report includes mitigating factors with respect to the RVV diffuser performance. Therefore, the staff considers Item 54 to be resolved and closed for this audit.

E. NuScale Report ER-B020-6289, “ECCS Valve Description”

1. Section 3.4 states that the diffuser for the RVV contains small holes to limit the outlet flow velocity and force of the flow stream on components in the vicinity of the RVV outlet. What are the plans to address the impact on the interior of the RVV and main valve control chamber? [Item 55]

Follow-Up Audit Finding: During the FMEA audit, NuScale and Target Rock personnel described the determination of the reaction load on the RVV caused by the flow through the holes in the diffuser. Specific comments on the RVV diffuser are addressed elsewhere in this audit report. Therefore, the staff considers Item 55 to be resolved and closed for this audit.

2. Section 3.7 describes the self-opening actuator feature at low pressure, such that the main valve return spring will open the valve without the need for trip valve de-energization. Does this also apply if the RPV is at high pressure and the differential pressure with the CNV is very small? [Item 56]

Follow-Up Audit Finding: NuScale updated ECCS Valve Description ER-B020-6289 in Revision 1 to specify that when the reactor pressure drops to approximately [   ] related to containment, the return spring will open the main valve, without the need for trip valve de-energization. With this clarification of the ECCS valve description, the staff considers Item 56 to be resolved and closed for this audit.

3. Section 3.7.1 states that the main disc feed orifice filter has a large area to mitigate debris. What are the plans to demonstrate that the filter design is adequate? [Item 57]

Follow-Up Audit Finding: See Item 47 above for the discussion of the NuScale response to Items 47, 53, and 57 in its letter dated August 21, 2019. Based on this information, the staff considers Item 57 to be resolved and closed for this audit.

4. Section 3.7.1 discusses the connecting tubing. What are the volumes of the connecting tubing for the RVV and RRV? [Item 58]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel provided the volumes of the RVV tubing and RRV tubing. NuScale personnel indicated that the water volume is important to confirm the proper opening time for the applicable ECCS valve. Based on the NuScale ECCS Valve Design Demonstration Testing, the staff considers Item 58 to be resolved and closed for this audit.

5. Figure 4, Main Valve Cross-Section, includes an adjusting nut. What is the purpose of this nut and when can it be adjusted? [Item 59]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel clarified that the adjusting nut in the main valve drawing is used for manufacturing adjustments rather than installed adjustments. Based on this clarification, the staff considers Item 59 to be resolved and closed for this audit.

6. Section 3.10 states that when the trip valve is activated, a small amount of control pressure will be vented before the IAB valve closes. What are the plans to demonstrate that the IAB will close promptly to prevent the main valve control chamber from losing sufficient pressure to allow the main valve to partially or full open? [Item 60]

Follow-Up Audit Finding: Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 60 to be resolved and closed for this audit.

7. Section 3.10 states that upon initial trip valve opening, the slight loss of control pressure will recover and will equalize with reactor pressure. If the main valve control chamber loses sufficient pressure to allow partial opening of the valve, will the control pressure recover and reclose the valve? [Item 61]

Follow-Up Audit Finding: As discussed regarding Items 9 through 13, the NRC staff reviewed the potential for partial opening of the main valve based on Target Rock calculations. Based on its review of the Target Rock calculations addressing Items 9 through 13, the staff considers Item 61 resolved and closed for this audit.

8. Section 3.10 states that the IAB valve setpoint is adjusted by bellows rod adjustment in the IAB disc and by shimming the spring. How and when can these adjustments be made? [Item 62]

Follow-Up Audit Finding: In response to Items 62 and 104 in its letter dated August 21, 2019, NuScale states that a washer component in the IAB valve has a thickness that is set at the factory to meet the required threshold and release pressure range. NuScale notes that the installed washer may be replaced with a washer of a different thickness, but the evaluation and modification should be performed by the valve designer. NuScale indicates that the pressure range in the DCA provides some margin to accommodate variation in performance without requiring physical adjustment. NuScale states that qualification and setting testing procedures will account for reactor operating conditions which could affect the valve performance. The NRC staff considers Item 62 to be clarified and resolved for this audit.

