SEISMIC HAZARD - ACNW

OCT 03 1989

MEMORANDUM FOR: Raymond F. Fraley, Executive Director
Advisory Committee on Nuclear Waste

FROM: Robert E. Browning, Director
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

SUBJECT: REVIEW OF TECHNICAL POSITION ON METHODS OF EVALUATING THE SEISMIC HAZARD AT A GEOLOGIC REPOSITORY

Enclosed for review by the Advisory Committee on Nuclear Waste (ACNW) is a public comment draft of our Technical Position (TP) on "Methods of Evaluating the Seismic Hazard at a Geologic Repository." We are currently scheduled to brief the ACNW on this TP in January 1990. At that time, we will be requesting any comments the ACNW will have on the TP.

We would appreciate the ACNW comments regarding this TP at your earliest convenience following the January 1990 meeting. Any questions that you have in the meantime should be directed to Mr. Ken Kalman, Project Manager for this TP. Mr. Kalman can be reached at X-20428.

ORIGINAL SIGNED BY

Robert E. Browning, Director
Division of High-Level Waste Management

Enclosure: As stated

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TECHNICAL POSITION ON

METHODS OF EVALUATING THE SEISMIC HAZARD

AT A GEOLOGIC REPOSITORY

Public Comment Draft - June 1989

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TECHNICAL POSITION ON

METHODS OF EVALUATING THE SEISMIC HAZARD PRESENT

AT A GEOLOGIC REPOSITORY

Public Comment Draft - June 1989

1. INTRODUCTION

The purpose of this Technical Position (TP) is to provide regulatory guidance to the U.S. Department of Energy (DOE) on appropriate methodologies that address seismic hazard at a geologic repository. This paper considers the seismic hazard for the construction and operation period through permanent closure ("preclosure"), and the period following permanent closure ("postclosure"). This position also considers differences that may exist, during the preclosure, among the surface facilities and the underground facility. The applicability of existing methodologies for establishing the seismic basis for the determination of the maximum vibratory ground motion at a geologic repository is discussed. This position does not address probabilistic seismic hazard analysis nor does it address the interpretation of anticipated and unanticipated processes and events, which are being addressed in other technical positions and potential rulemakings. The term seismic hazard, as used in this TP, is meant to encompass the hazard due to either vibratory

ground motion or coseismic faulting, or both, that can affect the design and performance of the geologic repository.

TPs are issued to describe and make available to the public criteria for methods acceptable to the U.S. Nuclear Regulatory Commission (NRC) staff for implementing specific parts of the Commission's regulations, or to provide guidance to DOE. TPs are not substitutes for regulations and compliance with them is not required. They suggest one approach which is acceptable to the NRC staff for meeting regulatory requirements. Methods and solutions different from those set out in the position will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission. A glossary of selected technical terms used in this paper may be found in Appendix A of this paper.

2. REGULATORY BACKGROUND

2.1 Regulations concerning Seismic Hazard

The regulatory background section of this TP outlines the significant elements of Title 10, Chapter I of the Code of Federal Regulations (10 CFR) that contain provisions for protection from seismic hazard. The elements of 10 CFR that will be discussed are: 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants" (see Ref. 1); 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (see Ref. 2); 10 CFR Part

72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)" (see Ref. 3); 10 CFR Part 40, Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content" (see Ref. 4); and 10 CFR Part 60, "Disposal of High-Level Radioactive Waste in Geologic Repositories" (see Ref. 5). With the exception of 10 CFR 100, Appendix A, the relevant text from the aforementioned parts of 10 CFR can be found in Appendix B of this paper. An outline of 10 CFR Part 100, Appendix A is found in Appendix C of this paper.

2.2 10 CFR Part 50, Appendix A

Early in the development of the use of nuclear material, it was generally recognized that special provisions would be needed in order to provide reasonable assurance that these materials could be used without undue hazard to the public health and safety. With regard to seismic hazard, these provisions were first embodied in Criterion 2 of 10 CFR Part 50, Appendix A, "Design bases for protection against natural phenomena." Criterion 2 generally requires that structures, systems, and components important to safety be designed so that their safety functions are preserved under the impact of the most severe adverse natural phenomena.

