June 19, 2020 Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Submittal of Riser Flow Hole Methodology and Associated Changes to Final Safety Analysis Report Incorporating Its Use

REFERENCES:

1. NuScale Letter to NRC, "NuScale Power, LLC Submittal of the NuScale Standard Plant Design Certification Application, Revision 4," dated January 16, 2020 (ML20036D336)
2. NuScale Letter to NRC, "Submittal of Updates to NuScale Power, LLC Standard Plant Design Certification Application," dated April 1, 2020 (ML20092L899)
3. NuScale Letter to NRC, "Submittal of Second Updates to NuScale Power, LLC Standard Plant Design Certification Application, Revision 4," dated May 20, 2020 (ML20141L787)
4. NRC Internal Memo, Audit Plan for the Regulatory Audit of NuScale Power, LLC Design Certification Application, Chapters 6, "Engineered Safety Features," Chapter 7, "Instrumentation and Controls," and Chapter 15, "Transient and Accident Analyses," Related to Change in Instrumentation and Controls Setpoints and/or Logic, dated March 02, 2020 (ML20059N687)

The NuScale Standard Plant Design Certification Application (DCA), Revision 4 was submitted to the NRC in Reference 1. Updates to the NuScale Standard Plant Design Certification Application, Revision 4 were submitted in References 2 and 3.

Subsequent to the DCA Revision 4 and update submittals (References 2 and 3), audit teleconferences (Reference 4) were held with NRC Staff. In the course of those discussions, NuScale Power, LLC (NuScale) agreed to provide a description of the methodology which was employed in Reference 3 of the NuScale Standard Plant Design Certification Application updates. Enclosure 1 provides the methodology description. This methodology addresses the adequacy of riser hole flow for acceptable boron redistribution during long term cooling while cooling with the Decay Heat Removal System (DHRS). Audit discussions also included analysis of Reactor Coolant System (RCS) leaks during the long term cooling phase relating to support of the NuScale General Design Criteria (GDC) 33 exemption criteria.

Enclosure 1 is the proprietary version of the “Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation.” NuScale requests that the proprietary version be withheld from public disclosure in accordance with the requirements of 10 CFR § 2.390. The enclosed affidavit (Enclosure 4) supports this request.

Enclosure 2 is the nonproprietary version of the “Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation.”

Enclosure 3 includes revisions to the Final Safety Analysis Report (FSAR) sections as summarized in the table on the first page of Enclosure 3. The FSAR changes in Enclosure 3 are nonproprietary. Enclosure 3 FSAR mark-up pages are in redline/strikeout format. NuScale will include this change as part of a future revision to the NuScale Design Certification Application.

This letter makes no regulatory commitments or revisions to any existing regulatory commitments.

If you have any questions, please feel free to contact John Fields at 541-452-7425 or at JFields@nuscalepower.com.

Sincerely,

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Enclosure 1: “Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation,” proprietary version
Enclosure 2: “Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation,” nonproprietary version
Enclosure 3: Changes to NuScale Final Safety Analysis Report to support incorporating the Enclosure 1 Methodology and Analysis Results
Enclosure 4: Affidavit of Zackary W. Rad, AF-0620-70463

Enclosure 1:

“Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation,” proprietary version

Enclosure 2:

"Analysis to Demonstrate Sufficient Riser Hole Flow During Extended DHRS Operation," nonproprietary version

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Analyses performed to demonstrate sufficient riser hole flow during extended decay heat removal system operation

As described in the FSAR 15.0.5, analyses were performed to demonstrate that the riser holes are adequately sized to provide sufficient flow to mitigate adverse reactor coolant system (RCS) boron concentration distribution during extended decay heat removal system (DHRS) operation following a non-loss of coolant accident (LOCA) event. During extended DHRS operation following a non-LOCA event, the DHRS can provide sufficient cooling to shrink the primary side inventory volume such that the RCS coolant level reaches the top of the riser and the primary side natural circulation flow becomes intermittent or interrupted. This is referred to as riser uncovery. With the riser uncovered, some portion of the upper steam generator tubes would be in contact with vapor at the top of the riser; as the DHRS continues to remove decay heat, condensation of primary side vapor at the top of the steam generator tubes could occur, with the diluted condensate mixing with liquid in the RCS downcomer around and below the steam generator tubes. The extended DHRS operation with riser uncovery redistributes boron in the RCS fluid. While the module remains in DHRS passive cooling conditions, boron could accumulate in the core region and therefore, there is not a reactivity insertion concern. However, if the emergency core cooling system (ECCS) valves open, fluid from the downcomer could be transported to the core region. In scenarios where loss of alternating current (AC) power supply is postulated, ECCS valves open at 24 hours. In scenarios where AC power is assumed to be available, and DHRS cooling is sufficiently effective, then in the 24-72 hours timeframe, the RCS pressure could be reduced sufficiently to reach low differential pressure across the ECCS valves, at which point the ECCS main valve spring force could overcome the differential pressure force across the valve disc so that the ECCS valve passively opens.

To demonstrate that the riser holes provide sufficient liquid flow from riser to downcomer, conservative analyses were performed to evaluate the steam generator condensation, riser hole flow, and resulting RCS boron transport during extended DHRS operation. Two general transient progressions were analyzed:

1. The subcooled convective case. During extended DHRS operation with nominal primary and secondary loop inventory, the uncovered portion of the steam generator is limited, and there is steam to steam heat transfer in the uncovered region. Internal recirculation flow develops in the riser and steam generator, and the majority of decay heat is removed by convective heat transfer and conduction across the riser wall. In this case, condensation heat transfer is limited by the capacity of the secondary side steam in the uncovered region. A large temperature difference develops between fluid in the riser and steam generator/downcomer in order to transfer heat across the riser wall. The temperature difference results in coolant volume shrinkage in the steam generator primary and downcomer, generating a level difference between hot side and cold side, generating a pressure difference at the riser holes driving liquid from riser to downcomer. To conservatively calculate the riser hole flow, a low temperature difference is used at each statepoint and the RCS pressure is treated conservatively to decrease the riser to downcomer density difference and riser hole flow rate.

