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

June 14, 2019

MEMORANDUM TO: Samuel S. Lee, Chief
Licensing Branch 1
Division of Licensing, Siting,
and Environmental Analysis
Office of New Reactors

FROM: Omid Tabatabai, Senior Project Manager ***/RA/***
Licensing Branch 1
Division of Licensing, Siting,
and Environmental Analysis
Office of New Reactors

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION NUSCALE POWER, LLC, SUMMARY REPORT OF REGULATORY AUDIT OF DESIGN DOCUMENTS FOR NUSCALE DESIGN CERTIFICATION PART 2, TIER 2, CHAPTER 20, "MITIGATION OF BEYOND-DESIGN-BASIS EVENTS"

On January 6, 2017, NuScale Power, LLC (NuScale) submitted a design certification (DC) application, for a small modular reactor, to the U.S. Nuclear Regulatory Commission (NRC) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17013A229). The NRC staff started its detailed technical review of NuScale's design certification application (DCA) on March 27, 2017.

On January 8, 2018, the NRC staff began an audit of the NuScale's non-docketed information to confirm the basis for the safety conclusions made in the applicant's DCA, Tier 2, Chapter 20 regarding mitigation strategies for extended loss of alternating current (AC) power transient analyses. The NRC staff's audit plan is available in ADAMS with Accession No. ML17356A120.

The NRC staff conducted the audit via 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."

Docket No. 52-048

Enclosure:
1. Audit Summary

cc w enclosure.: DC NuScale Power, LLC Listserv

CONTACT: Omid Tabatabai, NRO/DLSE
301-415-6616

SUBJECT: U.S. NUCLEAR REGULATORY COMMISSION NUSCALE POWER, LLC, SUMMARY REPORT OF REGULATORY AUDIT OF DESIGN DOCUMENTS FOR NUSCALE DESIGN CERTIFICATION PART 2, TIER 2, CHAPTER 20, "MITIGATION OF BEYOND-DESIGN-BASIS EVENTS"
DATED: June 14, 2019

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ADAMS Accession No.: ML19151A658 *via email NRO-002

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U.S. NUCLEAR REGULATORYB COMMISSION

AUDIT REPORT FOR THE REGULATORY AUDIT OF NUSCALE POWER, LLC, FINAL SAFETY ANALYSIS REPORT CHAPTER 20, "MITIGATION OF BEYOND DESIGN-BASIS EVENTS," AND TOPICAL REPORT, TR- 0816-50797-P, "MITIGATION STRATEGIES FOR EXTENDED LOSS OF AC POWER EVENT"

DOCKET NO. 52-048

I. INTRODUCTION AND BACKGROUND

NuScale Power, LLC (NuScale) submitted by a letter dated December 31, 2016, to the U.S. Nuclear Regulatory Commission (NRC) a Final Safety Analysis Report (FSAR) for its Design Certification (DC) application of the NuScale design (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17013A229). The NRC staff initiated this DC review on March 27, 2017.

II. REGULATORY AUDIT BASES

Title 10 of the *Code of Federal Regulations*, Section 52.47(a)(2) states that a DC application must contain an FSAR that includes:

> *A description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished.*

JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," states:

> *Section 3.2.1.7 of Nuclear Energy Institute (NEI) 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 2, specifies that strategies "that have a time constraint to be successful should be identified and a basis provided that the time can reasonably be met."*

Also, NEI 12-06, Section 3.2.1, "General Criteria and Baseline Assumptions," provides the general criteria and assumptions to be used in establishing the baseline coping strategy. Past regulatory precedence have included the need for reactor designs, including other passive designs, to demonstrate the success of the strategies or include the ability to indicate core conditions.

III. AUDIT PURPOSE

The purpose of the audit is to confirm the basis for the safety conclusions made in the applicant's DCA Tier 2 Chapter 20, "Mitigation of Beyond Design-Basis Events," mitigation strategies for extended loss of AC power transient analyses. This includes an evaluation and better understanding of (1) the detailed calculations, analyses, and bases underlying applicant's Chapter 20 and (2) the methodology and analysis supporting NuScale's extended long-term cooling (greater than 72 hours) conclusions in TR-0816-50797, "Mitigation Strategies for Extended Loss of AC Power Event."

IV. AUDIT LOCATION AND DATES

The audit was conducted from the NRC headquarters via NuScale's electronic reading room.