9. Section 4.1.1 indicates the RVV and RRV nozzle opening diameters. How do these dimensions compare to the detailed drawings for the RVV and RRV? [Item 63]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel clarified that the minimum flow areas for the RVV and RRV are indicated in the latest design diagrams. Based on this clarification, the staff considers Item 63 to be resolved and closed for this audit.

10. Section 4.2.2 states that the TRV, TV, and main valve tubing is NuScale equipment. What are NuScale's plans to demonstrate the performance of this tubing? [Item 64]

Follow-Up Audit Finding: In its letter dated August 21, 2019, NuScale indicates that the ECCS hydraulic lines are Quality Group A and Seismic Category I per DCA Part 2, Tier 2, Table 3.2-1, and designed to meet the requirements for Class 1 requirements in the ASME BPV Code. NuScale states that the tubing performance will be verified by the ASME QME-1 functional qualification testing. Based on this information, the NRC staff considers Item 64 to be resolved and closed.

11. Section 4.2.3 indicates that provisions for detection of coolant leakage from the TRV and TV bonnet gaskets will be provided. What are these provisions? [Item 65]

Follow-Up Audit Finding: In its September 21, 2018, letter, NuScale indicated that the FMEA would be updated to address this item. During this audit, the staff found that the revised FMEA addresses potential coolant leakage from the TRVs and TVs in failure modes 6-1-8, 6-6-20, and 6-6-66. Based on the revised FMEA, the staff considers Item 65 to be resolved and closed.

12. Section 4.4 indicates that the main valve has two open switches and two closed switches for position indication. Do these switches indicate partial main valve positions, or only fully open and closed? [Item 66]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel stated that the position indication switches only indicate full open or full closed positions of the main valve. Based on this clarification, the staff considers Item 66 to be resolved and closed for this audit.

13. Section 4.4 discusses the prototype development for the main valve position switch that needed design changes based on performance degradation from high temperature conditions. What is the status of the development of the prototype position switch?   [Item 67]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel stated that an upgrade to the main valve position switch is being designed for high temperature applications. NuScale plans to test the upgraded main valve position switch when available. During the follow-up audit, NuScale reported that the upgrade of the main valve position switch will be finalized as part of the qualification process. Based on this information, the staff considers Item 67 to be closed for this audit.

14. The pdf files attached to Appendix B of the ECCS Valve Description Report do not open for viewing. [Item 68]

Follow-Up Audit Finding: The NRC staff was able to review drawings of the ECCS valves as part of its audit activities. Therefore, the staff considers Item 68 to be resolved and closed for this audit.

F. NuScale ER-B020-6052, ECCS RVV Diffuser Report

1. In Section 4.1, Target Rock recommends that the design specification be changed to make the diffuser a separate item so as to not be installed during the pressure test. What are NuScale plans regarding the RVV diffuser as a separate item for testing? [Item 68]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale personnel stated that the ECCS Valve Design Specification will address the evaluation of the RVV diffuser as a separate item for testing. Revision 3 to NuScale ER-B020-2140 in Section 3.11.4.7 specifies that the flow diffuser is considered an attachment to the main valve for the pressure boundary hydrostatic testing. Based on this information, the staff considers Item 69 to be resolved and closed for this audit.

2. In Section 4.3, Target Rock indicates that there is a significant change in density between the main valve section and outlet section resulting in sonic velocity at the outlet with choked flow and higher pressure drop through the diffuser. What are NuScale plans to address this performance attribute? [Item 70]

Follow-Up Audit Finding: The staff reviewed the information provided in the appendices describing the RVV reaction loads and flow and pressure drop calculations in Revision 1 to ECCS RVV Diffuser Report ER-B020-6052. Based on this information, the staff considers Item 70 to be resolved and closed for this audit.

3. Section 4.3 indicates that a nonsafety-related computational fluid dynamics (CFD) analysis was applied to cross-check the hand calculations. How was the CFD analysis verified to be acceptable? [Item 71]

Follow-Up Audit Finding: The staff reviewed the information provided in the CFD analysis in Revision 1 to ECCS RVV Diffuser Report ER-B020-6052. Based on this information, the staff considers Item 71 to be resolved and closed for this audit.

