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L Shao
7/31/91

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 30 1991

MEMORANDUM FOR: Lawrence C. Shao, Director
Division of Engineering, RES

FROM: James E. Richardson, Director
Division of Engineering Technology, NRR

SUBJECT: COMMENTS ON PROPOSED REVISION TO 10 CFR PART 100, APPENDIX A AND ASSOCIATED DOCUMENTS

In response to your July 3, 1991 memorandum, the Structural and Geosciences Branch has reviewed the documents associated with the proposed revision of Appendix A "Seismic and Geologic Siting Criteria for Nuclear Power Plants." Enclosed is a markup of the text with our comments. These comments were prepared by Robert Rothman, Section Chief, Geosciences Section, Phyllis Sobel, Geophysicist and Sang Bo Kim, Structural Engineer.

J E Richardson
James E. Richardson, Director
Division of Engineering Technology

cc: B. D. Liaw

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 8 1991

MEMORANDUM FOR: J. E. Richardson, Director
Division of Engineering Technology, NRR

A. C. Thadani, Director
Division of Systems Technology, NRR

D. M. Crutchfield, Director
Division of Advanced Reactors, NRR

W. Minners, Director
Division of Safety Issue Resolution, RES

S. A. Treby, Assistant General Counsel
for Rulemaking and Fuel Cycle, OGC

FROM: L. C. Shao, Director
Division of Engineering, RES

SUBJECT: RULEMAKING REVIEW REQUEST, PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

Your assistance is requested in reviewing the documents associated with the proposed revision of Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Siting Criteria." Your comments will be considered for input into the package that will be circulated for Office-level concurrence. Enclosure 1 is a list of the documents that are to be reviewed; Enclosure 2 is the rulemaking package.

The current version of Appendix A to Part 100 will remain in effect for existing plants. The proposed rulemaking, which is applicable to applicants applying for a CP after the effective date of the rule, covers a new Appendix B to Part 100 on Seismic and Geologic Siting Criteria, and a new Appendix S to Part 50 on Earthquake Engineering Criteria.

Several basic assumptions or guidelines were used in the preparation of these documents. They are:

1. The Commission safety goal policy states that the current nuclear power plants taken as a group are at an appropriate level of safety, that is, the current plants are safe enough and future plants should maintain that level of safety.
2. To the maximum extent practical, the technical guidance for complying with the regulation will be in the regulatory guides or standard review plan sections.
3. The new seismic and geological siting criteria will make use of both deterministic and probabilistic techniques to meet the regulation.

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JUL 3 1991

The current package represents the current status of the proposed rulemaking on Appendix B to Part 100 and S to Part 50 with only a few technical details requiring verification, for instance, the one-third factor associated with the elimination of the Operating Basis Earthquake (OBE) response analysis. These details will be available over the next several weeks (before ACRS and CRGR review) as input is received from our contractor and peer panel.

A significant industry interest in the Appendix A revision has been expressed through the Nuclear Management and Resources Council (NUMARC) and the Electric Power Research Institute (EPRI). The staff had two public meetings (March 6 and April 17, 1991). Based on industry presentations made at the second meeting, there is major philosophical agreement between industry and staff regarding the regulation revision. The staff has not received the written suggestions that NUMARC said would be forthcoming in May.

There are two specific items pertaining to the Draft Federal Register Notice th I want to call to your attention.

1. Section VII, Future Regulatory Action, notes that several existing regulatory guides will be revised to incorporate editorial changes or maintain the existing design or analysis philosophy. These guides will be issued coincident with the publication of the <u>final</u> regulations unless additional changes are made to the technical position which would require a public comment period. During your review of the rulemaking package please indicate if any of the noted guides need to have their technical position changed.
2. Only one paragraph within Part 100 is revised to cite the new Appendix B.

Your review and comments are needed by the July 16, 1991 so that Office review and concurrence can be obtained by the scheduled date of August 1, 1991.

for L.C. Shao, Director
Division of Engineering, RES

Enclosures: As Stated (2)

Contact: A. J. Murphy, SSEB, DE, RES
49-23860

cc: E. S. Beckjord, RES
T. P. Speis, RES
C. J. Heltemes, RES
D. L. Meyer, ADM/RPB
M. A. Cunningham, RES/PRAB
C. E. Ader, RES/SAIB

Enclosure 1

CONTENTS OF THE RULEMAKING PACKAGE, PROPOSED REVISION TO 10 CFR PART 100, APPENDIX A "SEISMIC AND GEOLOGIC SITING CRITERIA FOR NUCLEAR POWER PLANTS"

TAB	DESCRIPTION
1.	10 CFR Part 100, Appendix B, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (Reduced Text Version)
2.	10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants" (Reduced Text Version
3.	10 CFR Part 100, Appendix B - Comparative Text Version
4.	10 CFR Part 50, Appendix S - Comparative Text Version
5.	Draft Federal Register Notice, "Seismic Siting and Engineering Criteria for Nuclear Power Plants"
6.	Draft Regulatory Guide RG text ~~D~~G-1015, "Identification and Characterization of Seismic Sources"
7.	Standard Review Plan 2.5.2, Proposed Revision 3, "Vibratory Ground Motion"
8.	Appendix A to Proposed Revision 3 to Standard Review Plan 2.5.2, "Probabilistic Consideration in Estimates of Vibratory Ground Motion"
9.	Draft Regulatory Guide DG-1016, Second Proposed Revision 2 to Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation for Earthquakes"
10.	Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions" (Also included are the standards endorsed by the guide).
11.	Draft Regulatory Guide DG-1018, "Restart of a Nuclear Power Plant Shut Down Due To a Seismic Event"
12.	Draft Regulatory Analysis, Proposed Revision of 10 CFR Part 100, Appendix A
13.	Draft Environmental Assessment and Finding of No Significant Impact, Proposed Revision of 10 CFR Part 100, Appendix A.

PROPOSED REVISION OF

APPENDIX A,
"SEISMIC AND GEOLOGIC SITING CRITERIA FOR NUCLEAR POWER PLANTS"

TO

10 CFR PART 100,
"REACTOR SITING CRITERIA"

TABLE OF CONTENTS
PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

10 CFR PART 100, APPENDIX B

REDUCED TEXT

McMullen comments in parentheses
(✓) = agree

10 CFR Part 100, Appendix B

Appendix B -- Seis and Geologic Siting Criteria for Nuclear Power Plants

GENERAL INFORMATION

This appendix applies to applicants who apply for a construction permit on or after [EFFECTIVE DATE OF THIS REGULATION]. Prior to [EFFECTIVE DATE OF THIS REGULATION] applicable seismic and geologic siting criteria, including application to engineering design, for nuclear power plants are contained in Appendix A to Part 100 of this chapter.

No (✓)

Criteria not associated with the selection of the site or establishment of the safe shutdown earthquake ground motion has been placed into Appendix S to Part 50 of this chapter, ~~consistent with the location in the regulation of~~ which contains other design requirements. The effective date of Appendix S is also [EFFECTIVE DATE OF THIS REGULATION]. Taken together, this appendix and Appendix S to Part 50 provide the seismic, geologic and earthquake engineering criteria for nuclear power plants.

Changes that were made to Appendix A to Part 100, as reflected in this appendix, in general, are clarifications and state-of-the-art advancements in the geosciences, for instance, the use of probabilistic analyses. Nuclear power plants licensed before these revisions to the regulation pose no undue risk to public health and safety and there is no present basis for immediate action on any regulatory requirements for these plants.[1]

I. PURPOSE

General Design Criterion 2 of Appendix A to Part 50 of this chapter requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. It is the purpose of these criteria to set forth the principal seismic and geologic considerations which guide the Commission in its evaluation of the suitability of proposed sites for nuclear power plants and the suitability of the plant design bases established in consideration of the seismic and geologic characteristics of the proposed sites.[2]

ok (✓)

These criteria are based on the current geophysical, ~~and~~ geological and seismological information concerning faults and earthquake occurrence and effect. They will be revised as necessary when more complete information becomes available.

---

[1] U.S. Nuclear Regulatory Commission (USNRC), "Policy Statement on Severe Accidents," Federal Register, Vol 50, 32138, August 8, 1985.

X Considerations presented in this regulation are general. Acceptable methods and additional discussion are provided in Regulatory Guides and Standard Review Plan Sections.

Put this at end of line 26

No (either way)

II. SCOPE

These criteria, which apply to nuclear power plants, describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. Geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants are identified.

The investigations described in this appendix are within the scope of investigations permitted by § 50.10(c)(1) of this chapter. (✓)

Each applicant for a construction permit shall investigate all seismic and geologic factors that may affect the design and operation of the proposed nuclear power plant irrespective of whether such factors are explicitly included in these criteria. Both deterministic and probabilistic evaluations shall be conducted. Additional investigations and/or more conservative determinations than those included in these criteria may be required for sites located in areas having complex geology or in areas of high seismicity. If an applicant believes that the particular seismology and geology of a site indicate that some of these criteria, or portions thereof, need not be satisfied, the specific sections of these criteria should be identified in the license application, and supporting data to justify clearly such departures shall be presented.

These criteria do not address investigations of volcanic phenomena required for sites located in areas of volcanic activity. Investigations of the volcanic aspects of such sites will be determined on a case-by-case basis. (✓)

see IV(e)

III. DEFINITIONS

As used in these criteria:

(a) The "magnitude" of an earthquake is a measure of the size of an earthquake and is related to the energy released in the form of seismic waves. "Magnitude" means the numerical value on a standardized scale such as, but not limited to, Moment Magnitude, Surface Wave Magnitude, Body Wave Magnitude or Richter Magnitude scales.

(b) An "expected maximum earthquake (EME)" is the largest earthquake that can reasonably be expected to occur in a given seismic source. The expected maximum earthquake is not necessarily associated with any given return period. Considerable judgement is involved in estimating the magnitude of the expected maximum earthquake.

(c) The "Safe Shutdown Earthquake Ground Motion (SSE)" is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

(1) The integrity of the reactor coolant pressure boundary,

(2) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

(3) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of <u>this part.</u>

Are the guide line exposures going to be in Part 100?

(d) "Operating Basis Earthquake." The definition and application of the Operating Basis Earthquake to engineering design is discussed in Appendix S to Part 50 of this chapter.

(e) A "fault" is a tectonic structure along which differential slippage of the adjacent earth materials has occurred parallel to the fracture plane. A fault may have gouge or breccia between its two walls and includes any associated monoclinal flexure or other similar geologic structural feature.

(f) "Surface faulting" is differential ground displacement at or near the surface caused directly by fault movement and is distinct from nontectonic types of ground disruptions, such as landslides, fissures, and craters.

(g) "Surface deformation" is distortion of soils and rocks at or near ground surface by the processes of folding, faulting, compression or extension as a result of various earth forces. Tectonic surface deformation is associated with earthquake processes.

(h) A "seismic source" is a general term referring to both seismogenic sources and capable tectonic sources.

(should come out)

(i) A "seismogenic source" is a portion of the earth's crust which is assumed to have uniform earthquake potential (same expected maximum earthquake and frequency of recurrence) distinct from the earthquake potential of the surrounding area. A seismogenic source is not expected to cause surface displacements. Seismogenic sources cover a wide range of possibilities from a well-defined tectonic structure to simply a large region of diffuse seismicity (seismotectonic province) thought to be characterized by the same earthquake recurrence model. A seismogenic source is also characterized by its envolvement in the current tectonic regime as reflected in the Quaternary (approximately the last 2 million years).

(j) A "capable tectonic source" is a tectonic structure which can generate both earthquakes and tectonic surface deformation such as faulting or folding at or near the surface in the present seismotectonic regime. It is characterized by at least one of the following characteristics:

(1) Presence of surface or near surface deformation of recurring nature of landforms or geologic deposits within the last 500,000 years or at least once in the last 50,000 years.

(2) A reasonable association with one or more large earthquakes or sustained earthquake activity which are usually accompanied by significant surface deformation.

(3) A structural association with a capable tectonic source according to characteristics (1) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

In some cases, the geologic evidence of past activity at or near the ground surface along a particular capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the structure is a capable tectonic source within this definition.

Notwithstanding the foregoing paragraphs III(j) (1), (2) and (3), structural association of a structure with geologic structural features which are geologically old (at least pre-Quaternary) such as many of those found in the Eastern region of the United States shall, in the absence of conflicting evidence, demonstrate that the structure is not a capable tectonic source within this definition. ← OK (✓)

(k) A "response spectrum" is a plot of the maximum responses (acceleration, velocity or displacement) of a family of idealized single-degree-of-freedom damped oscillators against natural frequencies (or periods) of the oscillators to a specified vibratory motion input at their supports.

IV. REQUIRED INVESTIGATIONS

The geological, seismological and engineering characteristics of a site and its environs shall be investigated in sufficient scope and detail to permit an adequate evaluation of the proposed site, and to provide sufficient information to support both probabilistic and deterministic determinations required by these criteria and to permit adequate engineering solutions to actual or potential geologic and seismic effects at the proposed site. The size of the region to be investigated and the type of data pertinent to the investigations shall be determined by the nature of the region surrounding the proposed site. The investigations shall be carried out by a review of the pertinent literature and field investigations as identified in paragraphs (a) through (d) of this section.

(↓) Leave in adds clarity (yes)

(a) Vibratory Ground Motion

The purpose of the investigations is to obtain information needed to describe the Safe Shutdown Earthquake vibratory ground motion. The seismic sources (capable tectonic sources and seismogenic sources) in the site region shall be identified and evaluated ~~and the expected maximum earthquake associated with each source shall be assessed. The ground motion at the site shall be estimated using the expected maximum earthquakes for those seismic sources which could cause significant ground motion at the site.~~ e

covered ~~[illegible]~~ by V(a) + V(b)

(b) Tectonic Surface Deformation

?

The purpose of the investigations is to determine whether or not there is the potential for tectonic surface deformation near ~~the site and, if so,~~ to what extent the nuclear power plant needs to be designed for these occurrences. Sites should not show evidence at or near the surface of tectonic deformation or local moderate to large earthquakes caused by Quaternary fault movement. The potential for surface tectonic deformation is defined by an evaluation of the regional and local geology and

in Part 50

OK

(should be left as is) (✓)

seismicity.

(c) Non-Tectonic Deformation

Paragraph (b) concerns investigations required for tectonic surface deformation which can occur coseismically. There are, however, other surface deformations not directly attributable to tectonics such as those associated with subsidence or collapse as in karst terrane, glacially induced offsets, and growth faulting. These phenomena can represent significant surface displacement hazards to a site, but can in many cases be monitored, controlled, or mitigated by engineering, or it can be demonstrated that conditions that were the cause of the displacements no longer exist. Thorough geological and geophysical investigations shall be carried out to identify and define nontectonic deformation features and, where possible, distinguish them from tectonic surface displacements. If such distinction is not possible, the questionable features shall be treated as tectonic deformation.

(d) Seismically Induced Floods and Water Waves

For coastal sites, the potential for nearby and distant tsunamis that could affect the site must be assessed. Included in this assessment is also the determination of the potential for undersea slides that could generate tsunamis. Information regarding distant and locally generated waves or tsunamis, which have affected the site, and available evidence of runup and drawdown associated with these events shall be analyzed. Local features of coastal or undersea topography which could modify tsunami runup or drawdown must be considered. For sites located near lakes or rivers, analyses shall include the potential for seismically induced floods or water waves, as, for example, from the failure during an earthquake of a dam upstream or from slides of earth or debris into a nearby lake. ~~Both deterministic and probabilistic analyses shall be used to assess these hazards~~..

(e) The purpose of the investigation is to ensure the site does not have potential volcanic hazards that would adversely affect the safe operation of the nuclear power plant

ok (✓)

V. SEISMIC AND GEOLOGIC DESIGN BASES

(a) Determination of the Expected Maximum Earthquake

For each seismogenic and capable tectonic source identified in part IV, the expected maximum earthquake shall be evaluated using both deterministic and probabilistic approaches. As a minimum the expected maximum earthquake shall be the maximum historical earthquake in each source. The uncertainty in determining the expected maximum earthquakes shall be accounted for in the probabilistic analysis. For each source the expected maximum earthquake is the mean estimate derived from a distribution of maximum magnitude earthquakes.

(b) Determination of the Ground Motion from the Expected Maximum Earthquake

ok (✓)

The ground motion at the site shall be estimated from the expected maximum earthquake associated with each source which could potentially affect the site. Appropriate models including local site conditions, shall be used to account for uncertainty in estimating the ground motion for the site. ~~For the case when the site is not located within a particular~~ For seismogenic or capable tectonic sources the expected maximum earthquake shall be located at the point of the closest

ok (✓)

estimates (✓)

in the ground motion (✓)

approach of the source to the site. For the case when the site is located within a seismogenic source, the expected maximum earthquake will be located in the vicinity of the site. The uncertainty shall be accounted for by using the mean plus one standard deviation (84th percentile) of the ~~composite of the ground motion~~s determined ~~in Paragraph V(b)~~. It is defined by both horizontal and vertical free-field ground motion response spectra at the free ground surface or hypothetical rock outcrop. for the site

Stated in the R.G

(c) Determination of Earthquake Ground Motion for the Seismic Design Basis

The Safe Shutdown Earthquake Ground Motion is determined by response spectra developed from the envelope of the composite of the ground motions determined in Paragraph V(b). Deterministic and probabilistic seismic hazard analyses shall be used to assess the adequacy of the Safe Shutdown Earthquake Ground Motion. The probability of exceeding the Safe Shutdown Earthquake Ground Motion is considered acceptably low if it is at least comparable to that of the majority of operating nuclear power plants.

The horizontal ~~peak~~ ground motion ~~acceleration~~ of the Safe Shutdown Earthquake ~~Ground Motion~~ shall be at least 0.1g with an appropriate response spectrum at the foundation ~~level~~ of the structures

(d) Determination of Need to Design for Surface Tectonic and Non-Tectonic Deformation

Where it is determined, based on geological, seismological and geophysical investigations, that surface deformation need not be taken into account in the design of a nuclear power plant, sufficient data to clearly justify that determination shall be provided in the license application. Where it is determined that surface deformation shall be taken into account in the design, assurance shall be provided that in the event of such deformation, those structures, systems and components necessary for safety shall remain functional. BELONGS IN PART 50

(sufficient data to support a design basis for surface faulting shall be provided)

(a statement is needed saying what to do if surface faulting is found)

(e) Determination of Design Bases for Seismically Induced Floods and Water Waves

(suggested rewrite)

The size of seismically induced floods and water waves which could affect a site from either locally or distantly generated seismic activity shall be determined, taking into consideration the results of the investigation required by paragraph (d) of section IV.

(f) Determination of Other Design Conditions

(1) Soil Stability. Vibratory ground motion associated with the Safe Shutdown Earthquake Ground Motion can cause soil instability due to ground disruption such as fissuring, lateral displacement, differential settlement, and liquefaction, which is not directly related to surface faulting. Geological features which could affect the foundations of the proposed nuclear power plant structures shall be evaluated, taking into account the information concerning the physical properties of materials underlying the site and the effects of the Safe Shutdown Earthquake Ground Motion.

The SSE horizontal ground motion at the foundation of the structures shall be an appropriate resp. spectrum with a zero period acceleration of

(2) Slope stability. Stability of all slopes, both natural and artificial, the failure of which could adversely affect the nuclear power plant, shall be considered. An assessment shall be made of the potential effects of erosion or deposition and of combinations of erosion or deposition with seismic activity, taking into account information concerning the physical properties of the materials underlying the site and the effects of the Safe Shutdown Earthquake Ground Motion.

(3) Cooling water supply. Assurance of adequate cooling water supply for emergency and long-term shutdown decay heat removal shall be considered in the design of the nuclear power plant, taking in to account information concerning the physical properties of the materials underlying the site and the effects of the Safe Shutdown Earthquake Ground Motion and the design basis for tectonic and nontectonic surface deformation . Consideration of river blockage or diversion or other failures which may block the flow of cooling water, coastal uplift or subsidence, or tsunami runup and drawdown, and failure of dams and intake structures shall be included in the evaluation where appropriate.

(4) Distant structures. Those structures which are not located in the immediate vicinity of the site but which are safety related shall be designed to withstand the effect of the Safe Shutdown Earthquake Ground Motion and the design basis for surface faulting determined on a comparable basis to that of the nuclear power plant, taking into account the material underlying the structures and the different location with respect to that of the site.

VI. APPLICATION TO ENGINEERING DESIGN

Pursuant to the seismic and geologic design basis requirements of paragraphs v(a) through (d), applications to engineering design are contained in Appendix S to Part 50 of this chapter for the following areas:

(a) Vibratory ground motion

  (1) Safe Shutdown Earthquake Ground Motion

  (2) Operating Basis Earthquake

  (3) Required Plant Shutdown

  (4) Required Seismic Instrumentation

(b) Surface Tectonic Deformation

(c) Seismically Induced Floods and Water Waves and Other Design Conditions.

10 CFR PART 50, APPENDIX S

REDUCED TEXT

10 CFR Part 50, Appendix S

Appendix S - Earthquake Engineering Criteria for Nuclear Power Plants

GENERAL INFORMATION

This appendix applies to applicants who apply for a construction permit on or after [EFFECTIVE DATE OF THIS REGULATION]. Prior to [EFFECTIVE DATE OF THIS REGULATION], applicable earthquake engineering criteria for nuclear power plants are contained in Section VI of Appendix A to Part 100 of this chapter.

Criteria associated with the selection of the site or establishment of the safe shutdown earthquake ground motion ~~is~~ are (✓) located in Appendix B to Part 100 of this chapter, consistent with the location in the regulation of other siting requirements. The effective date of Appendix B is also [EFFECTIVE DATE OF THIS REGULATION]. Taken together, this appendix and Appendix B to Part 100 provide the seismic, geologic and earthquake engineering criteria for nuclear power plants.

Changes that were made to Appendix A to Part 100, as reflected in this appendix, in general, are clarifications and state-of-the-art advancements in earthquake engineering. Consistent with Appendix B to Part 100, this appendix is general in nature with more detailed information contained in supporting regulatory guides or standard review plan sections. Nuclear power plants licensed before these revisions to the regulation pose no undue risk to public health and safety and there is no present basis for immediate action on any regulatory requirements for these plants.[1]

IV (✓)

I. INTRODUCTION

Each applicant for a construction permit is required by §50.34(a)(12) and General Design Criterion 2 of Appendix A to this Part to design nuclear power plant structures, systems, and components important to safety to withstand the effects of natural phenomena, such as earthquakes, without loss of capability to perform their safety functions. Also, a condition of all operating licenses for nuclear power plants, as specified in §50.54(ee), is plant shutdown if the critera in Paragraph (a)(3) of this appendix are exceeded. The investigations required to obtain the geologic and seismic data necessary to determine site suitability are described in Appendix B to Part 100 of this chapter. Also identified are the geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants. (✓)

It is the purpose of these criteria to set forth the principal considerations which guide the Commission in its evaluation of the suitability of the plant design bases established in consideration of the seismic event.

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[1] U.S. Nuclear Regulatory Commission (USNRC), "Policy Statement on Severe Accidents," Federal Register, Vol 50, 32138, August 8, 1985.

design basis requirements No(✓)

seismic and geologic

II. SCOPE

~~These criteria~~, which apply to nuclear power plants, provide reasonable assurance that a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public.

The evaluations described in this appendix are within the scope of investigations permitted by §50.10(c)(1) of this chapter.

NOT USED IN PART 50

III. DEFINITIONS

As used in these criteria:

No(✓)

(a) An "expected maximum earthquake (EME)" is the largest earthquake that can reasonably be expected to occur in a given seismic source. The expected maximum earthquake is not necessarily associated with any given return period. Considerable judgement is involved in estimating the magnitude of the expected maximum earthquake.

(b) The "Safe Shutdown Earthquake Ground Motion (SSE)" is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

(1) The integrity of the reactor coolant pressure boundary,

(2) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

(3) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of Part 100 of this chapter.

(c) The "Operating Basis Earthquake" produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional.

(d) A "response spectrum" is a plot of the maximum responses (acceleration, velocity or displacement) of a family of idealized single-degree-of-freedom damped oscillators against natural frequencies (or periods) of the oscillators to a specified vibratory motion input at their supports.

IV. APPLICATION TO ENGINEERING DESIGN

The following are pursuant to the seismic and geologic design basis requirements of paragraphs V(a) through (f) of Appendix B to Part 100 of this chapter:

(a) Vibration Ground Motion

(1) Safe Shutdown Earthquake Ground Motion. The Safe Shutdown Earthquake Ground Motion shall be defined by free-field ground motion response spectra at the free ground surface or hypothetical rock outcrop. In view of the limited data available on vibratory ground motions of strong earthquakes, it usually will be appropriate that the design response spectra be smoothed spectra developed from a series of response spectra related to the vibratory motions caused by more than one earthquake. The horizontal peak ground acceleration of the Safe Shutdown Earthquake Ground Motion shall be at least 0.1g with an appropriate response spectrum at the foundation level.

The nuclear power plant shall be designed so that, if the Safe Shutdown Earthquake Ground Motion occurs, certain structures, systems, and components will remain functional. These structures, systems, and components are those necessary to assure (i) the integrity of the reactor coolant pressure boundary, (ii) the capability to shut down the reactor and maintain it in a safe condition, or (iii) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of Part 100 of this chapter. In addition to seismic loads applicable concurrent normal operating, functional and accident-induced loads shall be taken into account in the design of these safety-related structures, systems, and components. The design of the nuclear power plant shall also take into account the possible effects of the Safe Shutdown Earthquake Ground Motion on the facility foundations by ground disruption, such as fissuring, lateral displacement, differential settlement, liquefaction, and landsliding, as required in Paragraph V(f) of Appendix B to Part 100 of this chapter.

The required safety functions of structures, systems and components shall be insured during and after the vibratory ground motion associated with the Safe Shutdown Earthquake Ground Motion through suitable analysis, testing or qualification method.

The evaluation shall take into account soil-structure interaction effects and the expected duration of vibratory motion. It is permissible to design for strain limits in excess of yield strain in some of these safety-related structures, systems, and components during the Safe Shutdown Earthquake Ground Motion and under the postulated concurrent conditions, provided that the necessary safety functions are maintained. Such inelastic analysis should be accompanied by analytic and experimental justifications. (seems like a good addition)

(2) Operating Basis Earthquake. The Operating Basis Earthquake shall be defined by response spectra. All structures, systems, and components of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional and within applicable stress and deformation limits when subjected to the effects of the vibratory motion of the Operating Basis Earthquake in combination with normal operating loads, The value of the OBE is set according to one of the following choices (✓.)

i. If the Operating Basis Earthquake is set at one-third of the

Comment
Table 1 of RG1.61 provides two damping values - one for OBE and one for SSE, indicating that damping is displacement dependent. This means that the structure is not responding elastically. This doesn't guarantee that 1/3 the SSE is in the elastic range.

Safe Shutdown Earthquake Ground Motion level, the function of the Operating Basis Earthquake, as stated above, can be satisfied without the applicant performing any explicit response analyses.[2]

ii. If an applicant chooses an Operating Basis Earthquake greater than one-third the Safe Shutdown Earthquake Ground Motion an explicit suitable analysis and design shall be performed to demonstrate that the function of the Operating Basis Earthquake, as stated above, is satisfied. The design shall take into account soil-structure interaction effects and the expected duration of vibratory ground motion.

(3) Required Plant Shutdown. If vibratory ground motion exceeding that of the Operating Basis Earthquake occurs, shutdown of the nuclear power plant will be required.[3] The value of the Operating Basis Earthquake is set pursuant to Paragraph IV(a)(2)(i) or (ii) of this appendix. Prior to resuming operations, the licensee will be 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. ?

(4) Required Seismic Instrumentation. Suitable instrumentation shall be provided so that the recorded seismic response of nuclear power plant features important to safety can be evaluated promptly to permit comparison of such response with that used as the design basis. Such a comparison is needed to decide whether the plant can continue to be operated safely and to permit such timely action as may be appropriate.

(b) Surface Deformation.

The design basis for surface deformation shall be taken into account in the design of the nuclear power plant by providing reasonable assurance that in the event of such deformation certain structures, systems, and components will remain functional. These structures, systems, and components are those necessary to assure (i) the integrity of the reactor coolant pressure boundary, (ii) the capability to shut down the reactor and maintain it in a safe shutdown condition, or (iii) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of Part 100 of this chapter. In addition to seismic loads, including aftershocks, applicable concurrent functional and accident-induced loads shall be taken into account in the design of such safety features. (accompanying surface deformation) ~~The design provisions shall be based on an assumption that~~

What does this have to do with the Surface deformation?

