[7590-01]

AVAILABILITY OF DRAFT STAFF TECHNICAL POSITION ON CONSIDERATION OF FAULT DISPLACEMENT HAZARDS IN GEOLOGIC REPOSITORY DESIGN

AGENCY: Nuclear Regulatory Commission.

ACTION: Notice of availability.

SUMMARY: The Nuclear Regulatory Commission is announcing the availability of the draft staff technical position (STP) on "Consideration of Fault Displacement Hazards in Geologic Repository Design."

DATES: The comment period expires _____ (90 days).

ADDRESSEES: Send comments to David L. Meyer, Chief, Regulatory Publications Branch, Division of Freedom of Information and Publications Services, Office of Administration, Nuclear Regulatory Commission, Washington, D.C. 20555. Copies of this document may be obtained free of charge upon written request to Anne E. Garcia, Repository Licensing and Quality Assurance Project Directorate, Division of High-Level Waste Management, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission, Mail Stop 4-H-3, Washington, D.C. 20555. Telephone 301/504-2438. A copy of this draft STP is also available for public inspection and/or copying at the NRC Public Document Room, 2120 "L" Street (Lower Level), N.W., Washington, D.C. 20555.

FOR FURTHER INFORMATION CONTACT: Dr. Keith I. McConnell, Geology and Engineering Branch, Division of High-Level Waste Management, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission, Mail Stop 4-H-3, Washington, D.C. 20555. Telephone 301/504-2532.

SUPPLEMENTARY INFORMATION: The Nuclear Regulatory Commission Staff Technical Position (STP) on "Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository" (see NUREG-1451) outlined an acceptable approach by which faults (or fault zones) of possible regulatory

concern to the geologic repository are identified and investigated. In the approach described in that STP, those faults that are considered to be of possible regulatory concern to the geologic repository are ones that are subject to displacement (i.e., stratigraphic offset) and that may affect the design or performance of structures, systems, and components important to safety or important to waste isolation, and/or may provide significant input into models used in assessments of design or performance of structures, systems, and components important to safety or important to waste isolation.

This STP addresses those situations in which faults of regulatory concern (designated as "Type I" faults in NUREG-1451) exist or are assumed to exist at the location of systems, structures, and components important to safety or important to waste isolation. Specifically, this STP recognizes the acceptability of designing the geologic repository to take into account the attendant effects (e.g., displacement) of faults of regulatory concern and expresses the staff's views on what is needed from the U.S. Department of Energy (DOE) if it chooses to locate structures, systems, and components important to safety or important to waste isolation in areas that contain "Type I" faults (e.g., faults with Quaternary-age displacement). Therefore, DOE should seek early resolution of fault-related design and performance issues, at the staff level, before submitting a license application to construct and operate a geologic repository.

Dated at Rockville, Maryland this 10th day of March, 1993.
For the Nuclear Regulatory Commission

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NUREG-1ZZZ

STAFF TECHNICAL POSITION ON CONSIDERATION OF FAULT DISPLACEMENT HAZARDS IN GEOLOGIC REPOSITORY DESIGN

Public Comment Draft -- March 1993

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ABSTRACT

Nuclear Regulatory Commission regulations for the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository recognize that fault displacement is a potentially adverse condition (10 CFR 60.122(c)(20)). However, they do not prohibit designing the geologic repository against the effects of such a potentially adverse condition. This Staff Technical Position recognizes the acceptability of designing the geologic repository to take into account the attendant effects (e.g., displacement) of faults of regulatory concern and expresses the staff's views on what is needed from the U.S. Department of Energy if it chooses to locate structures, systems, and components important to safety or important to waste isolation in areas that contain faults of regulatory concern.

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ACKNOWLEDGMENTS

The authors gratefully acknowledge substantial contributions from the staffs of the Division of High-Level Waste Management, the Office of the General Counsel, and the Center for Nuclear Waste Regulatory Analyses, which have been incorporated into the text of this Staff Technical Position, as well as from Ellen Kraus, for editorial guidance.

