U.S. NUCLEAR REGULATORY COMMISSION

PRE-DECISIONAL
DRAFT REGULATORY GUIDE DG-XXXX

Proposed new Regulatory Guide 1.XXX

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This pre-decisional draft regulatory guide (pre-decisional DG) has not been subject to complete NRC management and legal reviews and approvals, and its contents are subject to change and should not be interpreted as official agency positions. The NRC staff is releasing this pre-decisional DG to facilitate discussion at upcoming public meetings and to further public understanding of the related Part 53 rulemaking. While the comment period on the preliminary proposed Part 53 rule language is closed, should comments be submitted on the pre-decisional DG, the NRC plans to consider these comments in further development of the pre-decisional DG to the extent practicable but will not provide written responses to those comments. The NRC staff plans to prepare a DG based on this pre-decisional DG, at which time the staff will request public comments on the DG and provide written responses, accordingly.

SEISMICALLY ISOLATED NUCLEAR POWER PLANTS

A. INTRODUCTION

Purpose

This pre-decisional DG provides the NRC staff's initial preliminary approach to guidance on the use of a technology-inclusive (TI) and risk-informed and performance-based (RIPB) approach that can be used for seismic isolation (SI) systems and seismically isolated nuclear power plants (SINPPs) as part of an application under proposed Title 10 of the Code of Federal Regulations (10 CFR) Part 53, "Risk Informed, Technology-Inclusive Regulatory Framework for Commercial Nuclear Plants, Framework A" (Ref. 1). The NRC staff plans to prepare a DG for public comment based on this pre-decisional DG and will consider discussion of the pre-decisional DG at ACRS meetings, ACRS views on the pre-decisional DG, and stakeholder input from public meetings and public comments. The preliminary staff views in pre-decisional DG-YYYY titled "Technology-Inclusive, Risk-Informed, and Performance-Based Methodology for Seismic Design of Commercial Nuclear Plants" (companion DG-YYYY, in preparation) are used in this pre-decisional DG with additional considerations specific to addressing the safety of the application of SI technologies. This pre-decisional DG on SI aligns closely on the seismic design framework with the companion pre-decisional DG-YYYY (in preparation) and is focused on technical criteria for the application of SI to NPPs. The staff expects that this pre-decisional DG on SI will be used in conjunction with the companion pre-decisional DG-YYYY (in preparation) on seismic design.

If the staff should publish a final RG on the topics discussed in this pre-decisional DG, it intends to also endorse, with clarifications and additions, Chapter 9 of the American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) 43-19, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities" (Ref. 2) and Chapter 12 of ASCE SEI 4-16 (Ref. 3).

Applicability

A Regulatory Guide (RG) developed from this pre-decisional DG would be applicable to designers, applicants, and licensees of commercial nuclear power plant applying for permits, licenses, certifications, and approvals under Framework A of 10 CFR Part 53, "Risk-informed, technology-inclusive regulatory framework for commercial nuclear plants."

Applicable Regulations

- Preliminary Proposed 10 CFR Part 53, Framework A, Subpart C, § 53.480, "Earthquake Engineering" provides regulatory requirements for engineering activities related to seismic design and analyses required for meeting Part 53 safety criteria, as well as shutdown of an operating reactor following an earthquake event.

- Preliminary Proposed 10 CFR Part 53, Framework A, Subpart D, § 53.500 General Siting, § 53.510 External Hazards, § 53.520 Site Characteristics provides siting requirements for site geologic, geophysical, geotechnical, and seismological investigations to characterize the seismic hazard and develop site specific earthquake ground motions. These earthquake ground motions are characterized by the design basis ground response spectra (DBGMs) that are used for performing the engineering design under 10 CFR Part 53, Framework A, Subpart C, § 53.480.

Related Guidance

- RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" (Ref. 4), provides a risk-informed and performance-based (RIPB) framework to establish the licensing basis for non-light-water reactors (non-LWRs).

- RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" (Ref. 5) provides guidance on site-specific ground motion development.

- RG 1.247 (for trial use), "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities" (Ref. 6), provides one approach acceptable to the staff for determining the acceptability of a design-specific or plant-specific probabilistic risk assessment used to support an application for non-LWR.

- RG 1.232, "Developing Principal Design Criteria for Non-Light Water Reactors" (Ref. 7), provides criteria for developing principal design criteria for non-LWRs.

- RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants" (Ref. 8), provides guidance on treatments for radioactive waste management systems against internal and external hazards, including seismic risk.

- RG 1.166, "Pre-Earthquake Planning, Shutdown, and Restart of a Nuclear Power Plant Following an Earthquake" (Ref. 9), provides guidance on actions to be taken by NPPs in response to earthquakes.

- Pre-decisional Draft Regulatory Guide (in preparation) DG-YYYY, "Technology-Inclusive, Risk-Informed, and Performance-Based Methodology for Seismic Design of Commercial Nuclear Plants", is a companion document to this pre-decisional DG. It provides the NRC staff's guidance on seismic designs.

- The NRC interim staff guidance (ISG), "Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap," issued December 2021, provides staff positions on a roadmap for advanced reactor applications (Ref. 10).

- NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (Ref. 11), contains guidance to the NRC staff on reviewing large light-water reactor (LWR) applications.

Purpose of Regulatory Guides

The NRC issues RGs to describe methods that are acceptable to the staff for implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. Regulatory guides are not NRC regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

[The Paperwork Reduction Act statement and public protection notice will be added to this location when this pre-decisional DG is published as draft guidance.]

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Issuance

This pre-decisional DG provides technology-inclusive guidance for seismically isolated NPPs for applications submitted under preliminary proposed 10 CFR Part 53, Framework A. This pre-decisional DG considers recent advances in SI engineering and available industry codes and standards for seismically isolated nuclear facilities and provides a potentially acceptable approach and information on the level of SI design information sufficient to enable the NRC to reach a safety conclusion before issuing a permit, license, or certification.

This pre-decisional DG follows the overall risk-informed approach as described in the companion pre-decisional DG-YYYY (in preparation) on seismic design and provides additional guidance addressing design, construction and operational issues relating to the deployment of an SI technology in support of advanced reactor applications to meet the regulatory requirements of 10 CFR part 53, § 53.480, "Earthquake Engineering." Therefore, this pre-decisional DG may be used together with the afore mentioned companion pre-decisional DG-YYYY (in preparation) to address the seismic safety of structure, system, and components (SSCs).

If the staff should publish a final RG on the topics discussed in this pre-decisional DG, it intends to endorse, with additions and clarifications, SI-specific provisions in Chapter 9 of ASCE-AEI 43-19, "Seismically Isolated Structures" (Ref. 2), and provisions for a corresponding analysis in Chapter 12 of ASCE/SEI 4-16, "Seismic Analysis of Safety-Related Nuclear Structures" (Ref. 3), in addition to the planned endorsement in the companion pre-decisional DG-YYYY (in preparation) of relevant provisions of ASCE-AEI 43-19 and ASCE/SEI 4-16. These standards include technical provisions for the design and analysis of SI systems, material properties, testing, aging management, and performance criteria.

This pre-decisional DG offers three proposed options consistent with the companion pre-decisional DG-YYYY (in preparation) on seismic designs that could be acceptable to meet the preliminary proposed 10 CFR Part 53 § 53.480.

Background

Currently, there are no seismically isolated NPPs in the United States (U.S.). Six seismically isolated commercial nuclear power reactors exist at two sites in Europe and Africa. There are four seismically isolated pressurized-water reactors at the Cruas-Meysse site in France and two seismically isolated pressurized-water reactors located at the Koeberg site in South Africa. In addition, the Jules Horowitz Reactor, which is a material test reactor, is now under construction at the Cadarache site in France and has an SI system like that at Cruas-Meysse.