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[2] A seperate analyses to compute structure, equipment and piping response associated with the Operating Basis Earthquake is not required. Applicable design provisions associated with this Operating Basis Earthquake, for instance, fatigue, are discussed in regulatory guides. ✓

[3] Plant shutdown criteria are provided in a regulatory guide.

the design basis for surface faulting can occur in any direction and azimuth and under any part of the nuclear power plant unless evidence indicates this assumption is not appropriate, and shall take into account the estimated rate at which the surface faulting may occur.

(c) Seismically Induced Floods and Water Waves and Other Design Conditions.

The design basis for seismically induced floods and water waves from either locally or distantly generated seismic activity and other design conditions determined pursuant to Paragraphs V(e) and (f) of Appendix B to Part 100 of this chapter shall be taken into account in the design of the nuclear power plant so as to prevent undue risk to the health and safety of the public.

D ✓

DRAFT FERERAL REGISTER NOTICE

PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

NUCLEAR REGULATORY COMMISSION

10 CFR PARTS 50, 52 AND 100

RIN [TO BE ASSIGNED BY RPB]

Seismic Siting and Engineering Criteria for Nuclear Power Plants

AGENCY: Nuclear Regulatory Commission.

Action: Proposed rule.

SUMMARY: The Nuclear Regulatory Commission proposes to amend its regulations to update the ~~criteria in regard to~~ seismic siting and engineering criteria for nuclear power plants. (✓) Experience gained in the application of the procedures and methods set forth in the current regulation, the difficulties encountered, and the rapid advancement in the state-of-the-art of earth sciences have made it necessary to update the present criteria which were issued in 1973. The proposed regulations reflect industry design practices and the associated staff review procedures that have evolved since the regulation was issued. The proposed regulatory action is applicable only to applicants that apply for a construction permit on or after the effective date of the regulations.

DATE: Comment period expires _ ________________. Comments received after this date will be considered if it is practical to do so, but the Commission is able to assure consideration only for comments received on or before this date.

ADDRESSES: Mail written comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch.

Deliver comments to: 11555 Rockville Pike, Rockville, Maryland, between 7:45 am and 4:15 pm federal workdays.

Copies of the regulatory analysis, the environmental assessment and finding of no significant impact, and comments received may be examined at: the NRC Public Document Room at 2120 L Street NW. (Lower Level), Washington, DC.

FOR FURTHER INFORMATION CONTACT: Dr. Andrew J. Murphy, Office of Nuclear

Regulatory Research, Mail Stop NL/S-217A, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3860.

SUPPLEMENTAL INFORMATION

I. Background

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Siting Criteria," was originally issued as a proposed rule on November 25, 1971 (36 FR 22601); published as a final rule on November 13, 1973 (38 FR 31279); and became effective on December 13, 1973. There have been two amendments to 10 CFR Part 100, Appendix A. The first amendment, issued November 27, 1973 (38 FR 32575), corrected 38 FR 31279 by adding the legend under the diagram. The second amendment resulted from a petition for rule making (PRM 100-1) requesting that an opinion interpreting and clarifying Appendix A with respect to the determination of the Safe Shutdown Earthquake be issued. A notice of filing of the petition was published on May 14, 1975 (40 FR 20983). The substance of the petitioner's proposal was accepted and published as an immediately effective final rule on January 10, 1977 (42 FR 2052).

II. Objectives

The objectives of the proposed regulatory action are:

1. Provide a stable regulatory basis for seismic and geologic siting and applicable earthquake engineering design of nuclear power plants that will avoid licensing delays due to unclear regulatory requirements and provide a flexible structure to permit consideration of new technical understandings, and

2. Have the revision to the regulation completed prior to the receipt of an early site application.

III. Genesis

The proposed regulatory actions reflect changes intended to (1) benefit from the experience gained in applying the existing regulation; (2) resolve interpretative questions; (3) provide needed regulatory flexibility to incorporate state-of-the-art improvements in the geosciences and earthquake engineering; (4) simplify the text language to a more "plain English" text; and (5) acknowledge various internal staff and industry comments.

Major points associated with the revision of the regulations are:

1. The proposed regulatory action will apply to applicants who apply for a construction permit on or after the effective date of the revised regulation, and

2. Criteria not associated with the selection of the site or establishment of the safe shutdown earthquake have been placed into Part 50 consistent with the location in the regulation of other design requirements.

Since the revision to the regulation will not be backfit, the licensing bases for existing nuclear power plants must remain in the regulation. Therefore, the revised regulation on seismic and geologic siting will be designated 10 CFR Part 100, Appendix B. In addition, earthquake engineering criteria will be located in 10 CFR Part 50, Appendix S. Since Appendix S is not self initiating, applicable sections of Part 50 (§50.34, §50.54) are revised to reference Appendix S. Also, Parts 52 and 100 (Paragraph 52.17(a)(1)(vi) and Paragraph 100.10(c)(1)) are revised to note Appendix B to Part 100.

IV. Alternatives

The first alternative considered was not to initiate a rulemaking proceeding. This is not an acceptable alternative. Although the siting related issues associated with the current generation of nuclear power plants are completed or nearing completion there is a renewed sense of urgency to initiate the proposed regulatory action in light of the current and future staff review of advanced reactor seismic design criteria. The current regulation has created difficulty for applicants and the staff in terms of inhibiting flexibility in applying basic principles to new situations and the use of evolving methods of analysis in the licensing process.

A second alternative considered was the deletion of the existing regulation (Appendix A to Part 100). This is not an acceptable alternative since it is the licensing bases for many of the operating nuclear power plants and others that are in various stages of obtaining their operating license.

A third alternative considered was the replacement of the regulation with a regulatory guide. This is not acceptable because a regulatory guide is non-mandatory. The staff believes that there could be an increase in exposure to the public if the siting and earthquake engineering criteria were non-mandatory.

The present approach of revising the regulation was chosen as the best alternative, benefitting all. The public will benefit from a clearer, more uniform and consistent licensing process subject to fewer interpretations. The NRC staff will benefit from improved regulatory implementation (both technical and legal), fewer interpretive debates, and increased regulatory flexibility. Applicants will derive the same benefits in addition to avoiding licensing delays due to unclear regulatory requirements. A revision to Appendix A would increase the efficiency of regulatory actions associated with any resurgence of licensing activity.

V. Major Changes

The following are major changes associated with this rulemaking:

1. Level of Detail. The level of detail in the proposed regulations has been limited. The proposed regulations identify requirements; detailed guidance, that is, procedures acceptable to the staff for meeting the requirements, have been removed and placed in regulatory guides or standard review plan sections

2. Greater Flexibility. The proposed regulations provide a flexible

structure that will permit consideration of new technical understandings and state of the art advancements.

3. Interpretations. Changes have been made to resolve past questions of interpretation. As an example, the definitions and required investigations sections of the proposed regulations have been significantly changed eliminating or modifying phrases that were more applicable to only the western United States.

4. Text Clarification. The proposed regulations use more explicit terminology. For instance, the Safe Shutdown Earthquake (SSE) is now referenced as the Safe Shutdown Earthquake Ground Motion (SSE). Associated changes within the text highlight that the ground motion used as the design basis is not associated with a single earthquake but a composite of many expected earthquakes.

5. Current practices will be reflected. The proposed regulations reflect industry design practices and the associated staff review procedures that have evolved since the initial regulation (Appendix A to Part 100) was issued in 1973. Many of these practices and procedures were incorporated into the revision of Standard Review Plan Sections 2.5.2, 3.7.1, 3.7.2 and 3.7.3 associated with the resolution of Unresolved Safety Issue (USI) A-40, "Seismic Design Criteria."

6. Seismic Sources. Better definition of seismic source types and streamlined procedures for their use in specifying ground motion expected at a plant site will eliminate what has been a major source of licensing delays.

7. Probabilistic Analyses. The use of probabilistic techniques will also permit easier handling of uncertainties associated with the process of defining relevant seismic sources and ground motions associated with them.

8. Eliminating the many facets of the Operating Basis Earthquake (OBE). The OBE is now only associated with the functionality of structures, equipment and components. Previously, the OBE was also associated with a likelihood of occurrence and a minimum percentage of the Safe Shutdown Earthquake (SSE). In some cases, for instance, piping, the multi-facets of the OBE made it possible for it to have more design significance than the SSE.

9. Potential for Reduced Analyses. Applicants that choose to set the Operating Basis Earthquake at one-third of the Safe Shutdown Earthquake Ground Motion can satisfy OBE functionality requirements without performing any explicit response analysis. Applicants have the option of selecting an OBE greater than one-third the SSE; however, a suitable analysis and design shall be performed.

10. Required Plant Shutdown. The revised regulations state in Part 50, consistent with other conditions of licenses, that plant shutdown is required if the Operating Basis Earthquake is exceeded. Specific guidance as to what

constitutes an OBE exceedance, thereby requiring plant shutdown is provided. In addition, guidance for an orderly plant shutdown and the re-starting of a plant that has been shut down due to earthquake ground motion is provided.

VI. Related Regulatory Guides and Standard Review Plan Section

The notice of availability of the following draft regulatory guides and standard review plan section is being published elsewhere in this Federal Register:

1. DG-1015, "Identification and Characterization of Seismic Sources." The draft guide provides general guidance and recommendations, describes acceptable procedures and provides a list of references that present acceptable methodologies to identify and characterize capable tectonic sources and seismogenic sources.

2. DG-1016, Second Proposed Revision 2 to Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation for Earthquakes." The draft guide describes seismic instrumentation type and location, operability, characteristics, installation, actuation, and maintenance that are acceptable to the NRC staff.

3. DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions." The draft guide provides guidelines that are acceptable to the NRC staff for a timely evaluation of the recorded seismic instrumentation data and to determine whether or not plant shutdown is required.

4. DG-1018, "Restart of a Nuclear Power Plant Shut Down Due to a Seismic Event." The draft guide provides guidelines that are acceptable to the NRC staff for performing inspections and tests of nuclear power plant equipment and structures prior to restart of a plant that has been shut down due to a seismic event.

5. Draft Standard Review Plan Section 2.5.2, Proposed Revision 3 "Vibratory Ground Motion." The draft describes procedures to assess the ground motion potential of seismic sources at the site and to assess the adequacy of the Safe Shutdown Earthquake Ground Motion seismic design.

VII. Future Regulatory Action

Several existing regulatory guides will be revised to incorporate editorial changes, or maintain the existing design or analysis philosophy . These guides will be issued coincident with the publication of the final regulations:

The following regulatory guides will be revised to incorporate editorial changes, for instance, reference new paragraphs in Appendix B to Part 100 or Appendix S to Part 50:

1. 1.29, "Seismic Design Classification"
2. 1.57, "Design Limits and Loading Combinations for Metal Primary Containment System Components"
3. 1.59, "Design Basis Floods for Nuclear Power Plants"
4. 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"
5. 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes"
6. 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis"
7. 1.102, "Flood Protection for Nuclear Power Plants"
8. 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes"
9. 1.122, "Development of Floor Response Spectra for Seismic Design of Floor-Supported Equipment or Components"

The following regulatory guides will be revised to maintain existing design or analysis philosophy, for instance, change OBE to 1/2 SSE:

1. 1.27, "Ultimate Heat Sink for Nuclear Power Plants"
2. 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants"
3. 1.124, "Service Limits and Loading Combinations for Class 1 Liner-Type Component Supports"
4. 1.130, "Service Limits and Loading Combinations for Class 1 Plate-and-Shell-Type Component Supports"
5. 1.132, "Site Investigations for Foundations of Nuclear Power Plants"
6. 1.138, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants"
7. 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)"
8. 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants"

During the revision of the regulatory guides cited above, if additional changes are made, the applicable guide(s) will be distributed for public comment.

VIII. Finding of No Significant Environmental Impact: Availability

The Commission has determined under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in Subpart A of 10 CFR Part 51, this rule, if adopted, would not be a major Federal action significantly affecting the quality of the human environment and therefore an environmental impact statement is not required. The amendment of Appendix A to 10 CFR Part 100 as stated in 10 CFR Part 100, Appendix B and 10 CFR Part 50, Appendix S reflect current licensing practice and will not change the radiological environmental impact offsite. Further, the Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants, published August 8, 1985 (50 FR 32138) affirms the Commission's belief that a new design for a nuclear power plant can be shown to be acceptable for severe accident concerns if the criteria and procedural requirements cited in 50 FR 32138 are met. Onsite occupational radiational exposure associated with inspection and maintenance will not change. These activities are principally associated with seismic instrumentation. The proposed amendments do not affect non-radiological plant effluents and have no other environmental impact. The environmental assessment and finding of no significant impact on which this determination is based are available for inspection at the NRC Public Document Room, 2120 L Street, NW. (Lower Level), Washington, DC. Single copies of the environmental assessment and finding of no significant impact are available from Dr. Andrew J. Murphy, Office of Nuclear Regulatory Research, Mail Stop NL/S-217A, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3860.

IX. Paperwork Reduction Act Statement

This proposed rule does not contain a new or amended information collection requirement subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). Existing requirements were approved by the Office of Management and Budget approval number 3150-0093.

X. Regulatory Analysis

The Commission has prepared a draft regulatory analysis on this proposed regulation. The analysis examines the costs and benefits of the alternatives considered by the Commission. The draft analysis is available for inspection in the NRC Public Document Room, 2120 L Street, NW. (Lower Level), Washington, DC. Single copies of the environmental assessment and finding of no significant impact are available from Dr. Andrew J. Murphy, Office of Nuclear Regulatory Research, Mail Stop NL/S-217A, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3860.

The Commission requests public comment on the draft regulatory analysis. Comments on the draft analysis may be submitted to the NRC as indicated under the ADDRESSES heading.

XI. Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, (5 U.S.C. 605(b)), the Commission certifies that this rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. This proposed rule affects only the licensing and operation of nuclear power plants. The companies that own these plants do not fall within the scope of the definition of "small entities" set forth in the Regulatory Flexibility Act or the Small Business Size Standard set out in regulations issued by the Small Business Administration at 13 CFR Part 121.

XII. Backfit Analysis

The NRC has determined that the backfit rule, 10 CFR 50.109, does not apply to this proposed rule, and therefore, that a backfit analysis is not required for this proposed rule, because these amendments do not involve any provisions which would impose backfits as defined in 10 CFR 50.109(a)(1).

XIII. Electronic Format Submittal of Public Comments

The comment resolution process will be improved if each comment is identified to the document title, section heading and paragraph number to which it responds. Commenters may submit, in addition to the original paper copy, a copy of the letter in an electronic format on IBM PC DOS compatible 3.5 or 5.25 inch double sided double density (DS/DD) diskettes. Data files should be provided in ASCII code, IBM Revisable-Form-Text Document Content Architecture (RFT/DCA) format (if formated text is required) or Wordperfect (including version 5.1).

XIV. List of Subjects in 10 CFR Part 50

Antitrust, Classified information, Fire protection, Incorporation by reference, Intergovernmental relations, Nuclear power plants and reactors, Penalty, Radiation protection, Reactor siting criteria, Reporting and recordkeeping requirements.

XV. List of Subjects in 10 CFR Part 52

Administrative practice and procedure, Antitrust, Backfitting, Combined license, Early site permit, Emergency planning, Fees, Inspection, Limited work authorization, Nuclear power plants and reactors, Probabilistic risk assessment, Prototype, Reactor siting criteria, Redress of site, Reporting and recordkeeping requirements, Standard design, Standard design certification.

XVI. List of Subjects in 10 CFR Part 100

Nuclear power plants and reactors, Reactor siting criteria.

For the reasons set out in the preamble and under the authority of the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and 5 U.S.C. 553, the NRC is proposing to adopt the following amendments to 10 CFR Parts 50, 52 and 100.

PART 50 - DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES

1. The authority citation for Part 50 continues to read as follows:

AUTHORITY: Secs. 102, 103, 104, 105, 161, 182, 183, 186, 68 Stat. 936, 937, 938, 948, 953, 954, 955, 956, as amended, sec. 234, 83 Stat. 1244, as amended (42 U.S.C. 2132, 2133, 2134, 2135, 2201, 2232, 2233, 2236, 2239, 2282); secs. 201, as amended, 202, 206, 88 Stat. 1242, as amended, 1244, 1246, (42 U.S.C. 5841, 5842, 5846).

Section 50.7 also issued under Pub. L. 95-601, sec. 10, 92 Stat. 2951 (42 U.S.C. 5851). Sec. 50.10 also issued under secs. 101, 185, 68 Stat. 936, 955 as amended (42 U.S.C. 2131, 2235), sec. 102, Pub. L. 91-190, 83 Stat. 953 (42 U.S.C. 4332). Sections 50.13 and 50.54(dd) also issued under sec. 108, 68 Stat. 939, as amended (42 U.S.C. 2138). Sections 50.23, 50.35, 50.55, and 50.56 also issued under sec. 185, 68 Stat. 955 (42 U.S.C. 2235). Sections 50.33a, 50.55a and Appendix Q also issued under sec. 102, Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332). Sections 50.34 and 50.54 also issued under sec. 204, 88 Stat. 1245 (42 U.S.C. 5844). Sections 50.58, 50.91 and 50.92 also issued under Pub. L. 97-415, 96 Stat. 2073 (42 U.S.C. 2239). Section 50.78 also issued under sec. 122, 68 Stat. 939 (42 U.S.C. 2152). Sections 50.80 through 50-81 also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). Section 50.103 also issued under sec. 108, 68 Stat. 939, as amended (42 U.S.C. 2138). Appendix F also issued under sec. 187, 68 Stat. 955 (42 U.S.C. 2237).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), §§ 50.46(a) and (b), and 50.54(c) are issued under sec. 161b, 68 Stat. 948, as amended (42 U.S.C. 2201(b); §§ 50.7(a), 50.10(a)-(c), 50.34 (a) and (e), 50.44(a)-(c), 50.46(a) and (b), 50.47(b), 50.48(a), (c),(d), and (e), 50.49(a), 50.54(a)(i), (i)(1), (l)-(n), (p), (q), (t), (v), and (y), 50.55(f), 50.55a(a), (c)-(e), (g), and (h), 50.59(c), 50.60(a), 50.62(c), 50.64(b), and 50.80(a) and (b) are issued under sec. 161i, 68 Stat. 949, as amended (42 U.S.C. 2201(i); and §§50.49d, (h), and (j), 50.54(w),(z),(bb),(cc), and (dd), 50.55(e), 50.59(b), 50.61(b), 50.62(d), 50.70(a), 50.71(a)-(c) and (e), 50.72(a), 50.73(a) and (b), 50.74, 50.78, and 50.90 are issued under sec. 161(o), 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

2. In §50.34, paragraph (a)(12) is added to read as follows:

<u>§50.34 Contents of applications; technical information</u>.

(a) * * *

(12) On or after [EFFECTIVE DATE OF THIS REGULATION] applicants who apply for construction permits for nuclear power plants, as partial conformance to

General Design Criteria 2 of Appendix A to this part, shall implement the earthquake engineering criteria in Appendix S of this part. Prior to [EFFECTIVE DATE OF THIS REGULATION], applicable earthquake engineering criteria for nuclear power plants are contained in Section VI of Appendix A to Part 100 of this chapter.

* * * * *

3. In §50.54, paragraph (ee) is added to read as follows:

§50.54 Conditions of licenses.

* * * * *

(ee) For licensee's of nuclear power plants that have implemented the earthquake engineering criteria in Appendix S of this part, plant shutdown will be required if the criteria in Paragraph IV(a)(3) of Appendix S are exceeded.

* * * * *

4. Add Appendix S to read as follows:

* * * * *

Appendix S -- Earthquake Engineering Criteria for Nuclear Power Plants

TEXT OF 10 CFR PART 50, APPENDIX S WILL BE INSERTED HERE

* * * * *

PART 52 - EARLY SITE PERMITS; STANDARD DESIGN CERTIFICATIONS: AND COMBINED LICENSES FOR NUCLEAR POWER PLANTS

5. The authority citation for Part 52 continues to read as follows:

AUTHORITY: Secs. 103, 104, 161, 182, 183, 186, 189, 68 Stat. 936, 948, 953, 954, 955, 956, as amended, sec. 234, 83 Stat. 1244, as amended (42 U.S.C.

2133, 2201, 2232, 2233, 2236, 2239, 2282); secs. 201, 202, 206, 88 Stat. 1242, 1244, 1246, as amended (42 U.S.C. 5841, 5842, 5846).

6. In §52.17, paragraph (vi) is revised to read as follows:
§52.17 Contents of applications.

* * * * *

(vi) The seismic, meteorological, hydrologic, and geologic characteristics of the proposed site (see Appendix A or B, as appropriate, to 10 CFR Part 100);

* * * * *

PART 100 - REACTOR SITE CRITERIA

7. The authority citation for Part 100 continues to read as follows:

AUTHORITY: Secs. 103, 104 161, 182, 68 Stat. 936, 937, 948, 953, as amended (42 U.S.C. 2133, 2134, 2201, 2232); sec. 201, as amended, 202, 88 Stat. 1242, as amended, 1244 (42 U.S.C. 5841, 5842).

8. In §100.10, paragraph c(1) is revised to read as follows:
§100.10 Factors to be considered when evaluating sites.

* * * * *

(c) Physical characteristics of the site, including seismology, meteorology, geology, and hydrology.

(1) On or after [EFFECTIVE DATE OF THIS REGULATION] applicants who apply for construction permits for nuclear power plants shall implement the seismic and geologic siting criteria in Appendix B of this part. Prior to [EFFECTIVE DATE OF THIS REGULATION], applicable seismic and geologic siting criteria are contained in Appendix A of this Part. Both Appendices A and B describe the nature of investigations required to obtain the geologic and seismic data necessary to determine site suitability and to provide reasonable assurance that

a nuclear power plant can be constructed and operated at a proposed site without undue risk to the health and safety of the public. They describe procedures for determining the quantitative vibratory ground motion design basis at a site due to earthquakes and describes information needed to determine whether and to what extent a nuclear power plant need be designed to withstand the effects of surface faulting.

* * * * *

9. Add Appendix B to read as follows:

* * * * *

Appendix B -- Seismic and Geologic Siting Criteria for Nuclear Power Plants

TEXT OF 10 CFR PART 100, APPENDIX B WILL BE INSERTED HERE

* * * * *

Dated at Rockville, Maryland, this __ day of _______, 1991.

For the Nuclear Regulatory Commission.

Sammuel J. Chick,
Secretary of the Commission.

DRAFT REGULATORY GUIDE DG-1015

SEISMIC SOURCES

DRAFT REGULATORY GUIDE DG-1015

IDENTIFICATION AND CHARACTERIZATION OF SEISMIC SOURCES

A. INTRODUCTION

10 CFR Part 100, Appendix B, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," requires that investigations and analyses be performed to identify and evaluate tectonic structures underlying the site and the region surrounding the site, whether buried or expressed at the surface, to determine their seismic potential or their potential for causing surface deformation at the site and, to what extent the nuclear power plant needs to be designed for these hazards. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," requires that structures, systems and components important to safety shall be designed to withstand the effects of natural phenomena. This guide provides general guidance and recommendations, describes acceptable procedures and provides a list of references that present acceptable methodologies to identify and characterize capable tectonic sources and seismogenic sources. Standard Review Plan 2.5.2 describes procedures to assesses the ground motion potential of these seismic sources at the site and to assess the adequacy of the Safe Shutdown Earthquake ~~seismic design~~. ground motion ?

The following are definitions of terms used in this regulatory guide.

1. Seismic Source

A "Seismic Source" is a general term referring to both seismogenic sources and capable tectonic sources.

2. Seismogenic Source

A "seismogenic source" is a portion of the earth's crust which is considered to have uniform seismicity (same expected maximum earthquake and frequency of recurrence) distinct from the seismicity of the surrounding area. A seismogenic source is not necessarily expected to cause surface displacement. Seismo-genic sources cover a wide range of possibilities from a well-defined tectonic structure to simply a large region of

do we need this? It may causing problems with Subduction Zones

?

diffuse seismicity (seismotectonic province) thought to be characterized by the same earthquake recurrence model.

A seismogenic source is also characterized by development and characteristics of the current tectonic regime that is reflected in the Quaternary (approximately the last 2 million years).

?

IS something missing here?? It does not make sense.

3. Capable Tectonic Source

A "capable tectonic source" is a tectonic structure which can generate both earthquakes and deformation such as faulting or folding at or near the surface in the present seismotectonic regime, excluding seismically induced soil deformation such as liquefaction features. It is characterized by at least one of the following characteristics:

(a) Presence of surface or near surface deformation of recurring nature of landforms or geologic deposits within the last 500,000 years or at least once in the last 50,000 years.

(b) A reasonable association with one or more large earthquakes which are generally accompanied by significant surface deformation.

(c) A structural association to a capable tectonic source according to characteristics (a) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

In some cases, the geologic evidence of past activity at or near the ground surface along a particular capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the structure is a capable tectonic source within this definition.

Notwithstanding the foregoing paragraphs, structural association of a structure with geologic structural features which are geologically old (at least pre-Quaternary) such as many of those found in the Eastern region of the

United States shall, in the absence of conflicting evidence, demonstrate that the structure is not a capable tectonic source within this definition.

4. Stable Continental Region

A "stable continental region" (SCR) is comprised of continental crust, including continental shelves, slopes and attenuated continental crust. It excludes active plate boundaries and zones of currently active tectonics directly influenced by plate margin processes. It exhibits no significant deformation associated with the major Mesozoic-to-Cenozoic (last 240 million-years) orogenic belts. It excludes major zones of Neogene (last 25 million years) rifting, volcanism or suturing.

5. Safe Shutdown Earthquake

The "Safe Shutdown Earthquake Ground Motion" is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional.

6. Characteristic Earthquake

Characteristic earthquakes are defined as those earthquakes that are characteristic for a particular area or fault zone. It is observed that segments (sections of a fault or faults that fail during individual earthquakes) of some fault zones fail repeatedly with earthquakes of similar size and in a similar manner. These earthquakes of similar size are called characteristic earthquakes, and the characteristic earthquakes are commonly associated with a recurrence interval that can be determined directly from seismic, paleoseismic, and geological data.

7. Expected Maximum Earthquake (EME)

An "expected maximum earthquake" (EME) is the largest earthquake that can reasonably be expected to occur in a given seismic source. The EME is not necessarily associated with any given return period. Considerable judgment is involved in estimating the magnitude of the EME.

8. Random Earthquakes

Random earthquakes ~~are~~ have been defined as those earthquakes that are not identified with Known seismic sources. They ~~are~~ have sometimes been referred to as "floating earthquakes." This, in probabilistic estimates of earthquake hazard, is also referred to as background seismicity and is commonly not related to specific faults.

In some areas, especially stable continental region (SCR) areas, seismic zones can be delineated, but the causative seismogenic structures cannot. A random earthquake can be assigned to these zones. Random earthquake magnitudes are often determined from historical seismicity and/or by comparing an area to a similar source area for which the seismic hazard is better known. Random earthquakes are usually small to moderate in size and can occur anywhere in a region or area. The larger random earthquakes can have magnitudes in the range of 5 to 6.5, depending on seismotectonic settings. Since the probability of the random earthquake occurring directly under a specific site is very low, the earthquake is sometimes assigned to occur randomly within a prescribed distance from the site (~~i.e. 25km~~ 15 Km).

This belongs in section B 5 c ✓

B. DISCUSSION

1. Purpose of Seismic Sources

The Safe Shutdown Earthquake (SSE) is compared to the expected ground motion from potential future earthquakes around the site of interest. The estimated ground motion at the site from each source depends upon the magnitude of the expected maximum earthquake, distance between ~~the ruptured surface of the causative fault~~ The source and the site, earthquake source parameters such as type of mechanisms, stress conditions (e.g. static and dynamic stress drop), rupture velocity, etc., transmission path, radiation pattern and possible directivity effects and local site soil and rock conditions. The role of seismic sources is to define where the future earthquakes are likely to occur, and provides some acceptable bases to characterize their source parameters, including EME's.

The type, quality and quantity of data needed depends upon the ground motion models deemed most appropriate and particularly for each seismogenic source. In the tectonically active regions, it is likely that more of the data will be available than in the SCR. In active tectonic regions the focus will be on the identification of both capable tectonic sources and seismogenic sources.

In the SCR east of the Rocky Mountains seismogenic source zones play a significant role because of the inability to correlate earthquake activity with known ~~tectonic~~ seismogenic structure. Some seismogenic source zones have been identified in the SCR (i.e. eastern Tennessee, Charleston and New Madrid) but specific tectonic structures have not been defined.