4. Table 3 indicates that the spherical end of the diffuser will pass a certain percentage of the total mass flow through its flow area while the straight section of the diffuser will pass a different percentage of the total mass flow through its flow area. How will this estimation be verified? [Item 72]

Follow-Up Audit Finding: The staff reviewed the information provided on the valve flow parameters and the plans to validate these parameters by qualification testing in Revision 1 to ECCS RVV Diffuser Report ER-B020-6052. Based on this information, the staff considers Item 72 to be resolved and closed for this audit.

5. Table 4 and Appendix C provide the CFD results for low pressure conditions. Were high pressure conditions evaluated? [Item 73]

Follow-Up Audit Finding: During the FMEA audit discussions, Target Rock personnel clarified that the CFD analysis was not performed for high pressure conditions. Based on this clarification, the staff considers Item 73 to be resolved and closed for this audit.

6. Section 4.4 specifies that the reaction force calculation is based on ASME BPV Code, Appendix O, “Rules for Design of Safety Valve Installations.” Paragraph O-1230, “Other Mechanical Loads,” specifies consideration of the transient impacting the valve mechanism. How has NuScale addressed this provision? [Item 74]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the potential effects on the valve mechanism from the reaction forces created by the turbulent flow in the RVV diffuser will be addressed as part of the final design. In its September 21, 2018, letter, NuScale stated that the reaction force will be addressed in the final design report. NuScale noted that the stem/disc side loading will be addressed as part of the partial open issue. As discussed regarding Items 9 through 13, the NRC staff reviewed the potential for partial opening of the main valve based on Target Rock calculations. Based on its review of the Target Rock calculations addressing Items 9 through 13, the staff considers Item 74 resolved and closed for this audit.

7. Figure 5 indicates the orientation of the installation of the RVVs on the pressure vessel head. How is the torque moment during RVV discharge addressed? [Item 75]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the torque moment during the RVV discharge will be addressed in the ASME Design Report. In its September 21, 2018, letter, NuScale states that this requirement is included in the design specification. Based on this clarification, the staff considers Item 75 to be resolved and closed for this audit.

8. Appendix B to the report describes the reaction load calculation. How will this reaction load calculation be verified? [Item 76]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the design will include this reaction load plus an additional safety margin. In its September 21, 2018, letter, NuScale stated that the required thrust load to be analyzed is provided in the valve design specification (EQ-B020-2140). Based on this information, the staff considers Item 76 to be resolved and closed for this audit.

G. NuScale ER-B020-6117 (Revision 0, dated March 27, 2018), "ECCS Valve Qualification Plan"

1. Section 2.0 in the Qualification Plan specifies that the demonstration of ECCS valve functionality shall use analysis, testing, or a combination of both. ASME Standard QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," Subarticle QV-7100, "General Requirements," states that Section QV, "Functional Qualification Requirements for Active Valve Assemblies for Nuclear Power Plants," provides for qualification of a valve assembly by a combination of testing and analysis. NuScale should ensure that Section QV provisions are met in the qualification of the ECCS valves. [Item 77]

Follow-Up Audit Finding: The staff found that Revision 1 to NuScale ER-B020-6117 specifies that qualification of a valve assembly will be a combination of testing and analysis. Based on this revision to the ECCS Valve Qualification Plan to be consistent with ASME Standard QME-1-2007, the staff considers Item 77 to be resolved and closed for this audit.

2. Section 2.0 in the Qualification Plan when discussing ASME QME-1-2007, Subarticle QV-7300, "Specific Qualification Requirements for Valve Assemblies," states that the ECCS valves are QME Category B such that end load testing is not applicable. QME Category A valves are defined as valves that isolate a blowdown transient. ASME QME-1-2007 was prepared prior to the development of reactor designs that use valves to create a reactor blowdown to reduce RCS pressure to allow passive gravity cooling of the reactor core. Similar to squib valves in the AP1000 reactors, the qualification of the NuScale ECCS valves needs to address the blowdown loads to demonstrate their performance capability. [Item 78]

Follow-Up Audit Finding: Based on discussions during the FMEA audit, NuScale plans to verify that the effects of the blowdown transient are addressed as part of the design of the ECCS valves. Based on this information, the staff considers Item 78 to be resolved and closed for this audit.