Date: January 8, 2018 through May 7, 2018

Locations: NRC Headquarters
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2738
NuScale Electronic Reading Room (eRR)

V. AUDIT TEAM MEMBERS

Jeff Schmidt (NRO, Audit Lead)
Rebecca Karas (NRO/SRSB, Branch Chief)
Don Palmrose (NRO)
Chang Li (NRO)
Raul Hernandez (NRO)
John Budzynski (NRO)
Clint Ashley (NRO)
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Alex Burja (NRO)
Ray Skarda (NRO)
Carl Thurston (NRO)
Shanlai Lu (NRO)
Jim Gilmer (NRO)
Omid Tabatabai (NRO, Senior Project Manager)

VI. APPLICANT AND INDUSTRY STAFF PARTICIPANTS

Liz English

Eric Coryell
Paul Infanger
Andy Lingenfelter
Jennie Wike
Ben Bristol
Steve Mirsky
Nadja Joergensen

VII. DOCUMENTS AUDITED

1. ER_0000_00003573_00, “Extended Loss of Alternating Current Power Assessment”

2. EC-0000-3070, “Station Blackout Analysis”

3. EC-B175-3252, “UHS Boil Off Calculation”

4. EC-A010-4270, “Long Term Cooling Analysis”

5. EC-0000-4576, “Reduction of Collapsed Primary Water Level in LTC due to Loss of Inventory”

6. EC-A030-00004366-01, “Passive Containment Cooling Inventory”

VIII. DESCRIPTION OF AUDIT ACTIVITIES AND SUMMARY OF OBSERVATIONS

ER_0000_00003573_00, “Extended Loss of Alternating Current Power Assessment”

NRC staff examined engineering calculation ER_0000_00003573_00, “Extended Loss of Alternating Current Power Assessment.” During this examination NRC staff noted the purpose of the calculation and identified key inputs and their sources. In particular, NRC staff noted:

- The purpose of this document is to develop a diverse and flexible coping strategies (FLEX) for the mitigation of beyond-design-basis-external-events (BDBEE) based on the assessment of the extended loss of AC power (ELAP).

- The scope of this document is to meet the regulatory requirements identified in NEI 12-06 and the Near-Term Task Force (NTTF) recommendations.

- Initial plant conditions and assumptions

    - BDBEE occurs impacting all units at site

    - All reactors on-site initially operating at 100 percent power for 100 days

    - Prior to event, reactor and supporting systems are within normal operating range

    - Each reactor is successfully shut down when

    - On-site staff is at site administrative minimum shift staffing levels

- No independent, concurrent events, e.g., no active security threat
- All personnel on-site are available to support site response
- Plant equipment designed to be robust for BDBEE is assumed to be fully available
- Plant equipment that is not robust is assumed to be unavailable
- Installed sources of emergency onsite ac power and station blackout (SBO) alternate ac power sources are assumed to be not available
- Station batteries and associated dc buses fed by station batteries through inverters remain available
- Cooling and makeup water inventories contained in robust systems or structures are available.
- Normal access to the ultimate heat sink (UHS) is lost, but the water inventory in the UHS remains available and robust piping connecting the UHS to plant systems remains intact

• Reactor Transient Assumptions

  - Reactor automatically trips and all rods are inserted
  - System necessary to maintain decay heat removal operate as designed
  - Safety relief valves initially operate in a normal manner
  - No independent failures are assumed to occur in the course of the transient

• Diverse and Flexible Coping Strategies Summary for Phase 1

  Core cooling function is automatically established and passively maintained by safety-related equipment as follows:

  - Decay hear removal system (DHRS) valves open to establish natural circulation flow and transfer heat to the passive condenser loops to UHS
  - Containment Isolation Valves (CIVs) close to maintain reactor coolant system (RCS) inventory
  - Emergency core cooling system (ECCS) valves open to establish natural circulation flow of reactor coolant between the reactor pressure vessel (RPV) and the containment vessel (CNV)

• Diverse and Flexible Coping Strategies Summary for Phase 2

  - Not used

• Diverse and Flexible Coping Strategies Summary for Phase 3

- Monitor UHS pool level and add inventory to the UHS as necessary to maintain UHS pool level

The staff noted that the conclusions related to core cooling referenced and relied on the results of the Station Blackout Analysis for the first 72 hours.