1.0 INTRODUCTION

The Nuclear Regulatory Commission Staff Technical Position (STP) on "Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository" (see NUREG-1451 (McConnell *et al.*, 1992)) described an acceptable approach to identify and investigate faults (or fault zones) of possible regulatory concern to the geologic repository. In the approach described in that STP, those faults that are considered to be of possible regulatory concern to the geologic repository are ones that are subject to displacement (i.e., stratigraphic offset) and that may affect the design or performance of structures, systems, and components important to safety or important to waste isolation, and/or may provide significant input into models used in assessments of design or performance of structures, systems, and components important to safety or important to waste isolation.[1]

This STP addresses those situations in which faults of regulatory concern (designated as "Type I" faults in NUREG-1451[2]) exist or are assumed to exist at the location of systems, structures, and components important to safety or important to waste isolation. Specifically, this STP recognizes the acceptability of designing the geologic repository to take into account the attendant effects (e.g., displacement) of faults of regulatory concern and expresses the staff's views on what is needed, from DOE, if DOE chooses to locate structures, systems, and components important to safety or important to waste isolation in areas that contain "Type I" faults (e.g., faults with Quaternary-age[3] displacement). Therefore, DOE should seek early resolution of fault-related design and performance issues, at the staff level, before submitting a license application to construct and operate a geologic repository.

1.1 Background

As with many potentially severe natural conditions, there is much uncertainty associated with the design and evaluation of nuclear facilities for seismic hazards (e.g., the effects of earthquake-related ground motion) and fault displacement hazards. Inadequate or inconclusive geologic evidence has made it difficult to establish accurate parameters for specific locations accurately or to establish the design basis for individual facilities.

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[1] 10 CFR Part 60 is structured around the multiple-barrier concept and the Commission's principles of defense-in-depth, and primarily focuses on repository performance. The applicant (the U.S. Department of Energy (DOE)) must demonstrate compliance with the performance objectives of Subpart E of 10 CFR Part 60, to have a potential geologic repository licensed. To ensure that such compliance can be demonstrated, 10 CFR Part 60 sets out a number of specific siting and design criteria. Performance issues are, therefore, closely linked with siting and design issues, and the staff position set out herein should be considered in that context.

[2] "Type I" faults refer to those faults or fault zones that are subject to displacement and of sufficient length and located in such a manner that they may affect repository design and/or performance. As such, they should be investigated in detail (McConnell *et al.*, 1992, p. 5).

[3] The staff has taken the position that, "for regulatory purposes," the age of the Quaternary Period is 2 million years (see NRC, 1983b, p. 373).

Despite recent advances in the treatment of seismic hazards (Bernreuter *et al.*, 1985 and 1989; EPRI, 1986), large uncertainties still remain regarding their characterization and in the characterization of fault displacement hazards. Because of these uncertainties, it has been difficult to place the contribution of geologic risk, specifically fault displacement, into proper perspective in the development of individual nuclear facility designs, thus typically leading to the assumption of conservative design bases (see NRC, 1979). For example, for existing nuclear power plants licensed under Appendix A to 10 CFR Part 100 (Seismic and Geologic Siting Criteria for Nuclear Power Plants) (*Code of Federal Regulations*, Title 10, "Energy"), NRC requires "detailed" faulting investigations over an area of up to 4 times that containing the fault (or fault zone) in question[4] to determine if the facility can be designed to withstand the effects of faulting. Because of the uncertainty associated with the assessment of the fault displacement hazard in the zone requiring detailed faulting investigation, the approach commonly used by past NRC license applicants has been to relocate nuclear facilities outside this zone, thereby obviating the need for such detailed investigations. Although not required by NRC's regulations, this practice has led to what could be referred to as a *de facto* "setback" criterion.

NRC regulations for the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository, 10 CFR Part 60 (*Code of Federal Regulations*, Title 10, "Energy") recognize that fault displacement can be a potentially adverse condition (10 CFR 60.122(c)(20)); however, they do not prohibit designing the geologic repository to accommodate the effects of such a potentially adverse condition. Given the differences in function and performance between geologic repositories and other nuclear facilities, the staff has developed this STP to express its views on an acceptable approach to the treatment of fault displacement in the design and operation of a geologic repository.