2.3 10 CFR Part 100, Appendix A

Appendix A of 10 CFR Part 100, hereafter referred to as Part 100, Appendix A, is the most comprehensive of the NRC regulations dealing with seismic and geologic criteria. Part 100, Appendix A, which was initially included in the Commission regulations in 1973, provides more specific regulatory guidance for the siting of nuclear power plants than 10 CFR Part 50, Appendix A. Although the guidance is primarily directed toward an assessment of hazards due to vibratory ground motion and surface faulting, it also includes guidance on floods, water waves, and other related natural hazards. Part 100, Appendix A describes three aspects of seismic and geologic hazard evaluation: 1) the required investigations; 2) the development of seismic and geologic design bases; and 3) the application of these bases to engineering design.

2.4 10 CFR Part 72 and 10 CFR Part 40, Appendix A

Following its issuance, Part 100, Appendix A came to be relied on during the promulgation of regulations addressing seismic hazard for nuclear facilities other than nuclear power plants. This reliance on Part 100, Appendix A sets an important precedent that needs to be considered when new types of nuclear facilities that require seismic hazard review are considered for licensing. 10 CFR Part 72 and 10 CFR Part 40, Appendix A are examples of such regulations that refer to Part 100, Appendix A.

The evaluation of geological and seismological characteristics of acceptable sites for independent spent fuel storage installations (ISFSIs), described in Section 72.66 of 10 CFR Part 72, defers to the techniques of 10 CFR Part 100, Appendix A, for sites west of the Rocky Mountain Front and other areas of potential seismic activity. Criterion 4(e) of the technical criteria of 10 CFR Part 40, Appendix A discusses the siting of impoundment structures for uranium mill tailings, with respect to capable faults as defined in 10 CFR Part 100, Appendix A.

2.5 10 CFR Part 60

In contrast to the aforementioned examples given for other nuclear facilities, 10 CFR Part 60 does not specifically rely on Part 100, Appendix A for guidance regarding provisions for dealing with the seismic hazard nor does it specifically require the development of a design basis earthquake. Instead, the performance objectives and siting and design criteria described in 10 CFR Part 60 establish the bases for considering seismic hazard for both the preclosure and the postclosure periods. According to Section 60.111, during the preclosure period, the geologic repository operations area is to be designed to provide protection against radiation exposures and releases of radioactive material in accordance with standards set forth in 10 CFR Part 20 (see Ref. 6) and standards established by the U.S. Environmental Protection Agency (EPA) in 40 CFR Part 191 (see Ref. 7). Also, during the preclosure period, the geologic repository operations area is to be designed so that the

option to retrieve the emplaced radioactive waste is preserved. The criterion set forth in Subsection 60.131(b)(1), which requires that facilities important to safety in the geologic repository operations area be designed so that natural phenomena do not interfere with their safety functions, forms the basis for evaluating the preclosure seismic hazard.

The overall performance objective presented in Section 60.112 requires that the geologic setting, the engineered barrier system, shafts and any boreholes and their seals be designed to limit the release of radioactive materials to the accessible environment in accordance with standards established by EPA. Section 60.113 provides specific performance requirements for both the engineered barrier system and the geologic setting. The seismic hazard associated with the engineered barrier system, as well as the overall system, is to be evaluated in accordance with the appropriate siting criteria of Subsection 60.122(c).

The evaluations performed, using the aforementioned postclosure and preclosure criteria, are necessary in order to satisfy the required input to the Safety Analysis Report (SAR) described in Subsections 60.21(1)(ii)(B) and (C) and Subsection 60.21(c)(3), respectively. It is expected that much of the information gathered to support the seismic hazard evaluation required by Subsection 60.131(b)(1) for the preclosure period can also be used to support the postclosure seismic hazard evaluation.