2. Deterministic and Probabilistics Analyses

The revised ~~Appendix A~~ siting regulation states that both deterministic and probabilistic evaluations shall be considered; that is because both approaches have their strengths and weaknesses. The identification of seismogenic sources for both deterministic and probabilistic evaluations of the SSE follow similar paths. The main difference between the two approaches is that in the probabilistic approach, particularly in the SCR, alternative sources are explicitly modeled and an attempt is made to include alternatives in the final assessment. In the deterministic approach alternatives are also evaluated, but alternatives that are considered highly unlikely are eliminated from further evaluation. A dual approach should be used in areas where significant uncertainty exists about the configuration and characterization of the seismogenic sources.

This is not needed here

Put this in section 5

3. Seismic Sources

a. Capable Tectonic Source

(1) General

A capable tectonic source is defined in 10 CFR PART 100 Appendix B as a tectonic structure that can generate both earthquakes and deformation such as faulting or folding at or near the surface in the present seismotectonic regime, excluding seismically induced soil deformation such as liquefaction features. Except for several regions such as Charlevoix, Quebec, eastern Tennessee, Charleston, South Carolina, and the New Madrid Seismic Zone, seismicity in eastern North America is relatively diffuse. In most of the eastern U.S. ~~tectonic~~ seismicity ~~structur~~es at seismogenic depths earthquake~~, as determined from hypocenters~~, apparently bears no relationship to ~~tectonic~~ geologic structures exposed at or near the earth's ~~ground~~ surface. Young faults either do not extend to ~~ground~~ the surface or there is insufficient geologic material of the appropriate age available to date the faults. Seismogenic faults are not always exposed at ground surface in the western U.S. as demonstrated by the blind reverse sources of the 1983 Coalinga and 1988 Whittier Narrows earthquakes. These factors emphasize the need to not only conduct thorough investigations at the ground surface but also to identify structures at seismogenic depths to the extent possible

Investigations of the site and region around the site are necessary to identify capable tectonic sources and determine their potential for generating earthquakes and for causing surface deformation. Where it is determined that surface deformation need not be taken into account, sufficient data to clearly justify the determination should be presented in the license application. The level of detail of investigations should be governed by the current and late Quaternary tectonic regime and the geological complexity of the site and region. A detailed geological investigation including the potential for surface deformation should be carried out within a radius of 5 miles (8 km) around the site. A thorough but less detailed investigation should be accomplished out to a radius of 25 miles (40 km). The regional investigations should extend to a radius of 200 miles (320 km). The area of detailed geological investigations may be larger than a 5-mile radius in regions of late Quaternary activity or historical seismic activity (including instrumental data) or where a site is located near a large capable tectonic source such as a fault zone.

Regional and site information needed to assess the integrity of the site with respect to potential ground motions and surface deformation caused by capable tectonic sources include determination of: (1) the lithologic, stratigraphic, hydrologic, and structural geologic conditions of the site and the area surrounding the site, including its geologic history; (2) geologic evidence of fault offset or other distortion such as folding at or near ground surface at or near the site; and (3) determination of whether or not any faults or other tectonic structures any part of which are within a radius of 5 miles (8km) are capable tectonic sources. This information will be used to evaluate tectonic structures underlying the site, whether buried or expressed at the surface, with regard to their potential for causing surface deformation at or near the site. The evaluation should consider the possible effects caused by human activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the loading effects of dams or reservoirs.

To identify and characterize the hazard of a capable tectonic source the following information is needed:

(a) The ~~length~~ dimensions of the structure.

(b) The strike and dip of that structure including, if possible, its geometry within the seismogenic zone and the orientation of regional and local tectonic stresses.

(c) History of Quaternary (last 2 million years) displacements such as age of last offset and previous displacements, estimated magnitudes per offset (i.e., characteristic earthquake), rupture length and estimate of rupture area per event, recurrence intervals (including the occurrence of temporal clustering), slip rate, and displacement history or uplift rates of seismogenic folds.

(d) Relationship of the ~~fault~~ structure to regional tectonic structures.

(e) The possibility of ~~fault~~ segmentation, both along strike and down dip through the seismogenic zone, with the bases for defining the segmentation points included.

(f) Seismicity associated with the structure.

(2) Reconnaissance Investigations, Literature Review and Other Sources of Preliminary Information

Planning of site and regional investigations and the interpretation of data require a thorough understanding of the geology and seismology of the site. This understanding can be obtained by field reconnaissances and reviews, either preceding or accompanying the actual field studies, of available documents and results of previous investigations. In most cases, a preliminary study of the regional and site geology and seismicity can be done by reviewing current and historical documents, including aerial photographs, satellite imagery and other remote-sensing imagery and earthquake catalogues. Possible sources of information may include:

(a) Geology, geophysics and engineering departments of state and local universities,

(b) State government agencies such as state geological surveys,

(c) U.S. Government agencies such as the U.S. Geological Survey and the U.S. Army Corps of Engineers,

(d) Topographic maps,

(e) Geologic and tectonic maps, particularly those showing Quaternary features, geophysical maps, structural geology maps, engineering geology maps, soil survey and hydrogeologic maps,

(f) Geological and geophysical cross sections,

(g) Seismicity catalogs, including maps and cross sections, and historical earthquake records,

(h) Geological reports and other geological literature,

(i) Geotechnical reports and other geotechnical literature,

(j) Water well boring information and water supply reports,

(k) Oil and gas well records,

(l) Mining history, old mine plans and subsidence records,

(m) Newspaper records of geological phenomena such as earthquakes, landslides, floods, subsidence and other events of geologic or geotechnical significance,

(n) Records of performance of structures in the vicinity, and

(o) Personal communication with local inhabitants and local professionals.

(3) <u>Regional and Site Investigations</u>

Geological investigations are typically evolutionary. As information is obtained, the next phase of the investigation is planned based on that information. The investigator moves from one level of knowledge to the next. Therefore, it is not possible in the beginning to provide guidance that will cover every situation. Many of the procedures listed below will not be applicable to every site. Likewise, situations will occur requiring investigations which are not included in the following list, and the state-of-the-art in the geosciences will develop newer technologies. These methods are suggested but they are not all-inclusive and investigations should not be limited to them.

This is a repeat of page 6 lines 10–25

Investigations should include detailed surface and subsurface exploration of the site area within a radius of five miles. Less detailed studies may be required out to a radius of twenty-five miles. Additional detailed investigations in areas more remote to the site area may be required to complete the geologic evaluation of the site or to conduct detailed investigations of significant capable tectonic sources beyond the 5-mile radius. After identifying the surface expression of a capable tectonic source it is necessary not only to determine the age of last activity on that structure, but also to estimate its history of Quaternary displacements for use in hazard characterization analyses.

Surface exploration needed to assess neotectonic conditions of the site area geology is dependent on the site location and may be carried out with the use of any appropriate combination of geological, geophysical, seismological and geotechnical engineering techniques. Capable tectonic sources are manifested at or near ground surface, therefore, by utilizing the following methodologies that are applicable to a specific site, even the most subtle evidence of surface deformation can likely be identified.

(a) Detailed mapping of topographic, geologic, geomorphic and hydrologic features at scales and contour intervals suitable for analysis, particularly Quaternary stratigraphy, surface tectonic structures such as fault zones, and Quaternary geomorphic features. For offshore sites, coastal sites, or sites located near lakes or rivers this includes topography, geomorphology (particularly mapping marine and fluvial terraces), bathymetry, geophysics (such as seismic reflection), and hydrographic surveys to the extent needed for evaluation.

(b) Detailed geological interpretations of aerial photographs and other remote-sensing imagery, as appropriate for the particular site conditions, to assist in identifying rock outcrops, tectonic features, soil conditions, evidence of past landslides or soil liquefaction, faults, fracture traces, geologic contacts, and lineaments.

(c) Identification and evaluation of vertical crustal movements by: (a) geodetic land surveying to identify and measure short term crustal movements, and (b) geological analyses such as analysis of regional dissection and degradation patterns, marine and lacustrine terraces and shorelines, fluvial adjustments such as changes in stream longitudinal profiles or terraces and other long term changes such as to lava flows, etc.

(d) Analysis of stream profiles such as the upstream migration of knickpoints.

(e) Analysis of offset, displaced or anomalous landforms such as displaced stream channels or changes in stream profiles, abrupt changes in fluvial deposits or terraces, changes in paleochannels across a fault, or uplifted, downdropped or laterally displaced marine terraces.

(f) Analysis of Quaternary sedimentary deposits within or near tectonic zones such as fault zones: (a) fault related or fault controlled deposits including sag ponds, graben fill deposits, and colluvial wedges formed by the erosion of a fault paleoscarp, and (b) non-fault related, but offset deposits including alluvial fans, debris cones, fluvial terrace and lake shoreline deposits.

(g) Identification and analysis of deformation features caused by vibratory ground motions including seismically induced liquefaction features (sand boils, explosion craters, lateral spreads, settlement, soil flows), mud volcanoes, landslides, rockfalls, deformed lake deposits or soil horizons, shear zones, cracks or fissures.

(h) Estimation of the ages of fault displacements by analysis of the morphology of topographic fault scarps associated with or produced by surface rupture. Fault scarp morphology is useful in estimating age of last displacement, approximate size of the earthquake, recurrence intervals, slip rate and the nature of the causative fault at depth.

(i) Listing of all historically reported earthquakes which can reasonably be associated with capable tectonic sources any part of which is within a radius of 200 miles (320 km) of the site, including date of occurrence and the following measured or estimated data: highest intensity and a plot of the epicenter or region of highest intensity, magnitude, hypocenter location, focal mechanisms, stress drop, crustal velocity model, etc. Historical seismicity includes both historically reported and instrumentally recorded data. For purposes of this regulatory guide the magnitude and epicenter values should be determined. For historically reported data, intensity should be converted to magnitude and epicenters shall be determined based on intensity contours. The intensity data should be preserved and the ~~way that it was~~ approach used to converted it to magnitude should be clearly documented.

Subsurface investigations that should be accomplished in the site area or within the region to identify and define capable tectonic sources may include:

(a) Geophysical investigations such as ground penetrating radar, air or ground magnetic and gravity surveys, borehole geophysics, etc. and seismic reflection or seismic refraction surveys.

(b) Core borings to map subsurface geology and obtain samples for ← testing such as age dating.

(c) Excavating and logging trenches across geological features as part of the neotectonic investigation and to obtain samples for age dating those features.

An important part of the geologic investigations to identify and define capable tectonic sources is the age-dating of geologic materials. The following techniques are useful in dating Quaternary deposits:

(a) Radiometric Dating Methods: Carbon 14, Potassium-Argon, Uranium Series methods, Fission Track, Thermo-luminescence (TL), and Electron-spin Resonance (ESR).

(b) Other Quantitative Numerical Methods: Paleomagnetism, Thickness of Weathering Rind on Clast Margins, Cation-ratio Dating of Desert Varnish, Tephrochronology, Amino-acid Racemization, Lichenometry, Soil Profile Ages, and Dendrochronology.

(c) Relative Age Dating Methods: Relative Degree of Soil Profile Development and Relative Degree of Weathering of Clasts in Sedimentary Deposits.

The above appropriate investigative procedures should also be applied, where possible, to define offshore structures (specifically faults or fault zones, but also including folds, uplift or subsidence related to faulting at depth) adjacent to coastal sites or those sites located adjacent to landlocked bodies of water. Investigations of offshore structures will rely heavily on seismicity, geophysics and bathymetry rather than conventional geologic mapping methods which can be used effectively onshore.

(4) Distinction Between Tectonic and Nontectonic Deformation

In past licensing activities surface displacements caused by phenomena other than tectonic phenomena have been confused with tectonically induced faulting. Such features include faults, the last displacement of which was induced by glaciation or deglaciation, collapse structures such as found in karst terrane, and growth faulting such as occurs in the Gulf Coastal Plain or in other deep soil regions subject to extensive subsurface fluid withdrawal. All of these phenomena can pose a substantial hazard to nuclear power plants; however, the differences between them and capable tectonic structures should be identified and documented. Glacially induced faults generally do not represent a deep seated seismic or fault displacement hazard because the conditions that created them are no longer present. However, residual stresses from Pleistocene glaciation may still be present in glaciated regions although they are of less concern than active tectonically induced stresses. These features should be investigated with respect to their relationship to current in-situ stresses.

The nature of faults related to collapse features can usually be defined through geotechnical investigations and can either be avoided, or if feasible, adequate engineering fixes can be provided.

Large, naturally occurring growth faults as found in the coastal plain of Texas and Louisiana can pose a surface displacement hazard even though offset most likely occurs at a much less rapid rate than that of tectonic faults. They are not regarded as having the capacity to generate damaging earthquakes, are easily identified and can be avoided in siting, and their displacements monitored. Antithetic faults related to growth faults are sometimes not easily identified; therefore, investigations described above with respect to capable tectonic faults and fault zones should be applied to large scale growth faults. Local human-induced growth faults can be monitored and controlled or avoided.

b. Seismogenic Source

A "seismogenic source" is a portion of the earth's crust which is considered to have uniform seismicity (same expected maximum earthquake and frequency of recurrence) distinct from the seismicity of ~~the~~ other surrounding areas. Seismogenic sources cover a wide range of possibilities from a well-defined tectonic structure to simply a large region of diffuse seismicity (seismotectonic province) thought to be characterized by the same earthquake recurrence model. A seismogenic source is not expected to cause surface deformation. A "capable tectonic source" on the other hand, is a fault or structure that is judged capable of both generating earthquakes and causing surface displacement. Reconnaissance investigations and regional and site investigations needed to identify seismogenic sources are the same as those used to identify capable tectonic sources. However, site investigations will rely more heavily on subsurface methods such as geophysics than on surface methods.

4. Seismic Sources and Predicting Future Seismicity

a. Correlation of Seismic Sources and Earthquakes

Section B above provides information on acceptable methods for identifying potential earthquake sources and quantifying recurrence intervals. This section discusses the relationship between earthquake sources, recurrence rates and earthquake magnitudes. The most accurate earthquake-tectonic structural association is possible when the ground is ruptured during the earthquake (capable tectonic source) and there are good records of foreshocks, the main shock, and aftershocks from which fault mechanisms and hypocenter locations can be calculated as well as information on the fault surface itself such as orientation, attitude, area, stress drop etc. Even in the western U.S. where coseismic surface faulting is common, it is unusual to have all of this information available regarding a specific earthquake. In the eastern and central U.S. (SCR) data is often limited to relatively poorly located hypocenters and focal mechanisms ~~with several different interpretations~~.

In regions of low seismicity such as the SRC, future seismicity can occur on a structure with no previously recognized earthquake potential or a large earthquake can occur on a fault with very long ~~nonhistoric~~ recurrence intervals, greater than the historic record. Future seismicity can occur by reactivitation of previously unrecognized or inactive structures by new, amplified or changing stress environments or development of new plate-stress domains associated with intraplate crustal and upper plate motions (ductile shear zones, rifts, or hotspots).

~~Precursors of moderate to large earthquakes have been extensively studied and quantified using probabilistic models and statistical analyses. Interpreting earthquake precursors reliably requires models of the fundamental tectonic processes that create the earthquake sources. Adequate and acceptable models are not yet available, nor are understandings of intraplate tectonic processes and available data adequate to assess causative models or describe sources of potentially large earthquakes with a high degree of certainty. The problems are most acute in the SCR, but similar problems also exist in the western U.S.~~

b. Fault Rupture and Seismicity

Fault models that relate rupture geometry to earthquake magnitude are based on empirical and theoretical relations between area of fault rupture, average fault slip and earthquake magnitude. From this information, it is possible to predict large-scale deformation patterns. There are two types of fault geometry-earthquake magnitude methodologies: rupture length to magnitude (an empirical correlation between the surface rupture length during an event and the magnitude of the event) and seismic moment (approximate linear relation between magnitude and rupture area). ~~Seismic moment can also be related to stress drop. Seismic moment studies predict the extent of rupture along the fault.~~

The potential rupture area can be predicted by knowing the following fault characteristics: length, shape, depth, orientation, area, amount of slip on rupture surface, recurrence interval and history of the source structure. The length, shape and surface orientation are determined from the topography or bathymetry. The depth and subsurface orientation are determined geophysically (seismologically and by seismic reflection profiling). The area of slip is defined after a coseismic rupture based on the length of surface offset, the extent of the seismically active zone during rupture, and the depth of the hypocenter.

These characteristics are not always easy to obtain in parts of the western U.S., where surface rupture recurrence intervals exceed the historic seismic record. To determine potential rupture areas for apparent inactive sources, the geometry of the ~~inactive~~ potential rupture should be estimated. This inactive section of the fault is then used to segment the fault zone into add a reference that

discrete lengths assumed to rupture coseismically ~~coherently~~. A fraction ~~percentage factor~~ of the total fault length can also be used to estimate rupture length, for example, 1/2 or 1/3. ~~Recurrence intervals can be calculated from historic seismicity and/or paleoseismicity.~~

In seismic regions, resolution of the seismic potential depends on a combination of detailed seismologic information, experience with past earthquakes and reliable geologic mapping of potentially active structures ~~faults~~. The methods to be employed depend to a great extent on the geological characteristics of the region, judgements ~~intuitive perceptions~~ about the composition and fabric of the crustal lithosphere beneath the region and specific site based on ~~low resolution~~ geophysical data, and comparisons with similar features elsewhere.

judgements

~~In both seismic and aseismic regions, predictions of magnitudes are based on qualitative~~ estimates ~~perceptions of possible extent of ruptures as quantitative data is sparse. However, the state-of-stress of a specific region, if it can be determined, can provide quantitative limits on effective stress release.~~

? How?

~~To improve the ability to predict recurrence intervals and determine maximum magnitudes for tectonic structures, more information with respect to the following is required: (1) a better understanding of tectonic processes and their relationship to the generation of earthquakes; (2) a refinement of age dating techniques for the Quaternary period; (3) a more complete earthquake historic record and paleoseismic record; (4) the development of quantitative landform analyses methods; (5) higher resolution of geophysical techniques; (6) new insight into crustal structure; (7) increased understanding of material properties and rheology of the earth's crust; and (8) statistical methods for evaluating divergent probabilistic estimates of earth science experts.~~

5. Expected Maximum Earthquake Evaluation

a. General

which can ~~have an~~ effect on the SSE estimation

not.

Expected maximum earthquakes (EMEs) should be assessed for each of the seismic sources (capable tectonic sources and seismogenic sources). ~~A critical view is that maximum earthquakes are not random events and the historic record is an inadequate data base for a valid statistical and probabilistic analysis, therefore, a deterministic evaluation is more appropriate. Another view~~ is

~~that because of uncertainties in the nature and location of future earthquakes, seismic risk cannot be expressed in deterministic terms and greater reliance should be placed on probabilistic analyses.~~ EMEs are used in the deterministic assessment, and, with associated uncertainties, in the probabilistic assessment. Several of the following approaches should be used for each seismic source and for each approach alternatives should also be considered. ~~Because each of these magnitude estimation approaches is subject to uncertainties due to the limited historical earthquake record and available geological information, uncertainties and subjective judgements should be acknowledged in these assessments. The preferred magnitude estimates are those that are best substantiated by the available data; however, the use~~ of ~~multiple approaches will~~ TO assess the uncertainties in the EME estimates and identify parameters which could be studied further.

(1) One approach is to consider the maximum historical earthquake associated with the fault, structure, or province. The maximum historical earthquakes have commonly been used as a lower bound for EME estimates. Because the historical record is usually short, the pattern and rate of seismic activity may suggest that an EME larger than the maximum historical earthquake should be considered. ~~Both~~ earthquake catalogs and geological observations ~~of surface offsets,~~ where available should be ~~should be~~ assessed.

(2) The paleoseismic approach is essentially an extension of the historical record by identifying and characterizing prehistorical earthquakes. The paleoseismic observations could be along the seismic source or in adjacent areas that have been affected by paleoseismic events. These studies provide information that can be used to estimate the EME. Reference (   )

(3) Another approach to estimating the EME is based on the physical characteristics of the capable tectonic source or seismogenic source. An EME may be based on fault parameters such as surface rupture length, surface fault displacement or fault rupture area. Reference (   )

(4) The relative comparison approach compares the seismic source with similar seismic sources. This approach extends the limited

seismicity and geological data available for the seismic source. The basis for the comparison must be established, such as tectonic regime, type of displacement, fault length or size of the seismotectonic province. Relative comparisons are commonly used as corroborative evidence to EMEs estimated by other approaches.

overlaps Section B2

For active tectonic regions all of the above methods can be applied. However in the SCR the problem of determination of the appropriate ~~magnitude~~ EME's to use for the SSE is more difficult. In the SCR a number of significant tectonic structures exist which could be considered as seismogenic sources. There is no clear procedure to follow to characterize the EME magnitude to associate with such possible seismogenic tectonic sources. First, it is most likely that the determination of the seismogenic nature of the source will be inferred rather than demonstrated by strong correlations with seismicity and/or geologic data. In fact, if such strong correlations and/or data exist, then approaches used for active tectonic regions can be applied. The historical record and judgment play key roles. The approach used to characterize the EME for the SSE for a deterministic model can be significantly different than for a probabilistic model.

this is very confusing and don't know if it is necessary

There is no definition of a "tectonic structure" in the front.

~~One possible~~ upperbound for the ~~appropriate magnitude for the SSE in the SCR~~ would be based on the size of the tectonic structure. However, such correlations based on active tectonic regions are not applicable for SCR as the tectonic structures of interest were developed under a totally different tectonic regime than the present regime. The present regime is characterized by stability, low seismicity and very low rates of deformation and thus the size of tectonic structure is not indicative of maximum magnitude of potential future earthquakes. Considerable judgment is required to estimate the appropriate magnitude for the earthquake to be used for the development of the SSE in the SCR. Factors that are important in estimating the EME include:

1. Maximum historical earthquake associated with the structure.
2. Pattern and rate of seismic activity.
3. Neotectonic (post-Miocene or about 5-million years and younger) development and characteristics of the source.
4. Current stress regime.
5. Paleoseimic data.

This is all mentioned before!

For the most significant seismogenic source zones, i.e., those zones which make a significant contribution to the SSE, additional information should be developed for instrumentally determined earthquakes such as focal mechanism, stress drop, etc., which would be useful in assessing the ground motion from earthquakes occurring in the seismogenic source zone.

~~Alternative seismogenic zone configurations should be assessed and the appropriate data developed to address why certain zones are to be rejected~~ if they could lead to a larger SSE.

should use the definitions from Appendix B strictly.

I think this whole ~~bus~~ business of tectonic structures and sources is confused and has to be structured out.

b. Deterministic Analyses

(1) Appendix A 10 CFR Part 100 Methodology

The investigations and analyses required by Appendix A 10 CFR, Part 100 are entirely deterministic studies. A methodology has been developed over the past two decades that is in relative accordance with that document. Probabilistic methodologies (LLNL, 1986, EPRI, 1986) have been developed since that time. However, continued use of deterministic methodologies is still required ~~recommended~~ due to the large uncertainties ~~differences~~ in results ~~between~~ of the probabilistic methodologies and the inapprop. iatness of using them in an absolute fashion.

The first step in determining the SSE and EME deterministically is to identify earthquake sources. This is accomplished by: (1) identifying and analyzing all significant earthquakes within a radius of 200 miles of the proposed site; (2) identifying potentially significant tectonic seismogenic structures within a radius of 200 miles of the site; (3) if possible correlating seismicity with ~~tectonic~~ structures; (4) if it isn't possible to associate earthquakes with ~~tectonic~~ structures, then defining seismotectonic provinces; (5) determining the maximum earthquake (EME) for each source--(a) for seismotectonic provinces, this is at a minimum the maximum historic earthquake or the maximum earthquake estimated from paleoseismic information, and (b) for ~~tectonic~~ structure this is the maximum earthquake that the structure is capable of generating based on its characteristics (length, area, segmentation, rupture length, offset per event etc.) The next step is determining the site ground motions by: (1) assuming that the maximum earthquake on each source (tectonic structures and seismotectonic provinces) can occur at the closest approach of that source to the site (for the host tectonic province the EME earthquake will be assumed to

(10 15 km)

occur near the site); (2)(a) estimating largest or controlling ground motions using intensity-acceleration relationships or magnitude-distance-acceleration relationships ~~(these are peak accelerations used to anchor Regulatory Guide 1.60), and/or~~ (b) selecting earthquake information from a larger data base (worldwide) from earthquakes of similar sizes as the EME's and located a similar distance from recording stations founded on similar foundation conditions and developing spectra from plots of these data (current practice uses the 84th percentile as SSE ground motions). (See SRP, Section 2.5.2 for detailed discussion of ground motion determination). This belongs in a ground motion R.G. or SRP 2.52

(1) Historic Seismicity

A seismic source zone ~~(seismotectonic~~ province) is a broad area that is believed to be characterized by relatively uniform seismicity from the standpoint of expected maximum earthquake and earthquake recurrence. Seismic source zone concepts are applied in the eastern and central U.S. because it is as yet not possible to correlate earthquakes with specific tectonic structures. A basic assumption of this concept is that future patterns of seismicity will be similar to those of the past, which is the primary basis for a given seismic source zone.

Much of the assessment of seismic source zones in the SCR is based on historic seismicity. However, as stated earlier, studies of the historic seismic record ~~are~~ may be inadequate by themselves in predicting future seismicity because of the shortness of the record, the ~~scarcity~~ long recurrence times of large earthquakes in the SCR and the limited empirical data base. For this reason, our understanding of the controls on maximum earthquakes is likely to come from an understanding of the physical process of strain accumulation and its effect on zones of weaknesses. ?

(2) Paleoseismicity

In addition to the historic and instrumental seismic record, another promising method to constrain the boundaries of seismic source zones and provide some information relating to their EME's is to identify and define geologic evidence for prehistoric eqarthquakes. For example, a recent investigation (Amick and others, 1989) along the Atlantic Coastal Plain from New Jersey to Georgia searching for paleoliquefaction features similar to those historic and prehistoric seismically induced liquefaction features mapped in the meizoseismal area of the 1386 Charleston Earthquake (Talwani and Cox, 1985; Gohn and others, 1986; Amick and others 1990) found no such evidence outside of South Carolina.

of large earthquakes

Other ~~ongoing~~ paleoseismicity studies include those ongoing in the eastern U.S. - paleoliquefaction investigations in New England and neotectonic studies in the southeastern U.S. by Ebasco Services, Inc., for the NRC, and paleoliqueraction investigations in the Wabash River Valley by the USGS; and those in the western U.S., such as paleoseismicity studies along coastal Washington and Oregon, and fault segmentation studies in California by the USGS.

? characterization

(4) Precursor Phenomena

Defining potential seismic sources and estimating their EME's in the SCR is very difficult. As indicated above, a study of precursors and associated deformation can be important in predicting future earthquake magnitudes on potential seismic sources. Such a prediction is based on identification and interpretation of long and short-term precursors from which models and the assignment of probabilities are derived. Long-term precursors include historic seismicity and crustal strain measurements. The usefulness of long-term precursors depends on historic seismicity records and knowledge about tectonic sources. Recognizing the shortcomings of historic seismicity, the historic record may be related to phenomenological or statistical relationships such as Weibull distributions, seismic gaps and migration of seismicity. These factors can be used to help ascertain or somewhat rectify historic incompleteness.

Measurements of crustal strain can provide such information as the accumulation rate of strain, the ultimate crustal strain, and site-specific and geodetic measurements. Measurement of crustal strain, which requires repeated geodetic surveys and experiments, probably has greater potential in the future of estimating EME's than analyzing historic seismicity.