3. Section 2.0 in the Qualification Plan when discussing ASME QME-1-2007, Subsubarticle QV-7410, "Initial Considerations," states that the ECCS valves are unidirectional. NuScale should address the qualification of the dual direction performance of the RRVs. [Item 79]

Follow-Up Audit Finding: The staff found that Revision 1 to NuScale ER-B020-6117 specifies that the RRV can experience flow in both directions during the ECCS function and will be qualified as such to ensure proper functionality. Based on this update to the ECCS Valve Qualification Plan, the staff considers Item 79 to be resolved and closed for this audit.

4. Section 2.0 in the Qualification Plan when discussing ASME QME-1-2007, Subsubarticle QV-7420, "Environmental and Aging," for the environmental and aging qualification of the pilot valves states that testing has been performed on a solenoid valve "essentially identical" to the trip and reset valves used in the NuScale ECCS valve. NuScale should provide additional direction for the justification that the environmental and aging qualification of the essentially identical solenoid valve is applicable to the trip and reset valves. [Item 80]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the Application Report for each ECCS valve will include the details to justify application of the environmental and aging qualification from similar valves. Based on this clarification, the staff considers Item 80 to be resolved and closed for this audit.

5. Section 2.0 in the Qualification Plan when discussing ASME QME-1-2007, Subsubarticle QV-7450, "Seismic Qualification," states that the main valve has no extended structure similar to self-actuated valve such that seismic testing is not required by QME-1. NuScale should provide additional justification to support the consideration that the main valve does not have an extended structure. [Item 81]

Follow-Up Audit Finding: Based on the FMEA audit discussions, NuScale plans to include the justification for considering the main valve to not have an extended structure in the Application Report in accordance with ASME QME-1-2007. Based on this information, the staff considers Item 81 to be resolved and closed for this audit.

6. Section 2.0 in the Qualification Plan when discussing Subsubarticle QV-7450 for the main valve states that a seismic test is not required. NuScale should ensure that the qualification plan addresses dynamic qualification of the ECCS valve in accordance with the provisions in ASME QME-1-2007, Paragraph QR-7312, "Dynamic loading." [Item 82]

Follow-Up Audit Finding: Based on the FMEA audit discussions, NuScale plans to clarify that dynamic loading as required by Paragraph QR-7312 in ASME QME-1-2007 for flow path and potential resonance response will be addressed as part of the Qualification Plan. Based on this information, the staff considers Item 82 to be resolved and closed for this audit.

7. Section 2.0 in the Qualification Plan when discussing Subsubarticle QV-7450 for the pilot valves states that seismic qualification will be performed by a seismic test with a static load applied at the center of gravity of the extended operator structure as allowed per IEEE 344, "Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations." NuScale should ensure that the qualification plan provides assurance for the following: (a) the static load is applied along the least rigid axis, and (b) the static load is applied at the center of gravity of the extended structure. QME Case QME-007, "Alternative Methods for Seismic Qualification of Power-Actuated and Relief Valve Assemblies," and ASME QME-1-2017, "Qualification of Active Mechanical Equipment Used in Nuclear Facilities,"

provides additional guidance on the use of static side load testing for seismic qualification of valves. [Item 83]

Follow-Up Audit Finding: The staff found that Revision 1 to NuScale ER-B020-6117 clarifies that for seismic testing, a static load will be applied to the center of gravity of the extended operator structure along the least rigid axis as allowed per IEEE 344. Based on this update to the ECCS Valve Qualification Plan, the staff considers Item 83 to be resolved and closed for this audit.

8. Section 3.0 of the Qualification Plan in Sequence 3 specifies that the main valve and the IAB valve will each undergo 750 cycles separately. NuScale should address the performance of the main valve and IAB valve to satisfy the 1E-4 per year failure rate to support the passive component assumption with respect to the single failure criterion. [Item 84]

Follow-Up Audit Finding: Based on the discussion above for Items 14 through 17, the staff considers Item 84 to be closed for this audit.

