POLICY ISSUE
(Information)

October 9, 2018 SECY-18-0099

FOR: The Commissioners

FROM: Margaret M. Doane
Executive Director for Operations

SUBJECT: NUSCALE POWER EXEMPTION REQUEST FROM 10 CFR PART 50, APPENDIX A, GENERAL DESIGN CRITERION 27, "COMBINED REACTIVITY CONTROL SYSTEMS CAPABILITY"

PURPOSE:

The purpose of this paper is to inform the Commission prior to the design certification rulemaking process about (1) NuScale Power, LLC's (NuScale's), request for an exemption, in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 52.7, "Specific Exemptions," to General Design Criterion (GDC) 27, "Combined Reactivity Control Systems Capability," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and (2) the criteria that the U.S. Nuclear Regulatory Commission (NRC) staff will use to evaluate whether the exemption is acceptable with regard to the protection of public health and safety. This paper does not address any new commitments or resource implications.

SUMMARY:

The NRC staff stated during preapplication interactions with NuScale that an exemption from GDC 27 was needed because the plant response to some postulated accidents (PAs) included the reactor returning to a critical condition beyond the short-term transient portion of the accident. The staff's view is that GDC 27, which was developed by the Atomic Energy Commission (AEC) for an earlier generation of reactor designs, requires a reactor to achieve

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and maintain long term subcriticality using only safety-related equipment following a PA with margin for stuck control rods. While not agreeing with the staff's view on the need for an exemption, NuScale included an exemption request for GDC 27 in its design certification application (DCA). The staff will evaluate whether the NuScale design achieves the fundamental safety functions for nuclear reactor safety, which are to control heat generation, to remove heat, and to limit the release of radioactive materials. The staff has defined criteria addressing safety margins, event frequencies, and the Commission's safety goals for evaluating the NuScale reactor design and the particular issue of recriticality during some PAs. The staff is informing the Commission of this issue during its evaluation of the design, prior to the design certification rulemaking process, as envisioned in SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Reactor Designs," March 28, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093290268). This will provide for more timely and effective regulation, minimize complexity, and add stability and predictability in the licensing and regulation of small modular reactor designs.

BACKGROUND:

The AEC incorporated the GDC into 10 CFR Part 50 in July 1971 (36 FR 12733) following several years of interacting with stakeholders and issuing drafts for public comment. The GDC establish minimum requirements for the principal design criteria for water-cooled nuclear power plants similar in design and location to the plants for which the AEC had issued construction permits. The introduction to the GDC acknowledges that additional or different criteria would be needed for water-cooled reactors of advanced design and that some of the published GDC may not be necessary or appropriate for some designs. For those designs, departures from the GDC must be identified and justified, namely through a 10 CFR 50.12 exemption.

The NuScale design is modern in comparison to currently operating plants and proposes some unique approaches to nuclear safety. However, as a water-cooled reactor, it is expected to meet or justify departures from the GDC that are required under 10 CFR 52.47, "Contents of Applications; Technical Information." The NuScale application includes requests for exemptions from several of the GDC on the basis that the requirements are not applicable to the specific design. One such exemption request relates to GDC 27, which addresses control of reactivity changes during PAs:

> *GDC 27—Combined reactivity control systems capability.* The reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes to assure that under postulated accident conditions and with appropriate margin for stuck rods the capability to cool the core is maintained.

The NuScale design incorporates several innovative features that reduce the overall complexity of the design and lower the number of safety-related systems necessary to mitigate PAs. One of these innovative design features is an emergency core cooling system (ECCS) that performs its safety function without reliance on safety-related electrical power or external sources of coolant inventory makeup. This unique ECCS design reduces the number of components but also eliminates one safety-related mechanism to control reactivity during PAs, as described further below. The NuScale design credits safety-related control rod assemblies (CRAs) to insert and shut down the reactor as part of mitigating PAs. NuScale performed an analysis, as part of its DCA (ADAMS Accession No. ML18086A187), that indicates that a posttrip cooldown could result in a return-to-power event beyond the short-term transient portion of the accident

under certain conditions when accounting for a stuck CRA. This analysis, which is currently under NRC staff review, concludes that design limits for fission product barriers are not exceeded during the return-to-power event.