An SI system like the one used at Cruas-Meysse was also used under the three spent fuel storage pools at the La Hague reprocessing plant. Although the application of SI systems in NPPs is limited, commercial buildings and bridges have used SI systems for a long period of time and developed a body of practice and experience from these applications. In the United States, SI is now used at more than 200 bridges (e.g., Ref. 12) and numerous prominent buildings in the U.S., China, France, Greece, Italy, Japan, New Zealand, and Russia, among other nations (Ref. 13).

Beginning in the 1980s with General Electric’s pre-application for a liquid metal fast breeder reactor, PRISM, the NRC began the process of developing necessary data to support any future application for the use SI systems in NPPs. The NRC initiated several research programs in the 2000s to examine potential regulatory paths and performance of selected SI systems through experimental studies. The NUREG/CR-7253, “Technical Considerations for Seismic Isolation of Nuclear Facilities,” issued February 2019 (Ref. 14), identifies some of the design criteria for SI systems and isolated facilities. The NUREG/CR-7254, “Seismic Isolation of Nuclear Power Plants using Sliding Bearings,” issued May 2019 (Ref. 15), and NUREG/CR-7255, “Seismic Isolation of Nuclear Power Plants using Elastomeric Bearings,” issued February 2019 (Ref. 16), describe test programs for two types of isolators. The U.S. Department of Energy has sponsored several studies related to SI systems in support of potential applications in the nuclear industry.

The Center for Civil Engineering Earthquake Research at the University of Nevada, in Reno, conducted an experimental simulation of a hybrid lead-rubber isolation system for a five-story steel moment-frame at the Hyogo Earthquake Engineering Research Center (E-Defense) of the National Institute for Earth Science and Disaster Prevention in Japan. The isolation system was developed for a potential nuclear site in central and eastern United States (CEUS) and tested for displacements representing beyond-design-basis ground motions for a CEUS site (Ref. 17).

ASCE/SEI 43-19 is the only consensus standard to provide criteria for the seismic design criteria for applications of SI systems in nuclear facilities. Incorporation of SI-based criteria in ASCE/SEI 43-19 was an important step in the application of SI in nuclear facilities. The application of ASCE/SEI 43-19 is consistent with the NRC’s commitment to the use of industry consensus codes and standards for the design, construction, and licensing of commercial nuclear power reactor facilities.

There are several technical motivations to develop this pre-decisional DG. First and foremost, it provides technical guidance for the safe design and regulation of NPPs with SI. Second, there are important recent advances in SI engineering and available industry codes and standards for seismically isolated nuclear facilities that should be incorporated in staff guidance. Third, the NRC staff is focused on enhancing and expanding a risk-informed and performance-based (RIPB) approach to licensing and regulating commercial NPPs. Fourth, the NRC staff wants to achieve these enhancements within guidance and regulations that are technology inclusive. The principal benefit of SI is that it leads to reduced seismic demands within isolated SSCs compared to a non-isolated structure when subjected to shaking of the same earthquake ground motion.

Key Concepts and Terminology of Seismically Isolated Structures and ASCE/SEI 43-19

ASCE/SEI 43-19 provides the seismic design criteria that are performance based and use multiple seismic design categories (SDCs) for the design of SSCs of a nuclear facility. There is a performance target for each SDC in terms of the acceptable annual exceedance frequency (AEF) of the design performance limit for an SSC designed to that SDC. The design performance limits are designated as limit states (LSs) in ASCE/SEI 43-19. A design-basis earthquake (DBE) is associated with each SDC and is described by the design response spectra (DRS). In ASCE/SEI 43-19, the design performance target is achieved by using the DBE (i.e., DRS) associated with the appropriate SDC and performing the analysis, design, and construction according to the codes and standards identified in ASCE/SEI 43-19. The adequate margins and balance in a design are achieved through the appropriate selection of design-basis ground motions (DBGMs) and design LSs. The detailed description of ASCE/SEI 43-19 can be found in the companion pre-decisional DG-YYYY (in preparation) on seismic design.

An example application of ASCE/SEI 43-19 would be a single seismic design-basis ground motion (DBGM) is selected for all safety-related (SR) SSCs. In accordance with ASCE/SEI 43-19, this DBGM corresponds to SDC-5. The SDC-5 ground motion has the lowest AEF among all SDCs. The elastic LS is specified for SSCs (although current regulations do not require that only the elastic limits be used, the practice and guidance are entirely built around elastic limits). The elastic design performance requirements correspond to LS-D in ASCE/SEI 43-19, the most stringent LS.[1]

The ASCE/SEI 43-19, along with ASCE/SEI 4-16, are performance-based standards for nuclear facilities. ASCE/SEI 43-19 contains a graded approach that allows for consideration of the risk significance of each component. The adequate margins and balance in a design are achieved through the appropriate selection of DBGMs and design LSs. These standards use established design methods and offer flexible options that the staff intends to reflect in RIPB guidance.

Figure 1 shows a schematic depiction of the components in a seismically isolated facility. The superstructure and basemat are isolated from the foundation through an SI system. The SI system is composed of many essentially identical isolators that act in parallel. The superstructure and SSCs housed therein experience reduced seismic demands compared to the non-isolated structure when subjected to the same DBGM because the motion is filtered by the SI system. The foundation is surrounded by a moat wall that provides a stop to the movement of the basemat during extreme shaking. The distance between the basemat and moat wall is called the clearance to the stop (CS) in ASCE/SEI 43-19. The CS is a critical parameter in setting the design and performance requirements and in the risk analysis for SI systems. Figure 1 depicts a seismically isolated NPP structure, but it does not preclude component isolation within an isolated or non-isolated structure, use of a three-dimensional (3-D) isolation system,

1 ASCE/SEI 43-19 specifies four LSs in terms of increasing structural deformations. LS-D is essentially elastic behavior with no permanent deformation after the DBE. LS-C, B, and A allow deformations beyond elastic limits in increasing order.

other types of horizontal-only bearings (than those suggested in Figure 1) and supplementary damping devices.

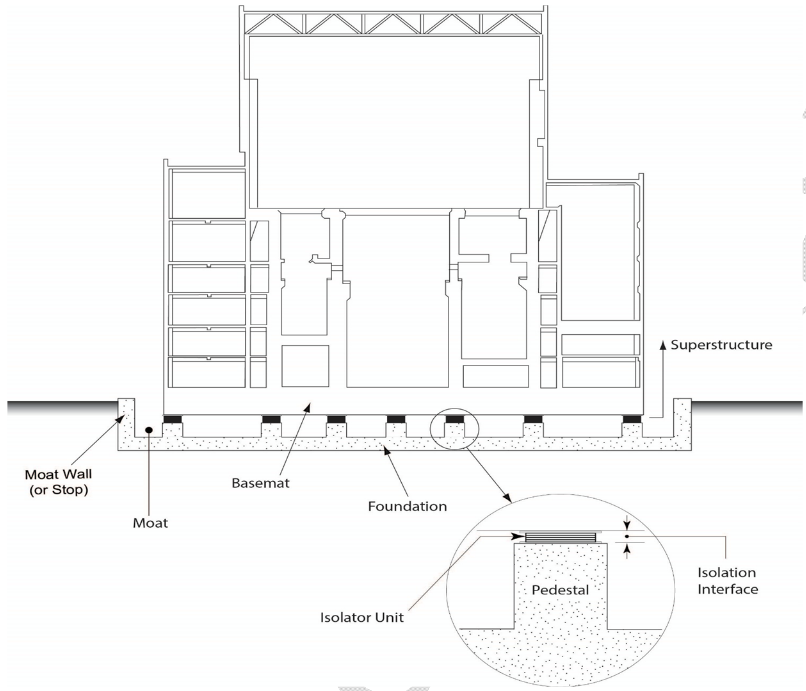

Figure 1. Schematic depiction of an SI system under an NPP, reproduced from Figure 31 of NUREG/CR-7253

Considering that the SI system is not redundant, and its failure can compromise seismic safety, ASCE/SEI 43-19 specifically requires that the SI system be designed and tested to an earthquake ground motion beyond the design-basis earthquake (or event) (BDBE) ground motion.[2] The CS and the level of BDBE are two key considerations in the design of an SI system and are among the important decision factors in selecting a framework from the three options that this pre-decisional DG offers. Table 12-1 of Chapter 12 of ASCE/SEI 4-16 lists performance provisions for safety-related nuclear structures for both DBE and BDBE. The value of BDBE and CS depend on the selected option, as discussed subsequently.