2. The saturated condensation case. Depending on the initiating event and event progression, extended DHRS operation could be postulated with lower primary inventory and/or higher

secondary inventory. Examples include an isolated break outside containment that decreases the primary inventory, an increase in feedwater flow initiating event, or a postulated single failure of a feedwater isolation valve to close, which increases the secondary inventory. For the saturated condensation case, it is conservative to assume that the majority of decay heat is removed through condensation heat transfer between primary steam and secondary two-phase mixture in the uncovered region. Two-phase level swell in the core and riser region generates a level difference between the hot side and the cold side, generating a pressure difference at the riser holes which drives liquid from the riser to the downcomer. To conservatively calculate the riser hole flow, the riser void fraction, the calculation is biased to give low void fraction results, to minimize the riser fluid level swell and riser hole flow rate.

These two scenarios were conservatively analyzed to demonstrate that the riser holes provide sufficient liquid flow over the range of conditions that could be postulated for extended DHRS operation following a non-LOCA event. Evaluation of one or more specific initiating events is not necessary. Non-LOCA events that actuate DHRS typically do so within the first 30 minutes of the event. In the timescale of the 72 hour cooling the specific event progression in the first 30 minutes is not critical to evaluating the boron transport. While specific initiating events and the early event progression are not evaluated in detail, the effect of different initial RCS fluid mass is considered in the analysis; the effect of a different secondary fluid mass is considered by evaluating the two scenarios as described above. No operator actions are credited.

A quasi-steady statepoint analysis is performed, which is appropriate for the slowly changing module conditions during extended DHRS operation. For each scenario, at each statepoint, the condensation rate and the riser hole flow rate are calculated. Then the condensation rate and riser hole flow rate are used to evaluate the RCS boron transport. The first statepoint is selected at {{ }}2(a),(c), which is before riser uncovery would occur following a non-LOCA event. Statepoints out to 72 hours are evaluated. Based on the observed trends and results of the calculations out to 72 hours, the longer term event progression out to 7 days is evaluated.

The acceptance criteria for the analysis is that the downcomer boron concentration remains above the critical boron concentration at beginning of cycle (BOC) and middle of cycle (MOC) conditions, and there is negligible dilution at end of cycle (EOC) conditions. This supports the conclusion that the return to power analysis performed at EOC conditions remains bounding of the postulated long-term reactivity insertion that could occur following a postulated event with highest worth control rod stuck out (WRSO). For the extended DHRS conditions, the critical boron concentration is evaluated at a conservatively low temperature, assuming no void, accounting for SIMULATE nuclear reliability factor uncertainty, and accounting for xenon reactivity.

The method for evaluating the subcooled convective case is summarized below:

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}}2(a),(c)

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}}2(a),(c)

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}}2(a),(c)

The method for evaluating the saturated condensation case is summarized below:

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}}2(a),(c)

{{

}}2(a),(c)

Summary of Results:

For the convective cooling scenario, the results of the boron transport analysis are summarized in Table 1. For the saturated condensation scenario, the results of the boron transport analysis are summarized in Table 2. Figure 1 and Figure 2 show the beginning of cycle and middle of cycle boron transport results, respectively, as a function of time. The variation in the RCS boron concentration early in the transient is due to the wave-front approach applied to the transport assumption and conservative calculation of riser hole flow and condensation rate. Considering the actual time to reach riser uncovery conditions, and that ECCS valves would open at 24 hours or later, realistically, the minimum margin conditions occur long-term after equilibrium concentration conditions are reached.

The analysis approach conservatively biases the calculated riser hole flow low, and condensation rate high. The acceptance criterion is conservatively defined, by using a conservatively low temperature; for the saturated condensation case, the acceptance criteria is also conservatively defined with zero void. For the saturated condensation case, for example, {{

}}[2(a),(c)] the critical boron concentration is 297 ppm, well below the 72 hour downcomer concentration of 538 ppm.

In both cases, for BOC and MOC conditions the downcomer boron concentration remains above the critical boron concentration for 72 hours. At EOC conditions there is minimal dilution. Based on these results and the method used to develop the conservatively high condensation rate and low riser mass flow rate, it is concluded that the downcomer concentration would remain above the critical concentration for at least 7 days after event initiation from BOC and MOC conditions, and there is negligible dilution at EOC conditions. This analysis demonstrates that the riser holes are adequately sized to provide sufficient liquid mass flow from riser to downcomer to mitigate significant RCS boron redistribution during extended DHRS operation. This supports the conclusion that the return to power analysis performed for EOC conditions remains bounding of the potential long-term reactivity insertion with highest worth control rod stuck out.