3. TECHNICAL POSITION

It is the NRC staff's position that the methodologies prescribed in Appendix A of 10 CFR Part 100 for investigating seismic and related faulting phenomena, for determining the need to design for surface faulting, and for establishing the seismic basis for the determination of the maximum vibratory ground motion at a site are considered to be appropriate for addressing preclosure and postclosure seismic and faulting hazards at a geologic repository operations area. Further, it is the position of the staff that the results of Part 100, Appendix A investigations can generally provide input for probabilistic and other methods of assessing seismic and faulting hazards for the postclosure period. The NRC staff will rely on the principles espoused in Part 100, Appendix A, in its review of the appropriate sections related to seismic investigations in the SAR, which forms a major portion of the license application for a repository. In particular, the NRC staff will review those sections of the SAR addressing Subsections 60.21(c)(1)(ii)(B) and (C) and Subsection 60.21(c)(3) of 10 CFR Part 60, in the light of Appendix A of 10 CFR Part 100. In addition, the methodology outlined in this Technical Position can be used in developing seismic and geologic bases for earthquake design criteria pertinent to Subsection 60.131(b)(1) of 10 CFR Part 60 and in assisting in demonstrating compliance with Sections 60.111, 60.112, and 60.113.

4. DISCUSSION

4.1 Seismic Hazard before and after Permanent Closure

Two very different timeframes are addressed with regard to the performance of a geologic repository. The first is the initial period of about one-hundred years, during which time nuclear material will be received and emplaced in the repository and the option to retrieve the nuclear material must be preserved. This "operational period" is comparable to the operational periods of other nuclear facilities. The second period of time is that following the permanent closure of the repository, during which time engineered and natural barriers must isolate the nuclear material from the accessible environment, in accordance with standards established by EPA. The surface facilities necessary during the operational period will not remain in the postclosure period. Since the repository location remains unchanged, the data that can be acquired to allow an estimation of the expected seismic hazard will be similar for both periods.

4.2 Other Nuclear Waste Facilities

For the preclosure period, it is reasonable to consider the way seismic hazard is treated at other nuclear waste facilities. One type of facility is the ISFSI, which is regulated under 10 CFR Part 72. Subsection 72.66(a)(2), which addresses massive water basin and air-cooled canyon types of ISFSI structures,

states, "West of the Rocky Mountain Front (west of approximately 104° west longitude), and in other areas of known potential seismic activity, seismicity will be evaluated by the techniques of Appendix A of Part 100 of this chapter [10]." Subsection 72.66(a)(6)(i) goes on to to state, "For sites that have been evaluated under the criteria of Appendix A of 10 CFR Part 100, the ISFSI-DE [ISFSI design earthquake] shall be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant." It is important to consider the guidance given for the ISFSI, because NRC has used this guidance to evaluate the DOE proposal for the Monitored Retrievable Storage (MRS) facility. The MRS facility is similar to the surface facilities of a geological repository operations area. Clearly, this presents a strong argument for following a similar path for evaluating the seismic hazard at a geologic repository, at least for the preclosure surface facilities.

Impoundment structures built to contain the tailings and wastes from a uranium mill constitute a second type of facility for which regulatory language exists regarding seismic hazard evaluation. In Section I, "Technical Criteria," of 10 CFR Part 40, Appendix A, Criterion 4(e) states, "The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. As used in this criterion, the term 'capable fault' has the same meaning as defined in Section III(g) of Appendix A of 10 CFR Part 100. The term 'maximum credible earthquake' means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake

potential considering the regional and local geology and seismology and specific characteristics of local subsurface material." Although this type of facility is not necessarily similar to a geologic repository, it does demonstrate that the NRC staff considers Appendix A of 10 CFR Part 100 to be applicable to nuclear facilities other than power plants.

4.3 Consideration of Part 100, Appendix A

A primary reason for taking the position that Part 100, Appendix A is an appropriate methodology for investigating the seismic hazard at a geologic repository is that much of the technology presented in Part 100, Appendix A is generic in nature. This is particularly true for the required investigations described in Section IV of Part 100, Appendix A. The following is a summary of these required investigations.

4.3.1 Part 100, Appendix A, Required Investigations

The types of investigations required by Part 100, Appendix A for both vibratory ground motion and surface faulting investigations are:

1) determination of the lithologic, stratigraphic, hydrologic, and structural geologic conditions of the site and the region surrounding the site, including its geologic history;

2) identification and evaluation of tectonic structures underlying the site and the region surrounding the site, whether buried or expressed at the surface, including, in particular, consideration of the possible effects caused by man's 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;

3) listing of all historically reported earthquakes, including appropriate parametric data that describe time, location and earthquake size; in particular, for investigations for vibratory ground motion, the compilation of any additional information on the nature of strong ground motion, and effects of local-site materials on seismic wave transmission;

4) determination of capable faults;

5) for a capable fault, a listing of the length of the fault, its relationship to regional tectonic structures, and the nature, amount, and geologic history of displacements along the fault, including, particularly, the estimated amount of the maximum Quaternary displacement related to any one earthquake along the fault; and

6) correlation of earthquakes, where possible, with capable faults or tectonic structures or, at least in the case of vibratory ground motion

investigations, with tectonic provinces, when specific structures cannot be identified.

The types of investigations required by Part 100, Appendix A specifically for vibratory ground motion investigation are:

1) evaluation of physical evidence on the behavior, during prior earthquakes, of the surficial geologic materials and the substrata underlying the site, considering the information acquired from the lithologic, stratigraphic, and structural geologic studies; and

2) determination of the static and dynamic engineering properties of the materials underlying the site, including properties needed to determine the behavior of the underlying material during earthquakes and the characteristics of the underlying material in transmitting earthquake-induced motion.

A specific investigation required by Part 100, Appendix A for surface faulting is the determination of geologic evidence of fault offset at or near the ground surface, at or near the site.

For some of the investigations summarized above, Section IV of Part 100, Appendix A establishes specific limits on the extent of the investigations. For vibratory ground motion, investigations are generally limited to ranges

that are within 200 miles of the site. For surface faulting, investigations are also generally limited to faults greater than 1000 feet in length that are within five miles of the site. Additional guidance is provided in Section IV, through footnotes, that makes it unnecessary to investigate features more remote from a site if it can be shown that features closer to the site will control the design basis.

4.3.2 Part 100, Appendix A, Seismic and Geologic Bases Development

Using information gathered from the vibratory ground motion investigations, Section V of Part 100, Appendix A describes specific procedures for establishing the seismic and geologic bases for developing design criteria related to earthquake protection. Section V(a) of Part 100, Appendix A states, "The design basis for the maximum vibratory ground motion and the expected vibratory ground motion should be determined through evaluation of the seismology, geology, and the seismic and geologic history of the site and surrounding region." Section V(a)(1) then prescribes a set of specific steps to take in evaluating the data gathered through the required investigations, to arrive at the earthquake that produces the maximum vibratory acceleration at the site above a threshold of 0.1g. This earthquake is termed the Safe Shutdown Earthquake (SSE). These basic procedures form the framework for establishing the seismic basis for determination of the maximum vibratory motion at any site at relevant times and are therefore considered to be appropriate to a geologic repository.

Section V(a)(2) addresses the determination of an Operating Basis Earthquake (OBE). In contrast to a nuclear power plant, a geologic repository is not likely to have components possessing high energy driving forces capable of broadly dispersing the contained radioactivity. Even with a gross failure of those components of a repository involved in containment, a loss of containment integrity would not be as likely to have as significant a consequence for public health and safety as a nuclear power plant, because the systems would be passive. Consideration should also be given to the safety of onsite personnel in recovering from such a gross failure. Since an OBE is intended to provide the basis for regulating those features of a nuclear power plant necessary for continued operation without undue risk to the health and safety of the public, and since those features are not likely to be incorporated into a geologic repository, the OBE will not be given further consideration in this discussion.