1.2 STPs as Technical Guidance

STPs are issued to describe, and make available to the public, methods acceptable to the NRC staff, for implementing specific parts of the Commission's regulations, and to provide regulatory guidance to DOE. STPs are not substitutes for regulations, and compliance with them is not required. Methods and solutions differing from those set out in the STPs will be

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[4] This is generally referred to as the "control width." See Table 2, contained in Item (b)(1), "Determination of Zone Requiring Detailed Faulting Investigation," in Section V -- "Seismic and Geologic Design Bases," in Appendix A to 10 CFR Part 100. It should be noted, though, that NRC recently proposed amendments, to 10 CFR Part 100, to update the criteria used in decisions regarding the siting of future nuclear power reactors, including geologic, seismic, and earthquake engineering considerations (see NRC, 1992; 57 *FR* 47802-47814). The proposed regulation would identify and establish basic requirements. Detailed guidance on procedures acceptable to the NRC staff for meeting the seismic and earthquake engineering regulations would be contained in a draft regulatory guide to be issued for public comment as "Draft Regulatory Guide, DG-1015: Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motion" (57 *FR* 47807).

acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

Published STPs will be revised, as appropriate, to accommodate comments and to reflect new information and experience.

2.0 REGULATORY FRAMEWORK

10 CFR Part 60 is structured around the multiple-barrier concept and the Commission's principles of defense-in-depth, and primarily focuses on repository performance objectives.

The applicant (DOE) must demonstrate compliance with the performance objectives of Subpart E of 10 CFR Part 60, to receive a construction authorization. 10 CFR Part 60 sets out a number of general siting (10 CFR 60.122(b-c)) and design criteria (10 CFR 60.131-134), to ensure that such compliance can be demonstrated. However, there are no specific site suitability or exclusionary technical criteria (NRC, 1981; 46 *FR* 35284). If potentially adverse conditions (10 CFR 60.122(c)) are identified as being present, they must be thoroughly analyzed, and it must be demonstrated that the conditions can be compensated for by the geologic repository design and/or by favorable conditions (10 CFR 60.122(b)) present in the geologic setting. Although the multiple-barrier concept allows for advanced engineering design, the technical criteria in Subpart E of 10 CFR Part 60 are structured in a manner so as to favor the selection of a candidate site with certain natural waste isolation capabilities.

Thus, because of site- and design-specific considerations, the language in 10 CFR Part 60 is intentionally non-prescriptive; that is, it leaves to DOE the opportunity and responsibility to determine, among other matters, how to site and design a potential geologic repository. As part of this process, DOE will conduct a program of site characterization (see DOE, 1988), during which it will gather sufficient information on the characteristics of a candidate site so as to permit an evaluation of its waste isolation capabilities and design in the context of the Subpart E performance objectives. Given this framework, it is the staff's expectation that DOE may propose engineering and/or design solutions to actual or potential geologic effects at a candidate site (such as fault displacement (60.122(c)(20)), in concert with the occurrence of certain favorable conditions (10 CFR 60.122(b)); these solutions may be sufficient to enable DOE to demonstrate that the pertinent 10 CFR Part 60 performance objectives have been satisfied. Performance, therefore, is closely linked with siting and design, and the staff position described here must be understood in that context.

Finally, as noted earlier, the staff has issued an STP, NUREG-1451 (see McConnell *et al.*, 1992) to provide guidance on investigations to identify fault displacement hazards and seismic hazards at a geologic repository. DOE should consider the earlier referenced STP in conjunction with this STP.

3.0 STAFF TECHNICAL POSITIONS

In view of the aforementioned policy considerations and statements of regulatory consideration underpinning 10 CFR Part 60, the staff has adopted the following technical positions concerning the geologic repository program:

(1) It is the NRC staff position that the presence of "Type I" faults,[5] as defined by NUREG-1451, inside the controlled area of a geologic repository, does not, by itself, represent a "disqualifying" feature of the candidate site for a geologic repository.

(2) In general, areas within the controlled area of a geologic repository that contain "Type I" faults should be avoided, where this can be reasonably achieved, when locating structures, systems, and components important to safety or important to waste isolation. However, if DOE chooses to locate structures, systems, and components important to safety or important to waste isolation in areas that contain "Type I" faults, then:

   (a) DOE should appreciate that reliance on engineering may be of limited value; and

   (b) DOE must be able to demonstrate, with reasonable assurance, that any proposed geologic repository designed to accommodate the effects of faulting meets the 10 CFR Part 60 design criteria, and pre- and post-closure performance objectives.

[5] NUREG-1451 specifies that faults not considered to be "Type I" faults (i.e., "Type II" and "Type III" faults) be periodically reevaluated, based on the results of subsequent site characterization activities, at which time they may be reclassified as "Type I" faults.