Short-term precursors in seismically active areas may include anomalous uplift, changes in sea level, tilt, strain, crustal deviatoric stress, premonitory earthquakes, geomagnetic and geoelectric precursors, geochemical, macroscopic phenomena (animal behavior, etc) and seismological precursors. Seismological phenomena are [illegible] important short-term precursors. Such

~~characteristics include foreshocks, anomalous seismic activity, seismic gaps, growth and decay of seismic activity, source mechanisms, hypocentral migration of microearthquakes and changes in seismic wave velocities.~~

~~Other, less important at this time, geophysical precursor phenoma are earthtides, potential field values such as geomagnetic and geoelectric and ground water data.~~

(5) Regional State of Stress and Strain

~~Seismic source zones can be defined and their EME's determined to some extent by estimating regional stress and strain characteristics. In order to estimate the regional stress-strain regime, it is necessary to determine the characteristics of the in-situ stress in the context of worldwide plate tectonics environment, and then integrate available earthquake information into the data set as there is likely to be a relationship between zones of weakness and seismicity. Geodetically and geologically observed strain as determined by using geomorphic and stratigraphic indicators described in Section B is important input in defining regional stress and strain.~~

(6) Tectonic Processes

~~Another proceedure that may be useful in defining seismic source zones and estimating their EME's is to estimate the tectonic processes that may be acting on the region to generate the measured or observed stresses in the region. Tectonic processes include plate tectonic phenomena such as ridge push or trench pull, thermal pertabations, variations in crustal and lithospheric thickness, membrane stresses caused by variations in the earth's curvature, erosion and sedimentation, and glacial rebound. Local processes may be stress corrosion due to chemical effects within the lithosphere, localized movement along zones of different mechanical properties, inhomogeneities in large and small-scale lithospheric composition or rheology, stress amplification, enhanced fluid pore pressure, hydrologic weakening of minerals in the upper lithosphere, stress-induced crack growth and brittle reactivation of previously ductile zones by uplift.~~

(7) Tectonic Features

~~Major tectonic structures of the region should be mapped based~~ on surface and near surface geology and subsurface crustal and lithospheric structures defined by interpretation of ~~low resolution~~ geophysical data. ~~Features that~~ should be concentrated on to define a source and to quantify a maximum magnitude earthquake and predict its location include: ductile shear zones (upper and middle lithosphere), plutons, other lithospheric inhomogeneities such as water at depth and brittle fracture zones (if zones of weakness can be defined), the stresses and strains around the zone, strain accumulation and mechanisms of failure, and ~~tectonic processes that could cause seismic activity on a structure.~~

Belongs in Section B4

In low seismicity ~~aseismic~~ areas in the western U.S. a ~~tha best~~ data set for determining EME recurrence on a tectonic structure or segment of a structure, is a recurrence based on well-dated stratigraphy that constrain ages of fault offsets. The ~~most accurate is nc older than late Quaternary to Holocene tectonism and related sedimentation.~~ Other databases can be obtained from stream profile analysis, fault scarp morphology analysis and analysis of vertical crustal movements related to tectonism.

Recurrence intervals in seismic areas are determined by a combination of seismic information along structures, geological mapping and experience with similar features at other locations. Belongs in Section B5C

~~In the SCR~~, most of the methods described above cannot be applied due to the lack of data and lack of understanding of the causes of seismicity and the relation of seismicity and tectonic structures in that region. A possible approach that is likely to become increasingly more important, is to first determine the state of the regional stress-strain regime, second is to consider the tectonic processes that are causing that stress regime, and finally, ~~identifying and defining the major tectonic features in that~~ region.

c. Probabilistic Analysis - SCR

Reference (EPRI & LLNL)

A probabilistic analysis is accomplished using the results of the deterministic studies and encompassing consideration of recurrence models and uncertainties. ~~The amount of data available about earthquakes and their causative sources varies substantially between the western U.S. and the SCR and also from region to region within these broad areas. Therefore, because~~

~~of this variability in quantity and quality of available data from one region to another, the approach used to estimate seismic potential should be a graded one. That is, in regions where there is a large amount of data, a deterministic analysis should predominate, but where there are large uncertainties, the probabilistic analysis should predominate. For example, in the SCR where there are extensive uncertainties about the nature and location of future earthquakes, it is necessary to rely heavily on probabilistic analyses. Seismic hazard analyses, which calculate the probability that some level of earthquake ground motion will be exceeded at a site depend on input data such as: identification, location and definition of seismic sources, estimation of the earthquake potential for each source, recurrence intervals and estimation of ground motions at the site.~~

~~(1) Recurrence Models~~

Recurrence models for each source are determined using historic seismicity and paleoseismicity ~~(determined by using the liner regression analysis relating to earthquake size (magnitude or intensity) to frequency of occurrence.~~ The recurrence models are terminated at the largest earthquake expected from each source. ~~The probabilistic models assume that earthquake occurrence either follows a Poisson process or earthquakes occur randomly with respect to time and space within a given source.~~ The ground motion (peak or spectral acceleration) at the site from the different earthquakes at different distances is estimated using a set of magnitude ~~(or intensity~~)--ground motion relationships that explicitly incorporate the dispersion of the data around such relationships. The effect of different size earthquakes from different locations in different sources is then integrated with the recurrence information and the probabilities that given levels of ground motion will not be exceeded within given time periods are calculated.

(2) Uncertainties

~~An acceptable approach to define the seismic hazard for a specific area is to: (1) form a panel of earth sciences experts (LLNL, 1986) or set of teams of experts (EPRI, 1986) with a broad range of expertise; (2) formalize a methodology for evaluating and ranking hazard assessments made by each expert or team; (3) develop consistent and generally accepted methods for assigning~~

pr~~obabilities to hazards; and (4) test the analyses by applying the techniques to a set of data in the Holocene and Quaternary in which historic data exist as well to see whether or not the analysis provides reasonable~~ probabilities ~~for events~~ that ~~have~~ already ~~occurred~~.

Both deterministic and probabilistic approaches are controlled by the choices of input parameters. To take into account the uncertainties, expert opinion may be convassed for such information as choices of input parameters, range of parameters, and what credibility could be given them. ~~Spectra~~ Ground motion calculation may then be computed for each expert at each site. ~~All~~ experts at each site based on their self-ranking may then be synthesized. I~~nput parameters may be (1) configuration of seismic source zones, (2) largest earthquake expected in~~ each zone (3) earthquake activity rate and recurrence statistics for each zone and (4) methods for predicting ground motion in the SCR from an earthquake of a given size at a given distance.

The team [illegible]

Examples of the way this deterministic data serves as input to probabilistic analyses for assessing the seismic hazard in the eastern and central U.S. is the EPRI Seismic Hazard Study (1986). The database used in this study consisted of that information that contributed to an understanding of the causes of crustal stress in the region, the present state of stress in the region, and the identity and characteristics of tectonic features in the region. These data formed a matrix of physical characteristics of the region and included tectonic mechanisms, magnitudes and orientations of crustal stresses, crustal and lithosphere features, surface and subsurface geology and earthquake history.

Based on that methodology the way to define the tectonic framework of a region is to first identify tectonic structures and filter geologic data using preestablished criteria. The criteria include size of the feature, the type of fault motion expected, the potential for large earthquakes, and deep crustal expression. The second step is to define the specific physical characteristics of each structure. The earthquake potential of each structure should be defined based on the known stress environment, orientation of the structure, and the tectonic processes that may act on it. Finally, a probability that an earthquake of a certain magnitude will occur on each structure is calculated.

Each EPRI geosciences team constructed a tectonic framework and each framework was equally weighted relative to the other frameworks. Each team ~~ranked its own expertise. Then all of the independent hazard estimates were~~

~~combined by the mechanical aggradation procedure in which a weighted average of the individual results was computed. This methodology has significant advantages in that it addresses the fact that there is a critical relationship between the processes and the physical features, i.e., an earthquake is the result of stress related to ongoing tectonic processes acting on a specific feature, and the aggradation procedure allows for quantitative statistical results to be developed for the assessments. The weaknesses of this methodology is that there is poor understanding of the relevant tectonic processes, a lack of available data for a region or a site, and there is little ability to test the probabilistic relationship in the real world.~~

~~As stated above, the best information to have in order to predict the seismic hazard of tectonic structures are recurrence data based on datable stratigraphic sequences in areas where there has been late Quaternery and Holocene tectonism and sedimentation.~~

d. Probabilistic ~~Seismic and~~ Fault Displacement Hazard Studies ~~Western U.S.~~

Note: Probabilistic seismic Hazard analysis methods will be discussed in another Reg Guide

Probabilistic evaluations should be performed to estimate the probability of exceeding the SSE and the probability of surface displacement at the site. The procedure for estimating the probability of exceeding the SSE is described in Standard Review Plan Section 2.5.2. This section describes the procedure for estimating the probability of seismic and fault displacement at the site.

Probabilistic estimates of the surface displacement hazard for each capable fault 5 miles (8 km) from the site should be calculated. Section B 3a(2) describes those situations where faults further from the site need to be considered. The underlying assumptions and associated uncertainties should be documented to assist in the staff's assessment of the potential for surface displacement at the site. ~~A thorough but less detailed investigation should be accomplished out to a radius of 25 miles (40km).~~ The regional investigations should extend to a radius of ~~150~~ 200 miles (~~40km~~ 20). In regions of late Quaternary activity or historical seismic activity (including instrumental data) or where a site is located within several tens of miles from a large capable tectonic source such as a fault zone, it may be necessary to extend the area of detailed investigations substantially beyond 5 miles from the site to include that structure. This assessment should consider alternative sources to bound the uncertainty. ~~Documents that describe~~

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currently acceptable methodologies are REFERENCES.

(1) Objectives

~~Seismic source characterization is the next step in defining the~~ earthquake (EME) and surface faulting potential to be used in a seismic hazard analysis and can be accomplished following the definition of seismogenic and capable tectonic sources using the investigation methodologies described in Section B. The objectives of programs to make these determinations in regions where seismogenic sources and capable tectonic sources are located at or near ground surface are:

1. Utilize the data and interpretations from geosciences investigations to define the earthquake environment of a site.

2. Incorporate fully the range of interpretations advocated in the scientific community and those derived from the investigations with complete consideration of uncertainties. Proper emphasis should be placed on those interpretations in accordance with the supporting data.

3. Develop, when appropriate and the data call for it, new or approved methods and approaches toward characterizing earthquake sources, in order to understand more fully the physical processes.

4. Document interpretations of source characterization and their bases in the geosciences data.

5. Present the conclusions in ways that are appropriate for subsequent in probabilistic and deterministics ground motion analyses.

(2) Background and Approach

Characterization of sources should be closely linked to the investigations program and be driven by the data rather than the preferred tectonic models. The geosciences program should be focussed on reducing uncertainties with emphasis on the most significant sources (i.e., closest, largest, or most active).

There are two principle aspects for understanding the future behavior of earthquake sources: the widely accepted relationships between fault rupture length and earthquake magnitude such as fault slip rate and magnitude, and earthquake recurrence and magnitude; and the still experimental aspect of fault characterization that includes fault segmentation and coseismic folding.

Hazard analyses of sites are usually based on intrepretations developed by experts to assess the range of interpretations and associated earthquake potential in a variety of interplate and intraplate tectonic settings (LLNL, 1985, EPRI, 1986). The range of these expert opinions and the uncertainties are large. The analyses are focussed on present understanding and not on gathering data to resolve or reduce the uncertainties. The hazard analyses recommended here for regions where seismic sources are near ground surface is opposite to this in that studies should be geared to reducing uncertainties through detailed geosciences investigations. There should be ongoing scientific peer review and interactions with the scientific community as the studies progress.

The studies should include both deterministic and probabilistic evaluations. The probabilistic analysis should encompass a broad range of physical characteristics regarding each source such as recurrence-related parameters, multiple sources and ranges of values. It should encompass uncertainties (scenarios and relative credibility of each) and sensitivity studies. The deterministic study should define the controlling source and evaluate the largest site ground motion parameters related to the maximum magnitude, and a conservative magnitude selected for that source. This earthquake should then be assumed to occur at the closest approach of the source to the site. The two studies should be complimentary.

(3) Methods for Characterizing Seismic Sources

of the complexity of

Because ~~there is never enough~~ geological, seismological and geophysical information, it is important to incorporate uncertainty into seismic source characterization analyses. In determining the seismic potential of sources with no recorded history of seismicity, indirect measures of size, frequency and location of earthquakes must be utilized. These measures are based on the structures ~~fault's~~ behavior in the recent geological past, which are determined by integrating available geological, seismological and geophysical data and analogies with other similar faults. There are a great deal of uncertainties due to an incomplete dataset and alternative interpretations of that data. The characterization of the source under consideration is based on the synthesis of available data, credible interpretations and scientific judgement. The probabilistic approach incorporates alternative interpretations (a measure of uncertainty in source characterization such as maximum magnitude and earthquake recurrence).

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One acceptable probabilistic approach that may be used is one based on logic trees such as that used by the Pacific Gas and Electric Company's (PG&E) Long-Term Seismic Program (LTSP) for the Diablo Canyon Nuclear Site. ~~Logic trees are composed of nodes~~ and branches in which each node represents a choice between alternative values of a parameter. Nodes are sequenced to provide for conditional aspects or dependencies among parameters and provide logical progression from general to specific source characteristics. At each node, probabilities are assigned to each branch that represent the relative likelihood of that branch being the correct value or state of the parameter considered.

LTSP Final Report 1988

Th~~e first node in the LTSP logic tree was style of faulting bec~~ause other characteristics of faults in that region are dependent on the mode of deformation. The next node considered the uncertainty in fault geometry. Sensitivity studies were carried out to determine the effects of using other characteristics on the first node, such as fault geometry. Two nodes farther out on the logic tree considered alternative methods of estimating recurrence intervals and for assessing maximum magnitudes, respectively. The LTSP used the seismic moment and recurrence rate techniques to estimate recurrence intervals. For maximum magnitude assessment PG&E used the results of rupture length-magnitude, rupture area-magnitude, total-fault length-magnitude, maximum surface displacement-magnitude, seismic moment, and maximum historic earthquake associated with fault methods in its logic tree.

The approach used to assess the maximum earthquake magnitudes is called the multifactor approach (fault characteristics correlated with magnitude). The resulting maximum magnitude is based on these fault characteristics--magnitude relationships, the calculation of magnitude given these fault characteristics, and scientific judgement regarding the weight of evidence, applicability of various data sets, and experience regarding historic earthquakes.

~~In a probability analysis a full distribution of maximum magitudes for various faults and a distribution that incorporates uncertainty in parameter values, relative credibility, and multiple techniques for estimating magnitude should be used. In a deterministic analysis, a maximum magnitude for the controlling source should be selected.~~

(4) Rupture Length and Segmentation

This section and the next section should be factored into Page 17

There are empirical ~~There is a direct~~ relationship between magnitude and rupture length, therefore, to estimate future earthquakes on a fault, maximum rupture lengths should ~~must~~ be determined. Faults rarely rupture their entire length during an earthquake so the portion of that total fault length most likely to rupture during a maximum earthquake should be estimated. There are two methods of estimating rupture length during a maximum earthquake: (1) fractional fault length such as one-half or one-fifth of the total length is assumed to rupture during the maximum earthquake (EME); or (2) the fault is considered to be segmented by geometric or geologic features.

Such features that may segment a fault include changes in surface trends, the presence of major range front salients along the fault, intersecting structural trends in bedrock geology, crossfaults, transverse trends in gravity data, and geodetic changes along the fault.

A number of characteristics of rupture end points have been identified. Those which most commonly characterize both strike and reverse slip end points are releasing and restraining double bends, en echelon stepovers, changes in senses of slip, fault and fold branches and crossfaults and folds. Those which most commonly characterize strike-slip rupture termination points are en echelon stepovers and changes in sense of slip. Single bends in fault traces are common termination points for reverse faults. Other characteristics of segmentation points are changes in slip rate, fault creep, changes in elapsed time (recency of slip), changes in trace complexity, fault terminations, gaps, changes in basement terranes, and basin boundaries.

It should be pointed out that most characteristics of end points occurred at rupture termination points in only 25 to 35% of the cases examined. In the remaining cases, they were ruptured through. Although no study has been completed that examines the effect on rupture termination of multi-characteristics, preliminary observations indicate that a combination of several characteristics of certain kinds can more effectively control fault rupture.

(5) Empirical Magnitude Relationships

A multifactor approach should be used in determining magnitude. The following empirical relationships are suggested: magnitude-fault rupture length, magnitude-fault rupture area, magnitude-displacement per event, magnitude-seismic moment and historic magnitude.

(6) Characteristics of Seismic Sources

Characteristics of western U.S. seismic sources that should be factored into the hazard analysis, (logic tree) are: sense of slip, dip, depth of faulting, total length, rupture length (segmented or fractional), average displacement per event, maximum historical earthquake, magnitude techniques used with relative weights indicating credibility, recurrence method-seismic moment (slip rate, total length and depth of faulting), slip rate, and magnitude distribution (i.e., exponential and characteristic earthquake model(s).

These elements are used to determine the EME for each source. A probability distribution is constructed for each source by repeating the calculation for all end branches of the logic tree and combining similar estimates. ~~As the mean of the distribution is the best estimate of the maximum magnitude~~ and the ~~tails of the~~ distribution ~~are unlikely scenarios~~ in the ~~logic tree,~~ the mean value plus one ~~standard deviation (84th percentile)~~ is regarded as the probabilistic ~~EME for~~ each ~~source~~. The deterministic EME is the maximum magnitude on the controlling structure based on an evaluation of the characeristics of that structure.

(7) Earthquake Recurrence

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Two approaches may be used in determining earthquake recurrence. Moment rate is a method where estimated slip of a fault is used to infer the rate of seismic moment release on the fault. From this the estimated rate of seismic moment release can be translated into earthquake frequency by using the relationship between seismic moment and magnitude and a magnitude-distribution model. Two forms of earthquake magnitude may be used: (1) truncated exponential distribution and (2) characteristic magnitude distribution.

The second approach should be a direct assessment of the frequency of surface rupturing events based on paleoseismic data (each event is considered to be within 0.5 magnitude units of the maximum event). The frequency of smaller events should then be specified by the appropriate form of the magnitude distribution anchored at the specified frequency of M_{max}, 0.5 magnitude events. The results should be compared with world-wide data.

~~(8) Maximum Earthquake Magnitude on Controlling Source~~

DOES NOT BELONG IN PROBABILISTIC SECTION

~~The deterministically defined EME is based on fault length, fault segmentation or fractional rupture length, potential fault displacement and other factors.~~

~~(9) Input to Subsequent Seismic Hazard Analysis~~

~~The logic trees should model all uncertainties considered in characterizing the seismic potential of seismogenic sources. The logic tree information may then be used directly on the seismic hazard analysis in condensed form.~~

~~Logic trees may be condensed by combining those elements of the logic tree used to estimate various parameters of maximum magnitude and earthquake recurrence into a single node for maximum magnitude and frequency of events of moment magnitude of M_w5.0 or greater.~~

~~The nodes for certain characteristics such as rupture length, maximum displacement, average displacement, maximum historic earthquake and magnitude determination technique may be combined to produce a discrete distribution for maximum magnitude conditioned on a particular sense of slip, dip, maximum depth and total length.~~

~~The nodes for recurrence methodology and slip rate/recurrence rate may be combined to produce a discrete distribution for annual frequency of events greater than M_w5.0 conditioned on a particular fault area and maximum magnitude.~~

C. REGULATORY POSITION

1. During the site selection phase, preferred sites are those where there is minimum likelihood of surface or near surface deformation, or the occurrence of earthquakes on faults in the site vicinity.

2. A site will be considered suitable if after thorough and currently acceptable investigations and analyses (deterministic and probabilistic) are conducted and there is reasonable assurance that:

   a. There are no capable tectonic sources in the site vicinity, or

   b. There are capable tectonic sources in the site vicinity but (1) there is no potential for surface or near surface fault induced deformation beneath the plant foundations, and (2) the probable, significant ground motions are, or can be enveloped by the site design basis spectra as prescribed in SRP Section 2.5.2.

3. Regional investigations such as geological reconnaissances and literature reviews (including remote sensing imagery) should be conducted within a radius of 200 miles (320km) of the site to identify seismogenic and capable tectonic sources.

4. Detailed geological, seismological, and geophysical investigations should be conducted within a radius of 5 miles (8km) of the site to determine the potential for tectonic deformation at or near ground surface in the site vicinity.

5. A less detailed geological, seismological, and geophysical investigation should be carried out within a radius of 25 miles (40km) to identify and characterize the seismic potential of capable tectonic and seismogenic sources, or demonstrate that such structures are not present.

6. Sites that are located such that there are capable and/or seismogenic faults within a radius of 25 miles, or within the near field, will require more extensive geologic and seismic investigations and analyses (similar to those within a 5 mile radius) and thus will require a more

extended and intensified licensing process.

7. Wherever possible earthquakes should be associated with seismogenic sources (tectonic structures or seismotectonic zones) or capable tectonic sources.

8. Deterministic studies, using state-of-the-art methodologies, should be conducted to reduce uncertainties and enlarge the data base. A deterministic EME should be determined. As a minimum the EME should be the maximum historic earthquake or the maximum late Quaternary earthquake as determined by paleoseismic studies. Acceptable methodologies are described in this guide or in the documents listed under references.

NOT IN SCOPE OF THIS Reg Guide

9. ~~For the SCR, probability evaluations should be conducted similar to the LLNL and EPRI Seismic Hazard Studies (LLNL, 1989; EPRI, 1989).~~

10. ~~For sites located in high seismic regions such as the western U.S.,~~ both ~~deterministic and probability~~ analyses should be accomplished to determine the potential for the EME and for surface deformation. ~~Acceptable deterministic and probabilistic methodologies are those described in the Diablo Canyon Long Term Seismic Program Final Report (PG&E, 1988).~~

11. An acceptable level of conservatism in determining the EME for both deterministic and probabilistic analyses is the mean~~, plus one standard deviation (84th percentile)~~. However, ~~recognizing the difficulty~~ in ~~developing a M_{max} distribution for the SCR, an acceptable practice of applying conservatism is to use the 84th percentile plus one~~ standard ~~deviation of the expected maximum earthquake ground motion~~. ~~Stat~~

D. IMPLEMENTATION

The purpose of this regulatory guide is to provide guidance to applicants and licensees regarding the NRC staff's review of capable tectonic sources and other active structures. The methods described herein will be used in the evaluation of construction permit applications docketed after May 1, 1991.

REFERENCES

STANDARD REVIEW PLAN SECTION 2.5.2

PROPOSED REVISION 3

STANDARD REVIEW PLAN 2.5.2
PROPOSED REVISION 3

2.5.2 VIBRATORY GROUND MOTION

REVIEW RESPONSIBILITIES

Primary - Structural and Geosciences Branch (ESGB)

Secondary - None

AREAS OF REVIEW

The Structural and Geosciences Branch review covers the seismological and geological investigations carried out to ~~establish~~ **evaluate** ~~the acceleration for~~ the safe shutdown earthquake (SSE) ~~and the operating basis earthquake (OBE)~~ for the site. ~~The safe shutdown earthquake is that earthquake that is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake that produces the maximum vibratory ground motion for which safety-related structures, systems, and components are designed to remain functional. The operating basis earthquake is that earthquake that, considering the regional and local geology, seismology, and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant; it is that earthquake that produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.~~ **The SSE represents the potential for earthquake ground motion at the site and is the vibratory ground motion for which all safety related structures, systems and components are designed to ensure public safety. The SSE is based upon a detailed evaluation of the expected maximum earthquake (EME) potential, taking into account regional and local geology, seismicity, and specific characteristics of local subsurface material. It is defined as the free-field ground response spectra at the plant site and is described by horizontal and vertical response spectra corresponding to the expected ground motion at the free-field ground surface or a hypothetical rock outcrop.**

Seismological and geological investigations are described in Regulatory Guide 1.xxx, Identification and Characterization of Seismic Sources. These investigations describe the seismicity of the site region and correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the EME magnitude associated with each seismic source. All seismic sources, any part of which is within ~~560~~ miles of the site, must be identified. Sources at larger distances which are

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capable of earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources; a seismotectonic province is a type of seismogenic source.

The principal regulation used by the staff in determining the scope and adequacy of the submitted seismologic and geologic information and attendant procedures and analyses is Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" to 10 CFR Part 100 (Ref. 1). Additional guidance (regulations, regulatory guides, and reports) is provided to the staff through References 2 through 8.

Specific areas of review include seismicity (Subsection 2.5.2.1), geologic and tectonic characteristics of the site and region (Subsection 2.5.2.2), correlation of earthquake activity with geologic structure or tectonic provinces (Subsection 2.5.2.3), maximum earthquake potential (Subsection 2.5.2.4), seismic wave transmission characteristics of the site (Subsection 2.5.2.5), **and** safe shutdown earthquake (Subsection 2.5.2.6)~~, and operating basis earthquake (Subsection 2.5.2.7)~~. **Both deterministic and probabilistic evaluations are used to assess the SSE.**

The geotechnical engineering aspects of the site and the models and methods employed in the analysis of soil and foundation response to the ground motion environment are reviewed under SRP Section 2.5.4. The results of the geosciences review are used in SRP Sections 3.7.1 and 3.7.2.

II. ACCEPTANCE CRITERIA

The applicable regulations (Refs. 1, 2, and 3) and regulatory guides (Refs. 4, 5, and 6) and basic acceptance criteria pertinent to the areas of this section of the Standard Review Plan are:

1. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." These criteria describe the kinds of geologic and seismic information needed to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants (Ref. 1).

2. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants"; General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena." This criterion requires that safety-related portions of the structures, systems, and components important to safety shall be designed to withstand the effects of earthquakes, tsunami, and seiches without loss of capability to perform their safety functions (Ref. 2).

3. 10 CFR Part 100, "Reactor Site Criteria." This part describes

criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors (Ref. 3).

4. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of site investigations related to geotechnical aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundations under anticipated loading conditions including earthquake. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, including the spacing and depth of borings as well as sampling intervals (Ref. 4).

5. Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations." This guide discusses the major site characteristics related to public health and safety which the NRC staff considers in determining the suitability of sites for nuclear power stations (Ref. 5).

6. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." ~~This guide gives one method acceptable to the NRC staff for defining the response spectra corresponding to the expected maximum ground acceleration (Ref. 6). See also~~ **For design purposes smoothed response spectra are generally used - for example, a standard spectral shape which has been used in the past is Regulatory Guide 1.60 (Ref. 6). These smoothed spectra are still acceptable when an appropriate peak acceleration is used as the high frequency asymptote and the smoothed spectra compare favorable with site specific response spectra derived from the deterministic and probabilistic procedures discussed** in Subsection 2.5.2.6.

The primary required investigations are described in 10 CFR Part 100, Section IV(a) of Appendix A (Ref. 1). The acceptable procedures for determining the seismic design bases are given in Section V(a) and Section VI(a) of the appendix. The seismic design bases are predicated on a reasonable, conservative determination of the SSE ~~and the OBE~~. As defined in Section 111 of 10 CFR Part 100, Appendix A (Ref. 1), the SSE ~~and OBE are~~ **is** based on consideration of the regional and local geology and seismology and on the characteristics of the subsurface materials at the site and ~~are~~ **is** described in terms of the vibratory ground motion ~~that they would produce~~ at the site. No comprehensive definitive rules can be promulgated regarding the investigations needed to establish the seismic design bases; the requirements vary from site to site.

2.5.2.1 Seismicity. In meeting the requirement of Reference 1, this subsection is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record. The listing should include all earthquakes having Modified Mercalli Intensity (MMI) greater than or equal to IV or magnitude greater than or equal to 3.0 that have been reported ~~in all tectonic provinces~~ **for all seismic sources**, any parts of which are within 200 ~~200, 150~~ miles of the site. A regional-scale map should be presented showing all listed earthquake epicenters and should be supplemented by a larger-scale map showing earthquake epicenters of all known events within 50 miles of the site. The following information concerning each earthquake is required whenever it is available: epicenter coordinates, depth of focus, origin time, highest intensity, magnitude, seismic moment, source mechanism, source dimensions, distance from the site, and any strong-motion recordings (references from which the information was obtained should be identified). All magnitude designations such as m_b, M_L, M_s, M_w, etc., should be identified. In addition, any reported earthquake-induced geologic failure, such as liquefaction, landsliding, landspreading, and lurching should be described completely, including the level of strong motion that induced failure and the physical properties of the materials. The completeness of the earthquake history of the region is determined by comparison to published sources of information (e.g., Refs. 9 through 13). When conflicting descriptions of individual earthquakes are found in the published references, the staff should determine which is appropriate for licensing decisions.

