POLICY ISSUE
(Notation Vote)

April 11, 2019 SECY-19-0036

FOR: The Commissioners

FROM: Margaret M. Doane
Executive Director for Operations

SUBJECT: APPLICATION OF THE SINGLE FAILURE CRITERION TO NUSCALE POWER LLC'S INADVERTENT ACTUATION BLOCK VALVES

PURPOSE:

The U.S. Nuclear Regulatory Commission (NRC or Commission) staff (staff) requests Commission direction in order to continue the technical review of NuScale Power, LLC's (NuScale) use of inadvertent actuation block (IAB) valves in the Emergency Core Cooling System (ECCS) in its design certification application (DCA). Consistent with the direction in SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Reactor Designs" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093290268), the staff is informing the Commission of this novel technical issue early in the review process. This paper identifies several proposed paths for the staff and NuScale to continue with the DCA review. Because some of these options would require changes in Commission policy, the staff is seeking Commission affirmation that the most damaging single active failure of safety-related equipment is required to be considered in performing design, and transient and accident analyses, unless such a failure can be shown with high confidence to not be credible.

SUMMARY:

The IAB valve is a safety-significant, first-of-a-kind design feature of the NuScale ECCS.

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The staff and NuScale have been discussing the proper treatment of IAB valves in the DCA since the application was submitted. A key consideration is whether the IAB valve performs a passive function that is not subject to the single failure criterion (SFC) or an active function that is subject to the SFC. Current policy guidance defines conditions under which the SFC is applied and notes that certain active components, such as a simple check valve, can be treated as performing a passive function. Unlike a simple check valve, for which there is substantial operating experience, NuScale's IAB valve is a spring-operated differential-pressure valve that is more complex than a simple check valve and subject to a number of uncertainties. Therefore, the staff considers the functions that the IAB valves perform in the NuScale reactor design during transient and accident scenarios to be active functions subject to the SFC, in accordance with current policy. NuScale reads the SFC policy differently, and in a letter to the Commission dated December 14, 2018 (ADAMS Accession No. ML18351A145), sets forth its position that the closing function of the IAB valve should either be treated as passive or that it performs an active function not subject to the SFC. After analyzing these technical arguments, the staff proposes options for completing the NuScale DCA review.

BACKGROUND:

The staff and NuScale have been in discussions regarding the treatment of the SFC to the IAB valves since NuScale submitted its DCA[1]. In its letter to the Commission dated December 14, 2018, NuScale presented its justification for the position that the closing function of the IAB valve should be treated as a passive function and not subject to the SFC in its accident analyses. As discussed in the General Design Criteria (GDC) in Appendix A, "General Design Criteria for Nuclear Power Plants," to Part 50, "Domestic Licensing of Production and Utilization Facilities," in Title 10, "Energy," of the *Code of Federal Regulations* (10 CFR Part 50), the design of systems in nuclear power plants shall include suitable redundancy and other features to assure that safety functions can be accomplished assuming a single failure (e.g., GDC 35, "Emergency core cooling," and GDC 38, "Containment heat removal"). Additionally, Appendix K, "ECCS Evaluation Models," to 10 CFR Part 50, includes requirements to consider the most damaging single failure of ECCS equipment. However, NuScale's DCA does not assume a single failure of the IAB valve in its design basis event analyses in Chapter 15, "Transient and Accident Analyses," of DCA Part 2, Tier 2. Instead of treating the IAB valve as an active component subject to the SFC, NuScale proposes treating the closing function of the IAB valve as a passive function that is not subject to single failure. The following sections provide an overview description of the IAB valve operation; regulatory and policy basis of the SFC; background on the application of the SFC; and a summary of key issues identified by NuScale.

A. Description of the Inadvertent Actuation Block Valve

The NuScale ECCS consists of three reactor vent valves (RVVs) and two reactor recirculation valves (RRVs) attached to the reactor pressure vessel (RPV). Each of the main ECCS valves has its own valve control system, which includes an IAB valve, a trip valve, and a reset valve. The valve control system positions the main ECCS valve by either pressurizing (to close) or venting (to open) a hydraulic control chamber on each main ECCS valve. When the IAB valve is open, it provides a vent path from the main ECCS valve hydraulic control chamber through the associated trip valve into the containment vessel (CNV). In its normal position during reactor power operation, the IAB valve is open to support operation of the ECCS. If the trip

[1] NuScale submitted its design certification application in letter dated December 31, 2016 (ML17013A229), and the staff accepted the application in letter dated March 23, 2017 (ML17074A087).

valve is opened at high reactor coolant system (RCS) pressure, the IAB valve is designed to close rapidly to prevent venting of the main ECCS valve control chamber. This closing, or blocking, function of the IAB valve prevents a spurious or premature opening of the main ECCS valve. When RCS pressure is below the blocking threshold, the IAB valve returns to its normally open position to allow its main ECCS valve to open. This is accomplished by venting the main ECCS valve control chamber into CNV through the open IAB and trip valves, which in turn allows the RCS pressure to open the main ECCS valve.