4.0 DISCUSSION

The following discussion parallels the list of technical positions given in Section 3.0.

(1) In the statement of considerations for the proposed rule, the Commission noted that in proposing siting requirements, there are no specific site suitability or exclusionary technical criteria in 10 CFR Part 60. Rather, the Commission encouraged "... the selection of a site with favorable geologic conditions ... [in order to] ... greatly enhance the Commission's ability to make the prescribed findings ...." (NRC, 1983a; 48 *FR* 28203)

However, the Commission identified certain site characteristics considered favorable for a geologic repository, as well as characteristics that, if present at the site, might compromise site suitability and that would require careful analysis and measures as may be necessary, to compensate for them adequately. In the case of potentially adverse conditions, the Commission noted that there is not "... the presumption of [site] unsuitability because of the presence of an unfavorable characteristic ...." (NRC, 1981; 46 *FR* 35284) This axiom was later reinforced in the final rule, where the Commission noted that a site "... was not disqualified as a result of the absence of a favorable condition or the presence of a potentially adverse condition ...." (NRC, 1983a; 48 *FR* 28201) This philosophy requires that if a potentially adverse condition, such as faulting, is present, then DOE is required by the regulations to thoroughly characterize and analyze the condition, and in doing so must demonstrate that the condition can be compensated for by repository design, certain limited engineering measures, and/or by other favorable conditions present at this site.

(2)(a) In promulgating 10 CFR Part 60, the Commission recognized that there would be considerable uncertainty in predicting the performance of a geologic repository for tens of thousands of years. Natural systems are difficult to characterize, and any understanding of a candidate site would have significant limitations and uncertainties. To overcome these limitations and uncertainties, the Commission adopted a multiple barrier, defense-in-depth approach consisting of engineered barriers (i.e., waste packages and the underground facility) and the natural barrier provided by the geologic setting. By partitioning the geologic repository into two major barriers, the Commission sought to exploit the ability to design those engineered features as a means of reducing some of the uncertainties in predicting the performance of the natural system.

However, the Commission recognized that, at some point, the containment capabilities of the engineered system might prove ineffective, and "the geologic setting must provide for the isolation of wastes" (NRC, 1981; 46 *FR* 35282). Moreover, the staff believes that the reliability of certain types of engineered measures are subject to limitations, and like the geologic setting, would represent an additional source of uncertainty in the evaluation of performance. Although (complex) engineering

measures are not inherently unacceptable, their reliability must be carefully scrutinized in the licensing process (NRC, 1983a; 48 *FR* 28213). In light of this consideration, the staff has attempted to identify and, when practicable, reduce sources of uncertainty in predicting geologic repository performance. Thus, the Commission adopted the provision, in the final rule, that rock or groundwater conditions that would require "complex" engineering measures could be viewed as "potentially adverse conditions" (10 CFR 60.122(c)(20)) (*Opt. cit*).

Although 10 CFR Part 60.122(c)(20) does not specify what types or kinds of engineering measures are regarded as "complex," and thus the predicate of a potentially adverse condition, the staff believes that attempting to design the repository for the effects of fault displacement may pose several engineering challenges that, historically, have proven to be difficult to address. Because of these challenges, engineering solutions cannot always be demonstrated to compensate for the effects of ground displacement phenomena.[6]

Therefore, because of the uncertainties in the characterization of tectonic hazards, it may be difficult for DOE to demonstrate, with "reasonable assurance," that its engineering solutions to the actual or potential effects of fault displacement will compensate for the condition. Thus, the staff believes that when locating structures, systems, and components important to safety or important to waste isolation, it may be preferable, for the reasons noted previously, to avoid areas subject to fault displacement, rather than attempting to design for their effects.

(2)(b) The Commission also noted, in the statement of considerations for the rule, that in addition to a site with superior waste isolation capabilities, DOE would have to rely on certain engineering and/or design measures to provide "reasonable assurance" of meeting the relevant 10 CFR Part 60 standards and criteria. To enable the Commission to reach the requisite findings, with reasonable assurance, 10 CFR Part 60 requires a careful and exhaustive analysis of all features of the repository. For example, the regulatory criteria set forth in 10 CFR 60.21(c)(1)(ii) require, from DOE, a description and assessment of the site at which the proposed geologic repository operations area (GROA) is to be located, with appropriate attention to those features (i.e., potentially adverse conditions, as defined in 10 CFR 60.122(c)) of the site that might affect GROA design and performance. The description and assessment called for in 10 CFR 60.21(c)(1)(i-ii) must be in sufficient depth to support the assessment of the effectiveness of engineered and natural barriers called for in 10 CFR 60.21(c)(1)(ii)(D), as well as the analysis of design and performance requirements for structures, systems, and components important to safety called for in 10 CFR