The design of the SI system, although focused on CS displacement capacity in the discussion above, necessarily includes other important performance provisions, such as testing of isolation system components (e.g., for vertical load stability at CS and durability during repeated cycles of earthquake loading) and design of components that cross the isolation interface. These performance provisions are

2 The SI system is the only SSC that is explicitly designed for the BDBE.

contained in ASCE/SEI 43-19, although some enhancements may be required to assure reliable performance at CS displacement, as discussed in Section C of this pre-decisional DG.

The current methods of ASCE/SEI 43-19 (with exceptions, clarifications, and additions noted in regulatory positions) using DBE and BDBE criteria (i.e., using reduced design demands due to SI) are applicable to the design of the balance of SSCs above the isolation system.

It should also be noted that ASCE/SEI 43-19 allows for other alternative approaches to meet its performance targets. These alternative approaches must be reviewed on a case-by-case basis and are subject to verification and peer review, as noted in pre-decisional draft regulatory position C.4.7.

Overview of Options

Figure 2 presents a high-level summary of the three options available to satisfy the intent of proposed § 53.480 for seismically isolated facilities. The guidance in the following sections provide additional detail on each option and the corresponding boxes in Figure 2. These three options are consistent with the options in the companion pre-decisional DG-YYYY (in preparation) on seismic design.

Option 1 is the traditional approach. Options 2 and 3 are risk-informed and provide greater flexibility in the design decisions using risk insights. Option 2 uses the Licensing Modernization Project (LMP) framework described in NEI 18-04, while Option 3 allows the use of graded seismic probabilistic risk analyses (SPRAs) and other risk-informed analysis methods. Option 3 would allow several variations to be considered based on the roles of deterministic considerations and probabilistic risk assessments (PRAs) in making design decisions considering the broad spectrum of risk-informed approaches.

The integrated decision-making process[3] (IDP) described in NEI 18-04, as endorsed in RG 1.233, is an important part of proposed Options 2 and 3. The IDP uses an RIPB integrated decision-making process. This is a structured, repeatable process by which decisions are made on significant nuclear safety matters, including consideration of deterministic and probabilistic inputs. The process is also performance based because it employs measurable and quantifiable performance metrics to guide the determination of defense-in-depth (DID) adequacy. For proposed Options 2 and 3, the IDP is key for making appropriate choices of ASCE/SEI 43-19 SDCs and LSs for SSCs.

Each box under a given option depicted in Figure 2 proposes key criteria which are described in more detail under each option heading below and relates to the regulatory positions described in Section C of this pre-decisional DG.

3 The IDP is a key element of the process. As discussed in the companion pre-decisional DG-YYYY on seismic design and NRC RIL 2021-04, "Feasibility Study on a Potential Consequence-Based Seismic Design Approach for Nuclear Facilities" (Ref. 18), there is no unique solution to meet a risk goal; because of the multitude of SSCs that are involved in an event sequence, there are many possibilities to meet risk goals. It is important that the decisions account for the appropriate risk-informed considerations, such as DID and balanced design.

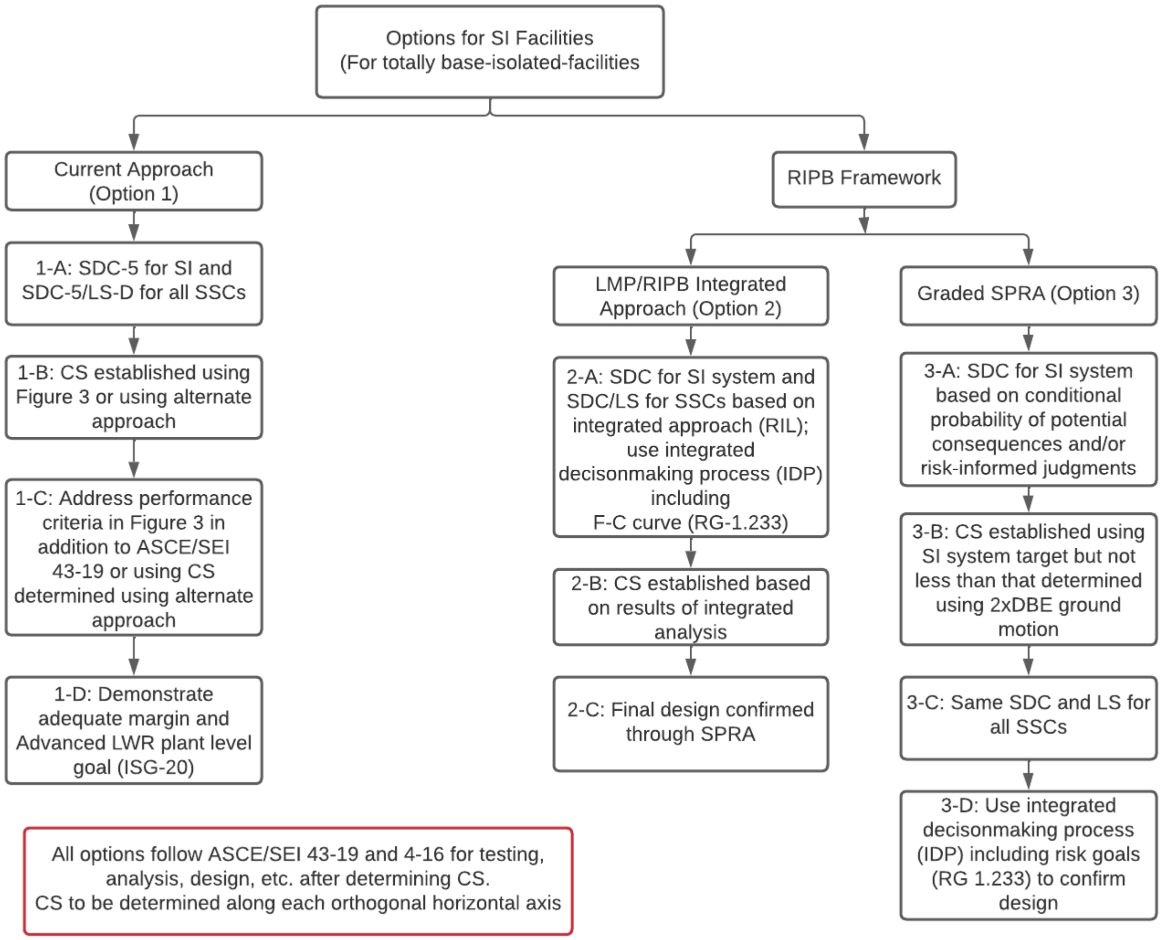

Figure 2. Three options for seismically isolated facilities

Note that, in all three proposed options, once the DBGMs are determined and LSs for SSCs are established, the design is expected to be carried out using ASCE/SEI 43-19, ASCE/SEI 4-16, and other associated codes and standards with exceptions, additions, and clarifications noted in the pre-decisional draft regulatory positions. All options follow ASCE/SEI 43-19 and 4-16 for testing, analysis, design, etc. after determining CS, along each orthogonal horizontal axis. In all three proposed options, an applicant could choose a CS that is beyond that called for in this pre-decisional DG and ASCE/SEI 43-19.