The ECCS valve control system trip valve is normally energized and closed using a solenoid valve powered from the direct current (dc) power system, which is not safety-related. During a loss of dc electrical power (which is assumed as an initial condition for design basis event analysis), the ECCS valve control system trip valve opens and the IAB valve must rapidly perform its closing function. Once the differential pressure between the RPV and CNV is reduced, the IAB valve shifts to its normally open position to permit opening of the associated main ECCS valve.

See the Enclosure to this paper for figures of the ECCS valves. Figure 1 illustrates the overall design of the NuScale ECCS. Figure 2 shows the valve control system for each RVV and RRV. Figure 3 provides a detailed view of the closing function of the IAB valve.

B. Regulatory and Policy Basis of the Single Failure Criterion

The SFC is a review tool that the NRC uses to assure reliable systems as one element of the defense-in-depth approach to reactor safety. As discussed below, the NRC has considered the appropriate role of the SFC many times. Single failure is defined in the regulations in Appendix A to 10 CFR Part 50 as "an occurrence which results in the loss of capability of a component to perform its intended safety functions." A fluid system, such as the ECCS, is "considered to be designed against an assumed single failure if" a single failure of any active or passive component does not result "in a loss of the capability of the system to perform its safety functions." An associated footnote states that "conditions under which a single failure of a passive component in a fluid system should be considered in designing the system against a single failure are under development." Further, 10 CFR Part 50, Appendix K, Section I.D.1, "Single Failure Criterion," requires that accident evaluations use the combination of ECCS subsystems assumed to be operative "after the most damaging single failure of ECCS equipment has taken place."

SECY-77-439, "Single Failure Criterion," (ADAMS Accession No. ML060260236) described how the staff applied the SFC in the reactor safety review (e.g., licensing) process. SECY-77-439 states that the objective of the SFC is "promoting reliability through the enforced provision of redundancy in those systems which must perform a safety-related function." However, SECY-77-439 acknowledges that a single-failure analysis is not required for any conceivable failure. Instead the analysis should focus on "components which are judged to have a credible chance of failure." SECY-77-439 further notes that certain components "when combined with other unlikely events, are not assumed to fail because the probabilities of the resulting scenarios of events are deemed to be sufficiently small." SECY-77-439 provides a detailed discussion of how the staff applied the SFC to various classes of safety systems. For the ECCS, the staff applies the most limiting single active failure in evaluating short-term ECCS performance capability.[2] SECY-77-439 specifies that "[a]n active failure in a fluid system means: (1) the

[2] For long-term ECCS coolant recirculation mode, SECY-77-439 notes that the most limiting active failure, or a single passive failure, is assumed.

failure of a component which relies on mechanical movement for its operation to complete its intended function on demand, or (2) an unintended movement of the component." SECY-77-439 further states that "[a] passive failure in a fluid system means a breach in the fluid pressure boundary or a mechanical failure which adversely affects a flow path." The SECY paper then describes the failure of a simple check valve to move to its correct position when required as an example of a passive failure.

As approved by the Commission Staff Requirements Memorandum (SRM) dated June 30, 1994 (ADAMS Accession No. ML003708098), SECY-94-084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs," (ADAMS Accession No. ML003708068) provided further clarification on application of the SFC to check valves. SECY-94-084 indicates that for current plants, the NRC staff normally treats check valves, except for those in containment isolation systems, as passive devices during transients or design-basis accidents. Recognizing the unique features for the passive safety system designs having low-driving force, SECY-94-084 reports that the staff examined the current regulatory practice to determine how it will apply to check valve failures for the passive plant designs. SECY-94-084 notes that check valves have high safety significance in the operation of passive safety systems, and operating experience of check valves suggests that they may have a lower reliability than originally anticipated. Therefore, SECY-94-084 redefined failure of check valves in passive safety system designs as active components subject to SFC, except where the check valve function can be demonstrated and documented such that valve reliability is comparable to a passive component. SECY-94-084 explains that demonstrating such reliability requires a comprehensive evaluation of check valve test data or operational data for similar valve types in similar applications and operating environments.

In SECY-05-0138, "Risk-Informed and Performance-Based Alternatives to the Single-Failure Criterion" (ADAMS Accession No. ML051950619), the staff provided a summary of an initial evaluation of risk-informed alternatives to the SFC in response to Commission direction in SRM-SECY-02-0057, "Update to SECY-01-0133 Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 and Recommendations on Risk-Informed Changes to 10 CFR 50.46," (ADAMS Accession No. ML030910476). In SECY-05-0138, the staff presented three alternatives for risk-informing the SFC: (1) risk-informing design basis accident analysis by eliminating sufficiently unlikely sequences and postulated single failures; (2) risk-informing the application of the SFC to safety systems based upon their safety significance; and (3) applying a number of blended considerations including diversity, redundancy, and unreliability. The staff then recommended that the Commission approve the issuance of the draft SFC technical report for public comment (ADAMS Accession No. ML051950625) and inclusion of any follow-up activities to risk-inform the SFC as part of the formal program plan to risk-inform 10 CFR Part 50. In the SRM to SECY-05-0138, the Commission approved the staff recommendations and noted that the staff should "consider the spectrum of issues relating to risk-informing the reactor requirements including the effort to develop risk-informed and performance-based alternatives to the single failure criterion. This will assure that efforts to risk-inform the reactor regulations are undertaken in an open, transparent, and integrated manner." Efforts to risk-inform the SFC were later subsumed as part of a broader effort to develop a risk-informed and performance-based revision to 10 CFR Part 50. Subsequently, the staff notes in SECY-07-0101, "Staff Recommendations Regarding a Risk-Informed and Performance-Based Revision to 10 CFR Part 50," (ADAMS Accession No. ML070790236) that new rulemakings are not warranted at this time, and the NRC should not undertake new risk-informed and performance-based revisions of 10 CFR Part 50 until specific rules are identified as needed. In SRM-SECY-07-0101, "Staff Requirements - SECY-07-0101 - Staff Recommendations Regarding a Risk-Informed and