EC-0000-3070, “Station Blackout Analysis”

The NRC staff examined engineering calculation EC-0000-3070, “Station Blackout Analysis.” During this examination NRC staff noted the purpose of the calculation and identified key inputs and their sources. In particular, NRELAP5 input use of nominal (average of minimum and maximum values) areas and flow coefficients for the ECCS valves. The NRC staff questioned if this method was appropriate for BDB analysis. Based on NuScale latest ECCS valve drawings, the RRVs are 2.0” minimum diameter and the RVVs are 4.625” minimum diameter. This indicates the RRV area is correct at 3.14 in^2 but the RVVs are under sized (16.8 in^2 verses 15.0 in^2 (averaged)). Staff also reviewed NRELAP5 results which were oscillatory at the end of the SBO transient giving the appearance that overall NPM RRV and RVV flow responses were not at steady state or near steady state condition. The applicant indicated that the overall integrated flow would indicate steady state however, it is typical for NRELAP5 to show this oscillatory behavior. Request for Additional Information (RAI) No. 9486 was issued to clarify the applicant’s response (ADAMS Accession No. ML18123A554.)

EC-B175-3252, “UHS Boil Off Calculation”

NRC staff examined engineering calculation EC-B175-3252, Rev 0, “UHS Boil Off Calculation.” During this examination NRC staff noted the purpose of the calculation and identified key inputs and their sources. In particular, NRC staff noted:

- The purpose of this calculation is to assess the level in the UHS pool over time based on an ELAP scenario with the decay heat load from 12 NuScale Power Modules (NPMs) and spent fuel assemblies. The calculation assumes uniform mixing in the UHS and DHRS and ECCS functions as expected in all of the NPMs.

- NuScale assumes that all of the water vapor from evaporation and boil-off exits the Reactor Building and does not re-condense and flow back into the UHS (carried into TR-0816-50797, under ADAMS Accession No ML17005A120, page 46).

EC-B175-3252, “UHS Boil Off Calculation”

Reviewed EC-B175-3252, “UHS Boil Off Calculation,” including visit to Rockville, Maryland, office to view the NuScale Microsoft Excel spreadsheets that provided the boil off results. The calculation included several different cases with varying assumptions depending on the purpose of each calculation. The spreadsheet uses basic conservation of energy assumptions where decay heat from all 12 NPM units are discharged to UHS for extended periods of time. The NRC staff examined engineering calculations methods and results and determined them acceptable to assess the water level in the UHS pool over time for the extended loss of AC power evaluations. For the most conservative case used to support long-term cooling out to 30 days, the applicant used a conservative 10 CFT Part 50, Appendix K, “ECCS Evaluation Models,” decay heat load with a 1.2 multiplier and conservative heat energy from spent fuel assemblies. The calculation uses an initial pool temperature of 140 degrees Fahrenheit (°F) and assumes uniform mixing in the UHS and DHRS and ECCS functions as expected in all of the NPMs. Additionally, the calculation considers all the initial stored energy in the RCS fluid and RPV metal mass. For other calculations, more nominal assumptions were used, and the time for the pool to drop to the top of the DHRS heat exchanger was determined to be 50 days.

EC-A010-4270, “Long Term Cooling Analysis”

The NRC staff examined engineering calculation EC-A010-4270, Rev 0, which considers long term cooling after limiting LOCA and non-LOCA chapter 15 events for ECCS performance and coolability out to 72 hours with UHS levels considered as low as 45 feet. During this examination, NRC staff noted the evaluation and its conclusions do not extend past 3 days.

EC-0000-4576 Rev. 0, “Reduction of Collapsed Primary Water Level in LTC due to Loss of Inventory”

THE NRC staff examined engineering calculation EC-0000-4576 Rev. 0, “Reduction of Collapsed Primary Water Level in LTC due to Loss of Inventory.” During this examination, NRC staff noted the purpose of the calculation and identified key inputs and their sources. In particular, NRC staff noted:

- The purpose of this calculation is to assess the reduction of collapsed primary water level due to the loss of inventory from containment fluid leakage. A fundamental figure of merit for long-term cooling (LTC) analysis is the collapsed primary water level. While the LTC analysis is for a range of initial and boundary conditions, the set of calculations does not include the effect of containment fluid leakage rate.

- For this analysis, a flange in the upper portion of the NPM is assumed to have the maximum Technical Specification for leakage and the fluid state of this leakage would be of vapor (steam).