Option 1

Option 1 is the traditional approach that will satisfy the intent of proposed § 53.480 for seismically isolated facilities. This option represents the traditional seismic safety approach related to seismic hazards and seismic design with criteria established in the SRP Chapters 2, 3, and 19, and related RGs such as RG 1.208. As stated in RG 1.233, the design-basis external hazard levels (DBEHLs) when determined using traditional NRC-approved methodologies, are generally consistent with current practice used for large LWRs to support appropriate protection of safety-related (SR) SSCs against external hazards.

The Option 1 approach for seismically isolated facilities is consistent with the Option 1 approach described in the companion pre-decisional DG-YYYY (in preparation) on seismic design. However, the focus of Option 1 in this pre-decisional DG is to provide additional guidance specific to the SI related technical issues. To implement Option 1, a single seismic DBGM is selected for all SR SSCs as explained in the companion pre-decisional DG-YYYY (in preparation). This DBE corresponds to the SDC-5 ground motion from ASCE/SEI 43-19 and an LS-D is specified for all SSCs. For Option 1, the staff intends to adopt the performance criteria in Figure 3, to ensure the seismic design for SI systems, superstructures, and umbilicals[4] provide adequate isolation for nuclear plant SSCs from being impacted by seismic hazards. For reference, consider detailed supporting information and technical rationale described in Chapter 8, "Recommended Performance Criteria for Seismically Isolated Nuclear Facilities," of NUREG/CR-7253.

The BDBE that NUREG/CR-7253 proposed is to ensure that the SI system margin is consistent with the plant-level margin ensuring the performance target for SI systems (and umbilicals) to a lower AEF closer to 1×10^{-6} than the ASCE/SEI 43-19 performance target of 1×10^{-5} for SDC-5. The design of other SSCs is carried out to achieve the ASCE/SEI 43-19 design performance target using the demands at the DBE ground motions.

As shown in Box 1-A of Figure 2, the SI system and all SR SSCs are designed based on the SDC-5 DBE and LS-D. As is the case for all three options, an SI system designed and constructed based on these performance criteria should result in a significant reduction in the vibratory motions felt inside a superstructure compared to responses in a non-isolated structure.

Boxes 1-B and 1-C of Option 1 in Figure 2 describe guidance specific to seismic design of the SI system. The clearance to stop (CS) is established using the performance criteria in Figure 3 (Table 8.1 of NUREG/CR-7253), and as shown in Box 1-B of Figure 2. In the proposed approach under consideration by the ASCE/SEI 43 Standard Committee for the next revision of the standards, the BDBE would be defined as a mean displacement resulting from the hazard spectra that is 2 × the DBE ground motions. This definition of the BDBE is intended to produce a similar AEF of unacceptable performance of the SI system as that resulting from the one NUREG/CR-7253 defined.[5]

Box 1-C of Figure 2 addresses the performance and design recommendations and technical considerations addressing the design, construction, and operational needs for SI systems that consider the seismic performance for the isolation system, isolators, moat, umbilicals, and SSCs, and is recommended to be followed. Provisions of ASCE/SEI 43-19, along with other ASCE/SEI codes for the design and analysis of isolated SSCs, should be implemented using the CS value determined in Box 1-B of Figure 2.[6]

Figure 3 provides a recommended matrix of performance criteria for the analysis and design of isolated nuclear power plants, where the overall goal is to achieve a mean annual frequency of exceedance of failure of the isolation system of less than 1×10^{-6}. The cells in the matrix provide a risk-informed, performance-based framework for analysis and design, including calculations for design basis shaking, and beyond design basis shaking. Performance criteria statements are made at each level of hazard for isolators and the isolation system, superstructure, umbilical lines, and the hard stop.

4 Umbilicals are the interconnecting systems, such as piping systems, between two adjacent but separate structures

5 However, this should be confirmed to ensure a similar level of margin that results from the new BDBE when compared to that resulting from using the NUREG/CR-7253 approach.

6 In the case of an alternatively determined CS based on the approach under consideration by the ASCE/SEI 43 Committee as discussed above, the requirements of ASCE/SEI 43 will be met using this CS value.

Figure 3. Performance Criteria for Adopting Seismic Isolation Systems for Commercial Nuclear Plants

Performance Criteria for Adopting Seismic Isolation Systems for Commercial Nuclear Power Plants[1]

	Isolation System		Superstructure design and performance	Umbilical line design and performance	Moat or stop design and performance
Ground motion levels	**Isolator unit and system design and performance criteria**	**Approach to demonstrating acceptable performance of an isolator unit**			
DBGM corresponding to SDC 5	No long-term change in mechanical properties. 95% confidence of the isolation system surviving without damage when subjected to the mean displacement of the isolator system under the DBGM loading.	Perform production testing on each isolator for the mean system displacement under the BDGM loading and corresponding axial force.	Superstructure design and performance to conform to current seismic design practice in SRP for DBGM loading after filtering through the seismic isolation system.	Umbilical line design and performance to conform to SRP for DBGM loading.	Moat gap sized such that there is less than 1% probability of the superstructure impacting the moat or stop for DBGM loading.
BDBE DBGM represents the envelope of 167% of the DBGM	90% confidence of each isolator and the isolation system surviving without loss of gravity-load capacity at the mean displacement under BDBE DBGM loading.	Perform prototype testing on a sufficient number of isolators at the clearance to the stop (CS) displacement and the corresponding axial force to demonstrate acceptable performance with 90% confidence. Limited isolator unit damage is acceptable but load-carrying capacity must be maintained.	Less than a 10% probability of the superstructure contacting the moat or stop under BDBE BDGM loading.	Greater than 90% confidence that each type of safety-related umbilical line, together with its connections, shall remain functional for the CS displacement. Performance may be demonstrated by testing, analysis or a combination of both.	Moat gap sized such that there is less than a 10% probability of the superstructure impacting the moat or stop for BDB BDGM loading. Stop designed to survive impact forces associated with isolation system displacement to 95th percentile BDBE BDGM isolation system displacement.[2] Limited damage to the moat or stop is acceptable but the moat/stop should perform its function.

1.Criteria developed in this Table used the supporting information documented in NUREG/CR-7253.
2. Impact velocity calculated at the displacement equal to the CS assuming cyclic response of the isolation system for motions associated with the 95th percentile (or greater) BDB DBGM displacement.

Box 1-D of Figure 2 represents the traditional role of a risk analysis to demonstrate the design meet proposed Part 53 safety criteria by adequately considering beyond-design-basis external hazards following the guidance in DC/COL-ISG-020, "Interim Staff Guidance on Implementation of a Probabilistic Risk Assessment-Based Seismic Margin Analysis for New Reactors," issued March 2010 (Ref. 19). Proposed Option 1 does not need an SPRA to make design decisions.

Option 2

Option 2 is based on the LMP framework described in NEI 18-04 and provides flexibilities afforded by RG 1.233.[7] The LMP/ASCE integration approach (Box 2-A) enables a graded approach to seismic design of SSCs that considers their safety functions and risk significance.[8] An example of its application can be found in RIL 2021-04. This graded approach supports a framework that links performance-based design of an individual SSC embodied in ASCE/SEI 43-19 to its functional role in event sequences and at the plant level through an integrated system analysis (e.g., SPRA).[9] It uses the frequency-consequence (F-C) targets defined in the LMP framework.[10] This option allows an applicant to use the LMP/ASCE/SEI integration approach that includes use of an SPRA to aid in the design itself. In this option, for example, the SSCs and the SI system can be designed to SDC-3, SDC-4, or SDC-5 ground motions and alternative LSs (less stringent than LS-D) based on their integrated contributions to meeting the risk goals. Option 2 thus provides the following alternatives to determining the CS.

