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OFFICE OF NUCLEAR REGULATORY RESEARCH

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IDENTIFICATION AND CHARACTERIZATION OF SEISMIC SOURCES AND DETERMINATION OF SAFE SHUTDOWN EARTHQUAKE GROUND MOTION

A. INTRODUCTION

In 10 CFR Part 100, "Reactor Site Criteria," Section 100.23, "Geologic and Seismic Siting Factors," paragraph (c), "Geological, Seismological, and Engineering Characteristics," requires that the geological, seismological, and engineering characteristics of a site and its environs be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, to provide sufficient information to support evaluations performed to arrive at estimates of the Safe Shutdown Earthquake Ground Motion (SSE), and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. Data on the vibratory ground motion, tectonic surface deformation, nontectonic deformation, earthquake recurrence rates, fault geometry and slip rates, site foundation material, and seismically induced floods, water waves, and other siting factors will be obtained by reviewing pertinent literature and carrying out field investigations.

In 10 CFR 100.23, paragraph (d), "Geologic and Seismic Siting Factors," requires that the geologic and seismic siting factors considered for design include a determination of the SSE for the site, the potential for surface tectonic and nontectonic deformations, the

sign bases for seismically induced floods and water waves, and other design conditions.

In 10 CFR 100.23, paragraph (d)(1), "Determination of the Safe Shutdown Earthquake Ground Motion," requires that uncertainty inherent in estimates of the SSE be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses.

This guide has been developed to provide general guidance on procedures acceptable to the NRC staff for (1) conducting geological, geophysical, seismological, and geotechnical investigations, (2) identifying and characterizing seismic sources, (3) conducting probabilistic seismic hazard analyses, and (4) determining the SSE for satisfying the requirements of 10 CFR 100.23.

This guide contains several appendices that address the objectives stated above. Appendix A contains a list of definitions of pertinent terms. Appendix B describes the procedure used to determine the reference probability for the SSE exceedance level that is acceptable to the staff. Appendix C discusses the development of a seismic hazard information base and the determination of the probabilistic ground motion level and controlling earthquakes. Appendix D discusses site-specific geological, seismological, and

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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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APPENDIX B REFERENCE PROBABILITY FOR THE EXCEEDANCE LEVEL OF THE SAFE SHUTDOWN EARTHQUAKE GROUND MOTION

B.1 INTRODUCTION

This appendix describes the procedure that is acceptable to the NRC staff to determine the reference probability, an annual probability of exceeding the Safe Shutdown Earthquake Ground Motion (SSE), at future nuclear power plant sites. The reference probability is used in Appendix C in conjunction with the probabilistic seismic hazard analysis (PSHA).

B.2 REFERENCE PROBABILITY FOR THE SSE

The reference probability is the annual probability level such that 50% of a set of currently operating plants (selected by the NRC, see Table B.1) has an annual median probability of exceeding the SSE that is below this level. The reference probability is determined for the annual probability of exceeding the average of the 5 and 10 Hz SSE response spectrum ordinates associated with 5% of critical damping.

B.3 PROCEDURE TO DETERMINE THE REFERENCE PROBABILITY

The following procedure was used to determine the reference probability and should be used in the future if general revisions to PSHA methods or data bases result in significant changes in hazard predictions for the selected plant sites in Table B.1.

The reference probability is calculated using the Lawrence Livermore National Laboratory (LLNL) methodology and results (Refs. B.1 and B.2) but is also considered applicable for the Electric Power Research Institute (EPRI) study (Refs. B.3 and B.4). This reference probability is also to be used in conjunction with sites not in the Central and Eastern United States (CEUS) and for sites for which LLNL and EPRI methods and data have not been used or are not available. However, the final SSE at a higher reference probability may be more appropriate and acceptable¹ for some sites considering the slope characteristics of the site hazard curves, the overall uncertainty in calculations (i.e., differences between mean and median hazard estimates), and the knowledge of the seismic sources that contribute to the hazard. Reference B.4 includes a procedure to determine an alternative reference probability

on the risk-based considerations; its application will also be reviewed on a case-by-case basis.

B.3.1 Selection of Current Plants for Reference Probability Calculations

Table B.1 identifies plants, along with their site characteristics, used in calculating the reference probability. These plants represent relatively recent designs that used Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" (Ref. B.5), or similar spectra as their design bases. The use of these plants should ensure an adequate level of conservatism in determining an SSE consistent with recent licensing decisions.

B.3.2 Procedure To Establish Reference Probability

Step 1

Using LLNL, EPRI, or a comparable methodology that is acceptable to the NRC staff, calculate the seismic hazard results for the site for spectral responses at 5 and 10 Hz (as stated earlier, the staff used the LLNL methodology and associated results as documented in Refs. B.1 and B.2).

Step 2

Calculate the composite annual probability of exceeding the SSE for spectral responses at 5 and 10 Hz using median hazard estimates. The composite annual probability is determined as:

$$\text{Composite probability} = 1/2(a_1) + 1/2(a_2)$$

where a_1 and a_2 represent median annual probabilities of exceeding SSE spectral ordinates at 5 and 10 Hz, respectively. The procedure is illustrated in Figure B-1.

Step 3

Figure B-2 illustrates the distribution of median probabilities of exceeding the SSEs for the plants in Table B.1 based on the LLNL methodology (Refs. B.1 and B.2). The reference probability is simply the median probability of this distribution.

For the LLNL methodology, this reference probability is $1E-5/\text{yr}$ and, as stated earlier, is also to be used in conjunction with the current EPRI methodology (Ref. B.3) or for sites not in the CEUS.

¹The use of a higher reference probability will be reviewed and accepted on a case-by-case basis.

REFERENCES

- B.1 D.L. Bernreuter et al., "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, January 1989.¹
- B.2 P. Sobel, "Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains," NUREG-1488, USNRC, April 1994.¹
- B.3 Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," Report NP-6395-D, April 1989.
- B.4 Attachment to Letter from D. J. Modeen, Nuclear Energy Institute, to A.J. Murphy, USNRC, Subject: Seismic Siting Decision Process, May 25, 1994.²
- B.5 USNRC, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.60.³

¹Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202)634-3273; fax (202)634-3343. Copies may be purchased at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-2249); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161.

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