9. Section 3.0 of the Qualification Plan in Sequences 3, 4, and 7 indicates that seat lapping is allowed during the qualification process. NuScale should provide guidance that the seat lapping must not impact the capability of the main valve, IAB valve, or trip and reset valves to perform their safety functions to maintain an acceptable seat seal. [Item 85]

Follow-Up Audit Finding: The staff found that Revision 1 to NuScale ER-B020-6117 specifies that guidance for the frequency of seat lapping operations will be developed with justification to support plant conditions and that seat lapping will be performed if seat leakage becomes significant enough to affect valve performance during qualification testing. Based on this update to the ECCS Valve Qualification Plan, the staff considers Item 85 to be resolved and closed for this audit.

10. Section 3.0 of the Qualification Plan in Sequence 8a, b, and c specifies high and low pressure performance of the main valve. NuScale indicated that the IAB valve will be disabled during these tests. NuScale should address the performance of the IAB valve during high and low pressure performance tests. [Item 86]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale clarified that Sequence 8 of the Qualification Plan applies only to the flow capability of the main valve. Based on this clarification, the staff considers Item 86 to be resolved and closed for this audit.

11. Section 3.0 of the Qualification Plan in Sequence 8a, b, and c specifies high and low pressure performance of the main valve. NuScale indicated that the fluid will be at the appropriate pressure and temperature conditions, but that the water will not be borated. NuScale will need to address the qualification of the ECCS valves for borated water conditions to address flashing and boron precipitation effects. [Item 87]

Follow-Up Audit Finding: During the audit review of the ECCS Valve Design Demonstration Testing, the staff focused on the information necessary for the NRC to make a safety finding on the application for design certification of the NuScale reactor. The NuScale DCA specifies that the ECCS valves will be qualified in accordance with ASME Standard QME-1-2007 as accepted in RG 1.100 (Revision 3). The NRC will evaluate the specific details of the qualification plan for the ECCS valves during its review of an application for a COL for all NuScale nuclear power plants. For example, a COL holder will address the lessons learned from the ECCS Valve

Design Demonstration Testing in an updated Qualification Plan to include the need to demonstrate that ECCS valves will perform their safety functions at the appropriate pressures and temperatures, in light of the small clearances with consideration of allowable manufacturing tolerances, fluid flashing effects, boric acid effects, and fluid allowable particulate size. Therefore, the staff considers Item 87 to be closed for this audit of the ECCS valve design in support of the NuScale DCA review.

12. Section 3.0 of the Qualification Plan in Sequence 8a indicates that a successful qualification flow will be less than the predicted flow. NuScale indicated that the minimum flow is addressed by Sequence 8b and c. NuScale should demonstrate that the minimum flow for adequate recirculation is provided by the qualification plan. [Item 88]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale clarified that the qualification testing will demonstrate the minimum flow performance for recirculation of the RRV will be addressed in Sequence 8b. Based on the clarification, the staff considers Item 88 to be resolved and closed for this audit.

13. Section 3.0 of the Qualification Plan in Sequence 8b indicates that the RRV will be tested to demonstrate that the C_v flow coefficient criteria are satisfied. NuScale should complete its demonstration of the acceptability of the acceptable range of the C_v flow coefficient specified in Design Specification. [Item 89]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale clarified that the Qualification Plan in Sequence 8b will address the acceptability of the full range of the C_v flow coefficient for the RRV, including both flow directions. Based on this clarification, the staff considers Item 89 to be resolved and closed for this audit.

14. Section 3.0 of the Qualification Plan in Sequence 8c indicated that the RVV will be tested with extrapolation of flow results to be justified by analysis to demonstrate that the flow is within the acceptable bounds. NuScale should provide guidance to justify the acceptable demonstration of the flow performance of the RVV to perform its safety function. [Item 90]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the extrapolation of flow results during the qualification of the RVV will be justified. The NRC staff notes that the QME-1 requirements for the extrapolation of valve qualification are provided in Paragraph QV-7462, “Extrapolation of Qualification to Another Valve Assembly.” Therefore, the qualification of the valve assembly should be described in the Functional Qualification Report in accordance with Subsubarticle QV-8310, “Functional Qualification Report,” in ASME QME-1-2007. Based on this information, the staff considers Item 90 to be resolved and closed for this audit.