2.5.2.2 Geologic and Tectonic Characteristics of Site and Region. In meeting the requirements of References 1, 2, and 3, this subsection is accepted when all ~~geologic structures within the region and tectonic activity~~ **seismic sources** that are significant in determining the earthquake potential of the region are identified, or when an adequate investigation has been carried out to provide reasonable assurance that all significant ~~tectonic structures~~ **seismic sources** have been identified. Information presented in Section 2.5.1 of the applicant's safety analysis report (SAR) and information from other sources (e.g., Refs. 9 and 14 through 18) dealing with the current tectonic regime should be developed into a coherent, well-documented discussion to be used as the basis for determining **seismo**tectonic provinces and the earthquake-generating potential of **seismogenic sources and capable tectonic sources** ~~the identified geologic structures~~. Specifically, each ~~tectonic province~~ **seismic source**, any part of which is within ~~200~~ ~~150~~ 200 miles of the site, must be identified. The staff interprets **seismo**tectonic provinces to be regions of uniform ~~earthquake potential (seismotectonic provinces)~~ **seismicity (same expected earthquake and frequency of recurrence) distinct from the seismicity of the surrounding area**. The proposed **seismo**tectonic provinces may be based on seismicity studies, differences in geologic history, differences in the current tectonic regime, etc. The staff considers that the most important factors for the determination of **seismo**tectonic provinces include both (1)

✓ (v)

development and characteristics of the current tectonic regime of the region that is most likely reflected in the ~~neotectonics (Post-Miocene or about 5~~ **current tectonic regime, that is reflected in the Quaternary (approximately the last 2** million years and younger geologic history) and (2) the pattern and level of historical seismicity. Those characteristics of geologic structure, tectonic history, present and past stress regimes, and seismicity that distinguish the various **seismo**tectonic provinces and the particular areas within those provinces where historical earthquakes have occurred should be described. Alternative regional tectonic models derived from available literature sources, including previous SARs and NRC staff Safety Evaluation Reports (SERs), should be discussed. The model that best conforms to the observed data is accepted. In addition, in those areas where there are capable ~~faults~~ **tectonic sources**, the results of the additional investigative requirements described in ~~10 CFR Part 100, Appendix A, Section IV(a)(8) (Ref. 1),~~ **SRP Section 2.5.1** must be presented. The discussion should be augmented by a regional-scale map showing the ~~tectonic provinces~~ **seismic sources**, earthquake epicenters, locations of geologic structures and other features that characterize the **seismotectonic** provinces, and the locations of any capable ~~faults~~ **tectonic sources**.

Seismic Sources

2.5.2.3 Correlation of Earthquake Activity with ~~Geologic Structure~~ **Seismogenic Sources, Capable Tectonic Sources or SeismoTectonic** Provinces. In meeting the requirements of Reference 1, acceptance of this subsection is based on the development of the relationship between the history of earthquake activity and the ~~geologic structures or seismotectonic provinces~~ of a region. The applicant's presentation is accepted when the earthquakes discussed in Subsection 2.5.2.1 of the SAR are shown to be associated with either ~~geologic structure or tectonic province~~ **capable tectonic sources or seismogenic sources**. Whenever an earthquake hypocenter or concentration of earthquake hypocenters can be reasonably correlated with geologic structures, the rationale for the association should be developed considering the characteristics of the geologic structure (including geologic and geophysical data, seismicity, and the tectonic history) and the regional tectonic model. The discussion should include identification of the methods used to locate the earthquake hypocenters, an estimate of their accuracy, and a detailed account that compares and contrasts the geologic structure involved in the earthquake activity with other areas within the **seismo**tectonic province. Particular attention should be given to determining the capability of faults with which instrumentally located earthquake hypocenters are associated. ✓(✓)

Seismic Sources

The presentation should be augmented by regional maps, all of the same scale, showing the ~~seismotectonic provinces~~, the earthquake epicenters, and the locations of geologic structures and measurements used to define provinces. Acceptance of the proposed ~~seismotectonic~~ provinces is based on the staff's independent review of the geologic and seismic information. ✓(✓) ✓(✓)

Seismic Sources

2.5.2.4 Maximum Earthquake Potential. In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion due to the ~~maximum credible earthquake~~ **EME** associated with each ~~geologic structure or the maximum historic earthquake associated with each tectonic province~~ **seismic source** has been assessed and when the earthquake**(s)** that would produce the ~~maximum~~ **most severe** vibratory ground motion at the site has been determined. The ~~maximum credible earthquake~~ EME is the largest earthquake that can reasonably be expected to occur on a ~~geologic structure~~ **given seismic source** in the current tectonic regime. **The EME is not necessarily associated with any given return period. Considerable judgement is involved in estimating the EME. Suggested procedures for estimating the magnitude of the EME are given in Regulatory Guide 1.xxx.** ~~Geologic or seismological evidence may warrant a maximum earthquake larger than the maximum historic earthquake.~~ Earthquakes associated with each ~~geologic structure or tectonic province~~ **seismic source** must be identified. Where an earthquake is associated with geologic structure, the ~~maximum credible earthquake~~ **EME** that could occur on that structure should be evaluated, taking into account significant factors, for example, the type of the faulting, fault length, fault slip rate, rupture length, rupture area, moment, and earthquake history (e.g., Refs. 19 through 22).

In order to determine the ~~maximum credible earthquake~~ **EME** that could occur on those faults that are shown or assumed to be capable **tectonic sources**, the staff accepts conservative values based on historic experience in the region and specific considerations of the earthquake history and geologic history of movement on the faults. Where the earthquakes are associated with a **seismotectonic** province, the largest historic earthquake within the province should be identified. Isoseismal maps should also be presented for the most significant earthquakes. The ground motion at the site should be evaluated assuming appropriate seismic energy transmission effects and assuming that the ~~maximum earthquake~~ **EME** associated with each ~~geologic stru~~ [illegible] ~~r with each tectonic province~~ **seismic source** occurs at the point of closest approach of the structure or province to the site. (Further description is provided in Subsection 2.5.2.6.)

The earthquake(s) that would produce the most severe vibratory ground motion at the site should be defined. If different potential earthquakes would produce the most severe ground motion in different frequency bands, these earthquakes should be specified. The description of the potential earthquake(s) is to include the maximum intensity or magnitude and the distance from the assumed location of the potential earthquake(s) to the site. **For the seismotectonic province surrounding the site, the EME is assumed to occur randomly within 25 km of the site.** The staff independently evaluates the site ground motion produced by the ~~largest earthquake~~ **EME** associated with each ~~geologic str~~ [illegible] ~~re or~~

~~tectonic province~~ **seismic source**. Acceptance of the description of the potential earthquake(s) that would produce the largest ground motion at the site is based on the staff's independent analysis.

2.5.2.5 Seismic Wave Transmission Characteristics of the Site. In meeting the requirements of Reference 1, this subsection is accepted when the seismic wave transmission characteristics (amplification or deamplification) of the materials overlying bedrock at the site are described as a function of the significant frequencies. The following material properties should be determined for each stratum under the site: seismic compressional and shear wave velocities, bulk densities, soil index properties and classification, shear modulus and damping variations with strain level, and water table elevation and its variation. In each case, methods used to determine the properties should be described in Subsection 2.5.4 of the SAR and cross-referenced in this subsection. For the ~~maximum earthquake~~ **EME**, determined in Subsection 2.5.2.4, the free-field ground motion (including significant frequencies) must be determined, and an analysis should be performed to determine the site effects on different seismic wave types in the significant frequency bands. If appropriate, the analysis should consider the effects of site conditions and material property variations upon wave propagation and frequency content.

The free-field ground motion (also referred to as control motion) should be defined to be on a ground surface and should be based on data obtained in the free field. Two cases are identified depending on the soil characteristics at the site and subject to availability of appropriate recorded ground-motion data. When data are available, for example, for relatively uniform sites of soil or rock with smooth variation of properties with depth, the control point (location at which the control motion is applied) should be specified on the soil surface at the top of the finished grade. The free-field ground motion or control motion should be consistent with the properties of the soil profile. For sites composed of one or more thin soil layers overlying a competent material, or in case of insufficient recorded ground-motion data, the control point is specified on an outcrop or a hypothetical outcrop at a location on the top of the competent material. The control motion specified should be consistent with the properties of the competent material.

Where vertically propagating shear waves may produce the maximum ground motion, a one-dimensional equivalent-linear analysis (e.g., Ref. 23 or 24) or nonlinear analysis (e.g., Refs. 25, 26, and 27) may be appropriate and is reviewed in conjunction with geotechnical and structural engineering. Where horizontally propagating shear waves, compressional waves, or surface waves may produce the maximum ground motion, other methods of analysis (e.g., Refs. 28 and 29) may be more appropriate. However, since some of the variables are not well defined and the techniques are still in the developmental stage, no generally agreed-upon procedures can be promulgated at this time. Hence, the staff must use discretion in reviewing any method of analysis. To insure appropriateness, site response characteristics determined from analytical procedures should be compared with historical and instrumental earthquake data, when available.

2.5.2.6 Safe Shutdown Earthquake. In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion specified for the SSE is described in terms of the free-field response spectrum and is at least as conservative as that which would result at the site from the ~~maximum earthquake~~ **EMEs** (determined in Subsection 2.5.2.4) considering the site transmission effects (determined in Subsection 2.5.2.5). If several different ~~maximum potential earthquakes~~ **EMEs** produce the largest ground motions in different frequency bands (as noted in Subsection 2.5.2.4), the vibratory ground motion specified for the SSE must be as conservative in each frequency band as that for each earthquake.

The staff reviews the free-field response spectra of engineering significance (at appropriate damping values). Ground motion may vary for different foundation conditions at the site. When the site effects are significant, this review is made in conjunction with the review of the design response spectra in Section 3.7.1 to ensure consistency with the free-field motion. The staff normally evaluates response spectra on a case-by-case basis. The staff considers compliance with the following conditions acceptable in the evaluation of the SSE. In all these procedures, the proposed free-field response spectra shall be considered acceptable if they equal or exceed the estimated 84th percentile ground-motion spectra from the ~~maximum or controlling earthquake~~ **EMEs** described in Subsection 2.5.2.4.

The following steps summarize the staff review of the SSE.

1. Both horizontal and vertical component site-specific response spectra should be developed statistically from response spectra of recorded strong motion records that are selected to have similar source, propagation path, and recording site properties as the controlling earthquake(s). It must be ensured that the recorded motions represent free-field conditions and are free of or corrected for any soil-structure interaction effects that may be present because of locations and/or housing of recording instruments. Important source properties include magnitude and, if possible, fault type, and tectonic environment. Propagation path properties include distance, depth, and attenuation. Relevant site properties include shear velocity profile and other factors that affect the amplitude of waves at different frequencies. A sufficiently large number of site-specific time histories and/or response spectra should be used to obtain an adequately

broadband spectrum to encompass the uncertainties in these parameters. An 84th percentile response spectrum for the records should be presented for each damping value of interest and compared to the SSE free-field and design response spectrum (e.g., Refs. 30, 31, 32, and 33). The staff considers direct estimates of spectral ordinates preferable to scaling of spectra to peak accelerations. In the Eastern United States, relatively little information is available on magnitudes for the larger historic earthquakes; hence, it may be appropriate to rely on intensity observations (descriptions of earthquake effects) to estimate magnitudes of historic events (e.g., Refs. 34 and 35). If the data for site-specific response spectra were not obtained under geologic conditions similar to those at the site, corrections for site effects should be included in the development of the site-specific spectra.

2. Where a large enough ensemble of strong-motion records is not available, response spectra may be approximated by scaling that ensemble of strong-motion data that represent the best estimate of source, propagation path, and site properties (e.g., Ref. 36). Sensitivity studies should show the effects of scaling.

3. If strong-motion records are not available, site-specific peak ground acceleration, velocity, and displacement (if necessary) should be determined for appropriate magnitude, distance, and foundation conditions. Then response spectra may be determined by scaling the acceleration, velocity, and displacement values by appropriate amplification factors (e.g., Ref. 37). ~~Where only estimates of peak ground acceleration are available, it is acceptable to select a peak acceleration and use this peak acceleration as the high frequency asymptote to standardized response spectra such as described in Regulatory Guide 1.60 (Ref. 6) for both the horizontal and vertical components of motion with the appropriate amplification factors.~~ For each ~~controlling earthquake~~ EME, the peak ground motions should be determined using current relations between acceleration, velocity, and, if necessary, displacement, earthquake size (magnitude or intensity), and source distance. Peak ground motion should be determined from state-of-the-art relationships. Relationships between magnitude and ground motion are found, for example, in References 38, 39, 40, and 41 and relationships between ground motion and intensity are found, for example, in References 41, 42, and 43. Due to the limited data for high intensities greater than Modified Mercalli Intensity (MMI) VIII, the available empirical relationships between intensity and peak ground motion may not be suitable for determining the appropriate reference acceleration for seismic design.

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4. Response spectra developed by theoretical-empirical modeling

or for deeper sources (No)

(seismic)

(out)

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of ground motion may be used to supplement site-specific spectra if the input parameters and the appropriateness of the model are thoroughly documented (e.g., Refs. 19, 44, 45 ~~and~~ 46, and 53). Modeling is particularly useful for sites near capable ~~faults~~ tectonic sources that may experience ground motion that is different in terms of frequency content and wave type from ground motion caused by more distant earthquakes.

(should read "modeling is particularly useful for sites near seismic sources that..."

5. Probabilistic estimates of seismic hazard should be calculated (e.g., Refs. 41 and 47) and the underlying assumptions and associated uncertainties should be documented to assist in the staff's overall deterministic approach. The probabilistic studies should highlight which seismic sources are significant to the site. ~~Uniform hazard spectra (spectra that have a uniform probability of exceedance over the frequency range of interest) showing uncertainty should be calculated for 0.01, 0.001, and 0.0001 annual probabilities of exceedance at the site.~~ The probability of exceeding the SSE response spectra should also be estimated and comparison of results made with other probabilistic studies. **Suggested procedures are contained in Appendix A to this SRP Section.**

The time duration and number of cycles of strong ground motion is required for analysis of site foundation liquefaction potential and for design of many plant components. The adequacy of the time history for structural analysis is reviewed under SRP Section 3.7.1. The time history is reviewed in this SRP section to confirm that it is compatible with the seismological and geological conditions in the site vicinity and with the accepted SSE model. At present, models for deterministically computing the time history of strong ground motion from a given source-site configuration may be limited. It is therefore acceptable to use an ensemble of ground-motion time histories from earthquakes with similar size, site-source characteristics, and spectral characteristics or results of a statistical analysis of such an ensemble. Total duration of the motion is acceptable when it is as conservative as values determined using current studies such as References 48, 49, 50, and 51.

~~2.5.2.7 Operating Basis Earthquake. In meeting the requirements of Reference 1, this subsection is acceptable when the vibratory ground motion for the OBE is described and the response spectrum (at appropriate damping values) at the site specified. Probability calculations (e.g., Refs. 41, 47, and 52) should be used to estimate the probability of exceeding the OBE during the operating life of the plant. The maximum vibratory ground motion of the OBE should be at least one-half the maximum vibratory ground motion of the SSE unless a lower OBE can be justified on the basis of probability calculations. It has been staff practice to accept the OBE if the return period is on the order of hundreds of years~~

~~(e.g., Ref. 31).~~

III. REVIEW PROCEDURES

Upon receiving the applicant's SAR, an acceptance review is conducted to determine compliance with the investigative requirements of 10 CFR Part 100, Appendix A (Ref. 1). The reviewer also identifies any site-specific problems, the resolution of which could result in extended delays in completing the review.

After SAR acceptance and docketing, those areas are identified where additional information is required to determine the earthquake hazard. These are transmitted to the applicant as draft requests for additional information.

A site visit may be conducted during which the reviewer inspects the geologic conditions at the site and region around the site as shown in outcrops, borings, geophysical data, trenches, and those geologic conditions exposed during construction if the review is for an operating license. The reviewer also discusses the questions with the applicant and his consultants so that it is clearly understood what additional information is required by the staff to continue the review. Following the site visit, a revised set of requests for additional information, including any additional questions that may have been developed during the site visit, is formally transmitted to the applicant.

The reviewer evaluates the applicant's response to the questions, prepares requests for additional clarifying information, and formulates positions that may agree or disagree with those of the applicant. These are formally transmitted to the applicant.

The safety analysis report and amendments responding to the requests for additional information are reviewed to determine that the information presented by the applicant is acceptable according to the criteria described in Section II (Acceptance Criteria) above. Based on information supplied by the applicant, obtained from site visits or from staff consultants or literature sources, the reviewer independently identifies and evaluates the relevant ~~seismotectonic provinces~~ seismogenic sources and capable tectonic sources, evaluates the capability of faults in the region, and determines the earthquake potential for each ~~province and each capable fault or tectonic structure~~ seismogenic source or capable tectonic source using procedures noted in Section II (Acceptance Criteria) above. The reviewer evaluates the vibratory ground motion that the ~~potential earthquakes~~ EMEs could produce at the site and ~~defines~~ compares that ground motion to the safe shutdown earthquake~~ and operating basis earthquake~~.

IV. EVALUATION FINDINGS

If the evaluation by the staff, on completion of the review of the

SSE(✓)

geologic and seismologic aspects of the plant site, confirms that the applicant has met the requirements or guidance of applicable portions of References 1 through 6, the conclusion in the SER states that the information provided and investigations performed support the applicant's conclusions regarding the seismic integrity of the subject nuclear power plant site. In addition to the conclusion, this section of the SER includes (1) ~~definitions~~ **an evaluation** of ~~tectonic provinces~~ **seismogenic sources and capable tectonic sources**; (2) evaluations of the capability of geologic structures in the region; (3) ~~determinations~~ **evaluation** of the ~~SSE earthquake(s)~~ **EMEs** and ^ free-field response spectra based on evaluation of the potential earthquakes; **and** (4) time history of strong ground motion~~, and (5) determinations of the OBE free-field response spectra~~. Staff reservations about any significant deficiency presented in the applicant's SAR are stated in sufficient detail to make clear the precise nature of the concern. The above evaluation determinations or redeterminations are made by the staff during both the construction permit (CP) and operating license (OL) phases of review.

OL applications are reviewed for any new information developed subsequent to the CP safety evaluation report (SER). The review will also determine whether the CP recommendations have been implemented.

A typical OL-stage summary finding for this section of the SER follows:

> In our review of the seismologic aspects of the plant site we have considered pertinent information gathered since our initial seismologic review which was made in conjunction with the issuance of the Construction Permit. This new information includes data gained from both site and near-site investigations as well as from a review of recently published literature.
>
> As a result of our recent review of the seismologic information, we have determined that our earlier conclusion regarding the safety of the plant from a seismological standpoint remains valid. These conclusions can be summarized as follows:
>
> 1. Seismologic information provided by the applicant and required by Appendix A to 10 CFR Part 100 provides an adequate basis to establish that no ~~capable faults~~ **seismic sources** exist in the plant site area which would cause earthquakes to be centered there.
>
> 2. The response spectrum proposed for the safe shutdown earthquake is the appropriate free-field response spectrum in conformance with Appendix A to 10 CFR Part 100.

The new information reviewed for the proposed nuclear power plant is discussed in Safety Evaluation Report Section 2.5.2.

The staff concludes that the site is acceptable from a seismologic standpoint and meets the requirements of (1) 10 CFR Part 50, Appendix A (General Design Criterion 2), (2) 10 CFR Part 100, and (3) 10 CFR Part 100, Appendix A. This conclusion is based on the following:

1. The applicant has met the requirements of:

   a. 10 CFR Part 50, Appendix A (General Design Criterion 2) with respect to protection against natural phenomena such as faulting.

   b. 10 CFR Part 100 (Reactor Site Criteria) with respect to the identification of geologic and seismic information used in determining the suitability of the site.

   c. 10 CFR Part 100, Appendix A (Seismic and Geologic Siting Criteria for Nuclear Power Plants) with respect to obtaining the geologic and seismic information necessary to determine (1) site suitability and (2) the appropriate design of the plant. Guidance for complying with this regulation is contained in Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Regulatory Guide 4.7, "General Site Suitability for Nuclear Power Stations," and Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants."

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant/licensee proposes an acceptable alternative method for complying with specific portions of the Commission's regulations, the methods described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides and NUREGs (Refs. 4 through 8).

The provisions of this SRP section apply to reviews of construction permit (CP), operating license (OL), preliminary design approval (PDA), final design approval (FDA), and combined license (CP/OL) applications docketed after the date of issuance of this SRP section.

VI. REFERENCES

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2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomana."

3. 10 CFR Part 100, "Reactor Site Criteria."

4. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."

5. Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations."

6. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants."

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NOTES: Need to revise reference list to add EPRI and LLNL probability study and other references that are significant. Also some of the older references could be deleted.

Add Appendix A - PROBABILISTIC INVESTIGATIONS

Appendix A to SRP Section 2.5.2

Probabilistic Considerations in Estimates of Vibratory Ground Motion

Introduction

Probabilistic estimates of seismic hazard should be calculated and the underlying assumptions and associated uncertainties should be documented to assist in the staff's overall evaluation of the site and the proposed design basis. The probabilistic criteria are not to be interpreted as a strict "go -no go" criteria in terms of determining the final site suitability or adequacy of the design basis. They provide additional perspective to form overall judgement and guidance on further investigations or revisions to design basis.

Uniform hazard spectra (spectra that have a uniform probability of exceedance over the frequency range of interest) should be calculated to estimate the probability of exceeding the SSE response spectrum. Probabilistic hazard estimates (peak ground acceleration vs. annual probability of exceedance) should also be documented. There are three major purposes for carrying out the probabilistic hazard analysis: (✓)

Purposes

(1) The first purpose is to systematically take into account uncertainties which exist in various factors (such as seismic sources, seismicity, and ground motion attenuation characteristics) involved in estimating ground motion and hazard estimates. (✓)

The probabilistic method allows for consideration of alternate hypotheses and diverse expert opinions which exist in estimating these factors in a quantitative fashion displaying the influence of these factors. (✓)

¶(2) The Second purpose ~~results of a probabilistic~~ hazard ~~analysis will~~ is to (✓) identify ~~reveal~~ significant contributions in terms of magnitude and distance, and identify seismic sources significant to the site. ~~Such information can vastly improve the staff's ability to assess the impact of discrepancies between the proposed smooth design response spectra for the site and the site-specific spectra derived from the considerations discussed in this SRP section. (Given that the standardize design, with a smooth design spectra selected much before a site selection, are more likely to be a next generation of plants, these considerations become more important as the opportunity to select a design spectra or to alter a plant design is minimized. Furthermore, explicitly accounting for various hypotheses and opinions earlier should result into a smoother and stable licensing process with the avoidance of answering many questions on these alternate views during licensing~~ (✓)

~~hearings. Even if a new information not considered in the original probabilistic analysis emerges, a framework and structured approach will exist by which an assessment of impact of this new information on the design basis ground motion can be quickly made avoiding extensive unnecessary plant reevaluations. For future plants, results of the probabilistic risk assessment and plant capacities will be available; this information coupled with the probabilistic hazard information can provide a quick assessment of impact of the new seismic information from the public health and safety view point.)~~ (✓)

3 third (✓)

(~~2~~) The ~~second~~ purpose is to demonstrate that the probability of exceeding the SSE compares favorably **(i.e. similar to that shown for the lower half of the population)** to that at operating nuclear power plants. A procedure for such an demonstration is described later. (✓)

4 fourth (✓)

(~~3~~) The ~~third~~ purpose of a probabilistic hazard analysis is to provide hazard estimates for use (or to demonstrate adequacy of the hazard estimates used at the design stage) in the seismic probabilistic risk assessments (PRA). (✓)

Review Procedure

The following procedure is one acceptable approach to assure that the probability of exceeding the SSE compares favorably to that at operating nuclear power plants. (ok as is) It must be emphasized that the probability of exceeding the design basis can not be translated directly into probabilities of seismically-induced core damage frequencies or other risk indices. A plant's ability to cope with a seismic event depends on many factors including the plant's design, site-specific features, and operational characteristics. A plant designed with a design basis exhibiting relatively higher probability of exceedance may very well have a higher seismic margin against the design basis. Mean estimates of core damage and risks are governed by the uncertainties in the hazard and shape (slope characteristics) of overall hazard curve. The probability of exceeding the design basis discussed here, essentially, only represents a single acceleration value on an hazard curve. The use of hazard curves in a PRA, therefore, requires different considerations than the steps outlined below to estimate the probability of exceeding the design basis.

This paragraph is not really necessary.

A. Eastern U.S. Sites. There are two state-of-the-art approaches (LLNL and EPRI) currently (July 1991) available to calculate the probabilistic seismic hazard for any site in the Eastern U.S. east of the Rockies (EUS). These approaches, however, produce different results for a given site. Also, the seismic hazard calculations exhibit large uncertainties, indicating a wide range of expert opinions. Therefore, the staff is recommending the following ~~procedure as an~~ interim procedure for comparison to operating plants (✓) until the differences between the

(✓)

two hazard methods are resolved. This procedure relies on relative measures to assure that the annual probability of exceeding the design basis is comparable to ~~the~~ that of (v) operating plants. The procedure is based on studies conducted for the Eastern Seismicity Issue and the IPEEE program (NUREG-1407). Although the following procedure is stated in terms of the LLNL method, the EPRI method can also be used in conjunction with the EPRI specific criteria stated in Step 4(c).

Step 1. The seismic source and ground motion data developed in the LLNL program should be used as inputs to the LLNL probabilistic seismic hazard methodology. ~~to characterize overall probabilistic results.~~ (v) ✓

Step 2. Since the above will produce probabilistic ground motion results compatible with generic site characteristics, these results should be modified for the proposed site, taking into account local site profile and properties, topographic features, and local geology, including uncertainties inherent in the parameters and calculations.

Step 3. The hazard should be calculated as Uniform Hazard Response Spectra (UHRS) with various probabilities of exceedances and associated with various statistical measures (e.g., mean, median, and 85th percentile). Such results are shown in ~~a~~ graphical form in Figure 1. The UHRS should be developed for the same location as the location of the SSE (i.e. either at the free ground surface or at a hypothetical rock outcrop). ✓(v)

Step 4. The following procedure should be used to calculate a composite annual probability of exceeding the design basis ground motion, and to compare ~~[illegible]~~ that composite to those of operating plants (v). The procedure is illustrated in Figure 2.

(a) Estimate the annual probability of exceeding the design spectrum at two discrete frequencies (5.0 and 10 Hz) using the UHRS.

(b) Calculate the composite annual probability using the following formula:

Comp. Prob. = 1/2(a1)+1/2(a2)

where a1 and a2 represent annual probabilities of exceeding design basis spectral ordinates at 5 and 10 Hz, respectively.

Example: From Fig. 2, for mean UHRS, at points a1 and a2 corresponding to 5 and 10 Hz:

Comp. Prob. = 1/2(4E-4)+1/2(8E-4)
= 6E-4.

Since composite probabilities should be calculated for mean, median, and 85th percentile UHRS, this will result in three measures of composite probabilities. For the above example, these measures make look like the following:

	Mean	Median	85 percentile
Composite Probability	6E-4	5E-5	8E-4

(c) Figs. 3(a), (b), and (c), respectively, show distributions of mean, 85 percentile, and median probabilities of exceeding design basis for sites with currently operating plants using LLNL hazard estimates. These figures also show limits which approximately represent values below which 50% of the currently operating plants fall. For the hypothetical example presented in Step (b) above, the selected SSE is adequate in terms of the probability of exceeding it when compared to the limits shown in the figures. (no-changes meaning)

For the hypothetical example,

		Limit
Mean prob. of exceedance	= 6E-4 <	2E-3
Median prob. of exceedance	= 5E-5 <	1E-4
85 % prob. of exceedance	= 8E-4 <	2E-3

Commentary on the Above Procedure

As stated earlier, the objective of this exercise is to assure that the probability of exceeding the SSE is comparable to those computed for the current plants, i.e., similar to that exhibited by the lower half of the population. Because of uncertainties involved in these probabilistic estimates, three summary statistics, mean, median, and 85 percentile, estimated in Step (b) above should be compared with the trend shown in Figs. 3(a), 3(b), and 3(c). Use of any one of these summary statistic by itself could be misleading. The mean statistic may be totally dominated by extreme opinions, and does not reflect a constant level of assurance from a site to site. The use of median measure by itself amounts to ignoring uncertainty. The 85th percentile reflects some uncertainty at a constant level of assurance.

Some other observations with regards to the information presented in these figures are also pertinent. For example, Fig. 3(a) indicates that for ninety percent of sites, the mean probability of exceeding the current design basis is less than or equal to 5E-3/yr. Other observations from these figures are as follows: (1) 80% of the population lies between a relatively narrow range of 2E-4/yr to 5E-3/yr; (2) A relatively small change in the range of probability of exceedance encompasses a significant number of plants; and (3) because of large uncertainties in these estimates difference between a site with a high probability of exceedance and a site with an average probability of exceedance is at best a relative measure.