The NRC staff became aware of the potential for a return-to-power event before NuScale submitted the DCA. In its letter to NuScale dated September 8, 2016 (ADAMS Accession No. ML16116A083), the staff explained that it has historically interpreted GDC 27 as requiring a reactor to be reliably controlled to achieve and maintain a safe, stable condition, including subcriticality, beyond the short term, using only safety-related equipment following a PA with margin for a stuck CRA. NuScale explained its view in its November 2, 2016, response (ADAMS Accession No. ML16307A449) that its design is consistent with the regulations and provides reasonable assurance of adequate safety, and that an exemption from GDC 27 should not be required to certify the NuScale reactor design. NuScale requested that, if the staff did not agree with them that an exemption request from GDC 27 was not warranted, the white paper with NuScale's regulatory analysis be included in any staff paper to the Commission (see enclosure). Although it did not agree with the staff's view on the need for an exemption, NuScale included an exemption request for GDC 27 in the DCA (ADAMS Accession No. ML17013A306). As explained in further detail below, the staff's view continues to be that GDC 27, when viewed as part of the requirements developed for earlier generations of light-water reactors, requires subcriticality beyond the short-term transient portion of the accident, and therefore an exemption from GDC 27 is appropriate for the NuScale design.

Development of GDC 27

The AEC incorporated the GDC into 10 CFR Part 50 following several years of interacting with stakeholders and issuing drafts for public comment. The initial draft GDC (ADAMS Accession No. ML043310029) included a proposed criterion requiring reactivity control systems be capable of making and holding the core subcritical under any conditions with appropriate margin for contingencies, but the AEC removed this language in the final issuance of the GDC. Several comments received on the draft GDC influenced the changes incorporated into the final version of the GDC. For example, comments from Oak Ridge National Laboratory (ORNL) on the draft GDC recommended that the criteria more clearly distinguish between reactivity requirements for transient conditions and static holddown functions (ADAMS Accession No. ML003726522). ORNL further stated, "The reliability with which each function must be carried out depends upon the seriousness of the consequences of failure of that function."

Comments received from Westinghouse on the draft GDC also addressed the shutdown language and identified inconsistencies between the draft GDC and plants that were already licensed by the AEC. Westinghouse proposed changes "to clarify the [reactivity holddown capability] criterion so that it does not arbitrarily rule out a short return to criticality during the shutdown transient" (ADAMS Accession No. 9210130230). Pressurized-water reactors for which the AEC had already issued licenses would not have satisfied the draft reactivity holddown capability criterion under PA conditions because these plants experience a brief return to power during the first several minutes of main steamline break accidents, but then control reactivity to achieve and maintain subcriticality throughout the remainder of the accident by adding soluable neutron poison via the safety-related ECCS. The Atomic Industrial Forum proposed similar changes accommodating a return to power following a PA, stating, "The reactivity control systems provided shall be capable of making the core subcritical under credible accident conditions with appropriate margins for contingencies and limiting any subsequent return to power such that there will be no undue risk to the health and safety of the

public" and "public health and safety will not be compromised by a return to low power" (ADAMS Accession No. ML003674718).

The comments received from ORNL, in combination with comments from Westinghouse and the Atomic Industrial Forum addressing inconsistencies between the draft GDC and plants that were already licensed by the AEC, influenced the language in the final GDC. The final GDC retained requirements for reactivity holddown (i.e., maintaining the core subcritical) in the last sentence of GDC 26, but the final version relaxed the requirement to include reactivity margin to address stuck control rods for cold conditions. However, the requirements of GDC 26 do not address the plant response to PAs. For postulated accident conditions, GDC 27 requires, in part, "reliably controlling reactivity changes" and specifically includes "in conjunction with poison addition by the emergency core cooling system," which is consistent with the design criteria applied to existing pressurized-water reactors.

The lack of specific language requiring subcriticality in the wording of GDC 27 results in questions of whether the intent of "reliably controlling reactivity changes" is only necessary to provide assurance that core power remains below the capability of heat removal systems, or if it was also intended to preclude a long term return-to-power as a result of a cooldown with a stuck CRA. Because NRC regulations do not otherwise address return-to-power events resulting from criticality beyond the short-term transient portion of a PA, the NRC staff supports the latter view that GDC 27 requires a reactor to achieve and maintain long term subcriticality. Additional discussion of the two interpretations is provided below:

Interpreting "Reliably Controlling Reactivity Changes" in GDC 27 to Mean Achieving and Maintaining Subcriticality Following a PA

