U.S. NUCLEAR REGULATORY COMMISSION

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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

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Electronic copies of this RG, previous versions of RGs, and other recently issued guides are also available through the NRC's public Web site in the NRC Library at https://nrcweb.nrc.gov/reading-rm/doc-collections/reg-guides/, under Document Collections, in Regulatory Guides. This RG is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession Number (No.) ML19266A616. The regulatory analysis may be found in ADAMS under Accession No. ML18268A187. The associated draft guide DG-1337 may be found in ADAMS under Accession No. ML18268A185, and the staff responses to the public comments on DG-1337 may be found under ADAMS Accession No. ML19266A619.

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 standards have 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, in 2015 EPRI significantly updated EPRI NP-6695 and the lessons were captured in EPRI Report 3002005284, "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 equipment 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 3002005284. ANSI/ANS-2.23-2016 provides guidance that implements both the observed damage level (DL) and earthquake shaking level (EL) 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.

This guide also endorses ANSI/ANS-2.10-2017, "Criteria for Retrieval, Processing, Handling, and Storage of Records from Nuclear Facility Seismic Instrumentation," because the standard provides guidance on the retrieval of recorded data from seismic instrumentation in the event that an earthquake occurs with sufficient ground motion to activate the instrumentation, and because of the importance of the

storage, handling, and maintenance of recorded data and calculations. This information is important because it is used to assess the short-term and long-term actions needed to ensure the plant can be operated safely.

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 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 the recording, retrieval, documentation and archiving of data from seismic instrumentation, subsequent to an earthquake sufficient to activate the instrumentation.

- 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 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 as required by 10 CFR 50.65.

C. 2 Clarification of Seismic Reevaluations in ANSI/ANS-2.23-2016, Section 9.1.3

Sections 9.1.3 provides guidance in selecting items for seismic reevaluations which include selecting items with the highest calculated stresses based on previous stress analysis results. The staff position is that items should also be selected where the fatigue Cumulative Usage Factor is highest.

C.3 Clarification of Equipment and Structures Qualified by Analysis in ANSI/ANS-2.23-2016, Section 9.1.4.1

When evaluating equipment and structures by analysis, staff finds it acceptable to use best estimate damping values and realistic material properties to determine if stresses or strains are greater than allowables. Strain based allowable values with adequate justification may be used when non-linear analyses are performed.

C.4 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.5 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.6 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.7 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 NRC Inspection Manual Chapter (IMC) 0326.

C. 8 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 NRC staff may use this regulatory guide as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this regulatory guide to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, "Backfitting," and as described in NRC Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests" (Ref. 18), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

REFERENCES[1]

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.[2]

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.[3]

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1 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.

2 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).

3 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 3002005284, "Guidelines for Nuclear Plant Response to an Earthquake," Palo Alto, California, 2015.

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.[4]

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

18. NRC, Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests," Washington, DC.

[4] 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.[5]

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.[6]

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

[5] 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).

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