If the EPRI Probabilistic methodology is used the limits will be different

(D) Figs. 4(a), (b), and (c) present ~~same~~ information resulting from the use of the EPRI UHRS estimates. These should be used when the EPRI method is used to calculate the probability of exceeding the SSE. It should be noted that estimates of probability of exceedance(particularly mean estimates) from these two methods differ significantly. However, some robustness exists in ranking of the sites in that the top groups (groups exhibiting relatively higher probability of exceedance compared to the rest of the population) is generally consistent using either LLNL or EPRI method or using mean, median, or 85 percentile statistics. It must be emphasized that strict numerical ranking is not implied here; given the uncertainties in these estimates, there is essentially no difference between, say probability of exceedance being 8E-3 vs. being 2E-2 or a numerical ranking obtained therefrom. Because of the above findings, a use of one hazard method is considered adequate for this purpose.

(?) similar to figure 3 but

Since several standard designs have been proposed with an SSE of 0.3g PGA, as a guidance, Figs. 5(a), (b), and (c) show probability of exceeding 0.3g, NUREG/CR-0098 spectra, for sites with the currently operating plants. Figs. 6(a), (b), and (c) show similar results for the EPRI method.

In summary, the staff will use the UHRS and the information presented in either Figs. 3(a) through (c) or Figs. 4(a) through (c), ~~and the information computed in Step 3 above to~~ judge the adequacy of an SSE for a site. ~~from the perspective of probability of exceeding it.~~

(seems ok as is)

B. Western U.S.Sites. For the Western U.S. (WUS) sites, a probabilistic data base, such as that compiled in the LLNL and EPRI studies, is not available. To date no procedure exists, similar to that described above, to compare the probability of exceeding the SSE to other sites in the WUS. In addition, the probabilistic hazard at a site in the WUS may be governed by clearly identifiable seismic sources, such as faults (or folds) observed at the surface, which have better defined seismicity characteristics. Therefore, for the WUS sites, a site-specific analysis using suitable methodologies should be carried out to calculate the probability of exceeding the SSE and to identify significant contributions to the hazard (Example-Diablo SSER).

Hazard Curves for PRA

For the purposes of carrying out a seismic PRA, the staff recommends (as an interim position) that for the EUS, hazard estimates obtained from the use of both the LLNL and EPRI methods be used. This is necessary to fully display uncertainties currently present in these estimates. The bottom line results, such as core damage frequencies or frequencies of large releases, are dominated by estimates of uncertainties in the hazard estimates. For the WUS, site specific hazard estimates developed as discussed earlier should be used in a PRA.

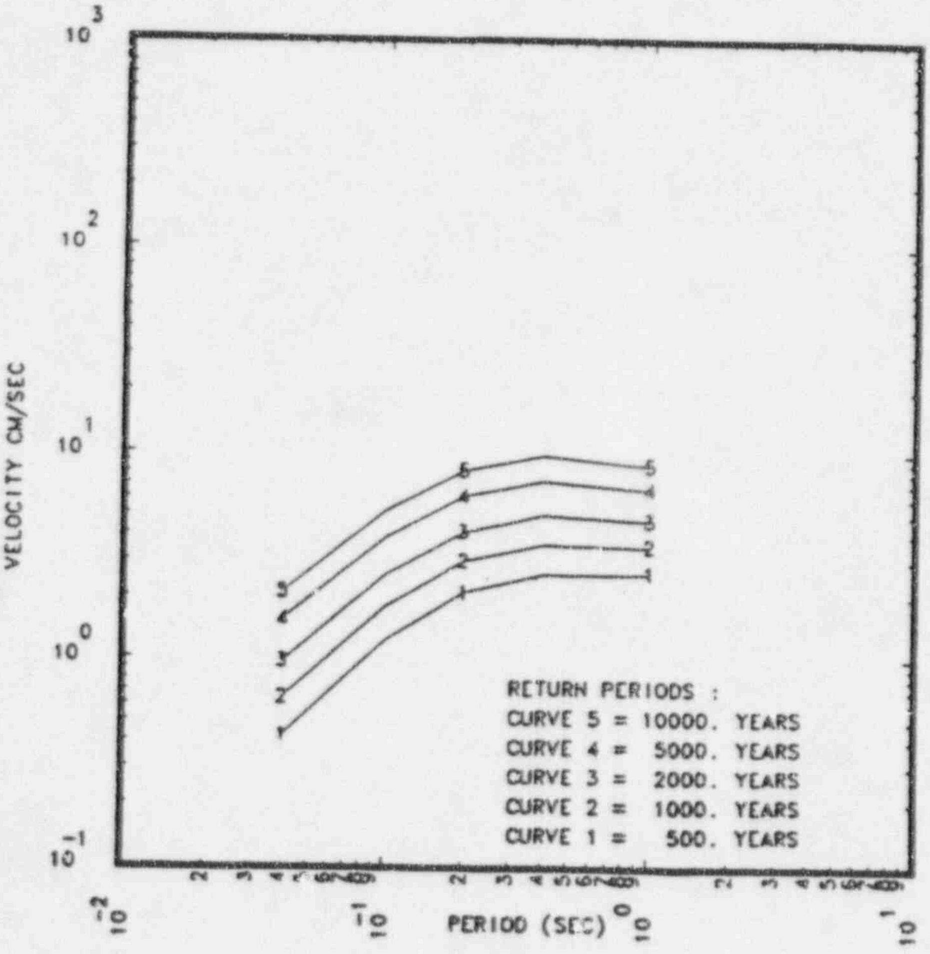

Fig. 1 Uniform Hazard Spectra (Mean, Median, or 85 Percentile)

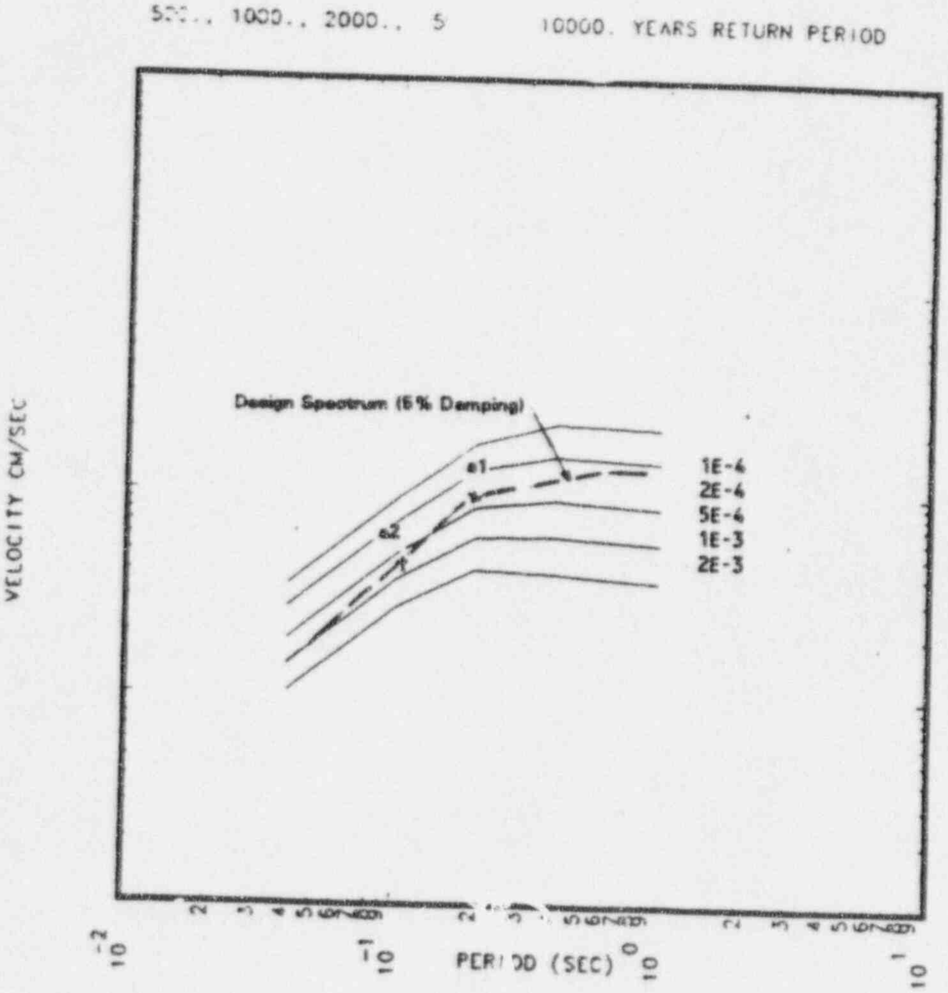

Fig. 2 Procedure to Compute Probability of Exceeding Design Basis

Comp. Prob. = 1/2(a1) + 1/2(a2)
= 1/2(4E-4) + 1/2(8E-4)
= 6E-4

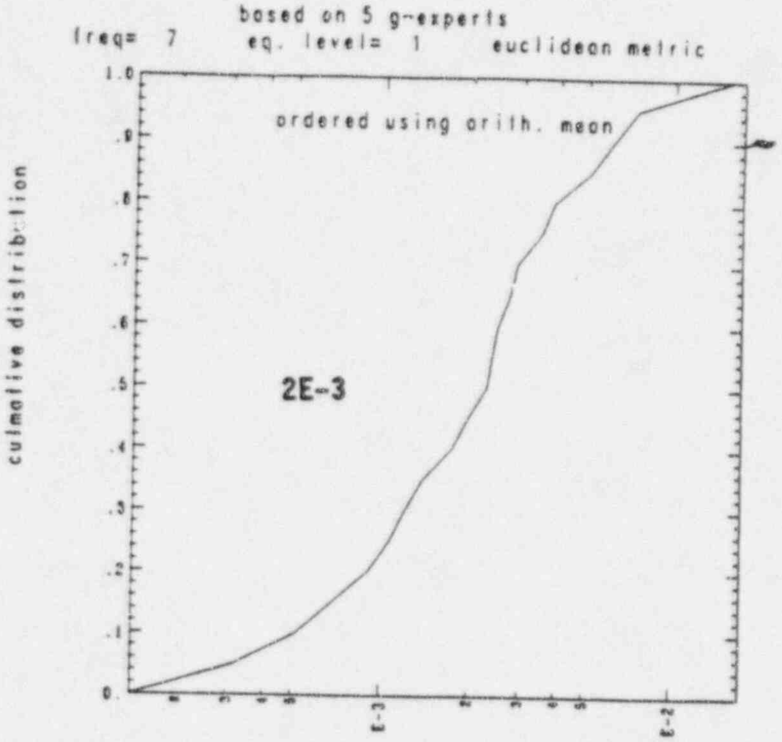

Fig. 3(a). prob. of exceedance

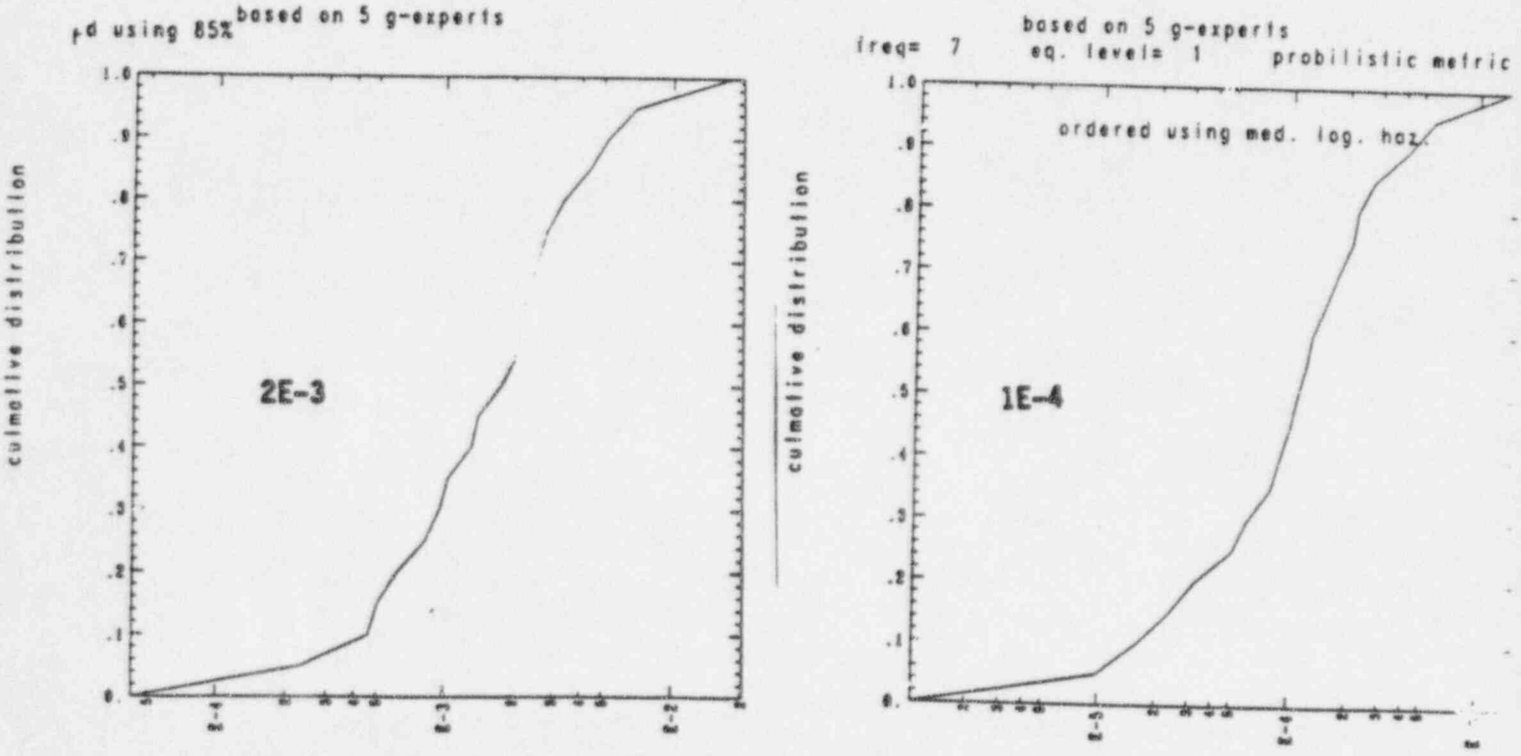

Fig. 3(b) prob. of exceedance

Fig. 3(c) prob. of exceedance

Fig.3 **Probability of Exceeding Design Basis Using LLNL Hazard Estimates**

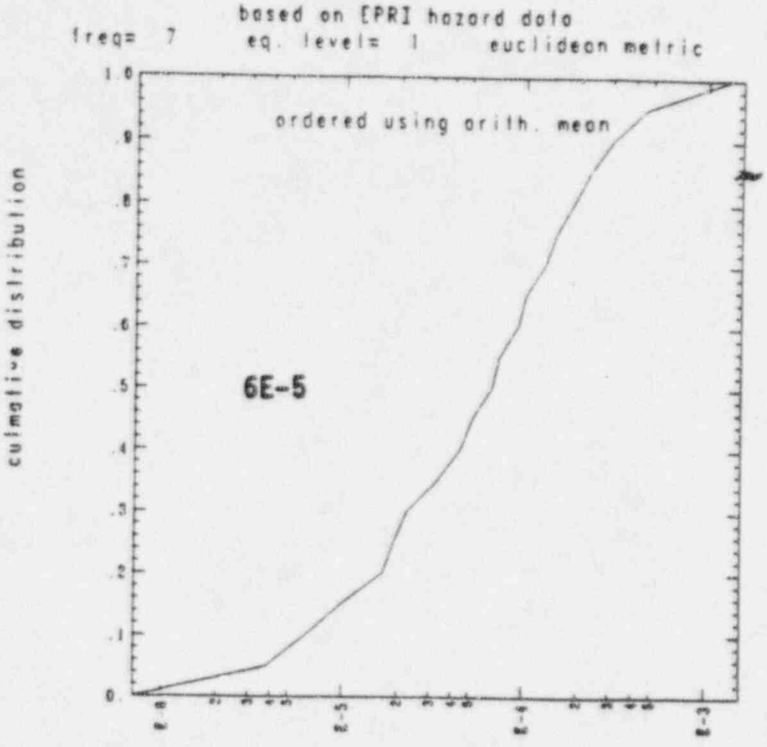

Fig. 4(a)

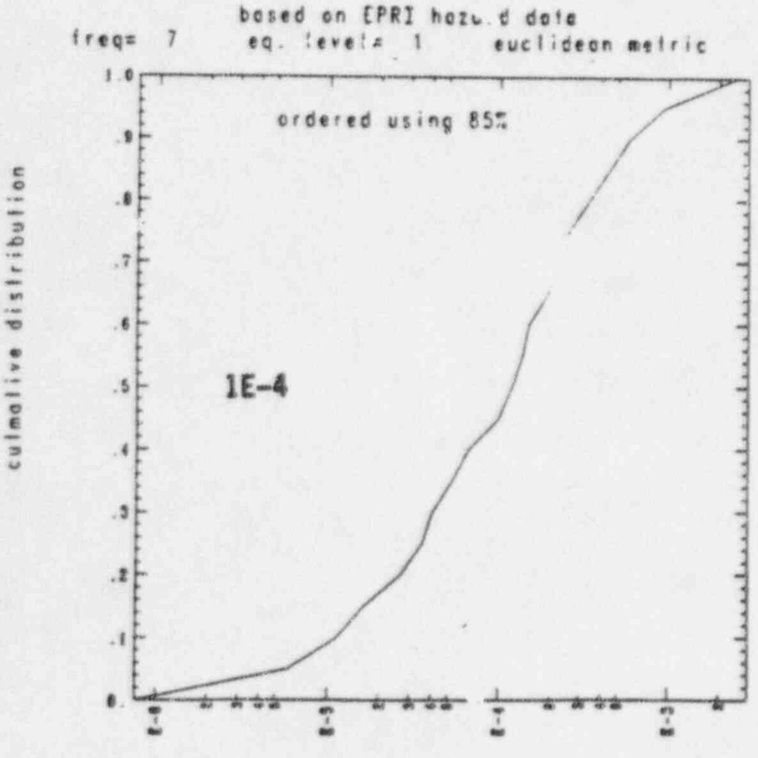

Fig. 4(b)

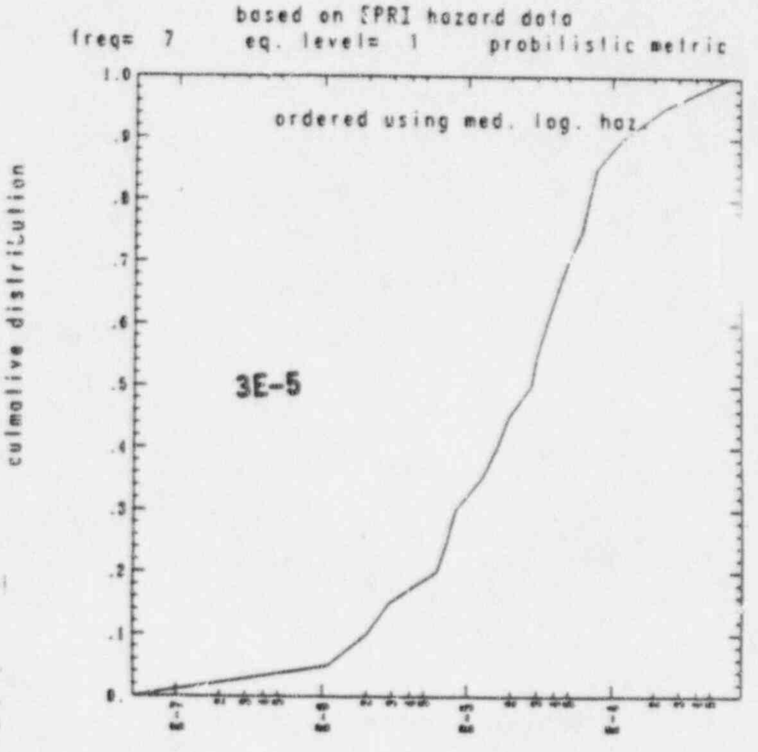

Fig. 4(c)

Fig.4 Probability of Exceeding Design Basis Using EPRI Hazard Estimates

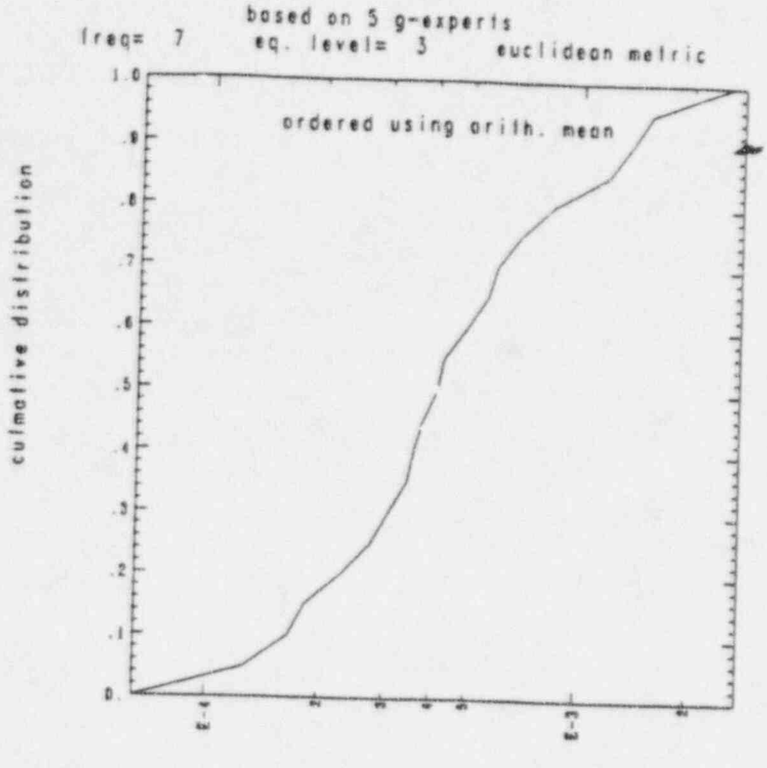

Fig. 5(a)

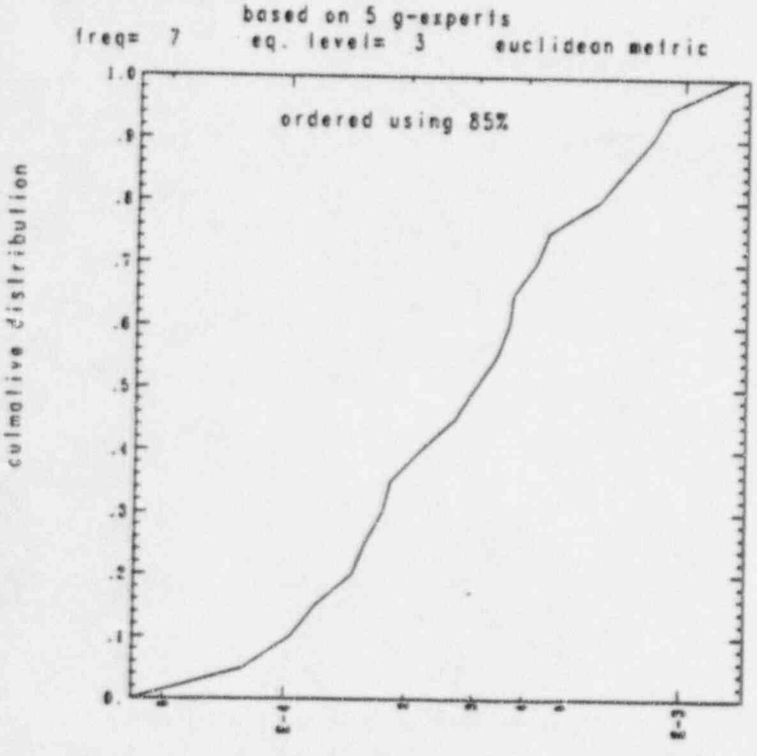

Fig. 5(b)

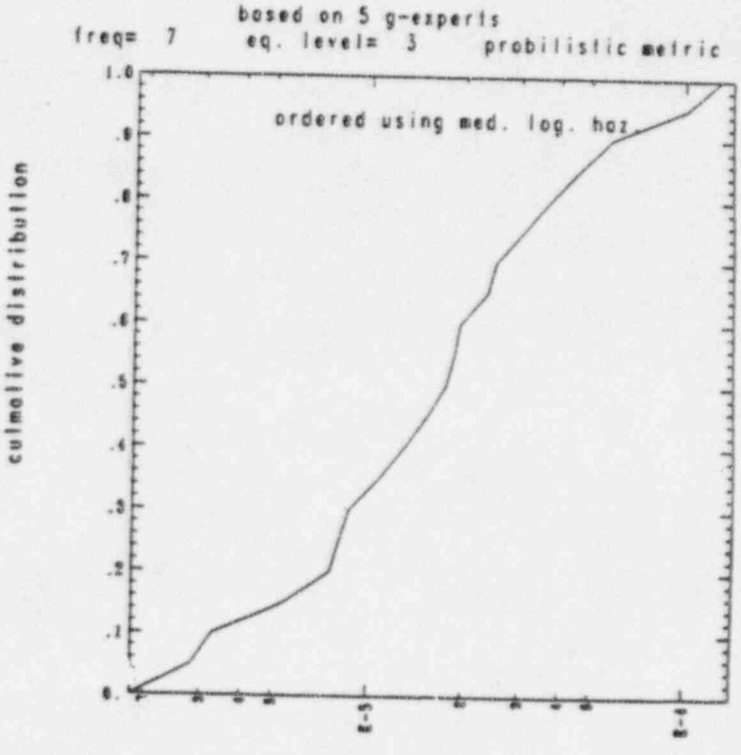

Fig. 5(c)

Fig.5 Probability of Exceeding NUREG/CR-0098 Median Spectrum (5% Damping, Anchored to 0.3g PGA) Using LLNL Hazard Estimates

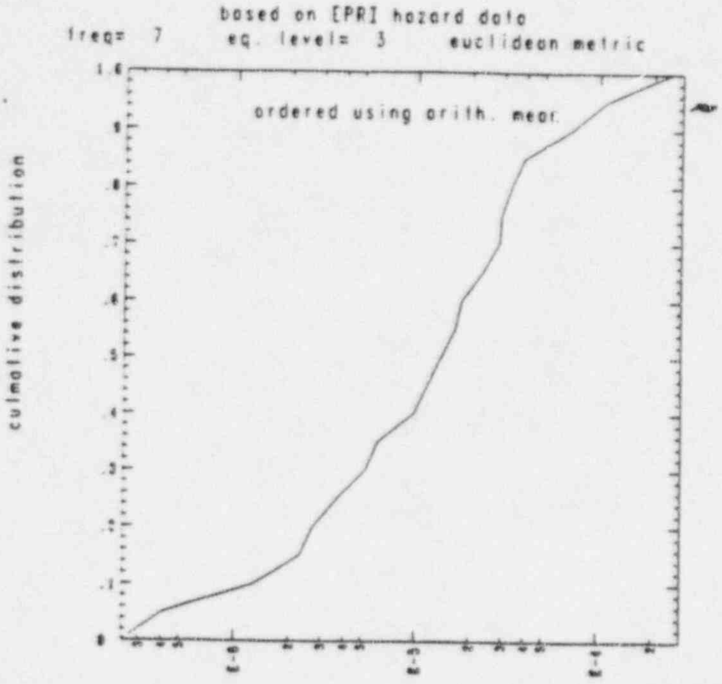

Fig. 6(a) prob. of exceedance

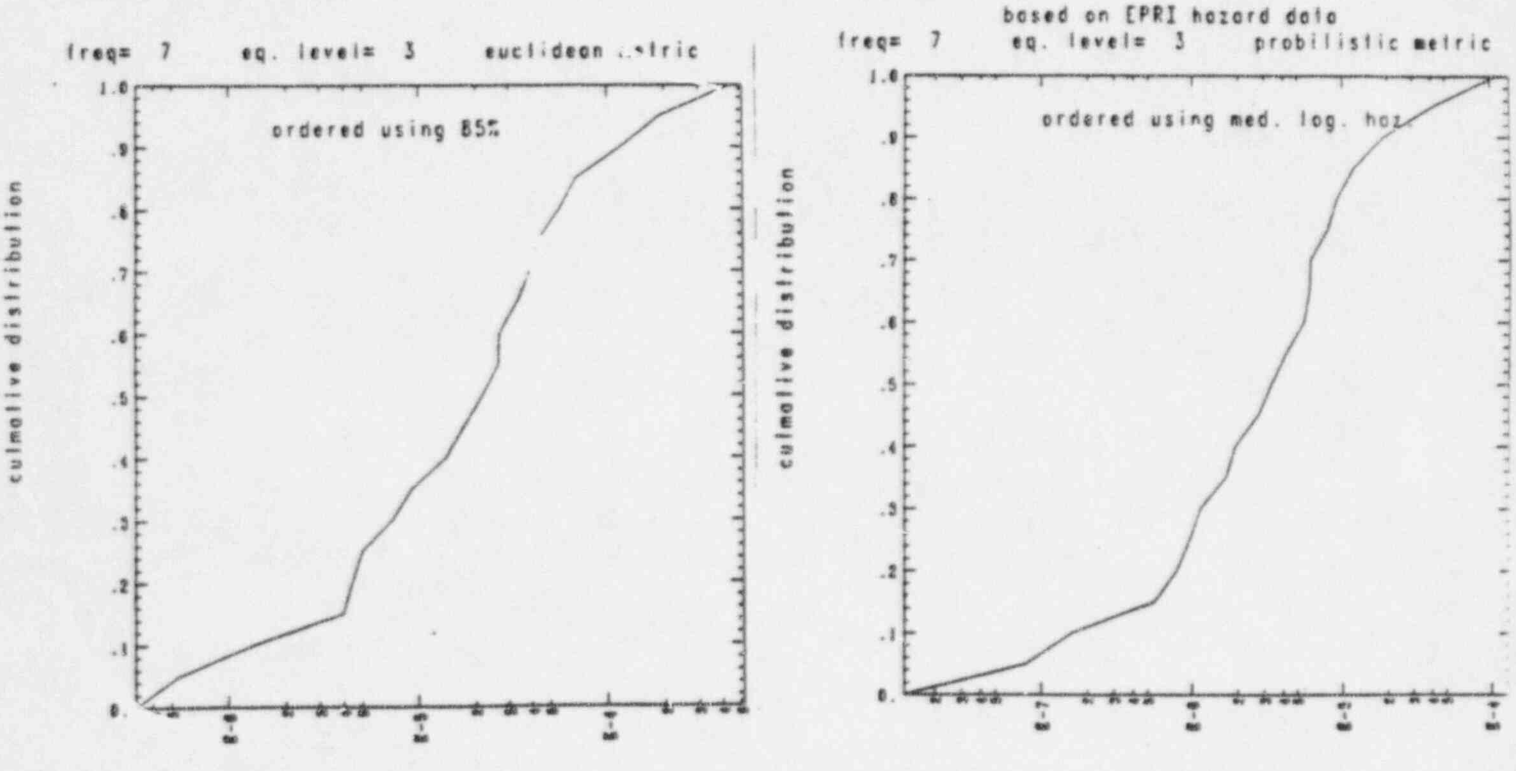

Fig. 6(b)

Fig. 6(c) prob. of exceedance

Fig.6 Probability of Exceeding NUREG/CR-0098 Median Spectrum (5% Damping, Anchored to 0.3g PGA) Using EPRI Hazard Estimates

DRAFT REGULATORY GUIDE DG-1016

SEISMIC INSTRUMENTATION

DRAFT REGULATORY GUIDE DG-1016
SECOND PROPOSED REVISION 2 TO REGULATORY GUIDE 1.12
NUCLEAR POWER PLANT INSTRUMENTATION FOR EARTHQUAKES

A. INTRODUCTION

Paragraph (c) of §20.1, "General Purpose," to 10 CFR Part 20, "Standards for Protection Against Radiation," requires licensees to make every reasonable effort to maintain radiation exposures, and release of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable. Paragraph (c) of §50.36, "Technical Specifications," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires the technical specifications of a facility to include surveillance requirements to ensure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the limiting conditions of operation will be met. Paragraph IV(a)(4) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires that suitable instrumentation shall be provided so that the recorded seismic response of nuclear power plant features important to safety can be evaluate promptly to permit comparison of such response with that used as the design basis. (Paragraph VI of Appendix B, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, Reactor Site Criteria," also cites Appendix S to 10 CFR Part 50). Paragraph (IV)(a)(3) of Appendix S to 10 CFR Part 50 also requires that if vibratory ground motion exceeding that of the Operating Basis Earthquake (OBE) occurs shutdown of the nuclear power plant will be required.[1] This guide describes seismic instrumentation that is acceptable to the NRC staff as satisfying the above-stated requirements of Parts 20, 50 and Appendix S to Part 50.

