



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

February 12, 2020

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

FROM: Getachew Tesfaye, Senior Project Manager /RA/
New Reactor Licensing Branch
Division of New and Renewed Licenses
Office of Nuclear Reactor Regulation

SUBJECT: AUDIT SUMMARY FOR PHASES 3 AND 4 OF THE
REGULATORY AUDIT OF NUSCALE TOPICAL REPORT
TR-0516-49416, "NON-LOSS-OF-COOLANT ACCIDENT
ANALYSIS METHODOLOGY"

By letter dated January 10, 2017, NuScale Power, LLC (NuScale, or the applicant) submitted Topical Report (TR) TR-0516-49416, Revision 0, "Non-Loss-of-Coolant Accident Analysis Methodology," for review and approval by the U.S. Nuclear Regulatory Commission (NRC) in support of the NuScale design certification application (DCA). On August 10, 2017, NuScale reissued the TR as Revision 1 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17222A827) by redacting unmarked proprietary information to create proprietary and nonproprietary versions.

On April 27, 2017, the U.S. Nuclear Regulatory Commission (NRC) staff issued a letter to notify NuScale that it has started its detailed technical review of TR-0516-49416 (ADAMS Accession No. ML17116A063). The first non-loss-of-coolant accident (non-LOCA) audit, which included Phases 1 and 2, began in May 2017, and was completed in January 2018 (ADAMS Accession No. ML19039A090). In April and May 2018, the NRC staff issued several requests for additional information (RAIs) resulting from its review of TR-0516-49416, as informed by audit Phases 1 and 2 (ADAMS Accession Nos. ML18156A171, ML18156A177, ML18129A407, ML18128A341, and ML18128A389). In addition, the applicant communicated its intent to update the NRELAP5 assessments against test data in TR-0516-49416 to use a newer version of NRELAP5 (Version 1.4).

CONTACTS: Getachew Tesfaye, NRR/DNRL Alexandra Siwy, NRR/DSS
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The NRC staff-initiated Phases 3 and 4 of the regulatory audits related to the review of the TR 0516 49416 on November 19, 2018, and January 22, 2019, respectively (ADAMS Accession No. ML18323A445). The objectives of these phases of the audit were: (1) for the NRC staff to gain a better understanding of new or changed calculations or information that supports the TR resulting from staff RAIs as well as the updates related to NRELAP5 Version 1.4, and (2) to confirm certain statements made in RAI responses.

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

Docket No. 52-048

Enclosure:
As stated

cc w/encl.: DC NuScale Power LLC Listserv

SUBJECT: AUDIT SUMMARY FOR PHASES 3 AND 4 OF THE REGULATORY AUDIT OF
 NUSCALE TOPICAL REPORT TR-0516-49416, "NON-LOSS-OF-COOLANT
 ACCIDENT ANALYSIS METHODOLOGY"
 DATED: FEBRUARY 12, 2020

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AUDIT SUMMARY FOR PHASES 3 AND 4 OF THE REGULATORY AUDIT
OF NUSCALE TOPICAL REPORT TR-0516-49416, "NON-LOSS-OF-COOLANT ACCIDENT
ANALYSIS METHODOLOGY"

1 BACKGROUND

By letter dated January 10, 2017, NuScale Power, LLC (NuScale, or the applicant) submitted Topical Report (TR) TR-0516-49416, Revision 0, "Non-Loss-of-Coolant Accident Analysis Methodology," for review and approval by the U.S. Nuclear Regulatory Commission (NRC) in support of the NuScale design certification application (DCA). On August 10, 2017, NuScale reissued the TR as Revision 1 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17222A827) by redacting unmarked proprietary information to create proprietary and nonproprietary versions.

On April 27, 2017, the U.S. Nuclear Regulatory Commission (NRC) staff issued a letter to notify NuScale that it has started its detailed technical review of TR-0516-49416 (ADAMS Accession No. ML17116A063). The first non-loss-of-coolant accident (non-LOCA) audit, which included Phases 1 and 2, began in May 2017, and was completed in January 2018 (ADAMS Accession No. ML19039A090). In April and May 2018, the NRC staff issued several requests for additional information (RAIs) resulting from its review of TR-0516-49416, as informed by audit Phases 1 and 2 (ADAMS Accession Nos. ML18156A171, ML18156A177, ML18129A407, ML18128A341, and ML18128A389). In addition, the applicant communicated its intent to update the NRELAP5 assessments against test data in TR-0516-49416 to use a newer version of NRELAP5 (Version 1.4).