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[6] In the context of the geologic repository program, the issue of engineering design and faulting was recently raised by the Nuclear Waste Technical Review Board (NWTRB). In this regard, the NWTRB critically noted that "... although engineering structures have been designed to accommodate the effects of fault displacement, such design is not common practice among engineers" (see NWTRB, 1992, p. 14).

60.21(c)(3).

5.0 REFERENCES

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APPENDIX A GLOSSARY

As used in this guidance:

"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.

"Faults of regulatory concern" means those "Type I" faults that: (1) are subject to displacement; and (2) may affect the design or performance of structures, systems, and components important to safety, containment, or waste isolation; and/or (3) may provide significant input to models used in assessments of design or performance of structures, systems, and components important to safety, containment, or waste isolation (see McConnell *et al.*, 1992).

"Geologic Setting"* means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

"Seismic hazard" is a set of conditions, based on the potential for the occurrence of earthquakes, that might have a negative effect on facilities that protect the health and safety of the public.

"Site"* means the location of the controlled area.

" 'Type I' faults" refers to those faults or fault zones that are subject to displacement and of sufficient length and located in such a manner that they may affect repository design and/or performance. As such, they should be investigated in detail (McConnell *et al.*, 1992, p. 5).

" 'Type II' faults" refers to those faults or fault zones that are candidates for detailed investigation (McConnell *et al.*, 1992, p. 5).

" 'Type III' faults" refers to those faults or fault zones either (1) not subject to displacement or (2) subject to displacement, but of such length, or located in such a manner, that they will not affect repository design and/or performance. Consequently, they do not need to be investigated in detail (McConnell *et al.*, 1992, p. 5).

For definitions of other relevant terms, see 10 CFR 60.2.

* *Code of Federal Regulations*, Title 10, "Energy."

APPENDIX B APPLICABLE 10 CFR PART 60 REGULATIONS

§ 60.21 Content of application.

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) 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.

(C) 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.

(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of

radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(E) An analysis of the performance of the major design structures, systems, and components, both surface and subsurface, to identify those that are important to safety. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, in situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

§ 60.122 Siting criteria.

(b) *Favorable conditions.* (1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(2) For disposal in the saturated zone, hydrogeologic conditions that provide:

(i) A host rock with low horizontal and vertical permeability;

(ii) Downward or dominantly horizontal hydraulic gradient in the host rock and immediately surrounding hydrogeologic units; and

(iii) Low vertical permeability and low hydraulic gradient between the host rock and the surrounding hydrogeologic units.

(3) Geochemical conditions that:

(i) Promote precipitation or sorption of radionuclides;

(ii) Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or

(iii) Inhibit the transport of radionuclides by particulates, colloids, and complexes.

(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.

(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

(6) A low population density within the geologic setting and a controlled area that is remote from population centers.

(7) Pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years.

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide --

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units;

(ii) A water table sufficiently below the underground facility such that fully saturated voids contiguous with the water table do not encounter the underground facility;

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility;

(iv) A host rock that provides for free drainage; or

(v) A climatic regime in which the average annual historic precipitation is a small percentage of the average annual potential evapotranspiration.

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

(2) Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity, or construction of large-scale surface water impoundments.

(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 groundwater 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 groundwater flow system.

(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(6) Potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes.

(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.

(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.

(9) Groundwater conditions in the host rock that are not reducing.

(10) Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets.

(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.

(15) Evidence of igneous activity since the start of the Quaternary Period.

(16) Evidence of extreme erosion during the Quaternary Period.

(17) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:

(i) Economic extraction is currently feasible or potentially feasible during the foreseeable future; or

(ii) Such materials have greater gross value or net value than the average for other areas of similar size that are representative of and located within the geologic setting.

(18) Evidence of subsurface mining for resources within the site.

(19) Evidence of drilling for any purpose within the site.

(20) Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts.

(21) Geomechanical properties that do not permit design of underground opening that will remain stable through permanent closure.