Table 1. Boron Transport Results – Convective Cooling Conditions

Time in Cycle	Initial boron concentration (ppm)(1)	CBC at 200°F(1)	Downcomer 72 hr Boron Concentration (ppm)
BOC	1238	962	1208
MOC	595	506	581
EOC	5	88	4.9

(1) Critical boron concentration for ARI-WRSO, zero void, no xenon

Table 2. Boron Transport Results - Saturated Condensation Conditions

Time in Cycle	Initial boron concentration (ppm)(1)	CBC at 200°F(1)	Downcomer 72 hr Boron Concentration (ppm)
BOC	1238	962	1120
MOC	595	506	538
EOC	5	88	4.5

(1) Critical boron concentration for ARI-WRSO, zero void, no xenon

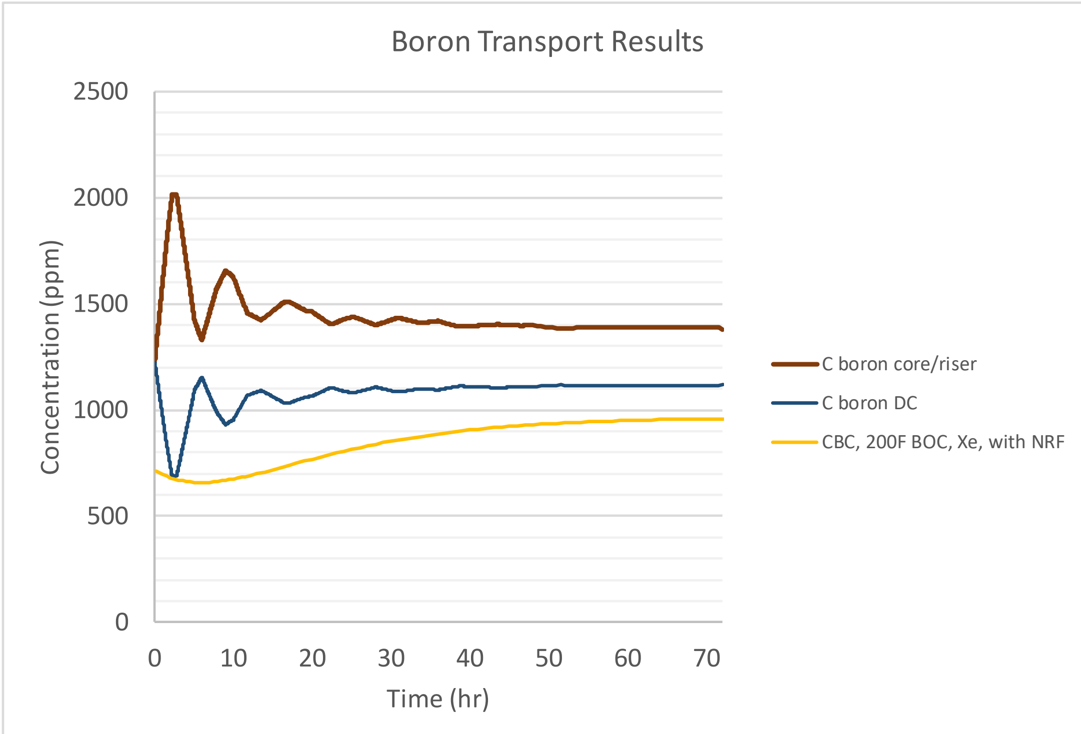

Figure 1. BOC Boron Transport Results, Saturated Condensation Conditions

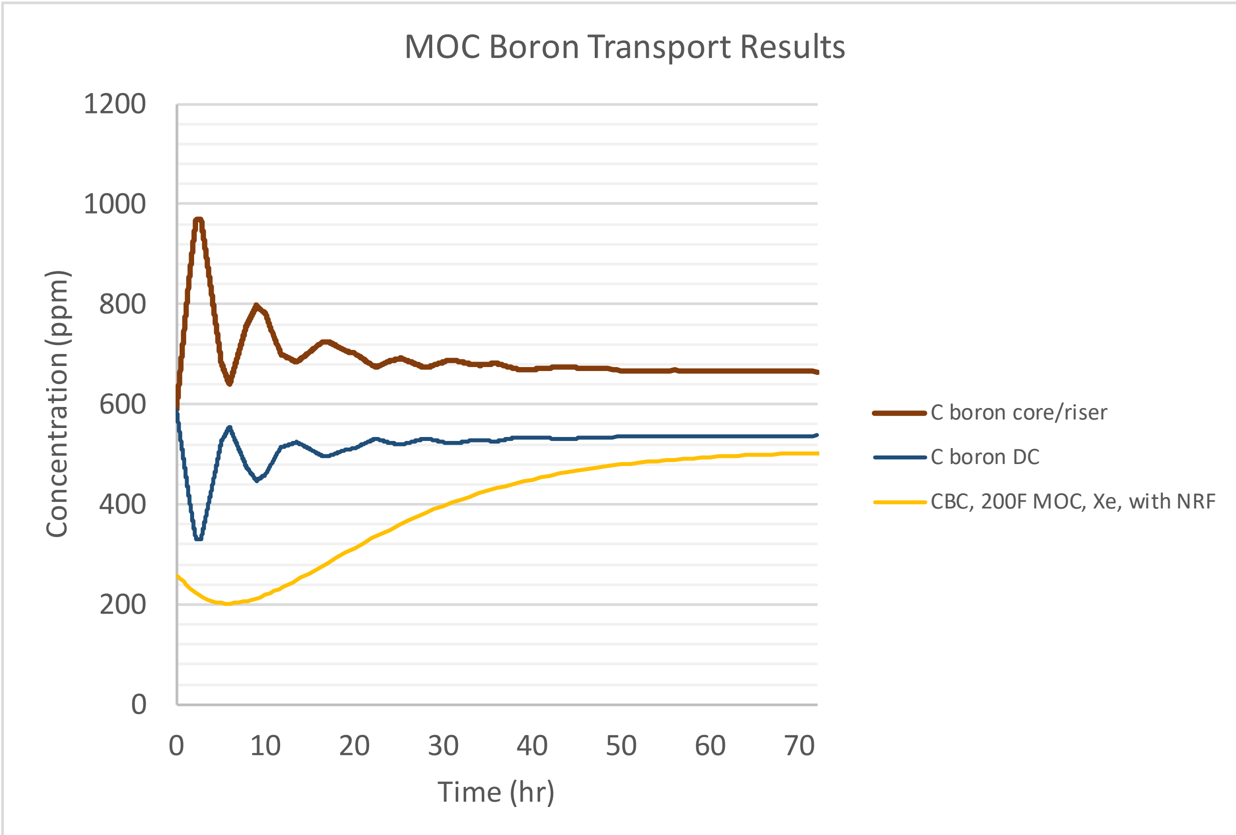

Figure 2. MOC Boron Transport Results, Saturated Condensation Conditions

References

1. Zuber, N. and Findlay, J. A, Average Volumetric Concentration in Two-Phase Flow Systems. J. Heat Transfer 87:453, 1965.