The CS can be established (Box 2-B) based on results of integrated analysis and risk insights to achieve an acceptable performance considering the RIPB decision-making process. An applicant could choose an CS considering ASCE/SEI 43-19 criteria, provided they include the corresponding analysis to substantiate it and it meets the following two additional considerations:

(1) If CS is less than that resulting from the 90th percentile displacement at 1.5 × DBE, as required in ASCE/SEI 43-19, the design of the SI system and the SSCs within the plant must account for the effects of contact with the moat (note that this approach reflects the exception permitted in ASCE/SEI 43-19, provision 9.3.3).

(2) If the CS is larger than that determined from the use of BDBE that is 1.5 × DBE ground motion, the design of isolated SSCs should not have to account for the effects of contact with the moat. However, in evaluating the functional fragilities of the SI system and other SSCs to be used in a risk analysis, the effects of contact may have to be accounted for, considering the BDBE.

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7 In a parallel effort, the NRC has developed the LMP/ASCE/SEI integration approach for conventionally founded (i.e., non-isolated) nuclear facilities described in NRC Research Information Letter (RIL) 2021-04, "Feasibility Study on a Potential Consequence-Based Seismic Design Approach for Nuclear Facilities," issued May 2021. This approach is being incorporated in pre-decisional DG-YYYY, "Technology-Inclusive Risk-Informed, and Performance-Based Methodology for Seismic Design of Advanced Reactors."

8 Pre-decisional DG-YYYY on seismic design incorporates this approach.

9 However, there are no base-isolated NPPs in the United States, and the United States has limited experience in performing SPRAs for base-isolated facilities. The specific challenge is how to account for responses in the isolated structure from earthquake-induced ground displacements that are larger than a displacement that would close the gap between the isolated structure and the SI moat (i.e., CS), which would result in contact between the isolated structure and the moat (perhaps several times) and may impose additional loads on the facilities' SSCs. Studies are underway to address this issue.

10 As noted in RG 1.233, the F-C target does not correspond to actual regulatory acceptance criteria but is a vehicle to assess a range of events to determine risk-significance, support SSC classification, determine special treatment requirements, identify appropriate programmatic controls, and confirm the adequacy of DID.

Once the CS is established, the design of isolated SSCs is expected to follow the ASCE/SEI 43-19 performance targets for the selected SDCs and LSs.

Because the CS is established considering the factors discussed above and the selected SDC for the SI system, one could choose an SDC other than SDC-5. Similarly, the design of isolated SSCs could take advantage of alternative SDCs and LSs, considering their risk and safety significance.

The final design is expected to be confirmed through the SPRA and the use of an LMP risk-informed framework (Box 2-C).

Option 3

Option 3 allows the use of graded SPRAs and other risk-informed analysis methods, considering the broad spectrum of risk-informed approaches, based on the roles of deterministic considerations and PRAs in making design decisions. The graded SPRA option relies on risk-analysis methods besides a traditional SPRA to demonstrate seismic safety. The risk-analysis approaches can depend on the size and type of the NPP, the seismic hazard levels, the spectral shape of the seismic response spectra, and the specific safety measures being proposed to mitigate any potential adverse consequences that could result from a seismic event. Several alternatives could be considered with Option 3 based on a broad spectrum of approaches that include deterministic inputs, risk insights, and a combination of approximate, bounding or conservative analyses, and quantitative risk information.

As an example when using Option 3, a graded SPRA approach for seismically isolated plants can be used to perform either a generic or a specific study towards establishing a risk-informed basis. By using analyses, available data, earthquake experience, and other quantitative or qualitative evaluations to demonstrate an acceptable conditional probability of damage caused by contact of the basemat with the moat wall. For example, if the performance target goal for SDC-4 (i.e., 5×10^{-5} AEF) is adequate considering other margins, such as the seismic capacities of SSCs, the SI system could be designed using the SDC-4 DBGMs, and the CS could be determined using the ASCE/SEI 43-19 approach.

The initial step is to choose the SDC for SI system based on conditional probability of potential consequences and/or risk-informed judgments (Box 3 A). The CS is then established using SI system target but not less than that determined using 2 × DBE ground motion (Box 3 B). The following step in the process requires that the same SDC and LS be used to design all SSCs (Box 3 C). The final step in the process is to confirm through an IDP and risk-informed framework the adequacy of the design (Box 3 D). For instance, with Option 3, an applicant could start a design with a selection of SDC-4 in Box 3 A, then determine the CS using the ASCE/SEI 43-19 method using 2 × DBE ground motion (or, 90 percent displacement resulting from 1.5 x DBE), Box 3 B, then design the SSCs using the same SDC and LS-D (Box 3 C), in accordance with ASCE/SEI 43-19, ASCE/SEI 4-16, and associated codes. Finally, the adequacy of the design is expected to be confirmed through an IDP and risk-informed framework (Box 3 D).

It is envisioned that Option 3 could facilitate the selection of an SDC category for the SI system other than SDC-5 but this may limit the determination of SDCs and LSs for each SSC, depending on the chosen risk analysis method. Some simplified analyses may not include explicit consideration of risk contributions from individual SSCs as in Option 2.

Relationship Between Proposed § 53.480 and Proposed Options 2 and 3

The section described under the title "Proposed Option 1" above explained how a seismic design using Option 1 satisfies the requirements of proposed § 53.480. The following paragraphs describe how proposed Options 2 and 3 could also be used to satisfy the requirements of proposed § 53.480. The description is provided using Option 1 as a reference since it is the established seismic design approach. The implementation considerations arise because proposed Options 2 and 3 expand the flexibility to allow the use of more than one DBGM in the seismic design.

DBGMs: Multiple DBGMs replace the concept of a single SSE used in Option 1.[11] This set of DBGMs could include ground motions from the SDCs defined in ASCE/SEI 43-19 (e.g., SDC-3, SDC-4, and SDC-5), taking into consideration the safety functions, risk significance, and the required design performance of each SSC. These DBGMs are derived from the site ground motion response spectra (GMRS) that are developed following the guidance in RG 1.208. The RG 1.208 establishes a risk-informed and performance-based approach to define the site-specific earthquake ground motions for a site, which captures the regional and local seismic hazard. Apart from establishing minimum seismic design requirements, the SDC-5 DBGM that come from ASCE/SEI 43-19, is equivalent to the GMRS. Both the GMRS and the DBGM response spectra are derived from the same mathematical equations. This is also true for SDCs other than SDC-5 that are established using ASCE/SEI 43-19 equations with input from site-specific hazard analysis used for the development of a GMRS. In this way, the DBGM response spectra for all SDCs also captures the regional and local seismic hazard.

Minimum DBGM: The minimum earthquake design level(s) for proposed Options 2 and 3 should be designated based on the specific design of the SSCs and associated SDCs following provisions in ASCE/SEI 43-19.[12] This would be needed because multiple design response spectra (DRS) [13] are possible under proposed Options 2 and 3, and some of these may have a peak ground acceleration (PGA) lower than 0.1g.[14] Therefore, the minimum earthquake design level(s) should be design specific (i.e., SDC specific).

Operating-Basis Earthquake Requirements: In the proposed position for Options 2 and 3, the operating-basis earthquake (OBE) ground motion is only associated with plant shutdown and inspections. This change would be needed because the RIPB seismic design alternative could result in more than one DBGM level (i.e., SSCs can have different SDCs based on their risk significance). In addition, the RIPB seismic design includes the option to design using LSs other than a purely elastic design (LS-D). For some low SDCs and low hazard areas, the application of the current one-third of SSE ground motion criterion may result in a very low threshold criterion that may not exceed the empirical criterion of 0.2g and thus might not govern a decision to shut down.[15] However, this change would be necessary for

11 In 10 CFR 100.23, the nomenclature "safe shutdown earthquake ground motion (SSE)" is used to describe the DBGM. The notion of safe shutdown as a required safety function is central to LWRs. In the context of a broad spectrum of advanced reactor designs, the concept of safe shutdown as currently defined is not universally applicable.