15. Section 3.0 of the Qualification Plan in Sequence 10 describes the functional testing for the IAB valve over a range of hydraulic fluid conditions to be applied to both the RVV and RRV. NuScale will need to address the qualification of the IAB valves in the ECCS valves for borated water conditions to address flashing and boron precipitation effects. In addition, NuScale will need to address the qualification of application of the IAB valve tests for both the RVV and RRV. [Item 91]

Follow-Up Audit Finding: During the audit review of the ECCS Valve Design Demonstration Testing, the staff focused on the information necessary for the NRC to make a safety finding on the application for design certification of the NuScale reactor. The NuScale DCA specifies that the ECCS valves will be qualified in accordance with ASME Standard QME-1-2007 as accepted in RG 1.100 (Revision 3). The NRC will evaluate the specific details of the qualification plan for the ECCS valves during its review of a COL application for all NuScale nuclear power plants. For example, a COL holder will address the lessons learned from the ECCS Valve Design Demonstration Testing in an updated Qualification Plan to include the need to demonstrate that ECCS valves will perform their safety functions at the appropriate pressures and temperatures, in light of the small clearances with consideration of allowable manufacturing tolerances, fluid flashing effects, boric acid effects, and fluid allowable particulate size. Therefore, the staff considers Item 91 to be closed for this audit of the ECCS valve design in support of the NuScale DCA review.

16. The Qualification Plan does not discuss post-installation testing specified in ASME QME-1-2007, Subsubarticle QV-7470, "Post-Installation Verification and IST Baseline," for the ECCS valves. NuScale should address its plans to satisfy the QV-7470 provisions. [Item 92]

Follow-Up Audit Finding: The staff found that Revision 1 to NuScale ER-B020-6117 specifies that Subsection QV-7470 of ASME QME-1-2007 requires post-installation verification and IST Baseline testing activities, but are outside the scope of this qualification plan as the responsibility of the plant owner. Based on this update to the ECCS Valve Qualification Plan, the staff considers Item 92 to be resolved and closed for this audit.

17. Section 4.0 of the Qualification Plan concludes that the Qualification Plan is intended to demonstrate how Target Rock plans to demonstrate that the ECCS valves have been designed and qualified in accordance with the design specification and ASME QME-1 Standard. Based on the comments on the qualification of the subcomponents of the ECCS valves, NuScale should address the design demonstration testing of the ECCS valves to support the DCA. [Item 93]

Follow-Up Audit Finding: Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 93 to be resolved and closed for this audit.

18. The Qualification Plan should discuss plans for batch testing of individual parts of the ECCS valves, such as bellows, springs, tubing, rods, filters, and bolts, to provide reasonable assurance in their capability to perform the applicable design-basis functions. [Item 94]

Follow-Up Audit Finding: During the FMEA audit discussions, NuScale indicated that the individual parts will be demonstrated (such as by batch testing) before being included in qualification testing. Based on this clarification, the staff considers Item 94 to be resolved and closed for this audit.

H. Preliminary ASME Design Reports

NuScale provided preliminary ASME design reports for the ECCS valves in its eRR during this audit. Based on the valve design modifications from the ECCS Valve Design Demonstration Testing, the NRC staff reviewed the ASME design reports in comparison to the final design features of the ECCS valves. The staff will track the plans to update the ASME design reports as part of **Audit Follow-Up Item 3**.

I. Initial ECCS Valve Audit Report Follow-Up Items

1. NuScale stated that the valve supplier (Target Rock) has conducted calculations and analyses to support the design and performance of the ECCS valves, including the main valve, 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 disc 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. [Item 95]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the calculations and documentation for the ECCS valves with NuScale and Target Rock personnel. In its September 21, 2018, letter, NuScale stated that the Target Rock flow/force balance calculations would be finalized as QA documents as part of the partial open technical issue. As discussed regarding Items 9 through 13, the NRC staff reviewed the potential for partial opening of the main valve based on Target Rock calculations. Based on its review of the Target Rock calculations addressing Items 9 through 13, the staff considers Item 95 resolved and closed for this audit.

