



REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.166

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PRE-EARTHQUAKE PLANNING AND IMMEDIATE NUCLEAR POWER PLANT OPERATOR POSTEARTHQUAKE ACTIONS

A. INTRODUCTION

Paragraph IV(a)(4) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that suitable instrumentation¹ be provided so that the seismic response of nuclear power plant features important to safety can be evaluated promptly. Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 requires shutdown of the nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake ground motion (OBE) or significant plant damage occurs. If systems, structures, or components necessary for the safe shutdown of the nuclear power plant are not available after occurrence of the OBE, the licensee must consult with the NRC and must propose a plan for the timely, safe shutdown of the nuclear power plant. Licensees of nuclear power plants that are subject to the earthquake engineering criteria in Appendix S to 10 CFR Part 50 are required by 10 CFR 50.54(ff) to shut down the plant if the criteria in Paragraph IV(a)(3) of Appendix S are exceeded.

¹Regulatory Guide 1.12, Revision 2, "Nuclear Power Plant Instrumentation for Earthquakes," describes seismic instrumentation that is acceptable to the NRC staff.

This guide provides guidance acceptable to the NRC staff for a timely evaluation after an earthquake of the recorded instrumentation data and for determining whether plant shutdown is required by 10 CFR Part 50.

The information collections contained in this regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget, approval number 3150-0011. The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

B. DISCUSSION

When an earthquake occurs, ground motion data are recorded by the seismic instrumentation.¹ These data are used to make a rapid determination of the degree of severity of the seismic event. The data from the nuclear power plant's free-field seismic instrumentation, coupled with information obtained from a plant walkdown, are used to make the initial determination of whether the plant must be shut down, if it has not already been shut down by operational perturbations resulting from the seismic event. If on the basis of these initial evaluations (instrumentation data and walkdown) it is concluded that the plant shutdown criteria have not been exceeded, it is presumed that the

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This guide was issued after consideration of comments received from the public. Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience.

Written comments may be submitted to the Rules Review and Directives Branch, DFIPS, ADM, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

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plant will not be shut down (or could restart following a post-trip review, if it tripped off-line because of the earthquake). Guidance on postshutdown inspections and plant restart is contained in Regulatory Guide 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event."

The Electric Power Research Institute has developed guidelines that will enable licensees to quickly identify and assess earthquake effects on nuclear power plants. These guidelines are in EPRI NP-5930, "A Criterion for Determining Exceedance of the Operating Basis Earthquake," July 1988²; EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake," December 1989²; and EPRI TR-100082, "Standardization of the Cumulative Absolute Velocity," December 1991.²

This regulatory guide is based on the assumption that the nuclear power plant has operable seismic instrumentation, including the computer equipment and software required to process the data within 4 hours after an earthquake. This is necessary because the decision to shut down the plant will be made, in part, by comparing the recorded data against OBE exceedance criteria. The decision to shut down the plant is also based on the results of the plant walkdown inspections that take place within 8 hours of the event. If the seismic instrumentation or data processing equipment is inoperable, the guidelines in Appendix A to this guide should be used to determine whether the OBE has been exceeded.

Shutdown of the nuclear power plant is required if the vibratory ground motion experienced exceeds that of the OBE. A criterion for determining exceedance of the OBE (based on data recorded in the free-field) is provided in EPRI NP-5930: a threshold response spectrum ordinate check and a cumulative absolute velocity (CAV) check. Seismic Category I structures at a nuclear power plant site may be designed using different ground motion response spectra; for example, one used for the certified standard design and another for site-specific applications. The spectrum ordinate criterion is based on the lowest spectrum used in the design of the Seismic Category I structures. A procedure to standardize the calculation of the CAV is provided in EPRI TR-100082. A spectral velocity threshold has also been recommended by EPRI since some structures have fundamental frequencies below the range specified in EPRI NP-5930. The NRC staff now recom-

mends 1.0 to 2.0 Hz for the range of the spectral velocity limit since some structures have fundamental frequencies below 1.5 Hz. This is instead of the 1.5 to 2.0 Hz range proposed by EPRI.

Because free-field seismic instrumentation data are used in the plant shutdown determination, it is important to ascertain that the time-history analysis hardware and software were functioning properly. Therefore, the response spectrum and CAV should be calculated using a suitable earthquake time-history or manufacturer's calibration standard after the initial installation and each servicing of the free-field instrumentation. After an earthquake at the plant site, the response spectrum and CAV should be calculated using the time-history or calibration standard that was used during the last servicing (or initial instrumentation installation if no servicing has been performed) and the results compared with the latest data on file at the plant.