12 ASCE/SEI 43-19 defines its own minimum PGA for various SDCs. For example, the minimum PGAs for SDC-4 and SDC-3 are 0.08g and 0.06g, respectively, with appropriate modifications to the entire DRS.

13 In ASCE/SEI 43-19, the DBGMs are described by DRS.

14 Under the requirements in 10 CFR Part 50, Appendix S, the minimum design requirement is a peak ground acceleration (PGA) of 0.1g and a broad ground response spectrum.

15 The current OBE shutdown criteria are described in American National Standard Institute (ANSI)/American Nuclear Standard (ANS) 2.23-2016, "Nuclear Power Plant Response to an Earthquake" (Ref. 23).

high-hazard sites, which may yield one-third of the DRS greater than 0.2g. The DRS check (i.e., the equivalent of SSE in the current approach) would be needed with a change to assure that a plant has not suffered permanent deformations that could lead to loss of safety functions, particularly when designed to LSs other than LS-D. The proposed changes accommodate more than one DBGM (and associated DRS).

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops safety requirements and safety guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports reflects an international perspective on what constitutes a high level of safety. To inform its development of this pre-decisional DG, the NRC staff considered IAEA safety requirements and safety guides pursuant to the Commission's "International Policy Statement," published in the *Federal Register* on July 10, 2014 (Ref. 20), and Management Directive and Handbook 6.6, "Regulatory Guides," dated May 2, 2016 (Ref. 21).

The following IAEA safety standards series document incorporates similar design and pre-operational testing guidelines and is consistent with the basic safety principles considered in developing this pre-decisional DG:

- IAEA TECDOC Series No. IAEA TECDOC-1905, "Seismic Isolation Systems for Nuclear Installations," issued 2020 (Ref. 22), was written to "(a) Provide technical basis to support the revision of IAEA Safety Guides for new design and re-evaluation of existing facilities to include seismic isolation; (b) Assemble technical elements to cover design, risk or margin evaluation, manufacture, construction, and operation activities; (c) Present basic technical considerations for base-isolated nuclear installations, and structures, systems and components (SSCs) as reflected by the current state of practice."

C. STAFF PRE-DECISIONAL DRAFT REGULATORY GUIDANCE

If the NRC staff should publish a DG on the topics discussed in this pre-decisional DG for the materials, analysis, design, fabrication, construction, examination, testing, and inservice inspections of SI systems and design of seismically isolated nuclear facilities, the staff plans to endorse, with the clarifications and exceptions noted below, Chapter 9 of ASCE/SEI 43-19 and Chapter 12 of ASCE/SEI 4-16. Note that the companion pre-decisional DG-YYYY (in preparation) on seismic design, if published as a DG, plans to endorse with exceptions, and clarifications the remaining provisions of ASCE/SEI 43-19 and ASCE/SEI 4-16, and therefore related proposed staff positions are not discussed in this section.

Chapter 9 of ASCE/SEI 43-19 and Chapter 12 of ASCE/SEI 4-16 make specific provisions for seismically isolated facilities that are considered acceptable to the NRC staff with the exceptions, additions, and clarifications discussed in the following regulatory positions. Unless otherwise stated, the regulatory positions indicated are in addition to the standard provisions.

This pre-decisional DG provides three proposed optional processes, as discussed in Section B. The following pre-decisional draft regulatory positions are divided into five categories: (1) those related to Option 1, (2) those related to Option 2, (3) those related to Option 3, (4) those common to all proposed options, and (5) those common to Options 2 and 3.

C. 1 Pre-decisional Draft Regulatory Positions Related to Option 1

C.1.1 An applicant should design all SSCs using SDC-5 ground motions and LS-D, as defined in ASCE/SEI 43-19, to meet the regulatory requirements of proposed 10 CFR 53.480.

C.1.2 The SI system, umbilicals, and CS should be designed based on the BDBE ground motions, in accordance with the performance criteria in Figure 3 (see also position C.4.1).

C.1.3 The performance criteria used for the BDBE consideration should be in accordance with Figure 3.

C.1.4 If an alternative BDBE is selected to establish the CS, as allowed by ASCE/SEI 43-19, the applicant should provide and justify the alternative method used to establish the CS and should confirm that this alternative BDBE results in sufficient margin. An example of a similar margin assessment is provided in NUREG/CR-7253.

C.1.5 The design and analysis of SI systems and SSCs should be conducted in accordance with the provisions in ASCE/SEI 43-19 and ASCE/SEI 4-16 (with clarifications, additions, and exceptions in Section C.4).

C.1.6 At the completion of the design, an applicant should conduct an analysis to demonstrate the design margins or performance in accordance with Part 53 safety criteria and DC/COL-ISG-020.

C.1.7 Conventionally founded (non-isolated) SR SSCs that are part of the overall NPP design (e.g., SR intake structure) should be designed using SDC5 and LSD to meet the requirements of proposed 10 CFR 53.480

C.1.8 RG 1.143 provides guidance for consideration of the seismic loads for waste management structures, systems, and components and should be used.

C.1.9 There are interactions among SR risk-significant SSCs, non-SR but safety significant (NSRSS) SSCs, and non-safety significant (NSS) SSCs.[16] To be acceptable, each NSS subsystem should be designed to be isolated from any seismic SR and NSRSS SSC by either a constraint or barrier or should be remotely located with regards to the SR and NSRSS SSCs. If this is not feasible or practical, then adjacent NSS subsystems should be analyzed according to the same seismic criteria that are applicable to the SR and NSRSS SSC. For NSS subsystems attached to seismic SR and NSRSS SSCs, the dynamic effects of the NSS should be simulated in the modeling of the seismic SR and NSRSS SSCs. The attached NSS subsystems, up to the first anchor beyond the interface, should also be designed in such a manner that, during an earthquake ground motion associated with SDC-5, it should not cause a failure of the seismic SR and NSRSS SSC.

C.2. Pre-decisional Draft Regulatory Positions Related to Option 2

This proposed option, as discussed in Section B, allows an applicant to use the LMP/ASCE/SEI integration approach described in the companion pre-decisional DG-YYYY (in preparation) on seismic design, Appendix A, that includes the use of an SPRA to aid in the design process.

C.2.1 Pre-decisional DG-YYYY, Appendix A, describes an acceptable procedure to determine SDCs and LSs for SR, NSRST, and other SSCs (including an SI system) in an SPRA. If an alternative process is used, the process and its technical basis should be provided.

C.2.2 The procedure uses the IDP considering both quantitative and qualitative risk information and other considerations listed in NEI 18-04. The IDP described in NEI 18-04 is not a technology sensitive aspect of the methodology and is an acceptable approach for proposed 10 CFR 53.480. The IDP should be described and its attributes can be compared to those in NEI 18-04 for any reactor technology.

C.2.3 Once the SDCs and LSs are established, the design of the SI system and SSCs should be based on ASCE/SEI 43-19 and ASCE/SEI 4-16- criteria, and referenced codes and standards, with exceptions, additions, and clarifications noted in Section C.4. Pre-decisional Draft Regulatory Position C.4.1 gives an alternative CS.

C.2.4 If the CS is greater than or equal to that resulting from the application of 1.5 × DBE (for the selected SDC level for the SI system), the design of isolated SSCs should not have to account for the effects of the impact to the moat. However, in the evaluation of the functional fragilities of an SI system and other SSCs to be used in a risk analysis, the effects of contact with the moat may have to be accounted for, considering the BDBE.

C.2.5 If the CS is less than that resulting from the application of 1.5× DBE, the effects of contact with the moat should be accounted for in the design of the SI system and the SSCs within the plant (note that this reflects the exception permitted in ASCE/SEI 43-19).

C.2.6 The applicant should demonstrate that the final design satisfies Part 53 safety criteria. An SPRA is conducted in accordance with the guidance provided in RG 1.247.

16 The applicable acceptance criteria for LWRs under Part 50 are in Section 3.7.3, "Seismic Subsystem Analysis," of NUREG-0800. These criteria are also applicable for this option for proposed 10 CFR 53.480.

C.3 Pre-decisional Draft Regulatory Positions for Option 3

C.3.1 The applicant should develop and provide an acceptable procedure and supporting technical basis to determine SDCs and LSs for SI system and SSCs. Alternatively, an applicant could assign SDCs and LSs to the SI system and SSCs based on their safety functions and risk importance using IDP considerations, provided these meet the requirement in position C.3.4.

C.3.2 If the IDP in position C.3.1 is used, considering both quantitative and qualitative risk information and other considerations listed in NEI 18-04, the applicant should describe its IDP and its attributes can be compared to those in NEI 18-04 for any reactor technology.

C.3.3 Once the SDCs and LSs are established, the applicant should design the SI system and SSCs based on ASCE/SEI 43-19 and ASCE/SEI 4-16, and referenced codes and standards, with the exceptions noted in the pre-decisional draft Regulatory Positions in Section C.4. Alternative codes could be used with appropriate justification, provided they meet pre-decisional draft Regulatory Position C.3.4. The pre-decisional draft Regulatory Position C.4.1 provides an additional option for CS.

C.3.4 The applicant should demonstrate that the final design satisfies Part 53 safety criteria which could be accomplished through a graded SPRA (or other risk-informed approaches) in accordance with the guidance provided in RG 1.233.

C.4 Pre-decisional Draft Regulatory Positions Applicable to All Proposed Options

C.4.1 An applicant may choose to have a CS associated with a low AEF of seismic hazard, such that the probability of contact with the moat is low and consistent with the intent of the overall risk goals.[17]

C.4.2 ASCE/SEI 43-19 does not address isolation of individual SR components and systems within the structure. However, consistent with ASCE/SEI 43-19, this pre-decisional DG does not preclude the use of SI for individual components. For the design of individual SR components, an applicant should demonstrate that the design of the component and its isolation system meet the performance and regulatory requirements using either of the three proposed options discussed above.

C.4.3 Vertical and 3-D Isolation: This pre-decisional DG provides for an exception to ASCE/SEI 43-19 by allowing the use of vertical isolation.[18] However, the advanced reactor license application should provide adequate justification (including testing) to support the use of vertical isolation in the isolation system and demonstrate that the performance provisions are met using either of the three proposed options discussed above.

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17 Because of the limited experience in performing SPRAs for seismically isolated NPPs, this option, when feasible, may simplify subsequent risk analysis and provide a risk-informed basis.

18 ASCE/SEI 43-19 states that the provisions in Chapter 9 of the standard are applicable for an SI in the horizontal plane only, excluding consideration of isolation in the vertical direction. The basis for precluding vertical isolation, as stated in the commentary, is that isolators available in the industry at that time were unable to provide vertical isolation. The upcoming revision of ASCE/SEI 4 expanded its scope to include a vertical SI, permitting consideration of 3-D isolation. Based on the upcoming revision of ASCE/SEI 43-19, this pre-decisional DG permits the vertical isolation.

C.4.4 Environmental Conditions: The design should account for aging effects of the isolation system. An applicant should develop and describe a long-term aging management plan that includes the effects of creep, operating temperature, and moisture. The advanced reactor license application should include a plan for inspection and monitoring.

C.4.5 Dynamic Analysis: This pre-decisional DG provides an exception for ASCE/SEI 43-19, in that the fixed-base analysis can be conducted instead of soil-structure interaction where applicable.[19] An applicant should justify using a fixed-base analysis. The SI structures using a fixed-base analysis should demonstrate performance requirements using either of the three proposed options discussed above.

C.4.6 Prototype Testing: ASCE/SEI 43-19 requires a lateral displacement equal to CS for reversed cycle loading for prototype testing (test 3, from provision 9.5.2.3 of ASCE/SEI 43-19). This pre-decisional DG provides a clarification with regards to the CS used in the testing. An applicant should use a CS derived from one of the three proposed options discussed above for prototype testing conducted in accordance with ASCE/SEI 43-19. The SI system should be verified to be stable at CS displacement under the imposed axial load combinations and testing requirements, in accordance with provision 9.5.2 of ASCE/SEI 43-19.

The following pre-decisional draft regulatory positions are based on the staff's review of ASCE/SEI 43-19, ASCE/SEI 4-16 and ASCE/SEI 43-18 (draft) as supported by RIL 2021-05, "Evaluation of ASCE/SEI 4-16 and ASCE/SEI 43-18 (Draft) for Use in the Risk-Informed, Performance-Based Seismic Design of Nuclear Power Plant Structures, Systems, and Components," issued July 2021 (Ref. 24).

C.4.7 Design Verification and Peer Review: This pre-decisional DG explains that applicants should conduct seismic design verification and peer reviews in accordance with the ASCE/SEI 43-19 requirements in Section 9.1, "Introduction"; Section 9.4, "Peer Review"; Section 10.1.1, "Seismic Design Verification"; and Section 10.1.2, "Independent Seismic Peer Review." Peer reviews should focus on the concepts proposed in this pre-decisional DG that are not traditionally used and the alternate provisions in ASCE/SEI 43-19, for example, an alternate design in accordance with SDC grade (e.g., LS-C and LS-B), nonlinear time domain analysis, deformation-based design, seismic separation and adjacent structure requirements, and nonlinear and 3-D approaches for building stability (e.g., sliding and overturning) analysis. The applicant should make the design verification and peer review findings and reports available to the NRC for inspection or audit.

C.4.8 Seismic Design Ground Motion: ASCE/SEI 4-16, Section 2.6, "Design Response Spectrum-Compatible Ground Motion Histories," and ASCE/SEI 43-19, Section 2.4, "Criteria for Developing Synthetic or Modified Recorded Time Histories," describe criteria for determining whether the generated time histories "match" or "envelop" the DRS. In particular, the ASCE/SEI guidance indicates that if the response spectrum for a generated time history does not exceed the DRS by more than 30 percent at any frequency, a power spectral density (PSD) check is not needed. However, the ASCE/SEI DRS matching criteria alone may not prevent a power spectrum deficiency in the time histories, which could lead to underpredictions of in-structure response spectra (ISRS) and other frequency-sensitive structural responses.

19 For a dynamic analysis of seismically isolated nuclear structures, ASCE/SEI 43-19 refers to the acceptable methods in Chapter 12 of ASCE/SEI 4-16, which requires an evaluation of soil-structure interactions for each of the dynamic analysis methods (coupled time domain, coupled frequency domain, and multistep).

This pre-decisional DG explains that a PSD check should be performed for multiple design time histories unless justification is provided that a stable mean ISRS can be achieved for the given number of design time histories. Therefore, either a single set or multiple sets of DRS matched, synthetic, or modified recorded time histories should be checked for power spectrum sufficiency by comparing them to a minimum target PSD function compatible with the DRS.

C.4.9 Missing Mass for Analysis of Structures: For mode-superposition time history analysis, ASCE/SEI 4-16, Section 4.2, "Linear Response-History Analysis Section," provides guidance on missing mass but also allows an alternative in which the number of modes included in the analysis should be sufficient to ensure that inclusion of the remaining modes does not result in more than a 10-percent increase in any response measure of interest. Similarly, for response spectrum analysis, ASCE/SEI 4-16, Section 4.3, "Linear Response-Spectrum Analysis Section," allows the 10-percent approximation approach, while providing an alternative to combine the high-frequency modes into a single residual mode.

This pre-decisional DG explains that the 10-percent approximation was replaced with a calculation of the missing mass contribution to total response in most recent practices by reference to RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis" (Ref. 25), and NUREG/CR-6645, "Reevaluation of Regulatory Guidance on Modal Response Combination Methods for Seismic Response Spectrum Analysis," issued December 1999 (Ref. 26), which presents the technical basis for eliminating the 10-percent criterion. The missing mass contribution should be incorporated in both mode superposition time history analysis and response spectrum analysis to ensure accurate results.

C.4.10 Seismic Qualification by Analysis: ASCE/SEI 43-19, Section 8.2, "Seismic Qualification by Analysis," describes the seismic qualification by analysis using either an equivalent static analysis or a dynamic analysis method. For the equivalent static analysis of piping systems, Section 8.2.1.1 (Equivalent Static Analysis) of ASCE/SEI 43-19 indicates that the method described in paragraph N-1225, "Simplified Dynamic Analysis," of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code), Section III, Division 1, Appendix N, "Dynamic Analysis Methods" (Ref. 27), is acceptable. For the dynamic analysis method, Section 8.2.1.2 (Dynamic Analysis) indicates that the approach in Appendix N to ASME Code, Section III, should be used. However, the approach in Appendix N has not been generally reviewed and endorsed by the NRC, and in some cases, it presents very specific and prescriptive methods for safety-significant NPP piping systems. This pre-decisional DG explains that consistent with the goal of using an RIPB approach, flexibility is permitted in the analysis approach to meet the performance objectives of the SSCs. However, the use of methods other than those previously endorsed, such as those in Appendix N, should be peer reviewed. The applicant should make peer review results and report available to the NRC for inspection or audit.

C.4.11 Qualification by Testing and Experience Data: In ASCE/SEI 43-19, Section 8.3.2, "Demand for Qualification by Testing and Experience Data," the use of Institute of Electrical and Electronics Engineers (IEEE) 344, "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations" (Ref. 28), for seismic qualification of electrical and mechanical components and the use of ASME/Qualification of Active Mechanical Equipment (QME)-1, "Qualification of Active Mechanical Equipment Used in Nuclear Facilities" (Ref. 29), are generally acceptable. However, some aspects in testing and experience data require adequate justification to demonstrate their seismic adequacy. These aspects include restricting the frequency range of testing up to 33 hertz (Hz), the use of earthquake experience data, test experience data, and consideration of the effects due to high-frequency ground motions, if applicable (see RG 1.100, "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants" (Ref. 30)). Therefore, this pre-decisional DG explains that the use of IEEE 344 and ASME/QME-1 is acceptable; in addition, the qualification and justification should be consistent with RG 1.100.

C.5 Pre-decisional Draft Regulatory Positions Common to Options 2 and 3:

C.5.1 Minimum Design Ground Motion: The minimum earthquake design level(s) should be design- or SDC-specific. ASCE/SEI 43-19 defines its own minimum PGA for various SDCs that are acceptable.

C.5.2 Operating Basis Earthquake: The OBE check uses both certified seismic design response spectrum (CSDRS) and another spectrum, such as a site-specific design response spectrum (SSDRS), as applicable. The staff extends the interpretation of the OBE exceedance in the context of both a CSDRS and an SSDRS[20] to make it applicable to multiple DRS that are possible for the alternative approaches of proposed Options 2 and 3. Considering these aspects, the following items provide the modified criteria from ANSI/ANS 2.23-2016, endorsed in RG 1.166.

C.5.2.1 The OBE response spectrum check is performed using the lower of the following:

a. the DRS associated with the DBGM(s) used in the certified standard design, or

b. the DRS other than (a) used in the site-specific design of SSCs required for safety functions.

C.5.2.2 The OBE shall be considered to have been exceeded if both of the following occur:

a. Response spectrum check:

(i) the 5-percent damped acceleration response spectrum for any directional component (two horizontal and one vertical) of the earthquake motion at the site at frequencies between 2 and 10 Hz exceeds the corresponding OBE response spectrum (one-third of a DRS) or 0.20g, whichever is greater, or

(ii) the corresponding OBE design spectral velocity or a spectral velocity of 6 inches per second, whichever is greater, is exceeded between 1 and 2 Hz.

b. Cumulative Absolute Velocity (CAV) Check: The computed standardized CAV value from any component of the free-field earthquake record is greater than 0.16g-sec.

C.5.2.3 The DRS[21] should be considered to have been exceeded if both of the following occur:

20 NRC DC/COL ISG 01, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," dated May 19, 2008 (Ref. 31), explains how to interpret the OBE exceedance in the context of both a CSDRS and an SSDRS.

21 The DRS for this purpose is equivalent to the SSE in the ANSI/ANS 2.23-2016 criteria.

a. Response spectrum check: The 5-percent damped acceleration response spectrum for any directional component (e.g., two horizontal and one vertical) of the earthquake motion at the site at frequencies between 2 and 10 Hz exceeds a DRS.

b. CAV check: The computed standardized CAV value from any component of the free-field earthquake record is greater than 0.16g-sec.

C.5.3 Radioactive Waste Management SSCs (Other Radiological Sources): RG 1.143 provides guidance for consideration of seismic loads which can be adopted for Options 2 and 3. Seismic loads are prescribed as OBE or one-half SSE. In the alternative approach in this pre-decisional DG, the DBGM should be associated with the SDC that will satisfy the dose criteria of NRC regulations.

C.5.4 Interactions among SR, NSRSS, and NSS SSCs:[22] To be acceptable, each NSS subsystem should be designed to be isolated from any seismic SR and NSRSS SSC by either a constraint or barrier or should be remotely located with regards to the SR and NSRSS SSCs. If this is not feasible or practical, then adjacent NSS subsystems should be analyzed according to the same seismic criteria as are applicable to the SR and NSRSS SSC. For NSS subsystems attached to seismic SR and NSRSS SSCs, the dynamic effects of the NSS subsystems should be simulated in the modeling of the seismic SR and NSRSS SSC. The attached NSS subsystems, up to the first anchor beyond the interface, should also be designed in such a manner that, during an earthquake ground motion of an applicable SDC, it should not cause a failure of the seismic SR and NSRSS SSC.

D. IMPLEMENTATION

If the NRC staff should publish a DG on the topics discussed in this pre-decisional DG, then the NRC staff would explain in this section of the DG how the NRC would use the final RG in its regulatory processes. The NRC would also describe its use of the final RG in the context of the backfitting and issue finality provisions of preliminary proposed Part 53.

22 The applicable acceptance criteria for LWRs under Part 50 are in Section 3.7.3 of NUREG-0800. The proposed position for the proposed 10 CFR 53.480 accounts for more than one seismic design classification of SSCs in the alternative approach.

REFERENCES [23]

1. *U.S. Code of Federal Regulations* (CFR), "Risk-Informed, Technology-Inclusive Regulatory Frameworks for Commercial Nuclear Plants," Part 53, Chapter 1, Title 10, "Energy."

2. American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 43-19, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," New York, NY, 2020.[24]

3. American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) 4-16, "Seismic Analysis of Safety-Related Nuclear Structures," New York, NY, 2017.

4. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," Washington, DC.

5. NRC, RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," Washington, DC.

6. NRC, trial RG 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light-Water Reactor Risk-Informed Activities," Washington, DC.

7. NRC, RG 1.232, "Developing Principal Design Criteria for Non-Light-Water Reactors," Washington, DC.

8. NRC, RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Washington, DC.

9. NRC, RG 1.166, "Pre-Earthquake Planning, Shutdown, and Restart of a Nuclear Power Plant Following an Earthquake," Washington, DC.

10. NRC, "Review of Risk-Informed, Technology-Inclusive Advanced Reactor Applications—Roadmap," Washington, DC, December 2021. (ADAMS Accession No. ML21336A702)

11. NRC, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Washington, DC.

23 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. The documents can also be viewed on line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

24 Copies may be purchased from the American Society for Civil Engineers (ASCE), 1801 Alexander Bell Drive, Reston, VA 20190 [phone: (800) 548-ASCE (2723)]. Purchase information is available through the ASCE Web site at http://www.pubs.asce.org.

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