June 20, 2014

MEMORANDUM TO: Chairman Macfarlane
Commissioner Svinicki
Commissioner Apostolakis
Commissioner Magwood
Commissioner Ostendorff

FROM: Glenn M. Tracy, Director ***/RA/***
Office of New Reactors

SUBJECT: STATUS OF MECHANISTIC SOURCE TERM POLICY ISSUE FOR SMALL MODULAR REACTORS

The purpose of this memorandum is to inform the Commission of the current status and planned activities related to the mechanistic source term (MST) issue for small modular reactors (SMRs). The U.S. Nuclear Regulatory Commission (NRC) staff previously described this issue in SECY-10-0034, "Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs," dated March 28, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093290268). The staff also issued a Commission memorandum, "Status of Staff Activities to Address Mechanistic Source Term Methodology and its Application to Small Modular Reactors," dated December 29, 2011, (ADAMS Accession No. ML113410366) to inform the Commission of ongoing and planned activities to address methods for determining a MST and to describe the circumstances in which a source term determined by such methods may be appropriate. Most recently, the staff issued another Commission memorandum, "Current Status of the Source Term and Emergency Preparedness Policy Issues for Small Modular Reactors," dated May 30, 2013, (ADAMS Accession No. ML13107A052) to provide the status of activities for the source term and emergency preparedness issues for small modular reactors. Since that time, NRC staff and external stakeholders have remained engaged on this issue. Current activities and interactions include public meetings with industry groups, closed meetings with potential SMR applicants, and reviews of position papers from industry groups and potential SMR applicants.

The Nuclear Energy Institute (NEI) submitted the position paper, "Small Modular Reactor Source Terms," on December 27, 2012 (ADAMS Accession No. ML13004A390). The paper established the NEI Licensing Task Force's positions on accident radiological source terms and related issues, with the premise that small modular reactors can be licensed within the existing regulatory framework. The NEI position paper is primarily focused on pressurized-water small modular reactors and only addressed non-light-water reactor accident source terms in general terms. NEI and NRC staff discussed the paper during public meetings held in the months of December 2012 and April 2013. Meeting summaries can be found in ADAMS, at Accession Nos. ML13079A205 and ML13115A038, respectively.

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During discussions with NEI at the public meetings listed above, the NRC staff stated that the NEI position paper was a good outline of options for the development of design-specific source terms but that more details and research plans are needed in subsequent papers or technical reports in order to validate the design-specific evaluations. Since then, NEI has not requested further interactions on this topic and has not submitted any additional documents for NRC staff review.

The NRC staff has had several interactions with potential small modular reactor design applicants regarding MST. These include interactions with Generation mPower LLC (GmP or mPower), NuScale Power (NuScale), and DOE/Idaho National Lab's (INL's) Next Generation Nuclear Plant (NGNP) project. Interactions with these potential applicants have been focused on design-specific activities regarding their accident source term position papers and are discussed below.

Generation mPower LLC is a joint company formed by The Babcock & Wilcox Company (B&W) and Bechtel to design, license, and build the next generation of nuclear power plants based on B&W mPower™ reactor methodology. This company submitted a proprietary position paper, "Radiological Source Term Methodology for the B&W mPower™ Reactor MPWR-EPP-005010-NP," on July 9, 2012 (proprietary version is at ADAMS Accession No. ML12192A586 and nonproprietary version is at ADAMS Accession No. ML12192A585). Generation mPower subsequently revised the position paper and resubmitted it on October 21, 2013 (proprietary version is at ADAMS Accession No. ML13296A582 and nonproprietary version is at ADAMS Accession No. ML13296A581). The paper discussed mPower's methodology for crediting the features in the B&W mPower reactor in meeting the current regulatory expectations established in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 100, "Reactor Site Criteria," 10 CFR 50.34 (a)(1), and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," for design-basis accident radiological consequences analyses. During a closed meeting on September 20, 2012, the NRC staff had the opportunity to discuss with mPower several areas of the paper that would require clarification if mPower submitted it as part of a license application for NRC review. The meeting summary is available at ADAMS Accession No. ML13099A241. On October 29, 2013, the NRC staff and mPower met again in a closed meeting to discuss the design-basis accident radiological source term methodology. In this meeting, mPower presented preliminary information on a loss-of-coolant accident (LOCA) as the maximum hypothetical accident and discussed the mPower design features that preclude core uncovery and mPower's approach to crediting aerosol deposition in the mPower containment. The meeting summary is available at ADAMS Accession No. ML13309A555.

NuScale submitted its position paper "NuScale Accident Source Term," dated December 31, 2013 (proprietary version is at ADAMS Accession No. ML14126A212, nonproprietary version at ADAMS Accession No. ML14134A261). The paper describes NuScale's proposed approach for assessing the radiological consequences of design-basis accidents, including the accident source terms, and methodology for crediting the features of the NuScale reactor in meeting the current regulatory expectations established in 10 CFR Part 100, 10 CFR 50.34 (a)(1), and 10 CFR Part 52 for design-basis accident radiological consequences analyses. NuScale submitted this position paper for consideration during the NRC's development of a design-specific review standard for the NuScale design review. During a March 19, 2014, closed meeting, NuScale representatives presented information related to NuScale's calculation of design-basis accident source terms.

The NRC staff also had the opportunity to ask questions on the associated design attributes for preparation of the NuScale design-specific review standard. The meeting summary is available at ADAMS Accession No. ML14090A166.

The NRC staff is currently evaluating the information in both the mPower and NuScale position papers on design-basis accident source terms. The staff believes that, with appropriate justification, applicants may be able to use information from current guidance on design-basis accident analysis for large light-water reactors on light-water small modular reactors. For example, applicants may be able to use Chapter 15 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition." They may also be able to use Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors" and related basis documents, as well as research and computer codes.

The staff can make some general observations based on its assessment of the light-water small modular reactor preapplication accident source term position papers. The NEI, mPower, and NuScale papers all address only design-basis accident source terms. Other source terms, such as effluent source terms, would be discussed in other design-specific papers or through preapplication meeting interactions. The methodologies that mPower and NuScale propose in their papers generally fit the concepts in the NEI white paper regarding accident source terms; however, the staff is not making a finding as to what extent and whether consistency with the NEI white paper is necessary. Although both designers propose design-specific design-basis accident source terms, neither mPower nor NuScale are proposing entirely mechanistic, scenario-specific source terms. Instead, the designers propose to use, as applicable, the guidance in Regulatory Guide 1.183 to determine which design-basis accidents are analyzed (except as precluded as not credible by design features) and for the majority of the assumptions used in the design-basis accident analyses. Both papers propose to use some design-specific information on the amount of fission product release from the core or timing of release to containment in the analysis of the core melt accident for siting and design review; neither paper proposes scenario-specific source terms for LOCAs or other core melt design-basis accidents.

Both mPower and NuScale propose methods that address the current siting and licensing requirements in 10 CFR Part 100, 10 CFR 50.34(a)(1), and 10 CFR 52.47(a)(2). Both the mPower and NuScale methodologies include analysis of a postulated core melt design-basis accident (such as a LOCA) which assumes a large release of fission products into the containment, with release to the environment by a containment leak rate which is demonstrated by surveillance testing. This design-basis accident modeling is in accordance with the cited regulatory requirements, including the footnote to 10 CFR 50.34 "Contents of Applications; Technical Information," and 10 CFR 52.47, "Contents of Applications; Technical Information," on the postulated source term, which states:

> The fission product release assumed for this evaluation should be based upon a major accident, hypothesized for purposes of site analysis or postulated from considerations of possible accidental events. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release into the containment of appreciable quantities of fission products.

Both the mPower and NuScale source term white papers propose to take credit for passive fission product removal processes, such as natural deposition in containment, which have been previously found acceptable for large light-water reactors.

Although the designs are still in the preapplication stage and are considered preliminary, features such as passive emergency safeguard features, natural circulation emergency core cooling, small core thermal power, and higher (relative to large light-water reactors) cooling water volume, all tend to increase the length of time that the core is covered and melt is precluded, according to the designers' preliminary analyses. Based on this, the designers are looking at modeling a design-specific time delay before core damage and fission product release, or reduction in amount of fuel damaged for the LOCA, potentially based on accident scenarios where the passive emergency core cooling system is in operation.

Such scenarios may potentially result in a delay of several days before core damage and fission product release. This new approach is compared to the current Regulatory Guide 1.183 modeling of a time delay after the pipe break of 30 seconds for pressurized-water reactors, 2 minutes for boiling-water reactors or 10 minutes for plants of either type with credit for leak before break. This several-day delay in core damage would result in a large reduction in the I-131 release, which is a major contributor to dose for design-basis accident analyses. The staff is currently considering the implications, both technical and potentially policy-related, of allowing credit for emergency core-cooling system operation in modeling the core fission product release timing. The NRC has not previously allowed such credit of emergency core-cooling system operation for large light-water reactors, including passive plants.

With regard to non-LOCA design-basis accident analyses, the staff has verbally informed both mPower and NuScale that their applications should provide information on the design-specific event classification, as well as the basis for ruling out any of the standard PWR design-basis accidents as listed in Regulatory Guide 1.183, and whether any new or unique design-basis accidents were found. The staff also informed the potential applicants that they should consider how the designers used information from their design probabilistic risk assessments (PRAs) to determine the potential for multi-module design-basis accidents.

With respect to NGNP, which is a non-light-water reactor design, DOE/INL submitted a white paper on MST on July 21, 2010, which summarized their recent activities and event-specific mechanistic approach to the development of an MST (ADAMS Accession No. ML102040260). The paper provides information on the safety design basis of the modular high-temperature gas-cooled reactor and the regulatory foundation for use of event-specific mechanistic source term. The safety case for the modular high-temperature gas-cooled reactor is that the fuel does not melt due to physical properties of the fuel, the inherently safe capacity for passive core decay heat removal, and negative temperature coefficient of reactivity. DOE/INL proposes that release of fission products from the primary circuit would be based on a spectrum of limiting mechanistically evaluated, risk-informed licensing basis event sequences supplemented by credible bounding event sequences.

The NRC staff held several public meetings with DOE/INL between September 2010 and December 2012 and provided formal feedback in February 2012 to address various aspects of the MST topic (ADAMS Accession No. ML120240669). NRC staff concluded that the proposed approach to NGNP MST is generally reasonable but subject to further consideration and resolution of issues that were noted in the assessment document. The staff will issue the final NRC report by the end of fiscal year 2014.

The staff will remain engaged with small modular reactor stakeholders in activities related to applications of design-specific mechanistic source terms. If appropriate, the staff will submit a notation vote paper to support any policy issue that is identified during the review that may warrant Commission review. The staff may propose changes to existing regulations or regulatory guidance to support development of review standards for small modular reactor designs accordingly.

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