Section V(b) of Part 100, Appendix A discusses the need to design for surface faulting. This section prescribes specific guidelines to follow in order to make this determination. For a geologic repository, it is necessary to consider these specific guidelines in light of the consequences of faulting. First, any guidelines for surface faulting should be considered applicable to the underground facility of a geologic repository as well, since it is very unlikely that a fault that ruptures the surface above the underground facility would not also create a rupture within the underground facility. Second, any faults discovered within the perimeter of the underground facility, through drifting or other means during site characterization, that cannot be associated

with surface faults, require special investigation similar to surface faults. Finally, faulting in a geologic repository can affect the integrity of the facilities important to safety at the surface, the integrity of the waste canisters in the underground facility, and the retrievability of the radioactive waste. Thus, the values used in the specific guidelines of Section V(b) need to be examined, but the basic principle, that is, the determination of a need to design for faulting, remains unchanged.

5. REFERENCES

1. U.S. Code of Federal Regulations, "General Design Criteria for Nuclear Power Plants," Chapter 10, Part 50, Appendix A, January 1988.

2. U.S. Code of Federal Regulations, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," Chapter 10, Part 100, Appendix A, January 1988.

3. U.S. Code of Federal Regulations, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)," Chapter 10, Part 72, Jaunuary 1988.

4. U.S. Code of Federal Regulations, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed

Primarily for Their Source Material Content," Chapter 10, Part 40, Appendix A, January 1988.

5. U.S. Code of Federal Regulations, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Chapter 10, Part 60, January 1988.

6. U.S. Code of Federal Regulations, "Standards for Protection against Radiation," Chapter 10, Part 20, January 1988.

7. U.S. Code of Federal Regulations, "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Chapter 40, Part 191, January 1988.

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Proposed Rule 10 CFR Part 60, 'Disposal of High-Level Radioactive Wastes in Geologic Repositories,'" USNRC Report NUREG-0804, December 1983.

U.S. Nuclear Regulatory Commission, "Staff Evaluation of U.S. Department of Energy Proposal for Monitored Retrievable Storage," USNRC Report NUREG-1168, March 1986.

U.S. Nuclear Regulatory Commission, "Summary Report of the Symposium on Seismic and Geologic Siting Criteria for Nuclear Power Plants," USNRC Report NUREG/CP-21039, June 1987.

APPENDIX A

GLOSSARY

As used in this guidance:

"Accessible environment" means: (1) the atmosphere, (2) land surface, (3) surface water, (4) oceans, and (5) the lithosphere that is outside the controlled area. (10 CFR 60)

"Anticipated operational occurrences" mean those conditions of normal operation which are expected to occur one or more times during the life of the geologic repository operations area and to include the loss of functionality of structures, systems, or components within the regulatory safety limits. (Based on 10 CFR 50, Appendix A; "geologic repository operations area" has been substituted for "nuclear power unit" and "the loss of functionality ... safety limits" has been substituted for "but are not limited to loss of power to all recirculation pumps, tripping of turbine generator set, isolation of main condenser, and loss of all offsite power.")

"Anticipated processes and events" means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved. To the extent reasonable in the light of the geologic record, it shall be assumed that those processes operating in

the geologic setting during the Quaternary Period continue to operate but with perturbations caused by the presence of emplaced radioactive waste superimposed thereon. (10 CFR 60)

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides. (10 CFR 60)

A "capable fault" is a fault which has exhibited one or more of the following characteristics:

(1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.

(2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.

(3) A structural relationship to a capable fault according to characteristics (1) or (2) 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 fault may be obscured at a particular site. This might occur, for example, at a site having deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably established. Such evidence shall be used in determining whether the fault is a capable fault within this definition.