(23) Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment.

(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment.

§ 60.131 General design criteria for the geologic repository operations area.

(a) *Radiological protection.* The geologic repository operations area shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in restricted areas within the limits specified in Part 20 of this chapter. Design shall include: designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(1) Means to limit concentrations of radioactive materials in air;

(2) Means to limit the time required to perform work in the vicinity of radioactive materials, including, as appropriate, designing equipment for ease of repair and replacement and providing adequate space for ease of operation;

(3) Suitable shielding;

(4) Means to monitor and control the dispersal of radioactive contamination;

(5) Means to control access to high radiation areas or airborne radioactivity areas; and

(6) A radiation alarm system to warn of significant increases in radiation levels,

concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with provisions for calibration and for testing its operability.

(b) *Structures, systems, and components important to safety* -- (1) *Protection against natural phenomena and environmental conditions.* 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.

(2) *Protection against dynamic effects of equipment failure and similar events.* The structures, systems, and components important to safety shall be designed to withstand dynamic effects such as missile impacts, that could result from equipment failure, and similar events and conditions that could lead to loss of their safety functions.

(3) *Protection against fires and explosions.* (i) The structures, systems, and components important to safety shall be designed to perform their safety functions during and after credible fires or explosions in the geologic repository operations area.

(ii) To the extent practicable, the geologic repository operations area shall be designed to incorporate the use of noncombustible and heat-resistant materials.

(iii) The geologic repository operations area shall be designed to include explosion and fire detection alarm systems and appropriate suppression systems with sufficient capacity and capability to reduce the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The geologic repository operations area shall be designed to include means to protect systems, structures, and components important to safety against the adverse effects of either the operation or failure of the fire suppression systems.

(4) *Emergency capability.* (i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste and radioactive effluents, and permit prompt termination of operations and evacuation of personnel during an emergency.

(ii) The geologic repository operations area shall be designed to include onsite facilities and services that ensure a safe and timely response to emergency conditions and that facilitate the use of available offsite services (such as fire, police, medical and ambulance service) that may aid in recovery from emergencies.

(5) *Utility services.* (i) Each utility service system that is important to safety shall be designed so that essential safety functions can be performed under both normal and accident conditions.

(ii) The utility services important to safety shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform their safety functions.

(iii) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and timely emergency power can be provided to instruments, utility service systems, and operating systems, including alarm systems, important to safety.

(6) *Inspection, testing, and maintenance.* The structures, systems, and components important to safety shall be designed to permit periodic inspection, testing, and maintenance, as necessary, to ensure their continued functioning and readiness.

(7) *Criticality control.* All systems for processing, transporting, handling, storage,

retrieval, emplacement, and isolation of radioactive waste shall be designed to ensure that a nuclear criticality accident is not possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Each system shall be designed for criticality safety under normal and accident conditions. The calculated effective multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5% margin, after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.

(8) *Instrumentation and control systems.* The design shall include provisions for instrumentation and control systems to monitor and control the behavior of systems important to safety over anticipated ranges for normal operation and for accident conditions.

(9) *Compliance with mining regulations.* To the extent that DOE is not subject to the Federal Mine Safety and Health Act of 1977, as to the construction and operation of the geologic repository operations area, the design of the geologic repository operations area shall nevertheless include such provisions for worker protection as may be necessary to provide reasonable assurance that all structures, systems, and components important to safety can perform their intended functions. Any deviation from relevant design requirements in 30 CFR, Chapter I, Subchapters D, E, and N will give rise to a rebuttable presumption that this requirement has not been met.

(10) *Shaft conveyances used in radioactive waste handling.* (i) Hoists important to safety shall be designed to preclude cage free fall.

(ii) Hoists important to safety shall be designed with a reliable cage location system.

(iii) Loading and unloading systems for hoists important to safety shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

(iv) Hoists important to safety shall be designed to include two independent indicators to indicate when waste packages are in place and ready for transfer.

§ 60.132 Additional design criteria for surface facilities in the geologic repository operations area.

(a) *Facilities for receipt and retrieval of waste.* Surface facilities in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility.

(b) *Surface facility ventilation.* Surface facility ventilation systems supporting waste transfer, inspection, decontamination, processing, or packaging shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111(a).