Performance-Based Revision to 10 CFR Part 50," (ADAMS Accession No. ML072530501) the Commission approved the staff recommendation to defer rulemaking for risk-informed and performance-based 10 CFR Part 50 reactor requirements.

As discussed in SECY-19-0009, "Advanced Reactor Program Status" (ADAMS Accession No. ML18344A618), the staff has issued preliminary Draft Regulatory Guide (DG)-1353, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," dated August 16, 2018 (ADAMS Accession No. ML18264A093). DG-1353 endorses Nuclear Energy Institute (NEI) Working Draft 18-04, Revision N, "Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development" (ADAMS Accession No. ML18271A172), which was produced as a result of the industry-led Licensing Modernization Project (LMP). The methodology described in NEI 18-04 uses probabilistic risk assessment (PRA) and defense in depth to assess event sequences, including consideration of failures of combinations of system, structure, and component failures, across a wide range of sequence frequencies. Consequently, the approach described in NEI 18-04 and DG-1353 can be viewed as an extension of the blended risk-informed single failure approach described in SECY-05-0138 and obviates the need to consider the SFC in evaluations of design basis accidents.[3]

C. NuScale's Position

The staff engaged NuScale on the application of the SFC to the IAB valves shortly after accepting the DCA for review.[4] In its responses (ADAMS Accession Nos. ML17202V093 and ML18065B273), NuScale asserted that the IAB valve is a passive component and not subject to the SFC. Following a detailed audit on the IAB valve design (ADAMS Accession No. ML18219B634), the staff determined that NuScale's responses did not demonstrate that the IAB valve can be treated like a passive component. The staff concluded that, due to its design and reliance on mechanical movement to accomplish its functions and the conditions under which it performs those functions, the IAB valve is not a passive component within current policy. The staff held additional public meetings with NuScale on this topic on July 17, 2018 (ADAMS Accession No. ML18292A737), August 22, 2018 (ADAMS Accession Nos. ML18285A032 and ML18236A543 (NuScale presentation)), January 9, 2019 (ADAMS Accession No. ML19042A203), and February 7, 2019 (ADAMS Accession No. ML19056A019).

In its letter dated December 14, 2018, NuScale described its position in more detail. NuScale presented five positions in its letter to support its assertion that the IAB valve should not be subject to the SFC, as follows:

- SECY-77-439 provides applicable SFC guidance for IAB valves;
- reliability data are not required to consider a component failure as passive under SECY-77-439;

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[3] The staff intends to submit to the Commission a voting paper related to the development of NEI 18-04 and DG-1353 and the resultant methodology supporting the design and licensing of non-light water reactors (non-LWRs). The staff's paper will describe the methodology, relationship to previous Commission decisions, and remaining policy issues. The staff is discussing NEI 18-04 and DG-1353 in this paper only to the extent necessary to respond to points made in NuScale's December 14, 2018, letter.

[4] On May 26, 2017, the staff issued a Request for Additional Information (RAI) requesting that NuScale provide justification for not assuming the single failure of an IAB valve (ADAMS Accession No. ML17146B305).

- a qualitative evaluation of a component's design and function, including comparison to other component functions that have been treated as passive, is sufficient to demonstrate a component's expected reliability;
- evaluating the IAB valve under the SECY-77-439 framework demonstrates that the IAB valve closure function is sufficiently reliable to be considered a passive failure; and
- consideration of new criteria (design, application, and function) based on the Exelon Backfit Appeal Review Panel Report (ADAMS Accession No. ML16236A208) could be used to establish the IAB valve closing function as a passive failure.

In its letter, NuScale noted that SFC policy may be ambiguous and would benefit from additional clarity through the Commission revisiting and clarifying how the SFC applies to active components whose failure can be treated as passive. NuScale also indicated that while there would be benefit to considering a broader generic policy question, it requested that the Commission address the application of the SFC to NuScale's IAB valves in the near term and develop broader solutions as a longer-term effort.

DISCUSSION:

After carefully considering NuScale's December 14, 2018, letter, and other information presented as part of the DCA review, the staff continues to support the position that the IAB valve is an active component that should be subject to the SFC as described in SECY-77-439. The basis for the staff's conclusion is provided in the following sections.