Notwithstanding the foregoing paragraphs (1),(2), and (3), structural association of a fault 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 fault is not a capable fault within this definition. (10 CFR 100, App. A)

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives. (10 CFR 60)

"Containment" means the confinement of radioactive waste within a designated boundary. (10 CFR 60)

"Controlled area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure. (10 CFR 60)

The "design basis earthquake" is that earthquake which is based on 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 which produces the maximum vibratory ground

motion for which certain structures, systems, and components are designed to remain functional. These structures, systems, and components are those necessary to assure the capability to prevent or mitigate the consequence of accidents which could result in potential offsite exposures comparable to the guideline exposures of this part. (Based on 10 CFR 100, App. A, Safe Shutdown Earthquake definition; reactor-specific references have been eliminated.)

"Disposal" means the isolation of radioactive wastes from the accessible environment. (10 CFR 60)

"Disturbed zone" means that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository. (10 CFR 60)

"Engineered barrier system" means the waste packages and the underground facility. (10 CFR 60)

A "fault" is a tectonic structure along which differential slippage of the adjacent earth materials has occurred parallel to the fracture plane. It is distinct from other types of ground disruptions such as landslides, fissures, and craters. A fault may have gouge or breccia between its two walls and

includes any associated monoclinal flexure or other similar geologic structural feature. (10 CFR 100, App. A)

"Geologic repository" means a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes: (1) the geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste. (10 CFR 60)

"Geologic repository operations area" means a high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where waste-handling activities are conducted. (10 CFR 60)

"Geologic setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located. (10 CFR 60)

"Ground water" means all water which occurs below the land surface. (10 CFR 60)

"High-level radioactive waste" or "HLW" means (1) irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated

reactor fuel, and (3) solids into which such liquid wastes have been converted. (10 CFR 60)

"Important to safety" with reference to structures, systems, and components means those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until permanent closure. (10 CFR 60)

"Isolation" means inhibiting the transport of radioactive material so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits. (10 CFR 60)

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 Richter scale. (10 CFR 100, App. A)

The "Operating Basis Earthquake" is that earthquake which, considering the regional and local geology and 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 which produces

the vibratory growth [sic] 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. (10 CFR 100, App. A)

"Permanent closure" means final backfilling of the underground facility and the sealing of shafts and boreholes. (10 CFR 60)

"Quaternary (Period)" means the period of time ranging from the present to approximately two million years before the present.

"Radioactive waste" or "waste" means HLW and other radioactive materials other than HLW that are received for emplacement in a geologic repository. (10 CFR 60)

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.

"Retrieval" means the act of intentionally removing radioactive waste from the underground location at which the waste had been previously emplaced for disposal.

"Safe Shutdown Earthquake" (See "design basis earthquake")

"Seismic hazard" is a set of conditions, based on the potential for the occurrence of earthquakes, that might operate against the health and safety of the public. Seismic hazard may be characterized in either deterministic or probabilistic terms.

"Site" means the location of the controlled area. (10 CFR 60)

"Site characterization" means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and the ranges of those parameters of a particular site relevant to the procedures under this part. Site characterization includes boring, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth needed to determine the suitability of the site for a geologic repository, but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken. (10 CFR 60)

"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. (10 CFR 100, App. A)

A "tectonic structure" is a large scale dislocation or distortion within the earth's crust. Its extent is measured in miles. (10 CFR 100, App. A)

"Unanticipated processes and events" means those processes and events affecting the geologic setting that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which are nevertheless sufficiently credible to warrant consideration. Unanticipated processes and events may be either natural processes and events or processes and events initiated by human activities other than those activities licensed under this part. Processes and events initiated by human activities may only be found to be sufficiently credible to warrant consideration if it is assumed that: (1) The monuments provided for by this part are sufficiently permanent to serve their intended purpose; (2) the value to future generations of potential resources within the site can be assessed adequately under the applicable provisions of this part; (3) an understanding of the nature of radioactivity, and an appreciation of its hazards, have been retained in some functioning institutions; (4) institutions are able to assess risk and to take remedial action at a level of social organization and technological competence equivalent to, or superior to, that which was applied in initiating the processes or events concerned; and (5) relevant records are preserved, and remain accessible, for several hundred years after permanent closure. (10 CFR 60)

"Underground facility" means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals. (10 CFR 60)

"Unrestricted area" means any area, access to which is not controlled by the licensee for the purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters. (10 CFR 60)

APPENDIX B

RELEVANT TEXT FROM TITLE 10, CHAPTER I, OF THE CODE OF FEDERAL REGULATIONS

10 CFR Part 40, Appendix A, Criterion 4(e)

The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. As used in this criterion, the term "capable fault" has the same meaning as defined in section III(g) of Appendix A of 10 CFR Part 100. The term "maximum credible earthquake" means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material.

10 CFR Part 50, Appendix A, Criterion 2, Design bases for protection against natural phenomena

Structures, systems, and components important to safety shall 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. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and

surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

10 CFR Part 60

Section 60.21(c)(1)(ii)(B)

[The assessment of the site at which the proposed geologic repository operations area is to be located, that is to be included in the Safety Analysis Report of the license application, shall contain:] Analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they affect isolation within the controlled area.

Section 60.21(c)(1)(ii)(C)

[The assessment of the site at which the proposed geologic repository operations area is to be located, that is to be included in the Safety Analysis Report of the license application, shall contain:] An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

Section 60.21(c)(3)

[The Safety Analysis Report of the license application, shall include:] A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. This analysis shall consider -- (i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

Section 60.111, Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) Retrievability of waste. (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic

repository operations area before the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

Section 60.112, Overall system performance objective for the geologic repository after permanent closure

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

Section 60.113, Performance of particular barriers after permanent closure

(a) General provisions -- (1) Engineered barrier system. (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered

barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete filling with ground water of available void spaces in the underground facility shall be appropriately considered and analyzed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in Subsection 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) Geologic setting. The geologic repository shall be located so that pre-waste-emplacement ground water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission..

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement ground water travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are:

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and ground water; and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

Section 60.122(c), Potentially Adverse Conditions

[Selected conditions considered directly or indirectly related to seismic hazard]

The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional ground water flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional ground water flow system.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

Section 60.131(b)(1), Protection against natural phenomena and environmental conditions

[With respect to the general design criteria for the geologic repository operations area,] The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

10 CFR Part 72

Section 72.66, Geological and seismological characteristics

(a) Massive water basin and air-cooled canyon types of ISFSI structures. (1) East of the Rocky Mountain Front (east of approximately 104 west longitude), except in areas of known seismic activity including but not limited to the regions around New Madrid, Mo., Charleston, S.C., and Attica, N.Y., sites will be acceptable if the results from onsite foundation and geological investigation, literature review, and regional geological reconnaissance show no unstable geological characteristics, soil stability problems, or potential for vibratory ground motion at the site in excess of an appropriate response spectrum anchored at 0.2 g.

(2) West of the Rocky Mountain Front (west of approximately 104 west longitude), and in other areas of known potential seismic activity, seismicity will be evaluated by the techniques of Appendix A of Part 100 of this chapter.

Sites that lie within the range of strong near-field ground motion from historical earthquakes on large capable faults should be avoided.

(3) Sites other than bedrock sites shall be evaluated for their liquefaction potential or other soil instability due to vibratory ground motion.

(4) Site-specific investigations and laboratory analyses must show that soil conditions are adequate for the proposed foundation loading.

(5) In an evaluation of alternative sites, those which require a minimum of engineered provisions to correct site deficiencies are preferred. Sites with unstable geologic characteristics should be avoided.

(6) The [Independent Spent Fuel Storage Installation] ISFSI design earthquake (ISFSI-DE) for use in the design of structures shall be determined as follows:

(i) For sites that have been evaluated under the criteria of Appendix A of 10 CFR Part 100, the ISFSI-DE shall be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant.

(ii) For those sites that have not been evaluated under the criteria of Appendix A of 10 CFR Part 100, that are east of the Rocky Mountain Front, and that are not in areas of known seismic activity, a standardized ISFSI-DE described by an appropriate response spectrum anchored at 0.25 g may be used. Alternatively, a site-specific ISFSI-DE may be determined by using the criteria and level of investigations required by Appendix A of Part 100 of this chapter.

(iii) Regardless of the results of the investigations anywhere in the continental U.S., the ISFSI-DE shall have a value for the horizontal ground motion of no less than 0.10 g with the appropriate response spectrum.

(b) Other types of ISFSI designs. For ISFSI designs that do not use massive water basins or air-cooled canyons, such as canisters, casks, or silos, a site-specific investigation is required to establish site suitability commensurate with the specific requirements of the proposed ISFSI.

[45 FR 74699, Nov. 12, 1980; 45 FR 80271, Dec. 4, 1980]

APPENDIX C

OUTLINE OF 10 CFR PART 100, APPENDIX A

10 CFR Part 100, Appendix A, Seismic and Geologic Siting Criteria for Nuclear Power Plants

I. PURPOSE

II. SCOPE

III. DEFINITIONS

(a) "magnitude"

(b) "intensity"

(c) "Safe Shutdown Earthquake"

(d) "Operating Basis Earthquake"

(e) "fault"

(f) "Surface faulting"

(g) "capable fault"

(h) "tectonic province"

(i) "tectonic structure"

(j) "zone requiring detailed faulting investigation"

(k) "control width"

(l) "response spectrum"

IV. REQUIRED INVESTIGATIONS

(a) Required Investigations for Vibratory Ground Motion

(1) Determination of geologic conditions of the site and vicinity

(2) Identification and evaluation of tectonic structures

(3) Evaluation of the behavior of geologic materials during prior earthquakes

(4) Determination of engineering properties of the materials

(5) Listing of all historically reported earthquakes affecting the site

(6) Correlation of epicenters with tectonic structures or provinces

(7) Determination of capable faults

(8) For capable faults, determination of:

(i) Length of the fault

(ii) Relationship of the fault to regional tectonic structures

(iii) Nature of displacements along the fault

(b) Required Investigations for Surface Faulting

(1) Determination of geologic condition of the site and vicinity

(2) Evaluation of tectonic structures

(3) Determination of geologic evidence of fault offset

(4) For faults greater than 1000 feet long, determination of whether these faults are capable faults

(5) Listing of all historically reported earthquakes associated with capable faults greater than 1000 feet long

(6) Correlation of epicenters of historically reported earthquakes with capable faults greater than 1000 feet long

(7) For capable faults, determination of:

(i) Length of the fault

(ii) Relationship of the fault to regional tectonic structures

(iii) Nature of displacements along the faults

(iv) Extent of the fault zone in the site vicinity

(c) Required Investigation for Seismically Induced Floods and Water Waves

(1) For coastal sites, determination of:

(i) Information regarding distantly and locally generated waves or tsunami affecting the site

(ii) Local features which might tend to modify tsunami effects

(iii) Appropriate evidence to provide information for designing for the effects of a local offshore earthquake

(2) For sites located near lakes and rivers, determination of effects of seismically-induced floods and water waves

V. SEISMIC AND GEOLOGIC DESIGN BASES

(a) Design Basis for Vibratory Ground Motion

(1) Determination of Safe Shutdown Earthquake

(2) Determination of Operating Basis Earthquake

(b) Need to Design for Surface Faulting

(1) Determination of zone requiring detailed faulting investigation

(c) Design Bases for Seismically Induced Floods and Water Waves

(d) Other Design Conditions

(1) Soil stability

(2) Slope stability

(3) Cooling water supply

(4) Distant structures

VI. APPLICATION TO ENGINEERING DESIGN

(a) Vibratory Ground Motion

(1) Safe Shutdown Earthquake

(2) Operating Basis Earthquake

(3) Required seismic instrumentation

(b) Surface Faulting

(c) Seismically induced floods and water wave and other design considerations