(c) *Radiation control and monitoring* -- (1) *Effluent control.* The surface facilities shall be designed to control the release of radioactive materials in effluents during normal operations so as to meet the performance objections of § 60.111(a).

(2) *Effluent monitoring.* The effluent monitoring systems shall be designed to measure the amount and concentration of radionuclides in any effluent with sufficient precision to determine whether releases conform to the design requirement for effluent control. The monitoring systems shall be designed to include alarms that can be periodically tested.

(d) *Waste treatment.* Radioactive waste treatment facilities shall be designed to process any radioactive wastes generated at the geologic repository operations area into a form suitable to permit safe disposal at the geologic repository operations area or to permit safe transportation and conversion to a form suitable for disposal at an alternative site in accordance with any regulations that are applicable.

(e) *Consideration of decommissioning.* The surface facility shall be designed to facilitate decontamination or dismantlement to the same extent as would be required, under other parts of this chapter, with respect to equivalent activities licensed thereunder.

§ 60.133 Additional design criteria for the underground facility.

(a) *General criteria for the underground facility.* (1) The orientation, geometry, layout, and depth of the underground facility, and the design of any engineered barriers that are part of the underground facility shall contribute to the containment and isolation of radionuclides.

(2) The underground facility shall be designed so that the effects of credible disruptive events during the period of operations, such as flooding, fires and explosions, will not spread through the facility.

(b) *Flexibility of design.* The underground facility shall be designed with sufficient flexibility to allow adjustments where necessary to accommodate specific site conditions identified through in situ monitoring, testing, or excavation.

(c) *Retrieval of waste.* The underground facility shall be designed to permit retrieval of waste in accordance with the performance objectives of § 60.111.

(d) *Control of water and gas.* The design of the underground facility shall provide for control of water or gas intrusion.

(e) *Underground openings.* (1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained.

(2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock.

(f) *Rock excavation.* The design of the underground facility shall incorporate excavation methods that will limit the potential for creating a preferential pathway for groundwater to contact the waste packages or radionuclide migration to the accessible environment.

(g) *Underground facility ventilation.* The ventilation system shall be designed to:

(1) Control the transport of radioactive particulates and gases within and releases from the underground facility in accordance with the performance objectives of § 60.111(a);

(2) Assure continued function during normal operations and under accident conditions; and

(3) Separate the ventilation of excavation and waste emplacement areas.

(h) *Engineered barriers.* Engineered barriers shall be designed to assist the geologic setting in meeting the performance objectives for the period following permanent closure.

(i) *Thermal loads.* The underground facility shall be designed so that the performance objectives will be met taking into account the predicted thermal and thermomechanical response of the host rock, and surrounding strata, groundwater system.

§ 60.134 Design of seals for shafts and boreholes.

(a) *General design criterion.* Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure.

(b) *Selection of materials and placement methods.* Materials and placement methods for seals shall be selected to reduce, to the extent practicable:

(1) The potential for creating a preferential pathway for groundwater to contact the waste packages or

(2) For radionuclide migration through existing pathways.

§ 60.135 Criteria for the waste package and its components.

(a) *High-level-waste package design in general.* (1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

(b) *Specific criteria for HLW package design* -- (1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials in an amount that could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives.

(2) *Free liquids.* The waste package shall not contain free liquids in an amount that could compromise the ability of the waste packages to achieve the performance objectives relating to containment of HLW (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of waste package perforation during the period through permanent closure.

(3) *Handling.* Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.

(4) *Unique identification.* A label or other means of identification shall be provided for each waste package. The identification shall not impair the integrity of the waste package and shall be applied in such a way that the information shall be legible at least to the end of the period of retrievability. Each waste package identification shall be consistent with the waste package's permanent written records.

(c) Waste form criteria for HLW. High-level radioactive waste that is emplaced in the underground facility shall be designed to meet the following criteria:

(1) *Solidification.* All such radioactive wastes shall be in solid form and placed in sealed containers.

(2) *Consolidation.* Particulate waste forms shall be consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.

(3) *Combustibles.* All combustible radioactive wastes shall be reduced to a noncombustible form unless it can be demonstrated that a fire involving the waste packages containing combustibles will not compromise the integrity of other waste packages, adversely affect any structures, systems, or components important to safety, or compromise the ability of the underground facility to contribute to waste isolation.

(d) *Design criteria for other radioactive wastes.* Design criteria for waste types other than HLW will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository.