U.S. NUCLEAR REGULATORY COMMISSION

DRAFT REGULATORY GUIDE DG-1337

Proposed Revision 1 to Regulatory Guide 1.166

Issue Date: June 2019
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PRE-EARTHQUAKE PLANNING, SHUTDOWN, AND RESTART OF A NUCLEAR POWER PLANT FOLLOWING AN EARTHQUAKE

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes guidance acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) regarding pre-earthquake planning actions; actions necessary to determine the need to shut down a nuclear power plant; and the short- and long-term processes, inspections, and tests to demonstrate that a nuclear power plant is safe for restarting after a shutdown in response to an earthquake.

Applicability

This RG applies to applicants and licensees under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1), 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2), and 10 CFR Part 100, "Reactor Site Criteria (Ref. 3).

Applicable Regulations

- 10 CFR 50.54(ff), "Conditions of Licenses," requires plant shutdown if the Operating Basis Earthquake has been exceeded or if significant plant damage occurs for licensees of nuclear power plants that have implemented the earthquake engineering criteria in Appendix S of Part 50. Prior to resuming operations, the licensee is required to demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public, and that the licensing basis is maintained..

- 10 CFR Part 50, Appendix A, provides the "General Design Criteria for Nuclear Power Plants," and establishes design, fabrication, construction, testing, and performance requirements for structures, systems, and components (SSCs) important to safety through general design criteria (GDC). The GDC applicable to this RG include GDC 2, "Design Bases for Protection against

Natural Phenomena," which requires, in part, that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, without loss of capability to perform their safety functions.

- 10 CFR 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," for plants licensed on or after January 10, 1997, requires, in part, plant shutdown if the Operating Basis Earthquake Ground Motion is exceeded or if significant plant damage occurs. Prior to resuming operations, the licensee must demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to health and safety of the public, and that the licensing basis is maintained.

- 10 CFR 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," Section V(a)(2), requires plant shutdown if vibratory ground motion exceeding that of the Operating Basis Earthquake occurs. Prior to resuming operations, the licensee must demonstrate to the Commission that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public.

Related Guidance

- RG 1.12, "Nuclear Power Plant Instrumentation for Earthquakes" (Ref. 4), provides guidance for seismic instrumentation that is acceptable to the NRC staff. RG 1.12 endorses, in part, American National Standards Institute/American Nuclear Society (ANSI/ANS)-2.2-2016, "Earthquake Instrumentation Criteria for Nuclear Power Plants" (Ref. 5), as an acceptable method for placement of seismic sensors for various nuclear power plant configurations.

- RG 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" (Ref. 6), provides guidance on the development of a site-specific ground motion response spectrum (GMRS).

- NRC Inspection Manual Chapter (IMC) 0326, "Operability Determinations & Functionality Assessments for Conditions Adverse to Quality or Safety" (Ref. 7), provides guidance to NRC inspectors in their review of licensee's operability determinations and resolution of degraded or nonconforming conditions.

Purpose of Regulatory Guides

The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated events, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50, 52, and 100 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget (OMB), approval numbers 3150-0011, 3150-0151, and 3150-0093. Send comments regarding this information collection to the Information Services Branch (T6-A10M), U.S. Nuclear Regulatory

Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0011, 3150-0151, 3150-0093), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW, Washington, DC 20503; e-mail: oira_submission@omb.eop.gov.

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 Revision

This guide merges two related RGs—RG 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Operator Postearthquake Actions," issued March 1997 (Ref. 8), and RG 1.167 "Restart of a Nuclear Power Plant Shut Down by a Seismic Event," issued March 1997 (Ref. 9)—into one and revises their technical content. The staff decided to combine these existing RGs because they are similar in nature and contain overlapping guidance. Both guides reference and endorse the same industry guidelines, which more recent industry guidance has superseded. The merged RG incorporates lessons learned following the shutdown and restart of nuclear power plants in response to earthquake ground motion and post-earthquake evaluations since issuance of the two RGs in 1997, through endorsement of ANSI/ANS-2.10-2017, "Criteria for Retrieval, Processing, Handling, and Storage of Records from Nuclear Facility Seismic Instrumentation" (Ref. 10), and ANSI/ANS-2.23-2016, "Nuclear Power Plant Response to an Earthquake" (Ref. 11), with exceptions and clarifications.

Background

The NRC endorsed Electric Power Research Institute (EPRI) NP-6695, "Guidelines for Nuclear Power Plant Response to an Earthquake," dated December 1, 1989 (Ref. 12), in the initial version of RG 1.166 (Rev. 0) and RG 1.167 (Rev. 0), issued in 1997. Following the issuance of EPRI NP-6695 in 1989, a significant amount of experience has been gained on the effects of earthquakes on nuclear power plants worldwide and the actions needed to restart a nuclear power plant after an earthquake. Based on these lessons learned, EPRI significantly updated EPRI NP-6695 and published it in 2013 as EPRI Report 3002000720, "Guidelines for Nuclear Plant Response to an Earthquake" (Ref. 13). In addition, experience has been gained from the shutdown and restart of the Virginia Electric and Power Company (VEPCO) North Anna Power Station following the August 23, 2011, earthquake in Mineral, Virginia. For example, the plant used older analogue recording instrumentation that took longer to process than modern digital instrumentation. This contributed to the delay in determining if the OBE and SSE were exceeded; in contrast, modern digital recording instrumentation would have facilitated the determination earlier. In response to the earthquake, VEPCO committed to a number of long-term actions to address exceeding the design basis as a result of the August 23, 2011, seismic event in a letter to the NRC dated November 7, 2011 (Ref. 14). NRC responded to the VEPCO letter with a Confirmatory Action Letter (CAL) on November 11, 2011 (Ref. 15), which remained in effect until NRC concluded that all the actions in the enclosure to the CAL were completed.

ANSI/ANS-2.23-2016, incorporates the significant changes and additions included in EPRI Report 3002000720. ANSI/ANS-2.23-2016 provides guidance that implements both the observed damage level and earthquake shaking level to determine post-earthquake actions for an event that exceeds the OBE, whereas EPRI NP-6695 considers only the observed damage level to determine post-earthquake actions. In addition, ANSI/ANS-2.23-2016 builds on EPRI NP-6695 by adding guidance on action levels that clarify what actions should be taken, when they should be taken, and who should perform them. It also provides more comprehensive guidance than EPRI NP-6695 for short-term actions that a licensee should perform following an earthquake and for long-term post-earthquake evaluations. Therefore, this RG endorses ANSI/ANS-2.23-2016 and no longer endorses EPRI NP-6695.

Harmonization with 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 standards

for protecting people and the environment from harmful effects of ionizing radiation. These standards provide a system of safety fundamentals, safety requirements, and safety guides reflecting an international consensus on what constitutes a high level of safety. Pertinent to this RG are:

- IAEA Safety Reports Series No. 66, "Earthquake Preparedness and Response for Nuclear Power Plants" (Ref. 16), which draws upon insights from three multiunit nuclear power plants in Japan and one in Armenia that experienced beyond-design-basis earthquakes. It addresses pre-earthquake planning, actions to follow when an earthquake is felt, actions to take before the restart of the nuclear power plant, and short- and long-term post-earthquake actions.

- IAEA Safety Guide NS-G-1.6, "Seismic Design and Qualification for Nuclear Power Plants" (Ref. 17), which provides guidance on seismic instrumentation.

This RG incorporates guidelines on actions by licensees to demonstrate plant readiness for restart similar to those in IAEA Safety Reports Series No. 66 and seismic instrumentation similar to IAEA Safety Guide NS-G-1.6.

Documents Discussed in Staff Regulatory Guidance

This RG endorses the use of one or more codes or standards developed by external organizations, and other third party guidance documents. These codes, standards and third party guidance documents may contain references to other codes, standards or third party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a RG, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice, and consistent with applicable NRC requirements.

C. STAFF REGULATORY GUIDANCE

This guide provides methods, approaches, or data that the staff considers acceptable for meeting the requirements of the Applicable Regulations stated in Section A. This guide endorses the following standards subject to the exceptions and clarifications noted in this section:

- ANSI/ANS-2.10-2017, "Criteria for Retrieval, Processing, Handling, and Storage of Records from Nuclear Facility Seismic Instrumentation." The standard addresses pre-earthquake activities for documentation and archival of information about seismic instrumentation, earthquake data recording, and processing and transmittal of recorded data after an earthquake.

- ANSI/ANS-2.23-2016, "Nuclear Power Plant Response to an Earthquake." The standard provides guidance regarding pre-earthquake planning actions; actions necessary to determine the need to shut down a nuclear power plant; and the short- and long-term processes, inspections, and tests to demonstrate that a nuclear power plant is safe for restarting after a shutdown in response to an earthquake.

C. 1 Exception to Post-Earthquake Action Levels Recommended in ANSI/ANS-2.23-2016, Section 7.3

Table 1 in ANSI/ANS-2.23-2016 directs the licensee to follow Action Level 1 when the earthquake level exceeds the SSE and the observed damage level is categorized as Damage Level 0 or Damage Level 1. Action Level 1 relies on focused visual inspections and tests, but it does not require the analysis of any structures, systems, and components (SSCs) after restart. The staff's position is that, following restart, licensees should select, on a sampling basis, components from among SSCs that were not in the scope of the focused inspections and tests, and perform analytical evaluation of selected components. These components are typically in inaccessible locations and include insulated piping. The evaluation should utilize response spectrum developed based on the time history obtained from the measured felt earthquake experienced at the facility site. The input in the evaluation should include best estimate damping values and actual material properties. The intent of the evaluation is to confirm that there are no unobserved latent or safety impacts on continued operation from components that were possibly damaged, but not inspected, as a result of the earthquake. Because plant configurations do not rapidly change, licensees should consider developing a list of these components in advance of an event. The method or logic for determining which components were selected and how the sample population was narrowed should be documented and available for NRC inspection. Any issues that are identified should be evaluated in accordance with the guidance provided in Section 9 of ANSI/ANS-2.23-2016 to ascertain operability consistent with NRC Inspection Manual Chapter (IMC) 0326.

C. 2 Clarification of Post-shutdown Inspection and Test Documentation Requirements in Section ANSI/ANS-2.23-2016, Section 8.8

The documentation described in Section 8.8 of ANSI/ANS-2.23-2016 should be available for NRC inspection prior to restart. The documentation should include the condition report methodology, assumptions, assessments, technical specification (TS) surveillance requirement number for each surveillance test, and other inspections that demonstrated that the operability of all safety-related SSCs was not affected. In addition, the documentation should demonstrate that any nonsafety-related SSC impacts are corrected or that the risk is properly managed in accordance with 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." Specifically, if

the plant is restarted with nonsafety-related equipment impacts left uncorrected or unevaluated, the increase in risk must be monitored and accounted for in daily risk assessments as required by 10 CFR 50.65.

C.3 Clarification of Seismic Evaluation and Verification Plans in ANSI/ANS-2.23-2016, Section 9.5

Section 9.5 of ANSI/ANS-2.23-2016 provides guidance on developing a seismic evaluation and verification plan. Section 9.5 states that the plan should require the new and replacement safety-related SSCs to be qualified to both the licensing-basis design spectra and the observed spectra unless the licensee can demonstrate using appropriate risk-informed or performance-based approaches that the SSCs involved do not pose a significant seismic risk. All new or replacement equipment must meet current or amended site licensing-basis requirements.

C.4 Clarification of Initial and Short-Term Evaluations in ANSI/ANS-2.23-2016, Section 6

If the seismic event resulted in a plant automatic shutdown, the licensee needs to understand the cause and evaluate the extent of the condition before plant restart to ensure that (1) operability exists for safety-related SSCs and (2) risk is managed as required by 10 CFR 50.65 for both safety- and nonsafety-related SSCs. To accomplish this, as is done after any automatic reactor shutdown, the licensee must assess the performance of both safety- and nonsafety-related SSCs to determine whether all SSCs had performed as designed, installed, and maintained.

C.5 Clarification of Long-Term Evaluations in ANSI/ANS-2.23-2016, Section 9

Coincident with the long-term evaluations, as described in ANSI/ANS-2.23-2016, Section 9, the plant SSCs should be restored to match their licensing basis.

C.6 Clarification Addressing Exceptions to Restoration of the Licensing Basis

When using ANSI/ANS-2.23-2016, licensees or applicants should note that correction of, or operation with, degraded or nonconforming conditions related to SSCs is accomplished, as appropriate, through evaluation, restoration, modification, license amendment, or regulatory relief (e.g., notice of enforcement discretion, emergency TS amendments, exigent TS changes, exemptions, relief requests, or other relief from a regulatory requirement as granted by the Commission). Operation with SSCs that are deemed operable/functional but are degraded or nonconforming is permitted if an analysis is performed and documented and if corrective actions are completed in a manner that meets the expectations of IMC 0326.

C. 7 Clarification Addressing Degraded or Inoperable Instrumentation

If the seismic instrumentation or data-processing equipment is degraded or inoperable, Appendix A, “Operating-Basis Earthquake Exceedance Guidelines if Instrumentation is Degraded or Inoperable,” of this guide should be used to determine whether the OBE ground motion has been exceeded.

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[1] may use this guide and information regarding the NRC's plans for using this RG. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting," and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

Use by Applicants and Licensees

Applicants and licensees may voluntarily[2] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this RG may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged**.**

Licensees may use the information in this RG for actions that do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59, "Changes, Tests, and Experiments." Licensees may use the information in this RG or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this RG. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this RG, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this RG to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this RG. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the RG, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this RG, generic communication, or promulgation of a rule requiring the use of this RG without further backfit consideration.

During regulatory discussions on plant specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this RG, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this RG are part of the licensing basis of the facility. However, unless this RG is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this RG constitutes a violation.

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1 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and the term "applicants" refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52 and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

2 In this section, "voluntary" and "voluntarily" means that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised RG and (2) the specific subject matter of this RG is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this RG or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to comply with new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

If a licensee believes that the NRC is either using this RG or requesting or requiring the licensee to implement the methods or processes in this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 18), and in NUREG-1409, "Backfitting Guidelines," (Ref. 19).

GLOSSARY

certified seismic design response spectra	Site-independent seismic design response spectra that have been approved by the NRC as the seismic design response spectra in a standard design approval or a certified design.
certified standard design	See "standard design certification."
free-field	Those locations on the ground surface or in the site soil column that are sufficiently distant from the nuclear power plant structures to be essentially unaffected by the vibration of these structures. Therefore, a time-history recorder located at the free-field records essentially the free-field ground motion.
ground motion response spectra	Site-specific GMRS that are characterized by horizontal and vertical response spectra that are determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in situ competent material.
instrumental intensity	Derived from ground motions recorded by seismographs. Unlike conventional intensity scales, the estimated intensities are not based directly on observations of earthquake effects on people or structures. An instrumental intensity map ranks the observed earthquake effect on a scale from I to X depending on the severity of shaking and provides a correlation to the potential damage, peak ground acceleration, and peak ground velocity. The U.S. Geological Survey produces these maps, which can be accessed at https://earthquake.usgs.gov/data/shakemap/.
moment magnitude M	The most common measure of earthquake size for medium to large earthquakes. The U.S. Geological Survey uses the moment magnitude scale **M** to report magnitudes for all modern earthquakes larger than **M** 4.0.
operating-basis earthquake ground motion	The vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to public health and safety will remain functional. The OBE is only associated with plant shutdown and inspection after an earthquake unless the applicant specifically selects it as a design input.
response spectrum	A plot of the maximum responses (acceleration, velocity, or displacement) of idealized single-degree-of-freedom oscillators as a function of the natural frequencies of the oscillators for a given damping value. The response spectrum is calculated for a specified input vibratory motion.

safe-shutdown earthquake ground motion	The vibratory ground motion for which certain SSCs are designed to remain functional. These SSCs are those necessary to ensure the following: • the integrity of the reactor coolant pressure boundary • the capability to shut down the reactor and maintain it in a safe-shutdown condition • the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures of nuclear radiation exceeding allowable amounts
standard design	A design for which the NRC has issued a standard design approval.
standard design certification or design certification	A standard design for a nuclear power facility that has been certified as a rule in 10 CFR Part 52.
spectral acceleration	Peak acceleration response of an oscillator as a function of period or frequency and damping ratio when subjected to a vibratory motion.
spectral velocity	Peak velocity response of an oscillator as a function of period or frequency and damping ratio when subjected to a vibratory motion.

REFERENCES[3]

1. *U.S. Code of Federal Regulations* (CFR), "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."

2. CFR, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."

3. CFR, "Reactor Site Criteria," Part 100, Chapter 1, Title 10, "Energy."

4. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.12, "Nuclear Power Plant Instrumentation for Earthquakes," Washington, DC.

5. American National Standards Institute/American Nuclear Society (ANSI/ANS)-2.2-2016, "Earthquake Instrumentation Criteria for Nuclear Power Plants," LaGrange, Illinois.[4]

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

7. NRC, Inspection Manual Chapter 0326, "Operability Determinations & Functionality Assessments for Conditions Adverse to Quality or Safety," Washington, DC.

8. NRC, RG 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions," Washington, DC.

9. NRC, RG 1.167, "Restart of a Nuclear Power Plant Shutdown by a Seismic Event," Washington, DC.

10. ANSI/ANS-2.10-2017, "Criteria for Retrieval, Processing, Handling, and Storage of Records from Nuclear Facility Seismic Instrumentation," LaGrange Park, Illinois.

11. ANSI/ANS-2.23-2016, "Nuclear Power Plant Response to an Earthquake," LaGrange Park, Illinois.

12. Electric Power Research Institute (EPRI) NP-6695, "Guidelines for Nuclear Power Plant Response to an Earthquake," Palo Alto, California, December 1, 1989.[5]

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[3] 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 online 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.

[4] Copies of ANSI/ANS standards may be purchased from the ANS Web site (http://www.new.ans.org/store/), or by writing to American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60526 (telephone: 800-323-3044).

[5] Copies of EPRI standards and reports may be purchased from Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304 (telephone: (800) 313-3774; fax: (925) 609-1310).

13. EPRI Report 3002000720, "Guidelines for Nuclear Plant Response to an Earthquake," Palo Alto, California, 2013.

14. Virginia Electric and Power Company, letter to NRC, November 7, 2011, "Virginia Electric and Power Company North Anna Power Station Units 1 and 2, Independent Spent Fuel Storage Installation Revised Long-Term Actions Commitment List," ADAMS Accession number ML11314A069.

15. NRC letter to Virginia Electric and Power Company, November 11, 2011, "Confirmatory Action Letter Regarding North Anna Power Station, Unit Nos. 1 and 2, Long-Term Commitments to Address Exceeding Design Bases Seismic Event (TAC Nos. ME7254 and ME7255)," ADAMS Accession number ML11311A201.