B. DISCUSSION

When an earthquake occurs, it is important to assess immediately the effects of the earthquake at the nuclear power plant. State-of-the-art solid-state digital time-history accelerographs installed at appropriate location will provide data on the frequency, amplitude, and phase relationship of the seismic response of the free-field, containment structure, and other Category I structures so that a comparison and evaluation of such response with that used as the design basis can be made.

(The following factors that should be considered in selecting the location for the instruments are highlighted. (this statement isn't needed at all)

It may not be necessary that each of two or more identical nuclear power units on a given site be provided with seismic instrumentation if essentially the same seismic response at each of the several units is expected from a given

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[1] Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions," provides plant shutdown criteria.

earthquake.

Time limits associated with an immediate evaluation of seismic instrumentation data are quantified.

Based upon an evaluation of seismic instrumentation operational experience, it was noted that instruments have been known to be out of service during plant shutdown. The instrumentation system should be operable at all times. The guidelines that will be followed by the NRC staff if the seismic instrumentation is inoperable are identified.

Information pertaining to instrumentation characteristics, installation, activation, remote indication and maintenance is provided to ensure (1) that the data provided are comparable with that used in the design of the nuclear power plant, (2) that exceedance of the Operating Basis Earthquake can be determined, and (3) that the equipment will perform as required.

C. REGULATORY POSITION

1. Seismic Instrumentation Type and Location.

   a. The use of state-of-the-art solid-state digital instrumentation enabling quick data processing at the plant site is required.

   b. A triaxial time-history accelerograph shall be provided at each of the following locations:

      (i) Free-field

      (ii) Containment foundation

      (iii) Two elevations (excluding the foundation) on the internal containment structure

      (iv) Two independent Category I structure foundations, for instance, the Diesel Generator Building and the Auxiliary Building, where the response is different from that of the containment structure.

      (v) An elevation (excluding the foundation) on the independent Category I structures selected in C(1)(b)(iv) above.

      (vi) If seismic isolators are used, instrumentation should be placed on the rigid and isolated portions of the structures at approximately the same elevations.

   c. The specific locations shall be determined by the nuclear plant designer to obtain the most pertinent information. Maintaining occupational radiation exposures as low as reasonably achievable (ALARA) for the location, installation and maintenance of seismic instrumentation should be considered in accordance with 10 CFR Part

20.1(c) and Regulatory Guide 8.8[2]. In general:

(i) an ALARA design review of location, installation and maintenance of proposed instrumentation should be performed in the planning stage by the facility in accordance with Regulatory Guide 8.8.

(ii) instrumentation should be located in as low a dose rate area as is practical, consistent with other requirements.

(iii) instruments should be selected which require minimal maintenance and in-service inspection, and minimal time and numbers of personnel to conduct installation and maintenance.

(iv) consistent with the requirements of this Regulatory Position, instrumentation should be located to facilitate maintenance, installation and removal; to minimally impact other maintenance and operations; and to require the minimal degree of plant modification (e.g., removal/replacement of interferences).

2. Instrumentation Required at Multi-Unit Sites.

Instrumentation in addition to that installed for a single unit will not be required if essentially the same seismic response is expected at the other units based on the seismic analysis used in the seismic design of the plant. However, in case of separate control rooms, annunciator requirements specified in C(7) shall be applicable to both control rooms.

3. Seismic Instrumentation Operability.

a. Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions," is based on the assumption that the nuclear power plant has operable seismic instrumentation[3], including the equipment and software required to process the data within four hours after an earthquake. This is necessary to compare the recorded data against OBE exceedance criterion and to evaluate the results of the operator walkdown inspections within eight hours of the event.

b. Instrumentation should be maintained in operation during periods of plant shutdown. The maintenance and repair procedures shall make

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[2] Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable."

[3] If the seismic instrumentation is inoperable the guidelines described in Appendix A to Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions," will be used to determine if the Operating Basis Earthquake has been exceeded.

provisions for keeping the maximum number of instruments in service during plant operation and shutdown.

4. Instrumentation Characteristics

a. In-service testing provisions shall be included in the design. These instruments shall be capable of periodic channel checks during normal plant operation.

b. The instruments shall have the capability for in-place functional testing.

c. The instrumentation of the foundation and at elevation within the same building/structure shall be interconnected for common starting and common timing, and shall contain provisions for an external remote alarm to indicate actuation.

5. Instrumentation Installation

a. The instrumentation shall be designed and installed so that the vibratory transmissibility over the amplified region of the design spectra frequency range is essentially unity, that is, rigid.

b. The instrumentation shall be oriented so that the horizontal axes are parallel to the orthogonal horizontal axes assumed in the seismic analysis.

c. Protection shall be provided against accidental impacts.

6 Instrumentation Actuation

a. Both vertical and horizontal input vibratory ground motion shall actuate the same time-history accelerograph.

b. Spurious triggering should be avoided.

c. The actuation mechanisms of the time-history accelerograph shall be set for a threshold ground acceleration of not more than 0.02g.

7. Remote Indication

Upon actuation of any time-history accelerograph a remote indication in the control room shall be activated.

8. Maintenance

a. The purpose of the maintenance program is to assure that the equipment will perform as required. As stated in C(4)(b), the maintenance and repair procedures shall make provisions for keeping the maximum number of instruments in service during plant operation and shutdown.

b. The frequency of maintenance is:

(i) Channel Checks:[4] Every Month

(ii) Channel Functional Test: Every 6 Months

(iii) Channel Calibration: Refueling

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 herein will be used in the evaluation of submittals docketed after [date]. If an applicant or licensee wishes to use this regulatory guide for submittals docketed before [date], the pertinent portions of the application will be evaluated on the basis of this guide.

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[4] Systems shall be given channel checks every two weeks for the initial three months of service after startup. Failures of active devices normally occur during the initial hours of operation. Successful results in at least three consecutive checks is sufficient to revert to the monthly channel check. The monthly channel check shall include checking the batteries.

APPENDIX A
DEFINITIONS

1. Acceleration Sensor. An instrument capable of sensing absolute acceleration and transmitting the data to a recorder.

2. Channel Calibration (Primary Calibration). The determination and adjustment, if required, of an instrument, sensor, or system such that it responds within a specific range and accuracy to an acceleration, velocity or displacement input, as applicable, traceable to the National Institute of Standards and Technology (NIST), or an acceptable physical constant.

3. Channel Check. The qualitative verification of the functional status of the instrument sensor. This check is an "in-situ" test and may be the same as channel functional test.

4. Channel Functional Test (Secondary Calibration). The determination without adjustment that an instrument, sensor, or system responds to a known input, not necessarily traced to the National Institute of Standards and Technology (NIST), of such character that it will verify the instrument, sensor or system is functioning in a calibratible manner.

5. Containment - See Primary Containment and Secondary Containment.

6. Containment Foundation. The foundation of the containment or reactor building. For the foundation which supports more than just the containment structure or reactor building, the area which is within the close proximity of the containment shell shall also be considered as part of the containment foundation.

7. Internal Containment Structure. A structure internal to the Primary or Secondary Containment and supported by the Containment Foundation.

8. Operating Basis Earthquake (OBE). The Operating Basis Earthquake produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional.

9. Primary Containment. The principle structure of a unit that acts as the barrier, after the fuel cladding and reactor pressure boundary, to control the release of radioactive material. It includes (1) the containment structure, and its access openings, penetrations, and appurtenances, (2) those valves, pipes, closed systems, and other components used to effect isolation of the containment atmosphere from the environment, and (3) those systems or portions of systems that, by their system functions, extend the containment structure boundary (e.g., the connecting steam and feedwater piping) and provide effective isolation.

10. Recorder. An instrument capable of simultaneously recording the data versus time from acceleration sensor(s).

11. Remote Indicating Instruments. Instruments whose output is transmitted to a location seperate from the sensor.

12. Safe Shutdown Earthquake Ground Motion (SSE). The Safe Shutdown Earthquake Ground Motion (SSE) is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

(a) The integrity of the reactor coolant pressure boundary,

(b) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

(c) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures exceeding allowable amounts.

13. Secondary Containment. The structure surrounding the primary containment that acts as a further barrier to control the release of radioactive material.

14. Seismic Isolator. A device, for instance, laminated elastomer and steel, installed between the structure and its foundation to reduce the acceleration of the isolated structure the attached equipment and components.

15. Shall, Should, and May. The word "shall" is used to denote a requirement; the word "should" to denote a recommendation; and the word "may" to denote permission, neither a requirement nor a recommendation.

16. Time-History Accelerograph. An instrument capable of measuring and permanently recording the absolute acceleration versus time.

17. Triaxial. Describes the function of an instrument or group of instruments in three mutually orthogonal directions, one of which is vertical.

NRR is Developing a position Paper on CAV and when it is finished we will coordinate it with this R.G.

DRAFT REGULATORY GUIDE DG-1017

PLANT SHUTDOWN

DRAFT REGULATORY GUIDE DG-1017
PRE-EARTHQUAKE PLANNING AND IMMEDIATE NUCLEAR POWER PLANT OPERATOR POST-EARTHQUAKE 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 instrumentation[1] shall be provided so that the recorded seismic response of nuclear power plant features important to safety can be evaluated promptly to permit comparison of such response with that used as the design basis. Such a comparison is needed to decide whether the plant can continue to be operated safely and to permit such timely action as may be appropriate. (Paragraph VI of Appendix S, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria," also cites Appendix S to 10 CFR Part 50). Paragraph IV(a)(3) of Appendix S to 10 CFR Part 50 also requires that If vibratory ground motion exceeding that of the Operating Basis Earthquake occurs, shutdown of the nuclear power plant will be required. The value of the Operating Basis Earthquake is set pursuant to Paragraph IV(a)(2)(i) or (ii) of Appendix S to Part 50. This guide provides guidelines that are acceptable to the NRC staff for a timely evaluation of the recorded instrumentation data and to determine whether or not plant shutdown is required as satisfying the above-stated requirement of Appendix S to 10 CFR Part 50.

B. DISCUSSION

When an earthquake occurs, ground motion data are recorded by the seismic instrumentation.[1] These data are used to make an early determination of the degree of severity of the seismic event. The data from the seismic instrumentation, coupled with information obtained from a plant walkdown, are used to make the initial determination of whether the plant should be shut down, if it has not already been shut down due to 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 plant will not be shut down. Post-shutdown inspections and plant restart are covered elsewhere.[2]

Working Group ANS-2.10 of Subcommittee ANS-2, Site Evaluation, of the American Nuclear Society Standards Committee has developed a standard that contains guidelines for the retrieval, and the subsequent processing, handling, storage

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[1] Draft Regulatory Guide DG-1016, Second Proposed Revision 2 to Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation for Earthquakes," describes seismic instrumentation acceptable to the NRC staff.

[2]. Draft Regulatory Guide DG-1018, "Restart of a Nuclear Power Plant Shut Down Due to a Seismic Event" describes inspections and tests acceptable to the NRC staff.

and evaluation of data obtained from nuclear power plant seismic instrumentation. This standard was approved and designated ANSI/ANS-2.10-1991, "Guidelines for Handling and Preliminary Evaluation of Records from Nuclear Power Plant Seismic Instrumentation,"[3] by the American Standards Institute on [date].

The Electric Power Research Institute has developed guidelines that will enable licensees to quickly identify and assess earthquake effects on nuclear power plants. This report is designated EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake,"[4] December 1989. Post-shutdown inspections and plant restart are covered elsewhere.[2]

The Regulatory Position merges the pre-earthquake actions, immediate post-earthquake operator actions, operator walkdown inspections, and pre-shutdown inspection that are contained in EPRI NP-6695 with the retrieval, and the subsequent processing, handling, storage and evaluation of data obtained from nuclear power plant seismic instrumentation contained in ANSI/ANS-2.10-1991.

This guide is based on the assumption that the nuclear power plant has operable seismic instrumentation. If the seismic instrumentation is inoperable the guidelines that will be followed by the NRC staff are identified.

Applicable portions of 10 CFR Part 50, Appendix S are repeated to highlight the changes in philosophy pertaining to the Operating Basis Earthquake that were made during the creation of 10 CFR Part 50, Appendix S and 10 CFR Part 100, Appendix B (revision of 10 CFR Part 100, Appendix A).

The definitions of Safe Shutdown Earthquake Ground Motion (SSE) and Operating Basis Earthquake in ANSI/ANS-2.10-1991 and EPRI NP-6695 are replaced to reflect changes that have been made during the creation of 10 CFR Part 50, Appendix S and 10 CFR Part 100, Appendix B (revision of 10 CFR Part 100, Appendix A).

ANSI/ANS-2.10-1991 is supplemented by quantifying time limits associated with a prompt evaluation of seismic instrumentation data. The timeliness is consistent with Figure 1 of ANSI/ANS-2.10 and EPRI NP-6695.

ANSI/ANS-2.10-1991 is supplemented by adding a definition of a Felt Earthquake. The revision provides, in one location within ANSI/ANS-2.10, what constitutes a felt earthquake and provides for consistency between ANSI/ANS-2.10 and EPRI NP-6695. The applicable paragraph within the text, Figure 1 and Table 1 of ANSI/ANS-2.10 have been revised accordingly.

As stated in ANSI/ANS-2.10-1991, the Response Spectrum Check associated with determining if the Operating Basis Earthquake has been exceeded requires eight frequency points between 2 and 10 Hz to be evaluated. However, some structures may have fundamental frequencies less than 2 Hz, therefore, the range of frequencies that need to be evaluated has been expanded.

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[3] Copies may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60525.

[4] Copies may be obtained from the Research Reports Center (RRC), Box 50490, Palo Alto, California 94303.

Supplemental information on the calculation of the Cumulative Absolute Velocity (CAV) is provided in the referenced document.

The definition of Felt Earthquake in EPRI NP-6695, is revised, deleting the phrase pertaining to "plants with operable seismic instrumentation." Nuclear power plants should have operable seismic instrumentation; further, the instrumentation shall be functioning in all modes of operation. If the seismic instrumentation is inoperable the guidelines that will be followed by the NRC staff are identified.

The staff does not support 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. Decisions on continued operation will be made by the licensee in conjunction with the staff on a case-by-case basis consistent with applicable regulations.

C. REGULATORY POSITION

1. This guide is based on the assumption that the nuclear power plant has operable seismic instrumentation. If the seismic instrumentation is inoperable the guidelines described in Appendix A will be used to determine if the Operating Basis Earthquake has been exceeded.

2. The following segments of 10 CFR Part 50, Appendix S, Paragraph IV(a)(2) are repeated to highlight changes in the regulation pertaining to the Operating Basis Earthquake that are not consistent with those contained in ANSI/ANS-2.10-1991 and EPRI NP-6695.

> "The Operating Basis Earthquake shall be defined by response spectra. All structures, systems, and components of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional and within applicable stress and deformation limits when subjected to the effects of the vibratory motion of the Operating Basis Earthquake in combination with normal operating loads.
>
> i. If the Operating Basis Earthquake is set at one-third of the Safe Shutdown Earthquake ground motion level, the function of the Operating Basis Earthquake, as stated above, can be satisfied without the applicant performing any explicit response analyses.[6]

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[6] A seperate analyses to compute structure, equipment and piping response associated with the Operating Basis Earthquake is not required. Applicable design provisions associated with this Operating Basis

ii. If an applicant chooses an Operating Basis Earthquake greater than one-third the Safe Shutdown Earthquake an explicit suitable analysis and design shall be performed to demonstrate that the function of the Operating Basis Earthquake, as stated above, is satisfied. The design shall take into account soil-structure interaction effects and the expected duration of vibratory motion.

3. Guidelines for the retrieval, and the subsequent processing, handling, storage and evaluation of data obtained from nuclear power plant seismic instrumentation specified in ANSI/ANS-2.10-1991, "Guidelines for Handling and Preliminary Evaluation of Records from Nuclear Power Plant Seismic Instrumentation," are acceptable to the NRC staff for satisfying the evaluation requirements indicated in Paragraphs IV(a)(3) and (4) of 10 CFR Part 50, Appendix S for ensuring the safety of nuclear power plants, subject to the following:[•]

   a. Section 1, at the end of the second paragraph add:

      It is recommended that the calibration standards, computer software, record analyzers, etc., required to process the records from the seismic instruments be on hand at the site so that the records can be processed within a time period of four hours. This is necessary to compare the recorded data against the Operating Basis Earthquake exceedance criterion and to evaluate the results of the operator walkdown inspections within eight hours of the event.

   b. Section 2, the following definitions should be added to, or supersede those, in the Standard:

      1. felt earthquake. An earthquake of sufficient intensity such that:

         (i) the vibratory ground motion is felt at the nuclear power plant site and recognized as an earthquake based on a consensus of the control room operators on duty at the time, or

         (ii) the seismic instruments installed at the plant are

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Earthquake, for instance, fatigue, are discussed in regulatory guides.

[•] Specific exceptions to the standard are noted. Not all of the definitions, instrumentation or steps discussed in the standard are applicable since they relate to instrumentation not described in Draft Regulatory Guide DG-1016, Second Proposed Revision 2 to Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation for Earthquakes."

activated.[7]

2. operating basis earthquake (OBE). The "Operating Basis Earthquake" produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional.

3. safe shutdown earthquake ground motion (SSE). The "Safe Shutdown Earthquake Ground Motion" (SSE) is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

   (i) The integrity of the reactor coolant pressure boundary,

   (ii) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

   (iii) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures exceeding allowable amounts.

c Section 3. Replace the first paragraph with the following:

After any felt earthquake (see item 2 of Table 1) at a nuclear power plant, the owner shall take appropriate action to determine if the OBE has been exceeded. The specific activities, their timing and the associated criteria are set forth graphically in Figure 1 - Preliminary Evaluation (level 1) Flowchart and in Table 1 - Activities Description.

d. Section 4.5.2(1)(b), <u>Response Spectrum Check</u>. Change as follows:

<u>Response Spectrum Check</u>. For the response spectrum check, spectral ordinates computed at a minimum of 11 frequency points approximately evenly spaced on a logarithmic scale between 1 and 10 Hz (e.g., 1.0, 1.3, 1.6, 2.0, 2.5, 3.0, 4.0, 5.0, 6.5, 8.0, and 10.0 hz), should be compared ...

e. Section 4.5.2(1)(c), <u>Cumulative Absolute Velocity (CAV) Check</u>. Add the following paragraph at the end of the section:

Additional guidance on how to determine the CAV is provided in "A Method to Standardize the Calculation of the Cumulative Absolute Velocity for Use With the EPRI OBE Exceedance Criterion" [7].

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[7] Spurious activation that can be clearly linked to a nonseismic event, for example, vehicular movement or construction, does not denote seismic instrumentation activation.

f. Section 5, References. Add the following:

[7] Electric Power Research Institute, NP-????, "A Method to Standardize the Calculation of the Cumulative Absolute Velocity for Use With the EPRI OBE Exceedance Criterion," January 1991.

g. Figure 1. Preliminary Evaluation (Level 1) Flowchart. Change Block 2 to: Felt Earthquake.

h. Figure 2. OBE Exceedance (Level 2) Flowchart.

1. Block 1 and footnote 1. Change to reflect that 11 frequency values approximately evenly spaced on a logarithmic scale between 1 and 10 Hz should be evaluated.

2. Footnote 2. Remove ii and iii.

i. Table 1 - Activities Description, Item 2. Change description to:

Felt earthquake.

Go to Item 3

4. The Definitions Section and the guidelines for pre-earthquake planning and immediate post-earthquake actions specified in Sections 5.3.1 (includes Section 5.3.2.1), 4.3.1, 4.3.2 (includes Section 5.3.2.1 and items 7 and 8 of Table 5-1) and 4.3.4 of EPRI NP-6695 "Guidelines for Nuclear Plant Response to an Earthquake," are acceptable to the NRC staff for satisfying the evaluation requirements indicated in Paragraph IV(a)(2) of 10 CFR Part 50, Appendix S for ensuring the safety of nuclear power plants, subject to the following:

a. Definitions, the following definitions should be added to, or supersede those, in the report:

1. felt earthquake. An earthquake of sufficient intensity such that:

(i) the vibratory ground motion is felt at the nuclear power plant site and recognized as an earthquake based on a consensus of the control room operators on duty at the time, or

(ii) the seismic instruments installed at the plant are activated.[7]

2. operating basis earthquake (OBE). The "Operating Basis Earthquake" produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional.

3. safe shutdown earthquake ground motion (SSE). The "Safe

Shutdown Earthquake Ground Motion" (SSE) is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

(i) The integrity of the reactor coolant pressure boundary,

(ii) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

(iii) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures exceeding allowable amounts.

b. Section 4.3.4, <u>Pre-Shutdown Inspections</u>. Delete the last sentence in the first paragraph.

5. Plant Shutdown Criteria

a. <u>OBE Exceedance</u>. If the Response Spectrum Check and the Time History (CAV) Check, performed in accordance with Section 4.5.2 of ANSI/ANS-2.10-1991 as modified per this Guide, were exceeded, than 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.

The determination of whether or not the OBE has been exceeded should be performed even if the plant automatically trips off-line as a result of the earthquake.

or

b. <u>Damage</u>. Shutdown of the plant is required if the walkdown inspections, performed in accordance with Section 4.3.2 of EPRI NP-6695, discover damage.

Paragraph C(4) of this Regulatory Position endorses the pre-shutdown inspections described Section 4.3.4 of EPRI NP-6695. However, they are repeated below for emphasis.

Prior to initiating plant shutdown, 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 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 plant 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 checks noted in Section 4.3.4 of EPRI NP-6695 should be made, if possible, before plant shutdown is initiated.

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

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 herein will be used in the evaluation of submittals docketed after [date]. If an applicant or licensee wishes to use this regulatory guide for submittals docketed before [date], the pertinent portions of the application will be evaluated on the basis of this guide.

APPENDIX A
INTERIM OPERATING BASIS EARTHQUAKE (OBE) EXCEEDANCE GUIDELINES

1. For plants at which only instrumentally determined foundation level data are available, the Cumulative Absolute Velocity (CAV) Check is not applicable, and a determination of Operating Basis Earthquake (OBE) exceedance is based on the Response Spectrum Check described in Section C(3)(d) of this regulatory guide. A comparison is made between the foundation level spectral accelerations used in design and those obtained from the foundation level instruments. If the Response Spectrum Check at one foundation level is exceeded the OBE is exceeded and shutdown is warranted.

2. For plants at which no instrumental data are available, the OBE will be considered to have been exceeded and shutdown to be warranted if the earthquake:

   a. was felt within the plant and resulted in MMI VI[*] or greater within 5 km[*] of the plant <u>or</u>

   b. was felt within the plant and was of magnitude 6.0[*] or greater <u>or</u>

   c. was felt within the plant, was of magnitude 5.0[*] or greater, and occurred within 200 km[*] of the plant.

3. A post-earthquake plant walkdown should be conducted. A procedure acceptable to the NRC staff is described in Paragraph C(4) of this regulatory guide.

4. If plant shutdown is warranted under the above guidelines, the plant should be shut down in an orderly manner. A procedure acceptable to the staff is described in Paragraph C(5) of this regulatory guide.

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[*] In these guidelines the U. S. Geological Survey, National Earthquake Information Center determinations of epicentral location, magnitude, and intensity 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 or lack of damage reports from the nuclear power plant site or its immediate vicinity will take precedence over more distant reports.

NRR is reviewing this issue in conjunction with its OBE shut down Requirements and we will coordinate our position with this R.G.

DRAFT REGULATORY GUIDE DG-1018

PLANT RESTART

DRAFT REGULATORY GUIDE DG-1018
RESTART OF A NUCLEAR POWER PLANT SHUT DOWN DUE TO A SEISMIC EVENT

A. INTRODUCTION

Paragraph (IV)(a)(3) of Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants" to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires that if vibratory ground motion exceeding that of the Operating Basis Earthquake occurs, shutdown of the nuclear power plant will be required.[1] The value of the Operating Basis Earthquake is set pursuant to Paragraph IV(a)(2)(i) or (ii) of Appendix S to Part 50. Prior to resuming operations, the licensee will be 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. This guide provides guidelines that are acceptable to the NRC staff for performing inspections and tests of nuclear power plant equipment and structures prior to restart of a plant that has been shutdown due to a seismic event as satisfying the above-stated requirements of Appendix S to 10 CFR Part 50.