Several of the applicant's RAI responses referred to new or revised test assessments or calculations that were relied upon to support the adequacy of the non-LOCA evaluation model (EM). Therefore, the NRC staff initiated Phases 3 and 4 of a regulatory audit related to the review of the TR-0516-49416 on November 19, 2018, and January 22, 2019, respectively (ADAMS Accession No. ML18323A445). The objectives of these phases of the audit were: (1) for the NRC staff to gain a better understanding of new or changed calculations or information that supports the TR resulting from staff RAIs as well as the updates related to NRELAP5 Version 1.4, and (2) to confirm certain statements made in RAI responses.

The NRC staff, assisted by Energy Research, Inc. (ERI) contractors, conducted the audit according to NRC Office Instruction NRO-REG-108, "Regulatory Audits," (ADAMS Accession No. ML081910260). The audit was performed primarily via the NuScale electronic reading room and included telephone audit discussions with the applicant.

2 REGULATORY AUDIT BASIS

Title 10 of the *Code of Federal Regulations* (CFR) 52.47(a)(4) states that a final safety analysis report submitted as part of a standard design certification must include:

[a]n analysis and evaluation of the design and performance of structures, systems, and components with the objective of assessing the risk to public health and safety resulting from operation of the facility and including determination of the margins of safety during normal operations and transient conditions anticipated during the life of the facility, and the adequacy of

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structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents.

The staff determined the need for an audit to better understand the bases for RAI responses related to, and applicant-initiated updates to, the non-LOCA EM. The non-LOCA EM is incorporated by reference into NuScale DCA Part 2, Tier 2, Chapter 15, and is used to develop safety conclusions.

The following general design criteria (GDC) from 10 CFR Part 50, Appendix A are applicable to non-LOCA analysis:

- GDC 5, “Sharing of structures, systems, and components”
- GDC 10, “Reactor design”
- GDC 13, “Instrumentation and control”
- GDC 15, “Reactor coolant system design”
- GDC 17, “Electric power systems”
- GDC 20, “Protection system functions”
- GDC 25, “Protection system requirements for reactivity control malfunctions”
- GDC 26, “Reactivity control system redundancy and capability”
- GDC 27, “Combined reactivity control systems capability”
- GDC 28, “Reactivity limits”
- GDC 31, “Fracture prevention of reactor coolant pressure boundary”
- GDC 34, “Residual heat removal”

In addition, relevant regulatory guidance includes:

- Regulatory Guide 1.203, “Transient and Accident Analysis Methods,” December 2005.
- NuScale Design-Specific Review Standard (DSRS) 15.0, “Introduction – Transient and Accident Analyses,” Revision 0, June 2016.
- Standard Review Plan (SRP) Section 15.0.2, “Review of Transient and Accident Analysis Method,” Revision 0, March 2007.
- DSRS 15.1.1-15.1.4, “Decrease in Feedwater Temperature, Increase in Feedwater Flow, Increase in Steam Flow, and Inadvertent Opening of the Turbine Bypass System or Inadvertent Operation of the Decay Heat Removal System,” Revision 0, June 2016.

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- DSRS 15.1.5, “Steam System Piping Failures Inside and Outside of Containment,” Revision 0, June 2016.
- DSRS 15.1.6, “Loss of Containment Vacuum,” Revision 0, June 2016.
- DSRS 15.2.1-15.2.5, “Loss of External Load; Turbine Trip; Loss of Condenser Vacuum; Closure of Main Steam Isolation Valve; and Steam Pressure Regulator Failure (Closed),” Revision 0, June 2016.
- DSRS 15.2.6, “Loss of Nonemergency AC Power to the Station Auxiliaries,” Revision 0, June 2016.
- DSRS 15.2.7, “Loss of Normal Feedwater Flow,” Revision 0, June 2016.
- DSRS 15.2.8, “Feedwater System Pipe Break Inside and Outside Containment,” Revision 0, June 2016.
- SRP Section 15.4.1, “Uncontrolled Control Rod Assembly Withdrawal from a Subcritical or Low Power Startup Condition,” Revision 3, March 2007.
- SRP Section 15.4.2 Revision 3, “Uncontrolled Control Rod Assembly Withdrawal at Power,” Revision 3, March 2007.
- SRP Section 15.4.3, “Control Rod Misoperation (System Malfunction or Operator Error),” Revision 3, March 2007.
- SRP Section 15.4.6, “Inadvertent Decrease in Boron Concentration in the Reactor Coolant System (PWR),” Revision 2, March 2007.
- SRP Section 15.4.7, “Inadvertent Loading and Operation of a Fuel Assembly in an Improper Position,” Revision 2, March 2007.
- DSRS 15.5.1 – 15.5.2, “Chemical and Volume Control System Malfunction that Increases Reactor Coolant Inventory,” Revision 0, June 2016.