The NRC staff interprets the language "reliably controlling reactivity changes" in GDC 27 to mean that reactor power is being controlled and the reactor is being moved towards a desired safe state. Under this interpretation, GDC 27 not only requires that reactivity control systems support maintaining core cooling, but it also specifies the means of achieving this goal (i.e., by "reliably controlling reactivity changes") and allows the ECCS to support the longer term control of reactivity. The desired core state to minimize risk to public health and safety following a PA is safe shutdown (i.e., subcriticality) to ensure that core heat generation is maintained below the capabilities of decay heat removal systems. The NRC staff described the prevailing view of a safe, stable condition as safe shutdown, which includes the reactor being subcritical, in SECY-94-084,[1] "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs," dated March 28, 1994 (ADAMS Accession No. ML003708068). The staff views the proposed NuScale design and safety analyses as proposing an alternative to the existing construct of the GDC and the related standard definition of safe, stable condition that would not depend on long-term subcriticality using only safety-related systems. As such, the NRC staff informed NuScale that an exemption to GDC 27 was warranted, that NuScale should propose and justify such an exemption, and that the acceptability of the design would be based on the merits of the safety case presented in the

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1 SECY-94-084 stated, "[t]he staff believes that [conditions other than cold shutdown] may constitute a safe shutdown state as long as reactor subcriticality, decay heat removal, and radioactive materials containment are properly maintained for the long term." In the associated staff requirements memorandum (SRM), dated June 30, 1994 (ADAMS Accession No. ML003708098), the Commission approved the concept of reliance on systems that are not safety related as support to the safety-related passive heat removal systems after 72 hours from the onset of a design-basis accident.

DCA. NuScale included justification for this exemption in its application and the staff is currently evaluating it.

Interpreting GDC 27 to Mean Controlling Reactivity to Maintain Capability to Cool the Core

NuScale's interpretation of GDC 27 is based on the absence of an explicit shutdown requirement in the criterion, and the fact that the AEC did not include the phrase "making and holding the core subcritical" when it issued the final GDC 27. Considering the specific language in GDC 27 in isolation, NuScale's view is that the NRC staff should interpret "reliably controlling reactivity changes" as not requiring the reactor to be held subcritical. GDC 27 could then be read only to require assurance that reactivity is controlled to reduce reactor power to levels to within the capacity of the core cooling systems. NuScale's reading of GDC 27 interprets the overall safety objective of GDC 27 as not requiring safety-related reactivity control systems beyond limiting the reactor power to be within the capacity of the safety-related heat removal systems. Under this interpretation, it could be concluded that an exemption to GDC 27 may not be required for a reactor design that does not maintain long-term subcriticality following a PA when accounting for stuck rods, provided reactivity control is sufficiently reliable to maintain reactor power within the capacity of heat removal systems. However, the staff's view, explained more fully below, is that this interpretation of GDC 27 does not account for integrated, interrelated requirements for reactivity control and heat removal within the GDC as a whole, which were developed for earlier generations of light-water reactors.

Basis for Staff's Recommendation That NuScale Request an Exemption From GDC 27

NRC regulations associated with reactivity control, heat removal, and limiting the release of radioactive materials are interrelated and together define an integrated set of requirements to ensure no undue risk to public health and safety. Requiring achievement of a shutdown state following a PA, as part of GDC 27, is consistent with GDC 34, "Residual Heat Removal," which requires, in part, "a system to remove residual heat...to transfer fission product decay heat and other residual heat from the reactor core." Although GDC 34 addresses decay heat and other residual heat, GDC 34 does not require capabilities to remove fission power from a sustained critical reaction. In addition to a long-term sustained return to criticality not being contemplated in GDC 34, 10 CFR 50.46(b)(5) specifies that "[a]fter any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core." The requirements of GDC 34 and 10 CFR 50.46(b)(5) were not developed considering the potential need to accommodate fission power from a sustained return to criticality.

Additionally, the Commission's SRM dated June 30, 1994 (ADAMS Accession No. ML003708098), approved the staff's recommendation on safe-shutdown requirements in SECY-94-084, in which the NRC staff described the conditions that constitute a safe, stable condition as including reactor subcriticality. The importance of achieving and maintaining safe shutdown is further emphasized in 10 CFR 50.2, "Definitions," which defines "Basic component" and "Safety-related structures, systems, and components" (SSCs) as those SSCs that are relied upon to shut down the reactor and maintain it in a safe-shutdown condition.

Based upon the issues and plant designs facing the AEC when the GDC were developed and on the function of GDC 27 within the NRC's regulations, the staff's position included in the letter to NuScale dated September 8, 2016, is that GDC 27 requires that the reactor be reliably

controlled and that the reactor achieve and maintain a safe, stable condition, including subcriticality beyond the short term, using only safety-related equipment following a PA with margin for stuck control rods. The staff is informing the Commission of this issue during its evaluation of the design, prior to the design certification rulemaking process, as envisioned in SECY-10-0034.

