UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DISCUSSION OF PROPOSED RULE IN FEDERAL REGISTER, 10 CFR Part 60, PERTAINING TO GROUND-WATER TRAVEL TIME--AN APPENDIX TO REPORT BY SANDIA NATIONAL LABORATORIES TO U.S. NUCLEAR REGULATORY COMMISSION, ASSESSING THE TECHNICAL CRITERIA FOR GEOLOGIC DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE

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Discussion of Proposed Rule in Federal Register, 10 CFR Part 60, Pertaining to Ground-Water Travel Time-- An Appendix to Report by Sandia National Laboratories to U.S. Nuclear Regulatory Commission, Assessing the Technical Criteria for Geologic Disposal of High-Level Radioactive Waste

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Introduction

The U.S. Geological Survey (USGS) was requested in December 1981 by Sandia National Laboratories, Albuquerque, New Mexico, acting on behalf of the U.S. Nuclear Regulatory Commission (NRC), to participate in a Panel to Assess the Technical Basis of the NRC's Proposed Rule for Disposal of High-Level Radioactive Wastes in Geologic Repositories (Federal Register, 10 CFR Part 60, July 8, 1981). Specifically, the Survey's expertise in hydrogeology was solicited.

The Panel discussed a series of written questions, listed below, which were submitted by the NRC. Each question was discussed in the context of the fields of specialization of the Panel members; hydrogeology, geology, geochemistry, mining engineering, and regulation. The Enviromental Protection Agency (EPA) standard, referred to in the questions, is unpublished draft number 19 of EPA's Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191), dated March 19, 1981.

1. Can the NRC quantify the major contributors to the uncertainty as to whether the EPA standard has been met?

2. Is it possible to quantify the reduction in uncertainty achieved by the technical criteria of 10 CFR 60?

3. If the uncertainty as to whether the EPA standard will be met is large, then how might 10 CFR 60 be modified so as to further the aims of its rationale?

4. What are the possible interpretations of the performance objectives?

5. What performance parameters could be selected to assess compliance with the performance objectives?

6. What are the implications of the possible interpretations of the performance objectives of 10 CFR 60 regarding compliance with the EPA draft standard?

7. What is the state of the art for determining the performance parameters? Are new research efforts needed to determine the performance parameters and for assessment of compliance with the performance objectives?

The author was requested to answer questions 4 and 5 with regard to the part of the proposed rule pertaining to ground-water travel time. Under Performance Objectives, section 60.112(c) of 10 CFR 60 (copy attached), the rule states (p. 35289):

> The geologic repository shall be located so that pre-waste emplacement ground water travel times through the far field to the accessible environment are at least 1,000 years.

In addition to questions 4 and 5, the author was requested to discuss the first part of question 7 with reference to the "state of the art" for measuring ground-water travel time.

To place this performance objective in the proper perspective, it should be mentioned that the movement and concentration of radionuclides in a ground-water system are related to several factors: (1) convective transport, (2) dispersion and diffusion, (3) chemical interaction with rocks along the flow path, and

(4) rates and concentrations at which the radionuclides leached from the solidified wastes enter the water. This discussion will consider only item (1).

Question 4. What are the possible interpretations of performance objectives of 10 CFR 60 (pertaining to ground-water travel time)?

If there were no ambiguity or uncertainty in the definitions of the terms far field, disturbed zone, and accessible environment (see 10 CFR 60, p. 35285), there should be little difficulty in interpreting this performance objective.

The far field means the portion of the geologic setting that lies beyond the disturbed zone.

The disturbed zone refers to that portion of the geologic setting that is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste. Obviously, definition of the limits of this zone hinges on the meaning of the term significantly. It may be difficult to obtain agreement on this meaning owing to the fact that the extent of the thermal effects of a repository will vary with the geologic environment and the amount of heat generated by the waste. It is assumed that the NRC will somehow develop a precise definition of the boundaries of the disturbed zone, and that the limits of the zone will be some distance below the repository and some lateral distance from the periphery of the repository tunnel system. The disturbed zone, therefore, would be a cylindrical volume extending vertically from the land surface to some depth below the repository and laterally some distance beyond the outermost limits of the tunnel system.

The accessible environment is defined as those portions of the environment directly in contact with or readily available for use by human beings. Generally, the accessible environment means ground-water resources and streams. Conceivably, it might include also mineral deposits, brine resources, or oil and gas in the far field. The accessible environment, therefore, is a site-dependent factor that is subject to interpretation. To determine its nature and extent, one must obtain information on the boundaries of the ground-water flow system, the three-dimensional flow pattern, the spatial distribution of head and permeability, the occurrence of ground-water resources (developed or undeveloped) and streams. To determine whether parts of the geohydrologic environment beyond the disturbed zone of a repository are accessible to humans, one must consider not only geologic and hydrologic processes affecting the ground-water transport of radionuclides to the land surface or close to it, but also features at depth that would invite human intrusion by drilling or excavation.

From a theoretical standpoint, once the boundary of the disturbed zone and the accessible environment are defined and fixed in space for a particular repository site, the only meaningful interpretation of travel time of "at least 1,000 years" is the average time for the first arrival of a solute plume moving along the most rapid flow paths between the disturbed zone and the nearest point in the accessible environment. From a practical standpoint, however, owing to the heterogeneity of natural hydrologic systems, it is unlikely that the most rapid flow paths will be identified in the field. Furthermore, it is a matter of interpretation as to what constitutes the nearest point in the accessible environment. Consequently, another more realistic interpretation of this performance objective is that the travel time is an average of various types of measurements in different parts of the system. It will be evident from the discussion of parameters involved in determining travel time at a field scale that this average will be derived from measurements that are essentially point determinations and from others that integrate the effects of variations in hydraulic properties of large volumes of the flow system.