The NRC staff does not endorse the philosophy discussed in EPRI NP-6695, Section 4.3.4 (first paragraph, last sentence), pertaining to plant shutdown considerations following an earthquake based on the need for continued power generation in the region. If a licensee determines that plant shutdown is required by the NRC's regulations, but the licensee does not consider it prudent to do so, the licensee would be required to consult with the NRC and propose a plan for the timely, safe shutdown of the nuclear power plant.

Because earthquake-induced vibration of the reactor vessel could lead to changes in neutron fluxes, a prompt check of the neutron flux monitoring sensors would provide an indication that the reactor is stable.

Since the containment isolation valves may have malfunctioned during an earthquake, inspection of the containment isolation system is necessary to ensure continued containment integrity.

Appendix B to this guide provides definitions to be used with this guidance.

C. REGULATORY POSITION

1. BASE-LINE DATA

1.1 Information Related to Seismic Instrumentation

A file containing information on all the seismic instrumentation should be kept at the plant. The file should include:

1. Information on each instrument type such as make, model, and serial number; manufacturers' data sheet; list of special features or options; performance

²EPRI reports may be obtained from the Electric Power Research Institute, EPRI Distribution Center, 207 Coggins Dr., P.O. Box 23205, Pleasant Hill, CA 94523.

characteristics; examples of typical instrumentation readings and interpretations; operations and maintenance manuals; repair procedures (manufacturers' recommendations for repairing common problems); and a list of any special requirements, e.g., for maintenance, operation, or installation.

2. Plan views and vertical sections showing the location of each seismic instrument and the orientation of the instrument components with respect to plant reference axes.

3. A complete service history of each seismic instrument. The service history should include information such as dates of servicing, description of completed work, and calibration records and data (where applicable). The documentation and retention of these data should be commensurate with the recordkeeping for other plant equipment.

4. A suitable earthquake time-history (e.g., the October 1987 Whittier, California, earthquake) or manufacturer's calibration standard and the corresponding response spectrum and cumulative absolute velocity (CAV) (see Regulatory Positions 4.1 and 4.2). After the initial installation and each servicing of the free-field instrumentation, the response spectrum and CAV should be calculated and filed (see Regulatory Position 4.3).

1.2 Planning for Postearthquake Inspections

Sections 4.3.4.1 and 5.3.1 of EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake," describe actions, such as selecting equipment and structures for inspections and the content of the baseline inspections, that are to be taken before an earthquake and that are acceptable to the NRC staff for satisfying the requirements in Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 for ensuring the safety of nuclear power plants.

2. ACTIONS IMMEDIATELY AFTER AN EARTHQUAKE

The guidelines for actions immediately after an earthquake that are specified in Sections 4.3.1 (with the exception specified below) and 4.3.2 of EPRI NP-6695 are acceptable to the NRC staff for satisfying the requirements in Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50.

In Section 4.3.1, a check of the neutron flux monitoring sensors for changes should be added to the specific control room board checks.

3. EVALUATION OF GROUND MOTION RECORDS

3.1 Data Identification

A record collection log should be maintained at the plant, and all data should be identifiable and traceable with respect to:

1. The date and time of collection,
2. The make, model, serial number, location, and orientation of the instrument (sensor) from which the record was collected.

3.2 Data Collection

3.2.1 Only personnel trained in the operation of the instrument should collect the data.

3.2.2 The steps for removing and storing records from each seismic instrument should be planned and performed in accordance with established procedures.

3.2.3 Extreme caution should be exercised to prevent accidental damage to the recording media and instruments during data collection and subsequent handling.

3.2.4 As data are collected and the instrumentation is inspected, notes should be made regarding the condition of the instrument and its installation, for example, instrument flooded, mounting surface tilted, or objects that fell and struck the instrument or the instrument mounting surface.

3.2.5 For validation of the collected data, the information described in Regulatory Position 1.1(4) should be provided.

3.2.6 If the instrument's operation appears to have been normal, the instrument should remain in service without readjustment or change that would defeat attempts to obtain postevent calibration.

3.3 Record Evaluation

Records should be analyzed according to the manufacturer's specifications and the results of the analysis should be evaluated. Any record anomalies, invalid data, and nonpertinent signals should be noted, along with any known causes.

4. DETERMINING OBE EXCEEDANCE

The evaluation to determine whether the OBE was exceeded should be performed using data obtained from the three components of the free-field ground motion (i.e., two horizontal and one vertical). The evaluation may be performed on uncorrected earthquake records. It was found in a study of uncorrected versus

corrected earthquake records (see EPRI NP-5930) that the use of uncorrected records is conservative. The evaluation should consist of a check of the response spectrum and CAV and a check on the operability of the instrumentation. This evaluation should take place within 4 hours of the earthquake.

4.1 Response Spectrum Check

4.1.1 The OBE response spectrum check is performed using the lower of:

1. The spectrum used in the certified standard design, or
2. A spectrum other than (1) used in the design of any Seismic Category I structure.

4.1.2 The OBE response spectrum is exceeded if any one of the three components (two horizontal and one vertical) of the 5 percent of critical damping response spectra generated using the free-field ground motion is larger than:

1. The corresponding design response spectral acceleration (OBE spectrum if used in the design, otherwise 1/3 of the safe shutdown earthquake ground motion (SSE) spectrum) or 0.2g, whichever is greater, for frequencies between 2 to 10 Hz, or
2. The corresponding design response spectral velocity (OBE spectrum if used in the design, otherwise 1/3 of the SSE spectrum) or a spectral velocity of 6 inches per second (15.24 centimeters per second), whichever is greater, for frequencies between 1 and 2 Hz.

4.2 Cumulative Absolute Velocity Check

For each component of the free-field ground motion, the CAV should be calculated as follows: (1) the absolute acceleration (g units) time-history is divided into 1-second intervals, (2) each 1-second interval that has at least 1 exceedance of 0.025g is integrated over time, (3) all the integrated values are summed together to arrive at the CAV. The CAV check is exceeded if any CAV calculation is greater than 0.16 g-second. Additional information on how to determine the CAV is provided in EPRI TR-100082.

4.3 Instrument Operability Check

After an earthquake at the plant site, the response spectrum and CAV should be calculated using the same input as that used in Regulatory Position 1.1(4), and the results should be compared with the latest filed data to demonstrate that the time-history analysis hardware

and software were functioning properly. The results of this comparison should be reported to the NRC.

4.4 Inoperable Instrumentation or Data Processing Hardware or Software

If the response spectrum and the CAV (Regulatory Positions 4.1 and 4.2) cannot be obtained because the seismic instrumentation is inoperable, data from the instrumentation are destroyed, or the data processing hardware or software is inoperable, the criteria in Appendix A to this guide should be used to determine whether the OBE has been exceeded.

5. CRITERIA FOR PLANT SHUTDOWN

If the OBE is exceeded or significant plant damage occurs, the plant must be shut down unless a plan for the timely, safe shutdown of the nuclear power plant has been proposed by the licensee and accepted by the NRC staff.

5.1 OBE Exceedance

If the response spectrum check and the CAV check (performed or calculated in accordance with Regulatory Positions 4.1 and 4.2) were exceeded, the OBE was exceeded and plant shutdown is required. If either check does not exceed the criterion, the earthquake motion did not exceed the OBE. If only one check can be performed, the other check is assumed to be exceeded; if neither check can be performed, see Regulatory Position 4.4. The determination of whether or not the OBE has been exceeded should be performed even if the plant automatically shuts down as a result of the earthquake.

5.2 Damage

The plant should be shut down if the walkdown inspections performed in accordance with Regulatory Position 2 discover damage. This evaluation should take place within 8 hours of the earthquake occurrence.

5.3 Continued Operation

If the OBE was not exceeded and the walkdown inspection indicates no damage to the nuclear power plant, shutdown of the plant is not required. The plant may continue to operate (or may restart following a post-trip review, if it automatically shut down because of the earthquake).

6. PRE-SHUTDOWN INSPECTIONS

The pre-shutdown inspections described in Section 4.3.4 of EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake," with the exceptions specified below, are acceptable to the NRC staff for

satisfying the requirements in Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 for ensuring the safety of nuclear power plants.

6.1 Shutdown Timing

Delete the last sentence in the first paragraph of Section 4.3.4 of EPRI NP-6695.

6.2 Safe Shutdown Equipment

In Section 4.3.4.1 of EPRI NP-6695, a check of the containment isolation system should be added to the minimum list of equipment to be inspected.

6.3 Orderly Plant Shutdown

The following paragraph in Section 4.3.4 of EPRI NP-6695 is printed here to emphasize that the plant should shut down in an orderly manner.

“Prior to initiating plant shutdown following an earthquake, visual inspections and control board checks of safe shutdown systems should be performed by plant operations personnel, and the availability of off-site and emergency on-site power sources should be determined. The purpose of these inspections is to determine the effect of the earthquake on essential safe shutdown equipment which is not normally in use during power operation so that any resets or repairs required as a result of the earthquake can be performed, or alternate equipment can be readied, prior to initiating

shutdown activities. In order to ascertain possible fuel and reactor internal damage, the following checks should be made, if possible, before plant shutdown is initiated”

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulations, the method described in this guide will be used in the evaluation of applications for construction permits, operating licenses, combined licenses, or design certification submitted after January 10, 1997. This guide will not be used in the evaluation of an application for an operating license submitted after January 10, 1997, if the construction permit was issued prior to that date.

Holders of an operating license or construction permit issued prior to January 10, 1997, may voluntarily implement the methods described in this guide in combination with the methods in Revision 2 to Regulatory Guide 1.12, “Nuclear Power Plant Instrumentation for Earthquakes,” and in Regulatory Guide 1.167, “Restart of a Nuclear Power Plant Shut Down by a Seismic Event.” Other implementation strategies, such as voluntary implementation of portions of the cited regulatory guides, will be evaluated by the NRC staff on a case-by-case basis.

APPENDIX A

INTERIM OPERATING BASIS EARTHQUAKE EXCEEDANCE GUIDELINES

This regulatory guide is based on the assumption that the nuclear power plant has operable seismic instrumentation and equipment (hardware and software) to process the data. If the seismic instrumentation or data processing equipment is inoperable, the following should be used to determine whether the operating basis earthquake ground motion (OBE) has been exceeded:

1. For plants at which instrumentally determined data are available only from an instrument installed on a foundation, the cumulative absolute velocity (CAV) check (see Regulatory Position 4.2 of this guide) is not applicable. In this case, the determination of OBE exceedance is based on a response spectrum check similar to that described in Regulatory Position 4.1 of this regulatory guide. A comparison is 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 6 inches per second (15.24 centimeters per second) spectral velocity limit stated in Regulatory Position 4.1.2.
2. 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 can not

be determined (Regulatory Positions 4.1 and 4.2), the OBE will be considered to have been exceeded and the plant must be shut down if one of the following applies:

1. The earthquake resulted in Modified Mercalli Intensity (MMI) VI or greater within 5 km of the plant,
2. The earthquake was felt within the plant and was of magnitude 6.0 or greater, or
3. The earthquake was of magnitude 5.0 or greater and occurred within 200 km of the plant.

A postearthquake plant walkdown should be conducted after the earthquake (see Regulatory Position 2 of this guide).

If plant shutdown is warranted under the above guidelines, the plant should be shut down in an orderly manner (see Regulatory Position 6 of this guide).

Note: The determinations of epicentral location, magnitude, and intensity by the U.S. Geological Survey, National Earthquake Information Center, will usually take precedence over other estimates; however, regional and local determinations will be used if they are considered to be more accurate. Also, 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.

APPENDIX B

DEFINITIONS

Certified Standard Design. A Commission approval, issued pursuant to Subpart B of 10 CFR Part 52, of a standard design for a nuclear power facility.

Design Response Spectra. Response spectra used to design Seismic Category I structures, systems, and components.

Operating Basis Earthquake Ground Motion (OBE). The vibratory ground motion for which those features of the nuclear power plant necessary for con-

tinued operation without undue risk to the health and safety of the public will remain functional. The value of the OBE is set by the applicant.

Spectral Acceleration. The acceleration response of a linear oscillator with prescribed frequency and damping.

Spectral Velocity. The velocity response of a linear oscillator with prescribed frequency and damping.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis, "Revisions of 10 CFR Part 100 and 10 CFR Part 50," was prepared for these amendments, and it provides the regulatory basis for this guide and examines the costs and

benefits of the rule as implemented by the guide. A copy of the regulatory analysis is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW. (Lower Level), Washington, DC, as Attachment 7 to SECY-96-118.



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