The result of this calculation is that the vapor mass loss rate would not affect the overall ECCS performance over 30 days or more of an ELAP scenario.

EC-A030-00004366-01, “Passive Containment Cooling Inventory”

The NRC staff examined engineering calculation EC-B175-3252, Rev 0, “UHS Boil Off Calculation.” During this examination NRC staff noted the purpose of the calculation provides an assessment of a filled module’s heat transfer while in the process of being moved. Cases 1 through 3 assess how much level to flood containment to maintain heat transfer to the UHS pool. Cases 4 and 5 assesses the situation of ELAP with Case 5 specifically addressing ELAP with pool boil-off based on one-day changes (references EC-B175-3252, “UHS Boil Off Calculation”). Principal assumptions include:

- Convection at the vessel surfaces is expected to be fully turbulent
- The maximum lift height is applied
- Three cases of UHS pool temperatures are analyzed
- Containment is at atmospheric pressure
- Linear changes in UHS pool level and temperature
- RCS is at safe shutdown temperature

A bounding assumption is made where the film heat transfer coefficient is reduced by 20 percent. Different assumptions on the level of liquid in the CNV annulus in relation to the UHS pool level are made with the steady-state conduction from the RCS to the CNV and to the pool are assessed for determining if the conditions allow for full transfer of the decay heat in the NPM to the UHS. This calculation file is referenced in the ER_0000_00003573_00.

- For this analysis, a flange in the upper portion of the NPM is assumed to have the maximum Technical Specification for leakage and the fluid state of this leakage would of vapor (steam).

The result of this calculation is that the vapor mass loss rate would not affect the overall ECCS performance over 30 days or more of an ELAP scenario.

In addition, NRC staff examined engineering calculation EC A030_00004366_Revision 1 related to a limiting case for keeping the NPM sufficiently cool while the module is held up by the crane during an ELAP event. The NRC staff noticed that under this condition the NuScale passive core cooling systems being used for mitigation strategies such as DHRS and ECCS are not available for the NPH being lifted, and a significant portion of this NPM is not submerged in the UHS pool. The heat removal analysis including the methodology, major assumptions, and results that support the calculation regarding sufficient decay heat removal were examined. More details were documented in a meeting summary report (ADAMS Accession No. ML17192A231).

IX. EXIT BRIEFING

The NRC staff conducted an audit closeout meeting on May 7, 2018. A t the exit briefing the NRC staff reiterated the purpose of the audit and discussed their activities. The NRC staff stated that they had identified areas where additional information is being requested to support the review, and briefly discussed the scope of these information requests. References to the detailed questions are provided in Section IX of this audit summary.

X. REQUESTS FOR ADDITIONAL INFORMATION RESULTING FROM AUDIT

The NRC staff issued one RAI with three questions based on information observations made during the audit. This RAI is available under the ADAMS Accession No. is provided in Table IX-1.

Table IX-1: RAIs Resulting from Audit

RAI Number	Question Number	Reference
9486	20.1-17, 20.1-18, and 20.1-19	ML18179A530

XI. OPEN ITEMS AND PROPOSED CLOSURE PATHS

NuScale's response to RAI No. 9486, Question 20.01-17, regarding the calculations, analyses, and bases underlying NuScale's SBO transient analysis thermal-hydraulic parameters of specific time frames during the first 72 hours is under evaluation. The proposed closure path is to conduct a second audit that links Chapter 15 RAI No. 9208 (ADAMS Accession No. ML19058A863) transient thermal-hydraulic analysis to the SBO analysis during the first 72 hours. This audit also includes a review to better understand the methodology and analysis supporting NuScale's response that during equilibrium ECCS operation, the water levels in the riser, downcomer, and containment vessel are all closely coupled with oscillations in the downcomer level to cause corresponding oscillations in the reactor recirculation valve (RRV) liquid flow rate with flow reversal.

XII. DEVIATIONS FROM THE AUDIT PLAN

None

XIII. REFERENCES

1. Letter from NuScale Power, LLC, "NuScale Power, LLC Submittal of the NuScale Standard Plant Design Certification Application," December 31, 2016 (ADAMS Accession No. ML17013A229).

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

3. Audit Plan for Regulatory Audit of NuScale Power, LLC, Final Safety Analysis Report – Chapter 20, "Mitigation of Beyond Design-Basis Events," ADAMS Accession No. M17356A120, December 27, 2017.

4. NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 2, December 2015.