A. Application of SECY-77-439 and SECY-94-084 to the IAB Valve

The IAB valve is a safety-significant, first-of-a-kind design feature of the NuScale ECCS, which is more complex and must operate in a more challenging operational environment than the valves used for comparison in NuScale's analysis. In its December 14, 2018, letter, NuScale asserts that "under SECY-77-439, reliability data is not required to justify the treatment of the IAB's function as passive." NuScale suggests that SECY-77-439 provides the applicable framework to address the SFC assumption for IAB valves. NuScale proposes using a qualitative approach to demonstrate that the IAB valve closing function is sufficiently reliable to be considered a passive failure. NuScale asserts that this approach is similar to the staff's determination in SECY-77-439, that the active failure of a simple check valve to move to its correct position is an example of a passive function not subject to the SFC. While there is an apparent conflict in treating an active function as a passive failure, the broader context of SECY-77-439 indicates the staff considered the likelihood of a simple check valve failure to be sufficiently low so that its failure could be considered not credible.

Unlike a simple check valve, for which substantial operating experience existed during the development of SECY-77-439, the staff considers the IAB valve to be a spring-operated differential-pressure valve that is more complex than a simple check valve and subject to a number of uncertainties. Among these uncertainties are that the IAB valve: (1) has no operating experience and limited testing to establish performance history or reliability, (2) involves a challenging operational environment that may include steam flashing of high-temperature borated water, and (3) must close rapidly and fully seal to prevent premature opening of the main ECCS valve. Based on this information, the staff's position is that the design, application, and functions of the IAB valve are not the same, nor as simple, as a check valve operating with piping flow. Therefore, the IAB valve should be subject to single failure considerations.

In its letter, NuScale also asserts that the SFC guidance in SECY-94-084, which redefined check valves in passive safety systems as active components subject to single failure consideration except where a check valve's proper functions can be demonstrated and documented, is not applicable to its IAB valve because SECY-94-084 only discusses the SFC application to low differential-pressure check valves in new reactors with passive core cooling systems. NuScale asserts that the IAB valve is inherently reliable because the IAB valve is under a high differential-pressure environment. However, unlike a simple check valve, the staff notes that the IAB valve internal mechanism exerts a significant resistance force to the differential pressure between the RPV and CNV, such that the inherent reliability of the IAB valve cannot be assumed. The operational environment of the IAB valve further increases the uncertainty in its reliability compared to a simple check valve. Although the staff agrees that the guidance in SECY-94-084 for SFC application to check valves in passive safety systems is not directly applicable to the spring-operated differential-pressure IAB valve in the NuScale reactor, the staff considers that this guidance is helpful in evaluating the reliability of an active function to determine whether the SFC should apply.

The staff notes that the safety-related IAB valves would be designed, fabricated, and tested in a manner consistent with the quality assurance program and the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* (BPV Code) requirements, as well as the valve qualification testing specified in ASME Standard QME-1-2007, "Qualification of Active Mechanical Equipment Used in Nuclear Power Plants," as accepted by the NRC 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." The application of these programs establishes the minimum requirements for safety-related structures, systems, and components (SSCs). The 10 CFR Part 50 SFC provisions discussed in this paper establish diversity and redundancy requirements for SSCs, including safety-related SSCs. Based on the staff's understanding of the Commission regulations and policy, the design and testing requirements of applicable ASME codes and standards, such as ASME Standard QME-1-2007, have not been considered sufficient to demonstrate that failure is not credible, or that reliability is sufficiently high to allow exclusion from the application of the SFC. If the staff were to take a position that these codes and standards, by themselves, provide a sufficient basis to allow an exclusion from the SFC, the implementation of diversity and redundancy design requirements would significantly depart from past precedent. For instance, such a position would appear to obviate the need for redundant pumps, pipes, and valves for emergency core cooling systems under GDC 35. Under the staff's existing understanding of 10 CFR Part 50, significant testing and operating experience beyond the base requirements of the applicable ASME codes and standards for safety-related SSCs have been necessary to conclude that SSC failure is not credible or that reliability is sufficiently high to allow exclusion from the SFC in accident analyses.

NuScale also suggests that the Report of the Exelon Backfit Appeal Review Panel, August 23, 2016, provided a general framework for classifying valve functions during the panel's review of the potential for the pressurizer safety valves (PSVs) at Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2, to stick open following water discharge. The panel found that the classification of a component as "active" or "passive" depends on its design, application, and function, while noting some ambiguity in the use of the terms. In addition, the panel noted that the passive or active classification of check valves or safety valves may differ based on design considerations, inservice testing, or accident analyses. The panel concluded that it is appropriate to consider the potential failure of a PSV to reclose following water discharge as a passive failure (consistent with the treatment of check valve failures for the operating fleet).

This conclusion was supported by in depth testing that gave confidence in the capability of those valves. While acknowledging differences between the Exelon example and the IAB valves, NuScale argues that the general factors specified in the Exelon Backfit Appeal Review Panel Report could be used to analyze the IAB valve. In particular, NuScale states that the valve's design, application, and function could determine whether it is passive or active consistent with SECY-77-439. NuScale asserts that applying that framework to the IAB valve would result in finding that the IAB valve is a passive component that is excepted from SFC application.