B. DISCUSSION

Data from seismic instrumentation[2] and a walkdown of the nuclear power plant were used to make the initial determination of whether the plant should be shut down, if it is not already shut down due to operational pertubations resulting from the seismic event.[1]

The Electric Power Research Institute has developed guidelines that will enable licensees to quickly identify and assess earthquake effects on nuclear power plants. This report is designated EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake,"[3] December 1989. This guide is addressing sections that relate to post-shutdown inspection and tests, inspection criteria, inspection personnel, documentation, and long-term evaluations.

Applicable portions of 10 CFR Part 50, Appendix S are repeated in the Regulatory Position to highlight the changes in philosophy pertaining to the Operating Basis Earthquake that were made during the creation of 10 CFR Part 50, Appendix S and 10 CFR Part 100, Appendix B (revision of 10 CFR Part 100, Appendix A).

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[1] Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions," provides plant shutdown criteria.

[2] Draft Regulatory Guide DG-1016, Second Proposed Revision 2 to Regul Guide 1.12, "Nuclear Power Plant Instrumentation for Earthqua describes seismic instrumentation acceptable to the NRC staff.

[3] Copies may be obtained from the Research Reports Center (RRC), Box 50490, Palo Alto, California 94303.

The Regulatory Position replaces the definitions of Safe Shutdown Earthquake Ground Motion (SSE) and Operating Basis Earthquake in EPRI NP-6695 to reflect changes that have been made during the creation of 10 CFR Part 50, Appendix S and 10 CFR Part 100, Appendix B (revision of 10 CFR Part 100, Appendix A).

C. REGULATORY POSITION

1. The following segments of 10 CFR Part 50, Appendix S, Paragraph IV(a)(2) are repeated to highlight changes in the regulation pertaining to the Operating Basis Earthquake that are not consistent with those contained in EPRI NP-6695:

> "The Operating Basis Earthquake shall be defined by response spectra. All structures, systems, and components of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional and within applicable stress and deformation limits when subjected to the effects of the vibratory motion of the Operating Basis Earthquake in combination with normal operating loads.
>
> i. If the Operating Basis Earthquake is set at one-third of the Safe Shutdown Earthquake Ground Motion level, the function of the Operating Basis Earthquake, as stated above, can be satisfied without the applicant performing any explicit response analyses.[4]
>
> ii. If an applicant chooses an Operating Basis Earthquake greater than one-third the Safe Shutdown Earthquake Ground Motion an explicit suitable analysis and design shall be performed to demonstrate that the function of the Operating Basis Earthquake, as stated above, is satisfied. The design shall take into account soil-structure interaction effects and the expected duration of vibratory motion.

2. The Definitions Section and the guidelines for post-shutdown inspections and tests, and long-term evaluations specified in Sections 5.3.2 (includes Tables 2-1, 2-2 and 5-1), 5.3.3 (includes Table 5-1), 5.3.4, 5.3.5, and 6.3 (all sections and subsections) of EPRI NP-6695 are acceptable to the NRC staff for satisfying the evaluation requirements indicated in Paragraph IV(a)(2) of 10 CFR Part 50, Appendix S for ensuring the safety

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[4] A seperate analysis to compute structure, equipment and piping response associated with the Operating Basis Earthquake is not required. Applicable design provisions associated with this Operating Basis Earthquake, for instance, fatigue, are discussed in regulatory guides.

of nuclear power plants, subject to the following:

Definitions, the following definitions should be added to, or supersede those, in the report:

1. felt earthquake. An earthquake of sufficient intensity such that:

   (i) the vibratory ground motion is felt at the nuclear power plant site and recognized as an earthquake based on a consensus of the control room operators on duty at the time, and

   (ii) the seismic switches installed at the plant are activated.

2. operating basis earthquake (OBE). The "Operating Basis Earthquake" produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall remain functional.

3. safe shutdown earthquake ground motion (SSE). The "Safe Shutdown Earthquake Ground Motion (SSE)" is the vibratory ground motion for which certain structures, systems, and components shall be designed to remain functional. These structures, systems, and components are those necessary to assure:

   (i) The integrity of the reactor coolant pressure boundary,

   (ii) The capability to shut down the reactor and maintain it in a safe shutdown condition, or

   (iii) The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures exceeding allowable amounts.

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 herein will be used in the evaluation of submittals docketed after [date]. If an applicant or licensee wishes to use this regulatory guide for submittals docketed before [date], the pertinent portions of the application will be evaluated on the basis of this guide.

DRAFT REGULATORY ANALYSIS

PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

DRAFT REGULATORY ANALYSIS

PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

STATEMENT OF THE PROBLEM

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Siting Criteria," sets forth a framework that guides the staff in its evaluation of the adequacy of applicants' investigations of geologic and earthquake phenomena and proposed plant design parameters. The issuance of Appendix A was an important step in establishing a definitive regulatory framework for dealing with earth science issues in the licensing of nuclear power plants. The Appendix contains the following statement:

> "These criteria are based on the limited geophysical and geological information available to date concerning faults and earthquake occurrence and effect. They will be revised as necessary when more complete information becomes available."

The bases for Appendix A were established in the late 1960's and it became effective December 13, 1973. Since then, with advances in the sciences of seismology and geology, along with the occurrence of some issues in licensing cases not foreseen in the development of Appendix A, a number of significant difficulties have arisen in the application of this regulation. Specific problematic areas include the following:

1. In making geoscience assessments, there is a need for considerable latitude and judgement. This latitude and judgement is required because of limitations in data, the state of the art of geologic and seismic analyses, and the rapid evolution taking place in the geosciences in terms of accumulating knowledge and in modifying concepts. This need appears to have been recognized when Appendix A was developed. However, having geoscience assessments detailed and cast in Appendix A, a regulation, has created difficulty for applicants and the staff in terms of inhibiting the use of needed judgement and latitude. Also, it has inhibited flexibility in applying basic principles to new situations and the use of evolving methods of analyses in the licensing process. ✓ (ok as is)

2. Various sections of Appendix A lack clarity and are subject to different interpretations and dispute. Also, some sections in the Appendix do not provide sufficient information for implementation. As a result of being both overly detailed in some areas and not detailed enough in others, the Appendix has been the source of licensing delays and debate and has inhibited the use of some types of analyses.

3. In other siting areas, such as hydrology, regulatory guidance has been handled effectively through use of regulatory guides. Many problems encountered in implementing Appendix A could best be alleviated through the use of regulatory guides and a program for continuous updating.

4. In the existing regulation, the Operating Basis Earthquake (OBE) is associated with functionality, likelihood of occurrence, and a minimum fraction of the Safe Shutdown Earthquake (SSE). These multi-aspects have resulted in seismic criteria that have led to overly stiff piping systems and excessive use of snubbers and supports which, in fact, could result in less reliable piping systems.

5. The stipulation in Appendix A that the Safe Shutdown Earthquake (SSE) response spectra be defined at the foundation of the nuclear power plant structures has often led to confrontations with many in the engineering community who regard this stipulation as inconsistent with sound practice.

OBJECTIVES

The objectives of the proposed regulatory action are:

1. Provide a stable regulatory basis for seismic and geologic siting and applicable earthquake engineering design of nuclear power plants,
    a. avoid licensing delays due to unclear regulatory requirements,
    b. provide a flexible structure to permit consideration of new technical understandings, and
2. Have the revision to the regulation completed prior to the receipt of an early site application.

The major points associated with the revision of the regulation are:

1. The proposed regulatory action will apply to applicants who apply for a construction permit on or after the effective date of the revised regulation.
2. Criteria not associated with the selection of the site or establishment of the safe shutdown earthquake ~~has~~ have (v) been placed into Part 50 consistent with the location in the regulation of other design requirements.

Since the revision to the regulation will not be backfit, the licensing bases for existing nuclear power plants must remain in the regulation. Therefore, the revised regulation on seismic and geologic siting will be designated 10 CFR Part 100, Appendix B.

Earthquake engineering criteria will be located in 10 CFR Part 50, Appendix S. Since Appendix S is not self initiating, applicable sections of Part 50 (for instance, §50.34, §50.54) will be revised to reference Appendix S.

In addition, Part 52, Paragraph 52.17(a)(1)(vi) and Part 100, Paragraph

100.10(c)(1), are revised to note Appendix B to Part 100.

Finally, in support of the above changes, regulatory guides and select standard review plan sections will be revised or developed.

ALTERNATIVES (✓)

Since there are problems ~~are~~ with implementing the existing regulation, the only satisfactory alternative is to revise the regulation. ✓

Deletion of the existing regulation (Appendix A to Part 100) is not being considered since it is the licensing bases for many of the operating nuclear power plants and others that are in various stages of obtaining their operating license.

Replacement of the entire (not needed) regulation with a regulatory guide is not being considered because a regulatory guide is non-mandatory. The staff believes that there could be an increase in exposure to the public if the siting and earthquake engineering criteria were non-mandatory. ✓

Doing nothing is also not an acceptable alternative. Although the siting related issues associated with the current generation of nuclear power plant (✓) are completed or nearing completion there is a renewed sense of urgency to initiate the proposed regulatory action in light of the current and future staff review of advanced reactor seismic design criteria. A revision to Appendix A would increase the efficiency of regulatory actions associated with any resurgence of licensing activity. ✓

Finally, the following memoranda or reports provide further support for a revision to Appendix A to Part 100:

1. Staff Requirements Memorandum from Chilk to Taylor dated January 25, 1991, Subject: SECY-90-341 - Staff Study on Source Term Update and Decoupling Siting from Design.

   > "The staff should further ensure that the revisions to Appendix A of Part 100 are available to support the time schedule shown in the paper [Commission Briefing on Source Term Update and Decoupling Siting from Design (SECY-90-341), dated December 13, 1990] for option 2, and are technically supportable with the information that will be available at the time the draft comes forward for Commission action."

2. Memorandum from Taylor to Beckjord dated September 6, 1990, Subject: Revision of Appendix A, 10 CFR Part 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

   > "I approve of your plan to begin work on the development of a revised regulation and this activity should be assigned a high priority status."

3. NUREG-0625, Siting Policy Task Force.

> "Revise Appendix A to 10 CFR Part 100 to better reflect the evolving technology in assessing seismic hazards."

4. NUREG-1061, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee," Vol 5, April 1985.

> "The Committee recommends that
>
> o Rulemaking amending Appendix A to 10 CFR Part 100 be undertaken to permit decoupling of the OBE and SSE. ...."

CONSEQUENCES

a. Costs and Benefits

Benefits

The revision of Appendix A to Part 100 will be beneficial to all. The public will benefit from a clearer, more uniform and consistent licensing process subject to fewer interpretations. The NRC staff will benefit from improved regulatory implementation (both technical and legal), fewer interpretive debates, and increased regulatory flexibility. Applicants will derive the same benefits in addition to avoiding licensing delays due to unclear regulatory requirements.

The revised regulations (Appendix B to Part 100 and Appendix S to Part 50) reflect changes resulting from (1) experience in applying the existing regulation; (2) interpretative questions; (3) needed regulatory flexibility to incorporate state of the art improvements in the geosciences and earthquake engineering; (4) simplifying the text language to a more "plain English" text; and (5) various internal staff and industry comments.

Benefits to applicants or NRC staff will result from the following changes:

to general guidance (✓)

1. Level of Detail. The level of detail in the proposed regulations has been limited. The proposed regulation identifies requirements; detailed guidance, that is, procedures acceptable to the staff for meeting the requirements, has been removed and placed in regulatory guides or standard review plan sections.

2. Greater Flexibility. The proposed regulations provide a flexible structure that will permit consideration of new technical understandings and state of the art advancements.

3. Interpretations. Changes have been made to resolve past questions of interpretations. As an example, the definitions and required investigations sections of the proposed regulations have been significantly changed eliminating or modifying phrases that were more applicable to only the western United States.

4. Text Clarification. The proposed regulations use more explicit terminology. For instance, the Safe Shutdown Earthquake (SSE) is now referenced as the Safe Shutdown Earthquake Ground Motion (SSE). Associated changes within the text highlight that the ground motion used as the design basis is not associated with a single earthquake but a composite of many expected earthquakes.

5. Current practices will be reflected. The proposed regulations reflect industry design practices and the associated staff review procedures that have evolved since the initial regulation (Appendix A to Part 100) was issued in 1973. Many of these practices and procedures were incorporated into the revision of Standard Review Plan Sections 2.5.2, 3.7.1, 3.7.2 and 3.7.3 associated with the resolution of Unresolved Safety Issue (USI) A-40, "Seismic Design Criteria."

6. Seismic Sources. Better definition of seismic source types and streamlined procedures for their use in specifying ground motion expected at a plant site will eliminate what has been a major source of licensing delays.

7. Probabilistic Analyses. The use of probabilistic techniques will also permit easier handling of uncertainties associated with the process of defining relevant seismic sources and ground motions associated with them.

8. Eliminating the many facets of the Operating Basis Earthquake (OBE). The OBE is now only associated with the functionality of structures, equipment and components. Previously, the OBE was also associated with a likelihood of occurrence and a minimum percentage of the Safe Shutdown Earthquake (SSE). In some cases, for instance, piping, the multi-facets of the OBE made it possible for it to have more design significance than the SSE.

9. Potential for Reduced Analyses. Applicants that choose to set the Operating Basis Earthquake at one-third of the Safe Shutdown Earthquake Ground Motion can satisfy OBE functionality requirements without performing any explicit response analysis. Applicants have the option of selecting an OBE greater than one-third the SSE; however, a suitable analyses and design shall be performed.

10. Required Plant Shutdown. The revised regulations has placed into Part 50, consistent with other conditions of licenses, that plant shutdown is required if the Operating Basis Earthquake is exceeded. Specific guidance as to what constitutes an OBE exceedance, thereby requiring plant shutdown is provided. In addition, guidance for an orderly plant shutdown and the re-starting a plant that has been shutdown due to earthquake ground motion is provided.

Costs

The costs associated with the revised regulations are subdivided into two categories; the first is associated with the geosciences and site investigations (Appendix B to Part 100), the second is associated with earthquake engineering

(Appendix S to Part 50).

Appendix B to Part 100

As substantiated below, the overall cost impact associated with revising the geosciences and site investigation aspects of the regulation are neutral. Specific examples include:

1. Reduced Licensing Delays. The licensing process will be enhanced because information needed for the staff review can be incorporated in the safety analysis reports at the time of docketing instead of later through staff questions and applicant responses.

2. Probabilistic Analyses. Probabilistic analyses to determine vibratory ground motion, surface tectonic deformation, and seismically induced floods and water waves will marginally increase the cost required for plant site investigations. However, the proposed revisions reflect what is already current staff practice. For sites in the eastern U.S., the availability of probabilistic methods may actually simplify the task of analyzing earthquake-induced ground motion. Furthermore, probabilistic analysis will make it possible to more readily incorporate additional data that may become available during site review.

3. Seismic Sources. The new approach towards seismic sources using seismogenic sources instead of tectonic provinces, better definition of the location to be used for sources in the site vicinity, and other streamlining in the licensing approach are expected to reduce time and costs required for obtaining site approval.

Appendix S to Part 50

As substantiated below, the overall cost impact associated with revising the earthquake engineering aspects of the regulation are neutral or reduced. Specific examples include:

1. Reduced OBE Analysis. The response analyses associated with the Operating Basis Earthquake (OBE) may be eliminated if the applicant sets the OBE at one-third of the Safe Shutdown Earthquake Ground Motion (SSE). Selecting an OBE value greater than one-third of the SSE does not increase the analytical effort above current requirements.

2. Control Point Location. Changing the location of the control point (the point at which the vibratory ground motion is applied) from the foundation level to the free-field does not affect costs. The following discussion from Section 2.1.1.4 of NUREC-1233 (pages 13 and 14) is applicable:

> "A number of recent plants were designed to the 1975 Standard Review Plan requirements which specified the free-field motion at the free-surface for soil-structure

interaction analysis. During the operating license (OL) review, the implementation of the current position of input motion at the foundation level in the free field resulted in a modification of some structural floor beams of seismic Category I structures at one plant. No hardware changes resulted at other plants. (Note that the staff's investigation was limited to the Safe shutdown systems and structures that housed them, and allowance was made for tested strength values in some cases.)"

3. Plant Shutdown. Although the new seismic instrumentation requirements are different, the cost is essentially the same as that currently used in operating plants. The maintenance and calibration costs with the new solid-state seismic instrumentation should be less than that associated with the current instrumentation. The time associated with the processing of instrumentation data will be less since data will not be shipped from the site for evaluation, thereby reducing the potential for prolonged plant shutdown while data are being evaluated. In general, the ability to expeditiously assess the effects of the earthquake on the plant will save both staff and licensee resources.

b. Impact on Other Requirements

Other NRC Programs

Although Appendix A to 10 CFR Part 100 is titled "Seismic and Geologic Siting Criteria for Nuclear Power Plants," it is also referenced in two other Parts of the regulation. They are (1) Part 40, "Domestic Licensing of Source Material," Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Waste Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," Section I, Criterion 4(e), and (2) Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," Paragraphs (a)(2)(b) and (a)(2)(f)(1) of §72.102. The revised regulation, Appendix B to Part 100, is still applicable only to nuclear power plants. The need to revise Part 72 and Appendix A to Part 40, subject to the implementation of Appendix B to Part 100, should be a separate rulemaking initiative.

Other Government Agencies

Since the seismic design review and acceptance for nuclear power plants is carried out solely by NRC staff, no impact is projected on other government agencies.

c. Constraints

None.

DECISION RATIONALE

The recommendations to revise the regulations pertaining to the geosciences and site investigations (Appendix B to Part 100), and earthquake engineering (Appendix S to Part 50) are based primarily on the deterministic and qualitative arguments. The staff's evaluation augments the regulatory analysis associated with the implementation of Unresolved Safety Issue (USI) A-40, Seismic Design Criteria (NUREG-1233). USI A-40 was implemented in August 1989 through the revision of Standard Review Plan Sections 3.7.1, Seismic Design Parameters, 3.7.2, Seismic System Analysis, 3.7.3, Seismic Subsystem Analysis, and 2.5.2, Vibratory Ground Motion.

The staff's conclusion is that for operating reactor and operating license applicants, the proposed changes to the regulations would have little effect on risk. Operating plants have generally been, and will be, seismically upgraded by plant-specific actions such as implementation of the Systematic Evaluation Program (SEP), the implementation of Generic Letter 88-20, Supplement 4, Individual Plant Examinations of External Events (IPEEE) for Severe Accident Vulnerabilities, the proposed implementation of USI A-46, Verification of Seismic Adequacy of Equipment in Operating Plants, and NRC Bulletin programs. Therefore, this regulatory action will be "forward-fit" applicable only to applicants who apply for a construction permit on or after the effective date of the revised regulations.

For new construction permit, preliminary design approval, final design approval, and combined license applicants, no significant increases in costs are envisioned to implement the revised regulations. The proposed revisions reflect current staff practice and most applicants are aware of these requirements. In addition, the proposed revisions to the regulations will reduce delays in the licensing process because information needed for the staff review can be incorporated in the safety analysis reports at the time of docketing instead of later through staff questions and applicant responses. Implementation of the proposed regulations will lead to more uniform safety margins. Therefore, the staff proposed that all new applicants be required to comply with the revised regulations.

The revised regulations will not reduce risk, but will improve the description in the regulation of current staff practice in licensing.

Current Regulatory Action

The current regulatory action consists of the following:

1. Revisions to §50.34, §50.54, and §52.17

2. New Appendix B to Part 100, Seismic and Geologic Siting Criteria for Nuclear Power Plants

3. New Appendix S to Part 50, Earthquake Engineering Criteria for Nuclear Power Plants

4. New Regulatory Guides:

  a. DG-1015, "Identification and Characterization of Seismic Sources"

  b. DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions"

  c. DG-1018, "Restart of a Nuclear Power Plant Shut Down Due to a Seismic Event"

5. Revised Regulatory Guide:

   DG-1016, Second Proposed Revision 2 to Regulatory Guide 1.12, "Nuclear Power Plant Instrumentation for Earthquakes"

6. Revised Standard Review Plan Section:

   2.5.2, Vibratory Ground Motion

Future Regulatory Action

Several regulatory guides will be revised to incorporate editorial changes or, maintain the existing design or analysis philosophy. The following guides will be issued coincident with the publication of the final regulations:

1. Incorporate Editorial Changes, for instance, reference new paragraphs in Appendix B to Part 100 or Appendix S to Part 50.
   - a. RG 1.29, Seismic Design Classification
   - b. RG 1.57, Design Limits and Loading Combinations for Metal Primary Containment System Components
   - c. RG 1.59, Design Basis Floods for Nuclear Power Plants
   - d. RG 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants
   - e. RG 1.83, Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes
   - f. RG 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analysis
   - g. RG 1.102, Flood Protection for Nuclear Power Plants
   - h. RG 1.121, Bases for Plugging Degraded PWR Steam Generator Tubes
   - i. RG 1.122, Development of Floor Response Spectra for Seismic Design of Floor-Supported Equipment or Components
2. Maintain Existing Philosophy, for instance, change OBE to 1/2 SSE
   - a. RG 1.27, Ultimate Heat Sink for Nuclear Power Plants

b. RG 1.100, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants

c. RG 1.124, Service Limits and Loading Combinations for Class 1 Liner-Type Component Supports

d. RG 1.130, Service Limits and Loading Combinations for Class 1 Plate-and-Shell-Type Component Supports

e. RG 1.132, Site Investigations for Foundations of Nuclear Power Plants

f. RG 1.138, Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants

g. RG 1.142, Safety Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)

h. RG 1.143, Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants

During the revision of the regulatory guides cited above, if additional changes are made, the applicable guide(s) will be distributed for public comment.

IMPLEMENTATION

This regulatory action is applicable only to applicants that apply for a construction permit on or after the effective date of the regulation.

DRAFT ENVIRONMENTAL ASSESSMENT AND FINDING OF NO SIGNIFICANT IMPACT

PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

DRAFT ENVIRONMENTAL ASSESSMENT AND FINDING OF NO SIGNIFICANT IMPACT

PROPOSED REVISION OF 10 CFR PART 100, APPENDIX A

The Nuclear Regulatory Commission is amending its regulations to update the criteria used in the seismic and geologic siting, and earthquake engineering for nuclear power plants.

Identification of Proposed Action

Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Siting Criteria," was originally issued as a proposed rule on November 25, 1971 (36 FR 22601); published as a final rule on November 13, 1973 (38 FR 31279); and became effective on December 13, 1973. There have been two amendments to 10 CFR Part 100, Appendix A. The first amendment, issued November 27, 1973 (38 FR 32575), corrected 38 FR 31279 by adding the legend under the diagram. The second amendment resulted from a petition for rule making (PRM 100-1) requesting that an opinion interpreting and clarifying Appendix A with respect to the determination of the Safe Shutdown Earthquake be issued. A notice of filing of the petition was published on May 14, 1975 (40 FR 20983). The substance of the petitioner's proposal was accepted and published as an immediately effective final rule on January 10, 1977 (42 FR 2052).

The proposed amendment will apply to applicants who apply for a construction permit on or after the effective date of the revised regulation. Since the revision to the regulation will not be backfit, the licensing bases for existing nuclear power plants must remain in the regulation. Therefore, the revised regulation on seismic and geologic siting will be designated 10 CFR Part 100, Appendix B.

Criteria not associated with the selection of the site or establishment of the safe shutdown earthquake has been placed into Part 50 consistent with the location in the regulation of other design requirements. Hence, earthquake engineering criteria is located in 10 CFR Part 50, Appendix S.

The proposed amendments to the regulations (Appendix B to Part 100 and Appendix S to Part 50) reflect changes resulting from (1) experience in applying the existing regulation; (2) interpretative questions; (3) needed regulatory flexibility to incorporate state of the art improvements in the geosciences and earthquake engineering; (4) simplifying the text language to a more "plain English" text; and (5) various internal staff and industry comments.

Need for the Proposed Action

The experience gained in the application of the procedures and methods set forth in the current regulation, the difficulties encountered, and the rapid advancement in the state-of-the-art of earth sciences have made it necessary to update the 1973 criteria.

Environmental Impacts of the Proposed Action

Appendix B to Part 100 contains the seismic and geologic considerations which guide the Commission in its evaluation of the suitability of proposed sites for nuclear power plants. Appendix S to Part 50 contains the earthquake engineering considerations which guide the Commission in its evaluation of the suitability of the plant design bases. The amendment of Appendix A to 10 CFR Part 100 as stated in Appendices B and S reflect current licensing practice and will not change the radiological environmental impact offsite. Further, the Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants, published August 8, 1985 (50 FR 32138) affirms the Commission's belief that a new design for a nuclear power plant can be shown to be acceptable for severe accident concerns if the criteria and procedural requirements cited in 50 FR 32138 are met. Stated differently, the proposed regulatory actions (Appendix B to Part 100 and Appendix S to Part 50) are specifically based on maintaining the present level of risk of radiological releases, thus having zero effect compared to the regulation (Appendix A to Part 100) they replace.

Onsite occupational radiational exposure associated with inspection and maintenance will not change. These activities are principally associated with seismic instrumentation. The regulatory guide pertaining to seismic instrumentation (Second Proposed Revision to Regulatory Guide 1.12, Nuclear Power Plant Instrumention for Earthquakes) specifically cites occupational radiation exposure as a consideration in selecting the location of the instruments.

The proposed amendments do not affect non-radiological plant effluents and have no other environmental impact. Therefore, the Commission concludes that there are also no significant non-radiological environmental impacts associated with the proposed amendments to the regulations.

Alternatives to the Proposed Action

As required by Section 102(2)(E) of NEPA (42 U.S.C.A. 4332(2)(E)), the staff has considered possible alternatives to the proposed action. One alternative was not to initiate a rulemaking proceeding. This is not an acceptable alternative. Although the siting related issues associated with the current generation of nuclear power plants are completed or nearing completion there is a renewed sense of urgency to initiate the proposed regulatory action in light of the current and future staff review of advanced reactor seismic design criteria. The current regulation has created difficulty for applicants and the staff in terms of inhibiting flexibility in applying basic principles to new situations and the use of evolving methods of analyses in the licensing process.

A second alternative considered was the deletion of the existing regulation (Appendix A to Part 100). This is not an acceptable alternative since it is the licensing bases for many of the operating nuclear power plants and others that are in various stages of obtaining their operating license.

(not needed)

A third alternative considered was the replacement of the entire regulation with a regulatory guide. This is not acceptable because a regulatory guide is non-mandatory. The staff believes that there could be an increase in exposure to the public if the siting and earthquake engineering criteria were non-mandatory.

The present approach of revising the regulation was chosen as the best alternative, benefitting all. The public will benefit from a clearer, more uniform and consistent licensing process subject to fewer interpretations. The NRC staff will benefit from improved regulatory implementation (both technical and legal), fewer interpretive debates, and increased regulatory flexibility. Applicants will derive the same benefits in addition to avoiding licensing delays due to unclear regulatory requirements. A revision to Appendix A would increase the efficiency of regulatory actions associated with any resurgence of licensing activity.

Alternative Use of Resources

No alternative use of resources was considered.

Agencies and Persons Consulted

Staff developed reports incorporating contractor evaluations are the bases for the Commission's recommendations.

Finding of No Significant Impact

The Commission has determined under the National Environmental Policy Act of 1969, as amended, that the proposed amendments to 10 CFR Parts 50 and 100, specifying seismic and geologic siting, and earthquake engineering criteria for nuclear power plants, if adopted, would not have a significant effect on the quality of the human environment and that an environmental impact statement is not required.

This determination is based on the following:

1. The proposed amendments to the regulations reflect current practice achieved through the the staff's evaluation of applicants safety analysis reports at the time of docketing and applicant's response to staff initiated questions based on their review of submitted information and the results of research in the earthsciences and seismic engineering.

2. The foregoing environmental assessment.

3. The qualitative, deterministic and probabilistic assessments pertaining to the seismic event in the cited references.

4. The Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants, published August 8, 1985 (50 FR 32138) affirming the Commission's belief that a new design for a nuclear power plant can be shown to be acceptable for severe accident concerns if the criteria and procedural requirements cited in 50 FR 32138 are met.

References

NUREG-1070, "NRC Policy on Future Reactor Designs, Decisions on Severe Accident Issues in Nuclear Power Plant Regulation," July 1985.

NUREG-1233, "Regulatory Analysis for USI A-40, "Seismic Design Criteria" Final Report," September 1989.

NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, Final Report," Attachment to Appendix D, Value/Impact Analysis for the Implementation of Individual Plant Examination of External Events, June 1991.