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 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. [Item 96]

Follow-Up Audit Finding: The NRC staff comments on the FMEA are discussed in this audit report. Therefore, the staff considers Item 96 to be closed for this audit.

3. NuScale Design Drawing NP12-00-B020-M-GA-2617, “Reactor Vent Valve Drawing,” identifies the RVV as Nominal Pipe Size (NPS) 5 with a specific inlet diameter and a specific discharge diameter. NuScale DCA Part 2, 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 RRV as NPS 2 with a specific inlet diameter and a specific discharge diameter. NuScale DCA Part 2, Tier 2, Section 6.3 specifies

the RRV as a 4-inch valve. The NRC staff will evaluate the differences between the DCA Part 2 descriptions and design drawings for the RVVs and RRVs. [Item 97]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the current design of the RVVs and RRVs with NuScale and Target Rock personnel. Based on the resolution of the design size of the RVVs and RRVs, the staff considers Item 97 to be closed for this audit.

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. [Item 98]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the filter assembly in the main valve with NuScale and Target Rock personnel. Based on the staff findings in this report, the staff considers Item 98 to be closed for this audit.

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. [Item 99]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the RVV diffuser assembly with NuScale and Target Rock personnel. Based on the staff findings in this report, the staff considers Item 99 to be closed for this audit.

6. NuScale stated that the design of the IAB valve is consistent with the description in the response to RAI 8815 (Question 15-2) provided in the NuScale letter dated July 21, 2017. 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. [Item 100]

Follow-Up Audit Finding: During the FMEA and follow-up audits, the NRC staff discussed the design of the IAB valve with NuScale and Target Rock personnel. Based on those discussions, the staff considers Item 100 to be resolved and closed for this audit.

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 RPV and 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. [Item 101]

Follow-Up Audit Finding: Based on the ECCS Valve Design Demonstration Testing, the staff considers Item 101 to be resolved and closed for this 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 IST program requirements in the 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. [Item 102]

Follow-Up Audit Finding: In the response to Follow-Up Item 102 in its letter dated August 21, 2019, NuScale reported that the IAB valve is a subcomponent of the ECCS valve and does not have a separate leakage category. The ECCS valves are categorized as OM Category BC in DCA Part 2, Tier 2, Table 3.9-16, in that they are self-actuating and seat leakage in the closed position is inconsequential for fulfillment of their safety function. NuScale states that the IAB valve drawing has been revised to remove a specific leakage categorization for the IAB valve. NuScale notes that the IST requirements for the ECCS valves as described in the DCA are still being reviewed in the scope of the audit. The NRC staff considers Item 102 to be **Confirmatory** pending incorporation of the IST provisions for the ECCS valves in the DCA when agreed upon by the NRC staff.

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 DCA Part 2, 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. [Item 103]

Follow-Up Audit Finding: During the FMEA audit, NuScale personnel clarified the planned orientation of the trip and reset valves for the RVVs and RRVs. With this clarification, the staff considers Item 103 to be resolved and closed for this audit.

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 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. [Item 104]

Follow-Up Audit Finding: In response to Items 62 and 104 in its letter dated August 21, 2019, NuScale states that a washer component in the IAB valve has a thickness that is set at the factory to meet the required threshold and release pressure range. NuScale notes that the installed washer may be replaced with a washer of a different thickness, but the evaluation and modification should be performed by the valve designer. NuScale indicates that the pressure range in the DCA provides some margin to accommodate variation in performance without requiring physical adjustment. NuScale states that qualification and setting testing procedures will account for reactor operating conditions which could affect the valve performance. The NRC staff considers Item 104 to be clarified and resolved for this audit.

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). [Item 105]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the position indication provisions for the main valve and trip/reset valves. NuScale indicated that the position indication assembly for the main valve is being upgraded to be able to perform at high temperature conditions. During this follow-up audit, NuScale reported that the upgrade of the main valve position switch will be finalized as part of the qualification process. Based on this information, the staff considers Item 105 to be closed for this audit.

12. NuScale stated that the trip/reset lines and control chamber of the ECCS main valve will be filled with borated water from the 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. [Item 106]

Follow-Up Audit Finding: During the FMEA audit, the NRC staff discussed the performance of the ECCS valves with hot pressurized borated water with NuScale and Target Rock personnel. NuScale performed ECCS Valve Design Demonstration Testing, including borated fluid, to demonstrate the performance of the ECCS valve system to support its DCA. The NRC staff considers Item 106 to be resolved and closed for this audit.

13. The NRC staff reviewed NuScale Report ER-B020-3817 on proof-of-concept (POC) 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 POC testing and the ECCS valves. Some of the differences are as follows:

a. The main valve used for the POC testing was a 2-inch Y-pattern globe valve. In the original design information, 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 DCA Part 2, Tier 2, Section 6.3, and associated design drawings. [Item 107]

Follow-Up Audit Finding: The final RRV design size is 2 inches and the final RVV design size is 5 inches. The ECCS Valve Design Demonstration Testing used a 2-inch valve. Therefore, the staff considers Item 107 to be resolved and closed for this audit.

b. The valve configuration used for the POC testing included a main valve separate from the IAB valve. The IAB valve used for the POC 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. [Item 108]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 108 to be resolved and closed for this audit.

c. The trip valve used for the POC testing had a solenoid-operated valve (energize to open) with a very small seat diameter for the water tests and a 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 larger seat diameter. [Item 109]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 109 to be resolved and closed for this audit.

d. The trip line configuration used in the POC 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 POC testing was less than will be present in the actual NuScale installed configuration. [Item 110]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 110 to be resolved and closed for this audit.

e. The accumulator used for the POC testing had significantly less volume for the main valve pressure than will be present in the NuScale RPV. The pressures applied in the POC testing were not always consistent with the actual pressures for operation of the ECCS valve and its subcomponent valves. The POC testing resulted in accumulator pressure reduction during the tests more significant than would occur during the actual ECCS valve operation. In addition, the POC testing provided the trip line exhaust to atmospheric conditions rather than the CNV conditions. [Item 111]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 111 to be resolved and closed for this audit.

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. [Item 112]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 112 to be resolved and closed for this audit.

14. The report of the POC 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. [Item 113]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 113 to be resolved and closed for this audit.

b. Sizing of the trip line, fittings, and orifice is critical to adequately vent the trip line. [Item 114]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 114 to be resolved and closed for this audit.

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. [Item 115]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 115 to be resolved and closed for this audit.

d. The effect on valve performance from the differences between test facilities and the RPV will need to be assessed. [Item 116]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 116 to be resolved and closed for this audit.

The NRC staff will evaluate the design testing of the ECCS valve (including its four valve subcomponents) to address the issues identified during the POC testing and issues identified during the detailed design process and NRC staff audit findings. [Item 117]

Follow-Up Audit Finding: Based on NRC staff audit review of the ECCS Valve Design Demonstration Testing, the staff considers Item 117 to be resolved and closed for this audit.

15. In its response to RAI 8820, dated August 1, 2017, 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. [Item 118]

Follow-Up Audit Finding: Based on NRC staff audits of the ECCS Valve FMEA, ECCS Valve Design Demonstration Testing, and associated documents, the staff considers Item 118 to be closed for this 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 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. [Item 119]

Follow-Up Audit Finding: Based on the discussion above for Items 14 through 17, the staff considers Item 119 to be closed for this audit.

17. In its response to RAI 8820, NuScale stated that the ECCS valves will be designed in accordance with the ASME BPV Code, including capacity certification, with ASME design reports developed in accordance with 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 2020. 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. [Item 120]

Follow-Up Audit Finding: The NRC staff is completing a follow-up audit of the NuScale design specifications, including the ECCS valve design specification. Therefore, the staff considers Item 120 to be closed for this audit.

18. In its response to RAI 8820, NuScale summarized the proposed DCA Part 2, Tier 1 inspections, tests, analyses, and acceptance criteria (ITAAC) for the ECCS valves. [Item 121]

Follow-Up Audit Finding: The NRC staff is reviewing the ITAAC for the ECCS valves through a separate RAI process. Therefore, the staff considers Item 121 to be closed for this audit.