DISCUSSION:

The NRC has previously approved only reactor designs that can achieve and maintain long-term shutdown using only safety-related equipment. However, the innovative features that make the NuScale design different from operating reactors could support deviations from this past practice through an exemption. The following discussion provides an overview of NuScale's exemption request for GDC 27 and the criteria the staff intends to use to evaluate the acceptability of the request. Although the safety review of NuScale's DCA is still in progress, the staff is informing the Commission early in the review process because the NuScale approach to reactivity control and maintaining core cooling following certain PAs is a proposed alternative to GDC 27 and the related standard definition of safe, stable condition. The staff further notes that its evaluation may provide insights useful to support future advanced nonlight-water-reactor licensing activities.

In its exemption request, NuScale stated that the shutdown function derived from the historical implementation of GDC 27 can be met for its design with all control rods inserted (i.e., without assuming a stuck CRA). NuScale noted that a return to criticality assuming a stuck CRA is very unlikely and that specified acceptable fuel design limits (SAFDLs) for critical heat flux would not be exceeded even if that event occurred. NuScale concluded that the reactivity control capability is sufficient because if a return to criticality occurs, the heat removal systems assure the capability to cool the core is maintained.

The staff is reviewing NuScale's exemption request and will base its recommendation on the acceptability of the exemption request on the criteria in 10 CFR 50.12, "Specific Exemptions." To ensure that the exemption will not present an undue risk to public health and safety, the staff will evaluate whether the NuScale design meets, or satisfies the 10 CFR 50.12 criteria for exemption from, each of the other GDC in Appendix A to 10 CFR Part 50, which together assure safety functions are provided to control heat generation, to remove heat, and to limit the release of radioactive materials. The staff will apply the following technical criteria to support its safety findings for the proposed exemption request:

- The design of the reactor must provide sufficient thermal margin such that a return to power does not result in the failure of the fuel cladding fission product barrier, as demonstrated by not exceeding SAFDLs for the analyzed events. The use of SAFDLs following a PA is an appropriate criterion to ensure that any return to power poses no undue risk to public health and safety.

- The combination of circumstances and conditions leading to an actual post reactor trip return to criticality would not be expected to occur during the lifetime of a module. The criterion that a recriticality is not expected to occur during the lifetime of a module is consistent with NuScale's classification of infrequent events and PAs (see Section 15.0.0.2.1, "Classification by Event Frequency and Type," in the NuScale DCA, Revision 1, issued March 2018 (ADAMS Accession No. ML18086A187)).

- The incremental risk to public health and safety from the hypothesized return to criticality at a NuScale facility with multiple reactor modules does not adversely erode the margin between the Commission's goals for new reactor designs related to estimated frequencies of core damage or large releases and those calculated for the NuScale design.[2]

In accordance with the design certification process in 10 CFR Part 52, the Commission will make the final determination on the acceptability of NuScale's proposed exemption to GDC 27 and the overall safety of the design based on NuScale's application and the NRC staff's review documented in the safety evaluation associated with the exemption request.

Deterministic Design-Basis Technical Review

NuScale requested an exemption from GDC 27 and proposed a design-specific principal design criterion to address the potential that the reactor could return to criticality under certain plant conditions if adequate passive heat removal capability exists. The staff is conducting its review consistent with the enhanced safety-focused review approach (ESFRA),[3] which was developed to make the level of staff reviews commensurate with the safety or risk importance of specific review areas.

NuScale documented its return-to-power analysis in Section 15.0.6, "Evaluation of a Return to Power," of the DCA, Revision 1 (ADAMS Accession No. ML18086A187). This analysis, which is currently under NRC staff review, concludes that design limits for fission product barriers are not exceeded during the return-to-power event. The staff will assess the safety basis of NuScale's position by evaluating the postevent power level, reactor flow stability, system capacity for heat removal, and margin to fuel safety limits, such as SAFDLs. As noted above, the staff will make a recommendation to the Commission, as part of the design certification process in 10 CFR Part 52, on the acceptability of NuScale's GDC 27 exemption request and the overall acceptability of the design.

Regulatory Perspective and Risk Analysis

From a regulatory perspective, the staff could support the NuScale exemption provided (1) fuel cladding integrity is shown to be maintained through meeting the SAFDLs for analyzed events, (2) the request demonstrates that an actual return to a critical condition is not expected to occur during the lifetime of a module, and (3) the overall risk of radiological releases remains very low. These findings would ensure that the departure for the NuScale design from the historical interpretation of GDC 27 requiring reactor core subcriticality beyond the short term will not present an undue risk to the public. The consideration of risk insights under this approach is consistent with the integrated decisionmaking process under the ESFRA. Given the unique capabilities of NuScale's passive safety features, the design could demonstrate core cooling capability using natural circulation without an emergency power source or operator action during

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2 The Commission has defined goals and expectations for new reactor designs in policy statements such as "Safety Goals for the Operations of Nuclear Power Plants," 51 FR 30028, August 21, 1986; and "Policy Statement on the Regulation of Advanced Reactors," 73 FR 60612, October 14, 2008.

3 The staff described the ESFRA for NuScale in SECY-17-0112, "Plans for Increasing Staff Capabilities to Use Risk Information in Decision-Making Activities," dated November 13, 2017 (ADAMS Accession No. ML17270A197 (package)), consistent with Commission direction in SRM-SECY-11-0024, "Staff Requirements—SECY-11-0024—Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated May 11, 2001 (ADAMS Accession No. ML111320551). The ESFRA guides reviewers in considering plant design features in 11 key areas to help formulate the scope and depth of review activities.

a return to critical condition. This capability does not exist in the current fleet of licensed power reactors, and the staff believes that the facts supporting the exemption could support a finding that the improved thermal margins provided by the NuScale design compensate for any decrease in safety associated with the inability to maintain subcriticality with only safety-related systems during some PAs.

For the NuScale design to return to criticality in the long term following a shutdown, a set of circumstances typically assumed within the analyses of PAs must occur simultaneously. These include a stuck CRA, unavailability of nonsafety systems for boration, and the reactor operating in a portion of the cycle with a sufficiently negative moderator temperature coefficient. NuScale estimated the probability of a return-to-power event to be less than 1E-6 per module year. The staff's review of the DCA will include confirmation that a return to criticality would not be expected to occur during the lifetime of a module.

The NuScale design contains nonsafety-related systems that could, if available and not isolated, restore the reactor to a subcritical condition. Assuming that a postevent recriticality is unlikely to occur during the life of a power module, with an adequate, highly reliable (passive) safety-related means of heat removal, and the availability of alternative means of ultimately achieving subcriticality, the staff finds that the facts supporting the exemption request could support an alternative design criterion, which includes protection of the SAFDLs, to govern this event. The applicant and related NRC staff assessments of the DCA will also need to confirm that the incremental risk to public health and safety from the hypothesized return to criticality at a multimodule NuScale facility does not adversely erode the margin between the Commission's goals for new reactor designs related to estimated frequencies of core damage or large releases and those calculated for the NuScale design.

The staff will include risk aspects in its safety evaluation of the exemption request and provide the evaluation to the Commission using the established design certification rulemaking process. The safety evaluation will also document the staff's findings on NuScale's safety analysis, performed using traditional deterministic methods. If NuScale demonstrates the SAFDLs are met, the probability of a return to criticality is sufficiently low, and the incremental and overall risks of a radiological release remain low, then the staff anticipates finding that the exemption poses no undue risk to public health and safety.

CONCLUSIONS:

The staff will document its technical evaluation in its safety evaluation report on the NuScale DCA. Should the staff review determine that the NuScale design provides an acceptable level of safety with respect to the control of reactivity in the reactor, the staff will explain in its safety evaluation report for the NuScale DCA the technical basis that would support granting the exemption from GDC 27.

COORDINATION:

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

The staff discussed this issue with the Advisory Committee on Reactor Safety (ACRS). The ACRS issued a letter on February 21, 2018 (ADAMS Accession No. ML18052A532), providing its conclusions and recommendations. The ACRS concluded that the staff's proposed criteria to evaluate the acceptability of NuScale's GDC 27 exemption request are reasonable, provided that the staff evaluates overall risk and that risk considerations are based on the facility rather than an individual module. The staff considered its interactions with the ACRS in finalizing this paper.

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Enclosure:
White Paper "NuScale Reactivity Control
Regulatory Compliance and Safety"

White Paper “
NUSCALE POWER EXEMPTION REQUEST FROM 10 CFR PART 50, APPENDIX A, GENERAL DESIGN CRITERION 27,“COMBINED REACTIVITY CONTROL SYSTEMS CAPABILITY” DATED OCTOBER 9, 2018.

ADAMS Accession No.: ML18065A431 (pkg.) *via e-mail SECY-012

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