2. Kataoka, Isao and Mamoru Ishii, "Prediction of Pool Void Fraction by New Drift Flux Correlation," NUREG/CR-4657, June 1986.

Enclosure 3:

Changes to NuScale Final Safety Analysis Report to support incorporating the Enclosure 1 Methodology and Analysis Results

FSAR Section/Table	Summary of Changes
4.3.1.5	Adds a discussion of the effects of riser hole flow on boron mixing for small Reactor Coolant System (RCS) leaks
6.3	Adds a discussion of the effects of Emergency Core Cooling System (ECCS) actuation setpoints and riser hole flow for RCS leaks with respect to Specified Acceptable Fuel Design Limits (SAFDL) acceptance criteria supporting the NuScale General Design Criteria (GDC) 33 exemption
15.0.5	Adds summary discussion for riser hole flow methodology and effect on boron redistribution for long term cooling using Decay Heat Removal System (DHRS)
Tables 6.3-1 and 15.0-7	Adds pointer to Section 7, Table 7.1-5 for ECCS actuation setpoint interlocks

signals on high CNV level and low RCS pressure are specifically designed to ensure ECCS actuation occurs prior to the development of conditions that could result in a core dilution event following ECCS actuation. For small RCS leaks where ECCS actuation setpoints are not reached within 72 hours, boron mixing is maintained through diverse flow paths until RPV level drops below the riser holes. After the riser holes are uncovered, some downcomer dilution may occur, however, core boron concentration remains above the initial RCS boron concentration. This function supports the exemption to GDC 33 discussed in Section 6.3 and Section 9.3.4.1.

In some Non-LOCA scenarios, DHRS can cool the RCS such that the level drops below the top of the riser and the natural circulation loop is interrupted. Without natural circulation flow, condensation of steam could reduce the downcomer boron concentration. Diverse flow paths through four holes located in the riser promote mixing to preclude positive reactivity insertion when natural circulation is restored. The riser holes are located at the SG midpoint, which is below the level resulting from RCS fluid contraction from DHRS cooldown. The method for evaluating the flow through the riser holes is described in Section 15.0.5.

4.3.1.6 Stability

The design of the reactor and associated systems, and the administrative controls on CRA position provide an inherently stable core with respect to axial and radial power stability.

In addition, oscillations in core power can be readily detected by the fixed in-core detector system which continuously monitors the core flux distribution.

The stability analyses are provided in Section 4.3.2.7.

This stability design satisfies GDC 12.

4.3.2 Nuclear Design Description

4.3.2.1 Nuclear Design Description

The NuScale core design is comprised of 37 fuel assemblies, each arranged in a 17x17 lattice and containing 264 fuel rods, 24 CRA guide tubes, and one central instrumentation tube. The fuel rods are supported by five spacer grids; each fuel rod consists of a column of stacked, cylindrical ceramic pellets of enriched uranium dioxide (UO_2) with gadolinium oxide (Gd_2O_3) as a burnable absorber homogeneously mixed within the fuel in selected locations. The fuel pellets are encapsulated in M5® cladding (a zirconium-based alloy) with an active fuel length of 78.74 inches. The fuel is enriched up to 4.95 percent.

Sixteen (16) of the fuel assembly positions contain CRAs. The CRAs are organized into two banks: a regulating bank and a shutdown bank. The regulating bank contains two groups of four (4) CRAs arranged symmetrically in the core. The regulating bank groups are used during normal plant operation to control reactivity and provide axial power shaping. The shutdown bank contains two groups of four (4) CRAs. The shutdown bank

that the RCPB behaves in a non-brittle manner and the probability of a rapidly propagating failure is minimized. Component descriptions with the applicable design codes and classifications are further discussed in Section 6.3.2.

GDC 33 requires a system to supply reactor coolant makeup for protection against small breaks in the RCPB. This GDC is not applicable to the NPM design because coolant makeup is not required to protect against breaks in the RCPB as described in Section 9.3.4.1 (see DCA Part 7, Section 5). The module protection system is designed to isolate postulated leaks that occur outside the containment thereby preserving the remaining inventory in the containment. This inventory is adequate to establish cooling using the ECCS.

The ECCS setpoints are chosen to ensure automatic actuation of ECCS valves in response to design basis LOCA events or 24 hours after a loss of AC power. The RPV and CNV design, in conjunction with the passive design and operation of ECCS and containment isolation, ensure that the core is not uncovered and adequate core cooling is maintained if a break occurs in the RCPB.

Postulated RCS leaks that are smaller than the CVCS makeup capacity, and that occur while the reactor pool is significantly below its normal operating temperature range, may not cause automatic ECCS actuation. However, an evaluation was performed to demonstrate that even at temperatures as low as the lower technical specification limit these events do not challenge SAFDL acceptance criteria. Boron mixing is maintained through diverse flow paths until RPV level drops below the riser holes. After the riser holes are uncovered, some downcomer dilution may occur, however, core boron concentration remains above the initial RCS boron concentration. This evaluation did not include or credit any non-safety related functions such as makeup or boration using the CVCS. Therefore, the ECCS design satisfies the underlying purpose of GDC 33 without reliance on a reactor coolant makeup system.

Facility design meets the regulatory requirements of principal design criterion 35, and GDCs 36 and 37 as they relate to the ECCS being designed to provide sufficient core cooling to transfer heat from the core at a rate such that fuel and cladding damage does not interfere with or prevent long-term core cooling, permit appropriate periodic inspection of important components, and provide for appropriate periodic testing. Redundancy of ECCS components, features, and capabilities is provided to ensure the system safety function can be accomplished assuming the single failure criteria.

The MPS provides the capability to perform periodic pressure and functional testing of the ECCS that ensures operability and performance of system components and the operability and performance of the system as a whole. This is further discussed in Section 7.2.15.

The ECCS meets the intent of the regulatory requirements of GDC 50, 51, 52 and 53 for those portions of the ECCS that are part of the containment pressure boundary in that the components are designed such that they can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions that result from any LOCA. The ECCS component design reflects consideration of service temperatures and the uncertainties in material property, stresses (residual, steady state and transient), and flaw size. The components are designed to accommodate the required containment integrated leakage rate and periodic inspection, surveillance, and penetration testing requirements. ECCS components that are part of the containment

Table 6.3-1: Emergency Core Cooling System Actuation Values

Parameter[2]	Value[1]
High CNV level actuation	252 inches above reactor pool floor
Low RCS pressure	800 psia
RPV low temperature & high pressure (LTOP) actuation	The LTOP pressure setpoint is a function of the RCS cold temperature (Refer to Table 5.2-10 and Figure 5.2-4).

Note 1: Additional information for ECCS actuation values is provided in Table 7.1-4.

Note 2: Interlocks for these signals are described in FSAR Table 7.1-5.

heat removal is discussed in Section 15.0.5 and a potential return to power is discussed in Section 15.0.6.

As discussed in Section 15.0.6, boron distribution is an important consideration during extended passive cooling conditions. Boron redistribution is determined to be acceptable during passive ECCS and DHRS cooling modes. Fluid boron concentration and boron distribution in the module continue to be important considerations when exiting these passive cooling modes, and must be accounted for to ensure shutdown margin limits are appropriately preserved during post-event recovery actions.

15.0.5 Long Term Decay and Residual Heat Removal

There are two systems that perform the safety-related function of decay and residual heat removal from the NPM following a DBE. The DHRS, described in Section 5.4.3, provides decay and residual heat removal while RCS inventory is retained inside the RPV, the containment is maintained in partially evacuated dry conditions, and power is available. The ECCS, described in Section 6.3, provides decay and residual heat removal when RCS inventory has been redistributed between the RPV and the CNV after the RVVs and RRVs are opened.

The DBEs listed in Table 15.0-1 progress from initiation of the event to effective DHRS or ECCS operation demonstrating that the NPM has reached a safe, stabilized condition, as described in Section 15.0.4. The decay heat removal process continues into the long-term phase, either with DHRS, natural circulation between the CNV and RPV through the RRVs and RVVs, or a combination of the two. A simplified evaluation methodology is used to bound a spectrum of possible primary to secondary side inventories which address non-LOCA and leakage cases. The non-LOCA cases are described in this section below while the leakage cases are described in Section 6.3.

There are four decay and heat removal scenarios:

1) DHRS,
2) DHRS with the RVVs and RRVs opening 24 hours after a loss of normal AC power,
3) DHRS with the RVVs and RRVs opening after a loss of normal AC and normal DC power when the IAB pressure threshold is reached, and
4) ECCS actuation following an inadvertent opening of a reactor coolant pressure boundary (RCPB) valve or a LOCA.

Significant boron redistribution prior to ECCS actuation and unacceptable positive reactivity insertion is precluded as noted in the Long Term Cooling technical report (Reference 15.0-7) and discussed below.

Scenario 1 - Decay and Residual Heat Removal using DHRS

Non-LOCA events progress from event initiation to the point where DHRS actuation valves open and the MSIVs and FWIVs close to allow DHRS operation. The progression of decay heat removal using DHRS depends on the availability of AC power.

With AC power available, DHRS cools the NPM and provides long term removal of decay heat while the RRVs and RVVs remain closed. Section 5.4.3 describes the operation of DHRS, including actuation, cooling to the safe, stabilized condition, and long term residual and decay heat removal.

In some scenarios, DHRS can cool the RCS such that the level drops below the top of the riser and the natural circulation loop is interrupted. Without natural circulation flow, condensation of steam in the riser could reduce the downcomer boron concentration. Diverse flow paths through four holes located in the riser promote mixing to preclude unacceptable positive reactivity insertion when natural circulation is restored. The riser holes are located at the SG midpoint, which is below the level resulting from RCS fluid contraction from DHRS cooldown. The methodology for evaluating the riser hole flow is described below in this section.

Scenarios 2 and 3 - Decay and Residual Heat Removal using DHRS followed by Natural Circulation through the RVVs and RRVs

For non-LOCA events that results in DHRS actuation, if onsite AC power is lost, DC power to the RVVs and RRVs is automatically removed after 24 hours and the RVVs and RRVs go to a fail-safe open position. If the non-LOCA event analysis assumes that AC and DC power are lost, which results in power removed from the RVVs and RRVs, then the RVVs and RRVs are maintained closed by the IAB mechanism. The IAB mechanism prevents RVV and RRV actuation at high RCS pressures. The RVVs and RRVs go to a fail-safe open position when the RCS pressure decreases below the IAB release pressure. Therefore, long-term decay and residual heat removal is accomplished with DHRS followed by natural circulation through the RVVs and RRVs.

Opening the RVVs and RRVs to depressurize the RCS and establish long term cooling is not considered an event escalation because the functions of the RCS barrier are not lost. The progression of cooling function from DHRS to natural circulation using the RVVs and RRVs is an inherent function in the passive design of the NPM. The RCS barrier continues to provide a confined volume for reactor coolant which allows a flow path for cooling the core and thus, confining fission products to the fuel and preventing an escalation of a DBE, including an AOO.

In some scenarios, DHRS can cool the RCS such that the level drops below the top of the riser and the natural circulation loop is interrupted. Without natural circulation flow, condensation of steam could reduce the downcomer boron concentration. Diverse flow paths through four holes located in the riser promote mixing to preclude ~~positive reactivity insertion~~unacceptable positive reactivity insertion when natural circulation is restored or ECCS flow is established. The riser holes are located at the SG midpoint, which is below the level resulting from RCS fluid contraction from DHRS cooldown. The methodology for evaluating the riser hole flow is described below in this section.

Scenario 4: Decay and Residual Heat Removal using ECCS following an Inadvertent Opening of an RCPB valve or LOCA

The system response in terms of potential challenge to the fuel from an inadvertent opening of an RVV, as described in Section 15.6.6, bounds other RCPB valve opening events as well as other non-LOCA events that transition from DHRS to natural circulation through

the RVVs and RRVs. The rate of depressurization after an inadvertent opening of an RVV is more rapid compared to the rate of depressurization after opening other RCPB valves at full power or the RVVs and RRVs following other non-LOCA events. After the RVVs and RRVs open, RCS inventory is redistributed between the RPV and CNV and the NPM enters the same cooling configuration, irrespective of the initiating event. The results of the long term cooling analysis are summarized in Table 15.0-22.

LOCAs or inadvertent RCPB valve opening events can result in condensation of unborated water in the CNV and RPV downcomer once the steam generator tubes become uncovered. The ECCS actuation signals on high CNV level and low RCS pressure are specifically designed to ensure ECCS actuation occurs prior to the development of conditions that could result in a core dilution event following ECCS actuation. The long term cooling model was used to evaluate a wide spectrum of conditions to demonstrate that ECCS actuation effectively precludes LOCA events from uncovering the riser for an extended period of time prior to ECCS actuation.

The LOCA analysis, including the analysis of long term cooling following a LOCA per 10 CFR 50.46(b)(5), is discussed in Section 15.6.5.

Riser Hole Diverse Flow Path Flow Evaluation

Analysis was performed to demonstrate that the riser holes are adequately sized to provide sufficient flow to mitigate adverse RCS boron concentration distribution during extended DHRS operation following a non-LOCA event. To demonstrate that the riser holes provide sufficient liquid flow from riser to downcomer, conservative statepoint analyses were performed to evaluate the steam generator condensation, riser hole flow, and resulting RCS boron transport during extended DHRS operation. Considering the range of conditions that could develop following a non-LOCA event with DHRS actuation, two general transient progressions were analyzed:

1) The subcooled convective case with steam to steam heat transfer in the uncovered region

   In this case, condensation on the steam generator is limited by the capacity of the secondary side steam in the uncovered region. The majority of decay heat is removed by convective heat transfer and conduction across the riser wall, and a temperature gradient from riser to downcomer develops to transfer heat across the riser wall. The temperature difference results in coolant volume shrinkage in the steam generator primary and downcomer, generating a level difference between hot side and cold side, generating a pressure difference at the riser holes driving liquid from riser to downcomer. To conservatively calculate the riser hole flow, a low temperature difference is used at each statepoint and the RCS pressure is treated conservatively to decrease the riser to downcomer density difference and riser hole flow rate.

2) The saturated condensation case with heat transfer between primary steam and secondary two-phase mixture in the uncovered region

   The majority of decay heat is conservatively assumed to be removed through condensation heat transfer at the top of the steam generator. Two-phase level swell in the core and riser region generates a level difference between the hot side and the cold side, generating a pressure difference at the riser holes which drives liquid from the

riser to the downcomer. To conservatively calculate the riser hole flow, the riser void fraction calculation is biased to give low void fraction results, to minimize riser fluid level swell and riser hole flow rate.

For each scenario, the condensation rate, biased high, and riser hole flow, biased low, at statepoints in the 72-hour analysis window are evaluated. Then the RCS boron distribution due to the condensation rate and riser hole flow is analyzed and the downcomer concentration is compared to the critical boron concentration acceptance criterion. The analysis demonstrates that for BOC and MOC conditions, the downcomer boron concentration remains above the critical boron concentration for 72 hours. At EOC conditions there is minimal dilution. This supports the conservative analysis of the return to power at end of cycle conditions where the initial boron concentration is minimal.

15.0.6 Evaluation of a Return to Power

RAI 15-6S1

Having all control rods inserted provides the safety-related means to maintain the reactor shut down for internal events and for hazards such as floods and fires in the plant, earthquakes, severe weather conditions, external fires, and external floods. With all control rods inserted, a return to power is precluded. For design basis analysis of internal events for which the worst control rod is assumed stuck out, a return to power is highly unlikely. However, a return to power is evaluated for various cooldown progressions to demonstrate that fuel design limits are not challenged. As described in Section 4.3, a failure in reactivity control system reliability to ensure long term shutdown is calculated to be less than 1E-5 per NPM-reactor year. With the highest worth control rod assembly stuck out and the chemical and volume control system unavailable, subcritical core conditions (k_{eff}<1.0) are demonstrated, for 72 hours after a DBE using nominal analysis assumptions, except for the condition where initial boron concentration is very low. The probability of reactivity control systems failing during the first 72 hours after shutdown within the small window of initial conditions that can lead to a return to power is conservatively calculated to be less than 1E-6 per NPM-reactor year.

In the unlikely event of a return to power, shutdown with margin for stuck rods is not required to demonstrate adequate fuel protection. Fuel is protected through physical processes inherent to the NuScale design that control reactivity and limit power compared to a design in which shutdown is required to limit power production to protect fuel integrity. In the NPM design, additional protection is provided by limiting power and passively removing heat. The means for limiting the power produced if the reactor does not remain shut down is dependent on the heat removal system used.

RAI 15-1, RAI 15-6S1, RAI 15-11

15.0.6.1 Identification of Causes and Accident Description

Design basis events are analyzed with an assumed highest worth control rod stuck fully withdrawn in order to evaluate the immediate shutdown capability of the negative reactivity insertion due to a reactor trip with the control rods inserting into the core, consistent with GDC 26 (See Section 3.1). In the event of an extended cooldown, when the RCS is at low boron concentrations and the CVCS is unavailable to add boron, it

RAI 06.02.01.01.A-18S1, RAI 15.00.02-20, RAI 15.01.01-2, RAI 15.04.01-4, RAI 15.04.01-6S1

Table 15.0-7: Analytical Limits and Time Delays

Signal[7]	Analytical Limit	Basis and Event Type	Actuation Delay
High Power	120%[5] rated thermal power (RTP) (≥ 15% RTP) 25% RTP (<15% RTP)	This signal is designed to protect against exceeding critical heat flux (CHF) limits for reactivity and overcooling events.	2.0 sec
Source and Intermediate Range Log Power Rate	3 decades/min	This signal is designed to protect against exceeding CHF and energy deposition limits during startup power excursions	Variable
High Power Rate	±15% RTP/min	This signal is designed to protect against exceeding CHF limits for reactivity and overcooling events.	2.0 sec
High Startup Range Count Rate	5.0 E+05 counts per second[6]	This signal is designed to protect against exceeding CHF and energy deposition limits during rapid startup power excursions.	3.0 sec
High Subcritical Multiplication	3.2	This signal is designed to detect and mitigate inadvertent subcritical boron dilutions in operating modes 2 and 3.	150.0 sec
High Reactor Coolant System (RCS) Hot Temperature	610°F	This signal is designed to protect against exceeding CHF limits for reactivity and heatup events.	8.0 sec
High Containment Pressure	9.5 psia	This signal is designed to detect and mitigate RCS or secondary leaks above the allowable limits to protect RCS inventory and emergency core cooling system (ECCS) function during these events.	2.0 sec
High Pressurizer Pressure	2000 psia	This signal is designed to protect against exceeding reactor pressure vessel (RPV) pressure limits for reactivity and heatup events.	2.0 sec
High Pressurizer Level	80%	This signal is designed to detect and mitigate chemical and volume control system (CVCS) malfunctions to protect against overfilling the pressurizer.	3.0 sec
Low Pressurizer Pressure	1720 psia[1]	This signal is designed to detect and mitigate primary high energy line break (HELB) outside containment and protect RCS subcooled margin for protection against instability events.	2.0 sec
Low Low Pressurizer Pressure	1600 psia[2]	This signal is designed to detect and mitigate primary HELB outside containment and protect RCS subcooled margin for protection against instability events.	2.0 sec
Low Pressurizer Level	35%	This signal is designed to protect the pressurizer heaters from uncovering and overheating during decrease in RCS inventory events.	3.0 sec
Low Low Pressurizer Level	20%	This signal is designed to detect and mitigate loss-of-coolant accidents (LOCAs) to protect RCS inventory and ECCS functionality during LOCA and primary HELB outside containment events.	3.0 sec
Low Low Main Steam Pressure	20 psia (at ≤15% RTP)	This signal is designed to detect and mitigate secondary HELB outside containment to protect steam generator inventory and decay heat removal system (DHRS) functionality.	2.0 sec
Low Main Steam Pressure	300 psia (at >15% RTP)	This signal is designed to detect and mitigate secondary HELB outside containment to protect steam generator inventory and DHRS functionality.	2.0 sec

Table 15.0-7: Analytical Limits and Time Delays (Continued)

Signal[7]	Analytical Limit	Basis and Event Type	Actuation Delay
High Main Steam Pressure	800 psia	This signal is designed to detect and mitigate loss of main steam demand to protect primary and secondary pressure limits during heatup events.	2.0 sec
High Main Steam Superheat	150°F	This signal is designed to detect and mitigate steam generator boil off to protect DHRS functionality during at power and post trip conditions.	8.0 sec
Low Main Steam Superheat	0.0°F	This signal is designed to detect and mitigate steam generator overfilling to protect DHRS functionality during at power and post trip conditions.	8.0 sec
Low RCS Flow	1.7 ft^3/s	This signal is designed to ensure boron dilution cannot be performed at low RCS flowrates where the loop time is too long to be able to detect the reactivity change in the core within sufficient time to mitigate the event.	6.0 sec
Low Low RCS Flow	0.0 ft^3/s	This signal is designed to ensure flow remains measureable and positive during low power startup conditions.	6.0 sec
High CNV Water Level	240-264"(3) (elevation)	This signal is designed to protect water level above the core in LOCA events.	3.0 sec
Low RCS Pressure	800 psia	This signal is designed to actuate ECCS for small LOCA events prior to extended riser uncovery where the SG can generate condensate causing boron distribution gradients in the RCS.	2.0 sec
Low AC voltage	Note 4	This signal is designed to ensure appropriate load shedding occurs to EDSS in the event of extended loss of normal AC power to the EDSS battery chargers.	60.0 sec
High Under-the-Bioshield Temperature	250°F	This signal is designed to detect high energy leaks or breaks at the top of the NuScale Power Module under the bioshield to reduce the consequences of high energy line breaks on the safety related equipment located on top of the module.	8.0 sec

Notes:

1. If RCS hot temperature is above 600°F. See Figure 15.0-9.
2. If RCS hot temperature is below 600°F. See Figure 15.0-9.
3. CNV water level is presented in terms of elevation where reference zero is the bottom of the reactor pool. The range allows ±12" from the nominal ECCS level setpoint of 252".
4. Normal AC voltage is monitored at the bus(es) supplying the battery chargers for the highly reliable DC power system. The analytical limit is based on Loss of Normal AC Power to plant buses (0 volts) but the actual bus voltage is based upon the voltage ride-thru characteristics of the EDSS battery chargers.
5. The overcooling event analyses account for a cooldown event specific process error analytical limit of 0.5%/°F.
6. The high count rate trip is treated as a source range over power trip that occurs at a core power analytical limit of 500kW which functionally equates neutron monitoring system counts per second to core power. This trip is bypassed once the intermediate range signal has been established.
7. Interlocks, permissives and overrides for these signals are described in FSAR Table 7.1-5.

Enclosure 4:

Affidavit of Zackary W. Rad, AF-0620-70463

NuScale Power, LLC

AFFIDAVIT of Zackary W. Rad

I, Zackary W. Rad, state as follows:

(1) I am the Director of Regulatory Affairs of NuScale Power, LLC (NuScale), and as such, I have been specifically delegated the function of reviewing the information described in this Affidavit that NuScale seeks to have withheld from public disclosure, and am authorized to apply for its withholding on behalf of NuScale

(2) I am knowledgeable of the criteria and procedures used by NuScale in designating information as a trade secret, privileged, or as confidential commercial or financial information. This request to withhold information from public disclosure is driven by one or more of the following:

(a) The information requested to be withheld reveals distinguishing aspects of a process (or component, structure, tool, method, etc.) whose use by NuScale competitors, without a license from NuScale, would constitute a competitive economic disadvantage to NuScale.

(b) The information requested to be withheld consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), and the application of the data secures a competitive economic advantage, as described more fully in paragraph 3 of this Affidavit.

(c) Use by a competitor of the information requested to be withheld would reduce the competitor's expenditure of resources, or improve its competitive position, in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

(d) The information requested to be withheld reveals cost or price information, production capabilities, budget levels, or commercial strategies of NuScale.

(e) The information requested to be withheld consists of patentable ideas.

(3) Public disclosure of the information sought to be withheld is likely to cause substantial harm to NuScale's competitive position and foreclose or reduce the availability of profit-making opportunities. The accompanying evaluation methodology summary reveals distinguishing aspects about the method by which NuScale develops its riser hole flow analysis.

NuScale has performed significant research and evaluation to develop a basis for this method and has invested significant resources, including the expenditure of a considerable sum of money.

The precise financial value of the information is difficult to quantify, but it is a key element of the design basis for a NuScale plant and, therefore, has substantial value to NuScale.

If the information were disclosed to the public, NuScale's competitors would have access to the information without purchasing the right to use it or having been required to undertake a similar expenditure of resources. Such disclosure would constitute a misappropriation of NuScale's intellectual property, and would deprive NuScale of the opportunity to exercise its competitive advantage to seek an adequate return on its investment.

(4) The information sought to be withheld is in the enclosed submittal entitled "NuScale Power, LLC Submittal of Riser Flow Hole Methodology and Associated Changes to Final Safety Analysis Report Incorporating Its Use." The enclosure contains the designation "Proprietary" at the top of each page containing proprietary information. The information considered by NuScale to be proprietary is identified within double braces, "{{ }}" in the document.

(5) The basis for proposing that the information be withheld is that NuScale treats the information as a trade secret, privileged, or as confidential commercial or financial information. NuScale relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC § 552(b)(4), as well as exemptions applicable to the NRC under 10 CFR §§ 2.390(a)(4) and 9.17(a)(4).

(6) Pursuant to the provisions set forth in 10 CFR § 2.390(b)(4), the following is provided for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld:

(a) The information sought to be withheld is owned and has been held in confidence by NuScale.

(b) The information is of a sort customarily held in confidence by NuScale and, to the best of my knowledge and belief, consistently has been held in confidence by NuScale. The procedure for approval of external release of such information typically requires review by the staff manager, project manager, chief technology officer or other equivalent authority, or the manager of the cognizant marketing function (or his delegate), for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside NuScale are limited to regulatory bodies, customers and potential customers and their agents, suppliers, licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or contractual agreements to maintain confidentiality.

(c) The information is being transmitted to and received by the NRC in confidence.

(d) No public disclosure of the information has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or contractual agreements that provide for maintenance of the information in confidence.

(e) Public disclosure of the information is likely to cause substantial harm to the competitive position of NuScale, taking into account the value of the information to NuScale, the amount of effort and money expended by NuScale in developing the information, and the difficulty others would have in acquiring or duplicating the information. The information sought to be withheld is part of NuScale's technology that provides NuScale with a competitive advantage over other firms in the industry. NuScale has invested significant human and financial capital in developing this technology and NuScale believes it would be difficult for others to duplicate the technology without access to the information sought to be withheld.

I declare under penalty of perjury that the foregoing is true and correct. Executed on June 19, 2020.

Zackary W. Rad