16. International Atomic Energy Agency Safety (IAEA) Report Series No. 66, "Earthquake Preparedness and Response for Nuclear Power Plants," Vienna, Austria.[6]

17. IAEA Safety Guide NS-G-1.6, "Seismic Design and Qualification for Nuclear Power Plants."

18. NRC, Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection," Washington, DC.

19. NRC, NUREG-1409, "Backfitting Guidelines," Washington, DC.

[6] Copies of IAEA documents may be obtained through the IAEA Web site at www.iaea.org/ or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria.

APPENDIX A

OPERATING-BASIS EARTHQUAKE EXCEEDANCE GUIDELINES IF INSTRUMENTATION IS DEGRADED OR INOPERABLE

If the seismic instrumentation or data-processing equipment is degraded or inoperable, the following should be used to determine whether the operating-basis earthquake (OBE) ground motion has been exceeded:

- For plants at which instrumentally determined data are available only from an instrument installed on a foundation, the cumulative absolute velocity (CAV) check does not apply. In this case, the determination of OBE exceedance is based on a response spectrum check described in Section 6.4.1 of American National Standards Institute/American Nuclear Society (ANSI/ANS)-2.23-2016, "Nuclear Power Plant Response to an Earthquake" (Ref. 1). A comparison should be made between the foundation-level design response spectra and data obtained from the foundation-level instruments. If the response spectrum check at any foundation is exceeded, the OBE is exceeded, and the plant must be shut down. At this instrument location, it is inappropriate to use the 0.2g spectral acceleration limit or the spectral velocity limit of 6 inches per second (15.24 centimeters per second) in Section 6.4.1 of ANSI/ANS-2.23-2016.

- For plants at which no free-field or foundation-level instrumental data are available or the data-processing equipment is inoperable and the response spectrum check and the CAV check cannot be determined, the OBE will be considered to have been exceeded, and the plant must be shut down if one of the following two conditions apply:

  (1) If instrumental intensity information is not available, the earthquake with moment magnitude **M** specified in Table B-1 occurred within a distance less than or equal to that specified in Table B-1.

Table B-1 Maximum Distance from an Earthquake with Moment Magnitude M at which the OBE Can Be Exceeded

Magnitude (M)	Distance (km)
5.0–5.5	80
5.6–6.0	150
6.1–6.5	250
6.6–7.0	300
7.1–7.5	380
7.6–8.0	480

If plant shutdown is warranted under the above guidelines, the plant should be shut down in an orderly manner (see Sections 6.2 and 6.5 of ANSI/ANS-2.23-2016).

The licensee should conduct a post-earthquake plant walkdown after the earthquake (see Section 6.2 of ANSI/ANS-2.23-2016).

(2) The earthquake resulted in Instrumental Intensity VI (Table B-2) or greater within 5 kilometers (km) of the plant.

Table B-2 ShakeMap Instrumental Intensity Scale (Ref. 2 and Ref. 3)

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-14	1.4-39	3.9-92	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Note that the determination of epicentral location, magnitude, and intensity by the U.S. Geological Survey, National Earthquake Information Center, will usually take precedence over other estimates. However, higher quality damage reports or a lack of damage reports from the nuclear power plant site or its immediate vicinity will take precedence over more distant reports.

REFERENCES

1. ANSI/ANS-2.23-2016, "Nuclear Power Plant Response to an Earthquake," LaGrange Park, IL.[7]

2. Wald, D.J., V. Quitoriano, T.H. Heaton, H. Kanamori, C.W. Scrivner, and C.B. Worden, "TriNet 'ShakeMaps': Rapid Generation of Peak Ground Motion and Intensity Maps for Earthquakes in Southern California," *Earthquake Spectra*, 15(3):537–556, 1991.[8]

3. U.S. Geological Survey, *ShakeMap 3.5 Manual*, available at https://usgs.github.io/shakemap/index.html.

[7] Copies of ANSI/ANS standards may be purchased from the ANS Web site (http://www.new.ans.org/store/), or by writing to American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60526 (telephone: 800-323-3044).

[8] Earthquake Engineering Research Institute, 499 14th Street, Suite 220, Oakland, CA 94612-1934 USA
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