However, when applying the framework to the NuScale IAB valve, the staff does not agree with NuScale's conclusion that the failure of the IAB valve to close on demand is a passive failure. The Exelon Backfit Appeal Review Panel relied on considerable operating experience and valve test information to support its determination that the potential failure of a PSV subject to the backfit evaluation at Byron and Braidwood was a passive failure. In contrast, NuScale did not address the absence of operating experience and test information for IAB valve performance under high fluid temperature, pressure, and borated water conditions for the NuScale reactor. Therefore, the staff considers that in absence of operating experience and test information under applicable reactor conditions, NuScale's reliance on the Exelon Backfit framework to justify not applying the SFC to the IAB valve is unsupportable.

B. <u>Crediting of IAB Valve Function in the NuScale Safety Analysis</u>

Application of the SFC to the NuScale safety analysis could result in a more significant challenge to fuel acceptance limits and peak containment pressure during certain licensing basis events. This is due, in part, to differences in the analysis assumptions used for safety-related functions and functions that are not safety-related for design basis events. Consistent with the definition of safety-related equipment provided in 10 CFR 50.2, equipment that is not safety-related, such as the dc power supply to the ECCS trip valves, is not credited in the safety analysis. However, the proper repositioning of the IAB valves to prevent early opening of the main ECCS valves is a safety-related function and is credited in the Chapter 15 safety analysis. Most Chapter 15 design basis events represent a potential challenge to the blocking function of all five IAB valves in the NuScale design. If a single failure of an IAB valve was considered, it is anticipated that several Chapter 15 design basis events would have more severe consequences. Currently, the most limiting[5] Chapter 15 event is a single ECCS valve inadvertently opening at high RPV pressure, which necessitates the other four IAB valves to rapidly close before their associated main ECCS valves open due to the assumption that their trip valves lose power. NuScale states there are no adverse single failures for this event. If single failure of an IAB valve is taken, two ECCS main valves open at high reactor pressure, which leads to faster inventory loss from the RCS and an increase in mass and energy flow into the CNV. The staff has performed sensitivity analyses and noted that an IAB valve single failure may result in exceeding fuel thermal limits (indicating potential fuel failure) and an increase in peak containment pressure. Although NuScale's letter indicates that "core damage" is avoided during this scenario, the NuScale analysis was performed for DCA Part 2, Tier 2, Chapter 19, "Probabilistic Risk Assessment and Severe Accident Evaluation," using PRA methods and considering the American Society of Mechanical Engineers/American Nuclear Society

[5] Most limiting, in this context, means the analysis case with the lowest margin to the acceptance criteria or figure of merit.

(ASME/ANS) PRA standard "core damage" definition rather than fuel integrity requirements specified in the GDC.[6]

C. Comparison to Other Valves

In its December 14, 2018, letter, NuScale compared operation of the IAB valve with the pilot assembly used in main steam safety relief valves (MSSRVs) for boiling water reactor (BWR) nuclear power plants as a surrogate for the IAB valve. However, NuScale did not address the significant differences in the operating environment, timing, operating mode, and normal standby condition between the two valves. First, the operating environment between the two valves is different. The fluid environment of an MSSRV pilot valve is saturated steam, while an IAB valve must perform its safety function in an environment where flashing of pressurized liquid borated reactor coolant is possible (which might cause pressure variations in the ECCS valves and tubing). Second, an IAB valve must quickly close to prevent the movement of the main ECCS valve, while an MSSRV pilot spring can act on longer time intervals. Third, an IAB valve is normally open and must fully seal on the first closure attempt, while an MSSRV pilot valve is normally closed with a proper seal and opens to allow the main valve to open. Fourth, in its normal standby condition, an IAB valve is part of a hydraulic system with chemical and volume control system (CVCS) borated water that remains stagnant until the system is required to perform its safety function. Further, there is considerable operating experience with MSSRVs, which is not the case for the IAB valve. Given these differences, the staff does not agree that the MSSRV pilot valve is a reasonable surrogate for the IAB valve.

NuScale also cites treatment of the pressurizer safety relief valve (PSRV) in the U.S. EPR design as a precedent for its approach. The U.S. EPR relies on PSRVs to open to provide overpressure protection of the RPV. The NRC staff's draft safety evaluation of the U.S. EPR DCA accepted that the SFC did not apply to the opening function of PSRV in U.S. EPR plant accident analyses for overpressure. The staff typically does not apply SFC to overpressure protection valves such as the U.S. EPR PSRVs because the ASME BPV Code contains requirements for redundancy and capacity of the valves. The staff believes that the ASME BPV Code reflects the best information on a very extensive operating history specifically applicable to overpressure protection relief valves. The overpressure requirements in the ASME BPV Code apply to PSRVs (and PSVs); however, the NuScale IAB valve is not a component used for overpressure protection, and thus not subject to the ASME BPV Code overpressure requirements. Further, NuScale's reliance on the IAB valves to close and seal rapidly to prevent the ECCS main valves from opening is significantly different from the U.S. EPR's reliance on PSRVs to open to provide overpressure protection of the RPV. Given the difference in function between the two valves in the two reactor designs and the difference in their treatment under the ASME BPV Code, the staff does not agree that the staff's draft safety evaluation of the PSRV in a U.S. EPR supports NuScale's position that its IAB valve should be treated as passive.

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[6] NuScale DCA Part 2, Tier 2, Chapter 19 defines core damage as occurring when "fuel peak cladding temperature, as determined by thermal-hydraulic simulation, exceeds 2200 degrees F." In this case, 2200 degrees Fahrenheit acts as a surrogate for core damage (severe fuel damage). Alternately, the ASME/ANS PRA standard currently endorsed by Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," (ADAMS Accession No. ML090410014) defines core damage as "uncovery and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage are anticipated and involving enough of the core, if released, to result in offsite public health effects." Conversely, NuScale considers a spurious opening of a main ECCS valve an anticipated operational occurrence, and therefore subject to the GDC 10, "Reactor Design," acceptance criteria, which requires appropriate margin to assure that specified fuel design limits are not exceeded (precluding any fuel damage).

In assessing the applicability of the cases cited by NuScale, the staff considered a combination of available analysis; testing and operational experience; and existing Code requirements. For the NuScale IAB valve, the staff noted the uncertainties in the NuScale analysis and the lack of directly applicable testing and operating experience in determining that NuScale has not demonstrated that the IAB valve is sufficiently reliable to be excluded from the SFC in the accident analyses.

D. Relationship to the Licensing Modernization Project

In its December 14, 2018, letter, NuScale states that in the near future the staff will recommend endorsement of NEI 18-04, developed as part of the LMP. NuScale reports that under the LMP approach, the concept of an SFC does not exist. While the NEI 18-04 approach, if it is ultimately approved by the Commission, would obviate the need to apply the SFC to licensing basis events for non-light water reactors (non-LWRs), this categorization is subject to a quantitative uncertainty assessment. This assessment would evaluate both event frequency and resulting consequences based on a PRA with an appropriate level of technical acceptability and defense-in-depth considerations. Furthermore, the consideration of SFC is obviated under the NEI 18-04 approach because the methodology considers single and multiple failures within a holistic risk-informed approach. To the staff's knowledge, NuScale has not performed such an assessment, and doing so is an important step in the holistic process proposed in NEI 18-04. Because NuScale has not performed this assessment, and because the LMP is still under review and will be the subject of a forthcoming Commission paper, this approach is not available to resolve NuScale's treatment of its IAB valve for this DCA review.

E. Summary

The NuScale IAB valve must immediately close and seal to prevent the main ECCS valve from opening during certain transient and accident conditions. Therefore, the staff considers the IAB valve to be a safety-significant design feature of the ECCS design for the NuScale reactor. SECY-77-439 specifies that a single failure should be applied for components that rely on mechanical movement (with the exception of highly reliable components such as simple check valves). NuScale's position is that the IAB valve is akin to a simple check valve and the SFC should not apply. The staff considers that the spring-operated differential-pressure IAB valve is more complex than a simple check valve, is subject to a number of uncertainties, and lacks directly applicable testing and operating experience. Due to the above factors, the staff has been unable to conclude that the SFC does not apply to the IAB valve, as requested by NuScale in its letter dated December 14, 2018. Based on its review and information obtained during public meetings with NuScale, the staff has developed several options below to continue with the safety review of NuScale's IAB valve.

Options for Reviewing the NuScale IAB Valves

- Option 1 - New Approach for Considering the Likelihood of a Scenario When Applying Single Failure Criterion

  This option would affirm that active component functions are subject to the SFC, but allow an exception for application of the SFC for an active component where it can be shown that, consistent with SECY-77-439, the inherent reliability of the component, combined with the frequency of challenge to the component,[7] results in scenario likelihood "deemed sufficiently small that they need not be considered." Under this approach, the staff could consider the IAB valve closing function within the broader context of the scenario where the active function is called upon rather than just focusing on the function itself. For example, the staff could consider the frequency of challenges to the IAB valve active closing function in combination with the inherent reliability of the safety-related IAB valve when determining if the closing function is subject to the SFC. This approach would be similar to the SFC treatment for unlikely design basis accident sequences discussed in SECY-05-0138. This approach raises policy issues in that it is a change from current practice in evaluating the SFC in Chapter 15 safety reviews.

To illustrate how this option could work, NuScale could potentially demonstrate the high reliability of the dc power system to the ECCS trip valves together with the inherent reliability of the ECCS IAB valve. A highly reliable dc power system could reduce the frequency of demands on the IAB valves to perform their closing safety function by keeping the associated trip valve closed. The capacity, capability, and augmented quality level of the dc power system would need to be assessed to demonstrate its high reliability. NuScale is required to demonstrate that the IAB valve satisfies the quality assurance requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and the regulatory requirements in 10 CFR 50.43(e) for this first-of-a-kind safety feature of the NuScale reactor.

The staff notes that there is precedent for reliance on mechanical components (including valves in the NuScale DCA review) that are not safety-related, to support safety functions where augmented performance demonstration and periodic testing will be applied. Under these circumstances, the staff could make a NuScale-specific finding similar to the treatment of highly reliable systems for SSCs that are not safety-related, as discussed in NUREG-0138 (November 1976), "Staff Discussion of Fifteen Technical Issues Listed in Attachment to November 3, 1976 Memorandum from Director, NRR to NRR Staff," Issue No. 1, "Treatment of Non-Safety Grade Equipment in Evaluations of Postulated Steam Line Break Accidents," (ADAMS Accession No. ML13267A423), except that in this case the finding would be limited to the application of the SFC for Chapter 15 events. The staff notes that NuScale currently has strong incentives to ensure that the dc power system is highly-reliable because loss of the system results in tripping the power module and would cause eventual RCS blowdown into containment.

If this option is pursued, the staff would review the approach chosen by NuScale and ensure that it includes appropriate augmented quality and programmatic controls necessary to provide a basis that the likelihood of challenges to the IAB valve closing function is sufficiently small. Additionally, the staff would verify that testing and maintenance considerations are consistent with a highly reliable system. Further, the staff would need to evaluate completed portions of the DCA review affected by the change in system requirements. NuScale has indicated that the dc power example described in this option is less desirable than other options given the licensing uncertainty and potential impacts to its current licensing approach for the dc power system.

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[7] The "frequency of challenge" refers to the frequency of failure of a support system following the initiating event, which as a result, requires the subject component to perform its safety function. For the NuScale-specific example given, "frequency of challenge" would be the frequency of loss of highly reliable dc power to the ECCS trip valve.

The staff notes that this option may establish an incentive for operating reactor licensees to request that the NRC allow a similar approach to modify the application of the SFC in their licensing bases. This may result in reclassification of existing safety-related systems to not safety-related with the application of augmented quality provisions as long as the margin of safety is maintained. This option does not involve any new commitments but may involve resource implications if many existing operating reactor licensees seek NRC approval to make plant specific changes to their licensing basis to eliminate certain applications of the SFC when high reliability of the associated function can be demonstrated.

- Option 2 - Affirm Applicability of the Single Failure Criterion to the Inadvertent Actuation Block Valve:

  This option would endorse the view that the IAB valve is an active component, and consistent with SECY-77-439, subject to single failure. With this option, NuScale could potentially pursue several different paths to implement the SFC for the IAB valve closing function to meet the regulatory acceptance criteria. The staff discussed these potential SFC implementation approaches with NuScale during the public meeting on February 7, 2019. Potential approaches that NuScale could implement under this option include the following:

  - NuScale could choose to revise the design basis analyses to accommodate a single failure of the IAB valve closing function. This approach could involve a combination of re-performing existing analyses, re-characterization of events and assumptions, and refinement of the evaluation model. Such an approach may involve additional testing or revisions to the existing design basis event analysis methodologies.

  - NuScale could choose to make design changes to either the IAB valve or other aspects of the ECCS valve system. Design changes to resolve the issue could vary, and as communicated by NuScale in the February 7, 2019, public meeting, could present other challenges to the overall plant design.

  - NuScale could choose to pursue an exemption request under 10 CFR 52.7, "Specific Exemptions," to the SFC as specified in 10 CFR Part 50, Appendix A, for the blocking function of the IAB valve. NuScale would provide a technical and legal basis in support of its exemption request, which the staff would evaluate using the criteria in 10 CFR 52.7 and 10 CFR 50.12, "Specific Exemptions." Under this approach, the staff would evaluate NuScale's exemption request and present its proposed findings to the Commission as part of the rulemaking for the design certification. To date, NuScale has not provided the staff with information on how the exemption criteria of 10 CFR 50.12 would apply in this case.

  This option is consistent with existing regulatory practice and the manner in which traditional LWR applicants address SFC application in their safety analysis. Because of this, it provides a reliable approach to continuing with the safety review. It also provides NuScale flexibility to find a new approach to demonstrate safety. Therefore, this option provides a high degree of regulatory certainty in that the staff would continue to apply existing policy and guidance to address this issue.

The timeline for this option varies widely depending on the approach chosen by NuScale. This option could require NuScale to reanalyze the applicable events, submit supporting justifications or methodologies, and potentially make design changes, depending on which specific approach it chooses. The staff notes that NuScale has not engaged the staff to explore the detailed technical resolution of the issues presented in this option. Therefore, the staff would need to further discuss this option with NuScale to fully understand the feasibility of the various alternatives for addressing single failure of the IAB valve. Further, changes to the design and methodologies would likely challenge the DCA review schedule and increase review costs as noted by NuScale. If NuScale pursued an exemption, the staff would still need to review the request and determine that NuScale provided an adequate legal and technical basis to support an exemption. This option does not involve any new commitments or resource implications.