3 AUDIT LOCATION AND DATES

Phases 3 and 4 of the audit were conducted from the NRC headquarters via NuScale’s electronic reading room and telephone.

Dates: Phase 3: November 19, 2018, through January 21, 2019
 Phase 4: January 22, 2019, through January 28, 2020

Phase 3 originally intended to focus on documentation supporting RAI responses, and Phase 4 originally intended to focus on updates due to NRELAP5 Version 1.4. However, there was significant overlap in the documentation such that there was not a clear delineation of the phases, in practice.

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5 APPLICANT PARTICIPANTS

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Meghan McCloskey
Steve Pope
Matthew Presson
Dean Throckmorton

6 AUDIT DOCUMENTS

The staff audited the following documents provided by the applicant:

- EC-T090-6756, Revision 0, "DHRs Condenser Parallel Channel Instability," October 18, 2018

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- EC-0000-5982, Revision 0, “Feedwater Oscillation Periods in Stability Analysis,” January 2, 2018
- EC-T080-6557, Revision 0, “NRELAP5 Assessment Against NuScale Loss of Feedwater Flow Test NIST-NLT-02a,” August 16, 2018
- EC-T080-4330, Revision 1, “NRELAP5 Assessment Against NuScale Loss of Feedwater Flow with DHRS Test NIST-NLT-02b,” October 3, 2018
- EC-T080-6594, Revision 0, “NRELAP5 Assessment Against NuScale Loss-of-Feedwater Flow with DHRS Test NIST-NLT-15 Phase 2,” October 5, 2018
- EC-T050-3638, Revision 1, “Assessment of NRELAP5 Using SIET Fluid Heated Test Facility (TF-2) Data,” May 24, 2018
- ECN-T050-6039, Revision 0, “Changes to SIET TF-2 NRELAP5 Base Model EC-T050-3234 Rev. 0,” March 14, 2018
- EC-T050-3234, Revision 0, “NRELAP5 Model for the SIET Fluid Heated Test Facility,” June 30, 2015
- EC-A010-1782, Revision 1, “Reactor Module NRELAP5 Model,” August 31, 2017
 - ECN-A010-6177, Revision 0, “Corrections to NRELAP5 Base Model,” February 28, 2018
- EC-A010-3204, Revision 1, “RCS Loop CFD,” July 11, 2017
- ECN-A010-6602, Revision 0, “Add Appendix of RELAP Riser Comparison,” August 15, 2018
- ECN-A010-7394, Revision 0, “Riser Mixing Figures,” July 29, 2019
- EC-T080-4161, Revision 2, “NRELAP5 Assessment Against NuScale Separate Effects High Pressure Condensation Test Series NIST-HP-03,” October 19, 2018
- EE-0000-6522, Revision 0, “DHRS-to-Pool Nucleate Boiling Heat Transfer Models Evaluation,” August 8, 2018
- **[[]]**, Revision 1, “Evaluation of Helical Geometry Effects for SG Heat Transfer and Pressure Drop,” October 4, 2016
- **[[]]**, Revision 2, “Primary and Secondary Steady State Parameters,” September 7, 2016
 - ECN-A030-4821, Revision 0, “Add Evaluation of CRUD,” November 16, 2016

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- ECN-A030-4716, Revision 0, “Update RCS Loop Transit Times,” October 17, 2016
- EC-0000-3155, Revision 1, “Assessment of NRELAP5 with KAIST Condensation Experiments,” August 6, 2018
- EC-0000-6568, Revision 0, “NRELAP5 Sensitivity Study on DHRS Heat Sink Modeling,” July 13, 2018
- EC-B030-2121, Revision 0, “DHRS Thermal Hydraulic Analysis,” August 21, 2018
 - ECN-B030-6521, Revision 0, “DHRS Critical Heat Flux and Pool Sensitivity,” August 16, 2018
 - ECN-B030-5567, Revision 0, “Higher Off-normal Transient Pool Temperature,” August 28, 2017
- “Talking Points-SG HT Uncertainty_NRCcall_with_plots”
- “Non-LOCA LTR Changes for SG and DHRS Nominal Heat Transfer”
- “DHRS Relative Importance Talking Points”
- EC 0000 2017, Revision 1, “Decrease in Feedwater Temperature Analysis,” April 30, 2019
- EC 0000 2016, Revision 1, “Increase in Feedwater Flow Analysis,” July 3, 2019
- EC 0000 2906, Revision 1, “Increase in Steam Flow/Inadvertent Opening of Steam Generator Relief or Safety Valve Analysis,” June 28, 2019
- EC 0000 2714, Revision 1, “Steam System Piping Failure Analysis,” July 29, 2019
- EC 0000 1997, Revision 2, “Turbine Trip, Loss of External Load, and Loss of Condenser Vacuum Transient Analysis,” November 28, 2018
- EC 0000 2995, Revision 2, “Main Steam Isolation Valve Closure Transient Analysis,” November 14, 2018
- EC 0000 2908, Revision 2, “Loss of Nonemergency AC Power to the Station Auxiliaries Analysis,” April 30, 2019
- EC 0000 1998, Revision 1, “Loss of Normal Feedwater Transient Analysis,” June 10, 2019
- EC 0000 2735, Revision 1, “Inadvertent Operation of the Decay Heat Removal System,” July 1, 2019

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- EC 0000 2250, Revision 1, “Feedwater Piping Failure Analysis,” July 2, 2019
- EC 0000 2726, Revision 1, “Increase in RCS Inventory from CVCS Malfunction,” July 12, 2019
- EC 0000 2786, Revision 3, “Failure of Small Lines Carrying Primary Coolant Outside Containment,” July 12, 2019
- EC 0000 1735, Revision 2, “Steam Generator Tube Failure Transient Analysis,” July 18, 2019

7 DESCRIPTION OF AUDIT ACTIVITIES AND SUMMARY OF OBSERVATIONS

In Phases 3 and 4 of the audit, the staff audited information that supported RAI responses related to the applicant’s non-LOCA analysis methodology as well as updates to the TR resulting from the use of NRELAP5 Version 1.4. The main audit observations are described in the following subsections.

7.1 Information supporting stability-related statements in the response to RAI 9158, Question 15.00.02-1

The staff audited underlying documentation to confirm statements made in the above RAI response (ML18270A466) related to secondary side flow oscillations. Documents EC-T090-6756, EC-0000-5982, ER-A014-2268, and EC-A010-1782 adequately confirmed the statements in question, which were:

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7.2 Revised NRELAP5 Assessment Against NIST NLT-02a Test (RAI 9158, Question 15.00.02-2)

The staff audited document EC-T080-6557 to examine the updated assessment of NRELAP5 against NIST test NLT-02a. The staff observed that the TR markups provided in the response to RAI 9158, Question 15.00.02-2 (ML18270A466), are consistent with EC-T080-6557. In addition, the staff noted that the updated assessment shows generally better agreement

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between the NRELAP5 prediction and the data than the assessment provided as part of TR Revision 1.

However, the riser mass flow rate exhibited worse agreement. EC-T080-6557 described a sensitivity study in which the applicant changed the [[

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The staff confirmed that the audited material adequately supported the response to RAI 9158, Question 15.00.02-2, including the proposed changes to the TR.

7.3 Revised NRELAP5 Assessment Against NIST NLT-02b Test (RAI 9158, Question 15.00.02-3)

The staff audited document EC-T080-4330 to examine the updated assessment of NRELAP5 against NIST test NLT-02b. The staff confirmed that the information and TR markups provided in the response to RAI 9158, Question 15.00.02-3 (ML18285A926), are consistent with EC-T080-4330. [[

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During an audit discussion with the applicant, the staff clarified some of this behavior. [[

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The staff pursued further questions related to this assessment via a public teleconference on RAI 9158, Question 15.00.02-3 (ML19289C398), since the questions involved material that was included in the docketed RAI response.

7.4 New NRELAP5 Assessment Against the NIST NLT-15p2 Test (RAI 9158, Question 15.00.02-3)

The staff audited document EC-T080-6594 to examine the new assessment of NRELAP5 against NIST test NLT-15p2. The staff confirmed that the information and TR markups provided in the response to RAI 9158, Question 15.00.02-3 (ML18285A926), are consistent with EC-T080-6594. In addition, EC-T080-6594 provided additional details on sensitivity calculations performed to better understand the NRELAP5-predicted behavior, [[

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The staff pursued further questions related to this assessment via a public teleconference on RAI 9158, Question 15.00.02-3 (ML19289C398), since the questions involved material that was included in the docketed RAI response.

7.5 Revised NRELAP5 Assessment Against the SIET TF-2 Tests (RAI 9158, Question 15.00.02-5, and RAI 9351, Question 15.00.02-33)

The staff audited document EC-T050-3638 to examine the new assessment of NRELAP5 against the SIET TF-2 tests. The staff confirmed that the information and TR markups provided

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in the responses to RAI 9158, Question 15.00.02-5 (ML18228A817), and RAI 9351, Question 15.00.02 33 (ML18194A749 and ML18234A531), are consistent with EC-T050-3638. [[

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Documents EC-T050-3234 and ECN-T050-6039 provided more detailed supporting information about the NRELAP5 SIET TF-2 model. In ECN-T050-6039, the staff noted that [[

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The audit documentation for this topic provided adequate clarification of the docketed information provided by the applicant.

7.6 Underlying Documentation for the Computational Fluid Dynamics (CFD) Calculation Results Provided in Response to RAI 9351, Question 15.00.02-31

The staff audited document EC-A010-3204 and the related ECN-A010-6602 to confirm information in the response to RAI 9351, Question 15.00.02-31 (ML18234A537). While the information was consistent, the staff engaged in audit discussions with the applicant to better understand the underlying calculation.

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The applicant prepared ECN-A010-7394 to assist the staff's understanding of the three-dimensional flow effects in the NuScale Power Module (NPM) riser. The staff audited the document and noted the following:

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The staff confirmed that the audit documentation for this topic provided adequate clarification of the docketed information provided by the applicant.

7.7 Revised NRELAP5 Assessment Against the NIST-1 HP-03 Test (RAI 9466, Question 15.00.02-11)

The staff audited document EC-T080-4161 to confirm information in the response to RAI 9466, Question 15.00.02-11 (ML18299A296). The staff noted that the information in this RAI response, as well as the response to RAI 9374, Question 15.00.02-23 (ML18270A472), is consistent with the underlying calculation.

The staff engaged in a public teleconference with the applicant primarily to better understand the modeling of heat transfer from the DHRS to the cooling pool (ADAMS Accession No. ML19289C398). As a result, the applicant provided document EE-0000-6522 for staff audit. The staff audited the document and noted the following:

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The staff confirmed that the audit documentation for this topic provided adequate clarification of the docketed information provided by the applicant.

7.8 [[]]

The staff primarily used document [[]] as a reference in its audit of other documents related to SG modeling and has no specific observations related to this document.

7.9 [[]]

The staff primarily used document [[]] as a reference in its audit of other documents since it calculates the steady-state primary and secondary parameters as a function of power level of the NPM. The staff has no specific observations related to this document.

7.10 **Revised NRELAP5 Assessment Against the KAIST Tests**

The staff audited document EC-0000-3155 to examine the new assessment of NRELAP5 against the KAIST tests. The staff noted that the applicant made minor error corrections and modeling changes in addition to the update to use NRELAP5 Version 1.4. These changes had an insignificant impact on the overall assessment conclusions. The staff confirmed that the information related to KAIST in TR-0516-49416, Revision 2, is consistent with EC-0000-3155. The audit documentation for this topic provided adequate clarification of the docketed information provided by the applicant.

7.11 **Calculations Supporting Removal of Steam Generator Heat Transfer Bias**

The staff audited the last several documents listed in Section 6 of this audit summary to confirm the applicant's bases for removing the SG heat transfer bias from the non-LOCA methodology described in the supplemental response to RAI 9466, Question 15.00.02 6 (ML19212A796). These calculations largely confirmed the effects of SG heat transfer on non-LOCA events described in the RAI response. [[

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8 EXIT BRIEFING

The staff conducted an audit closure meeting at NuScale's Rockville, MD, office on January 28, 2020. During the meeting, the staff reiterated the purpose of the audit and discussed the audit

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activities and outcome. The staff thanked NuScale personnel and indicated that the information was sufficient to close the audit without any follow-up items.

9 REQUESTS FOR ADDITIONAL INFORMATION RESULTING FROM AUDIT

Not applicable.

10 OPEN ITEMS AND PROPOSED CLOSURE PATHS

Not applicable.

11 DEVIATIONS FROM THE AUDIT PLAN

The audit was originally scheduled to exit following the original audit end date of July 31, 2019, but was extended to January 28, 2020, to accommodate the examination and discussion of additional documentation requested by the NRC staff.