- Option 3 - NuScale Request for Inadvertent Actuation Block Valve Exception from the Single Failure Criterion:

  This option would accept NuScale's request in its letter dated December 14, 2018, and find that NuScale's IAB valve active closing function is not subject to single failure for the review of the NuScale DCA. NuScale's position is described in more detail earlier in this paper and in NuScale's December 14, 2018, letter. Staff views on NuScale's position are presented in the Discussion section of this paper.

  Because much of the current SFC approach is based on policy described in SECY-77-439 and SECY-94-084 and its associated SRM, the Commission could choose to make a design-specific exception to the SFC policy in this case, which would quickly bring the issue to resolution with respect to SFC application to the IAB valve during the staff review of the NuScale DCA. During the public meeting on February 7, 2019, NuScale indicated that a design-specific determination that the closing function of the IAB valve is not subject to the SFC is one of its preferred options because it would provide the quickest path to issue closure with the least resource impact.

  The Commission could approve this option based, in part, on Commission determinations that NuScale has adequately demonstrated the proper functioning of the IAB valve with respect to the SFC and failure of the IAB valve closing function is not credible for the purpose of the NRC evaluation of the ECCS design. This option would represent a significant departure from past practice where staff's approved exceptions to the SFC were based on testing and operating experience combined with high confidence in component performance. Many of the involved staff believe that this option would represent a reduction in the defense-in-depth provided for the ECCS design compared to Options 1 and 2. This reduction in defense-in-depth could challenge meeting fuel acceptance criteria intended to preclude fuel damage should the IAB valve closing function fail upon demand in service. If the Commission approves this option, NuScale would not be required to demonstrate that fuel acceptance criteria are met assuming an IAB valve closing failure because NuScale would not be required to assume a single failure of the IAB valve closing function. Nevertheless, based on the PRA results reported by NuScale, the NuScale design is expected to continue to meet the Commission's safety goal policy and associated core damage and large release frequency goals[8] even with this reduction in defense-in-depth. As a matter of policy, the Commission could conclude that NuScale's position is reasonable and that treating the IAB valve as an active component not subject to the SFC would satisfy the applicable regulatory requirements. This option does not involve any new commitments or resource implications.

Assessment of Options

The staff believes Options 1 and 2 allow the staff to come to a technical position that is within existing SFC policy and practice, in a timeframe that supports the overall 42-month schedule for the NuScale DCA review. While Option 3 could bring the quickest resolution to the IAB valve SFC issue, it is a new policy position on the application of the SFC, and could be considered a reduction in the defense-in-depth provided for the NuScale ECCS design.

Opportunity for Enhancing Single Failure Criteria Policy Guidance

The staff recognizes that certain aspects of the SFC policy outlined in SECY-77-439 and SECY-94-084 and its associated SRM can lead to ambiguity and therefore could potentially benefit from updating. While enhancements to the SFC policy alone would not support a timely resolution of the IAB valve issue for the NuScale DCA review, this issue presents an opportunity for the Commission to direct an update of the SFC guidance. The current policy guidance could be updated to resolve areas lacking clarity in the existing SFC approach defined by SECY-77-439 and SECY-94-084 and its associated SRM. The staff could revisit the risk-informed and performance-based alternatives for the SFC outlined in SECY-05-0138, or extend the exception for not applying the SFC to other types of active components where proper function and high reliability can be demonstrated. The update could also consider the insights provided in the Exelon Backfit Appeal Review Panel Report. This effort would require further development to determine its appropriate application for the current operating nuclear power plants. At this time, the operating reactor business line has no current concerns with application of the SFC and does not have an immediate need for an updated policy.

Should the Commission choose to use this opportunity to direct the staff to update SFC policy guidance, undertaking this effort has resource implications. Because the level of effort would depend on the priority and extent to which the Commission directs the staff to update the SFC policy, resource impacts for this activity have not been developed. If the Commission directs that enhancement to the SFC policy guidance are needed, the staff would provide the Commission a resource estimate prior to commencing work.

RECOMMENDATION:

The staff recommends that the Commission affirm that the most damaging single active failure of safety-related equipment is required to be considered in performing design, and transient and accident analyses, unless such a failure can be shown with high confidence to not be credible. With this affirmation, the staff requests that the Commission approve staff engagement with NuScale under Options 1 and 2. If the Commission approves this approach, the staff would engage with NuScale on these options and ultimately review the approach selected by NuScale as part of the DCA safety evaluation.

[8] 51 *FR* 28044, "Safety Goals for the Operations of Nuclear Power Plants Policy Statement," *Federal Register*, Volume 51, No. 149, pp 28044-28049, August 4, 1986 and SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and their Relationship to Current Regulatory Requirements," and associated SRM (ADAMS Accession Nos. ML003707849 and ML003707885).

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection.

Margaret M. Doane
Executive Director for Operations

Enclosure:
NuScale's Emergency Core Cooling
System Valve Figures

SUBJECT: APPLICATION OF THE SINGLE FAILURE CRITERION TO NUSCALE'S INADVERTENT ACTUATION BLOCK VALVES DATED: April 11, 2019

ADAMS Accession No.:
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