<u>Question 5. What performance parameters could be selected to assess compliance with the performance objectives?</u>

Owing to the heterogeneity of the flow system, there is no single, simple and direct method for assessing compliance with the ground-water travel time requirement by measuring a few parameters. Considerable interpretation and judgement are involved.

Ground-water travel time from the disturbed zone of the repository through the far field to the accessible environment would be derived from the average interstitial velocity in the rocks in this part of the flow system. Owing to the fact that one must assume that the velocity field is uniform both in time and space, the value for travel time derived from the average interstitial velocity, although useful, is only a crude measure of how far radionuclides might be transported. To determine average interstitial velocity, it is necessary to know the effective porosity which refers to the amount of interconnected pore space available for fluid movement. The effective porosity is expressed as a percentage of the total volume of rock occupied by interconnecting interstices. According to Darcy's law, for the simplest one-dimensional case in which flow is through a granular medium, average velocity (v) is directly proportional to the product of hydraulic conductivity (K) and hydraulic gradient (I), and inversely proportional to the effective porosity (ϕ). In view of the fact that $v=\frac{L}{T}$, where L is length of path, and T is time, $T=\frac{L\phi}{KI}$. These are the basic hydraulic parameters that must be evaluated in this method of assessing compliance with the specific performance objective pertaining to ground-water travel time. These parameters and their spatial distribution would be the essential components of a digital model of the pre-waste emplacement ground-water flow system. In addition, however, definition of the flow system would have to consider the spatial distribution and geometry of the various rock units. In view of the fact that ground-water flow may occur through the intergranular pores of sedimentary rocks as well as interconnected fractures and cavities in any type of rock, the evaluation of the spatial distribution of average values for the hydraulic parameters is not a simple task. For this reason, it is vital that the geologic and hydrologic characteristics of the environment selected for a repository be as simple and predictable as possible, so that with a minimum of destructive exploration and testing one can infer the spatial distribution of average values for these parameters.

Another method of calculating average velocity requires knowledge of the effective porosity and the water balance (rates of input and output and the storage characteristics) of the system. Reliable data on recharge, discharge, and the boundary conditions of the system are required to make this estimate.

This method integrates the effects of variations in hydraulic properties in a large segment of the flow system. In this method, the average velocity is calculated using the relationship $v=\frac{q}{\phi}$, where q is the specific discharge of the ground-water pathway as the volume of water flowing per unit of time past a unit area measured at right angles to the direction of flow. The method is similar to that described earlier because q = KI (Darcy's law) and $T=\frac{L\phi}{q}$. Both methods can sometimes be applied independently to a system to estimate average velocity; however, the parameter effective porosity is needed in each.

Under limited conditions, ground-water travel time can be calculated from the direct measurement of tracer flow rates (naturally occurring or injected tracers) and the use of techniques for the isotopic age dating of water. However, these methods are of limited reliability.

State of the Art for Measuring Ground-Water Travel Time

It is apparent from the previous discussion that there are many problems in determining meaningful average values for the above-mentioned basic hydraulic parameters which are used to assess, by predictive modeling, compliance with ground-water travel time. The essential consideration is whether or not average values of several point measurements can be meaningful in view of the fact that the critical value is the average for the most rapid flow paths. Furthermore, the point measurements are distributed in space in a flow field through rocks with variable hydraulic properties. Another factor contributing to the difficulty in deriving meaningful values for travel time is the magnitude of the volume of rock in which the flow is to be modeled. If one assumes that the distance from the repository to a discharge area is tens of kilometers or more, the flow-field width is as much as ten kilometers, and the repository horizon is several hundred meters deep, the volume of rock in which the flow velocity has to be evaluated may be on the order of hundreds of cubic kilometers.

There are numerous laboratory and field techniques for measuring the hydraulic conductivity and effective porosity of granular rocks and for obtaining field measurements of static head from which hydraulic gradients can be computed. However, much of the ground-water flow in the host rock and associated rocks in the far field of a repository likely will be in fractures. The problem is complicated further by the fact that the velocity of flow in fractures may be a few orders of magnitude faster than in granular media, and retention by sorption is likely to be lower. Also, neither the theory or field methodology required to measure or model the flow characteristics in a fractured medium have been developed to a satisfactory level.

The method for estimating average ground-water velocity based on the water balance of the flow system involves defining the system's boundaries, measuring recharge rates from precipitation, rates of streamflow losses, rates of discharge from springs, seepage rates to surface-water bodies, rates of deep infiltration and interbasin movement, and so on. Some of these parameters can be measured directly, others can only be estimated by indirect means. The average ground-water velocity is computed from the rates of input (recharge) to and output (discharge) from the system and the average effective porosity. In view of the fact that the resulting number is an integration of a range of flow properties, judgement based on knowledge of the system's geohydrologic properties is required to use the number in developing a flow model.

Because volumes of rock of the magnitude mentioned above can be expected to have significant variations in hydrologic properties, it is obvious that laboratory techniques for measuring the conductivity and porosity of drill cores and small samples generally are of little value for deriving meaningful large-scale average parameter values. Of most use are field methods for measuring the flow properties of relatively large rock volumes in the vicinity of test holes. However, it must be remembered in view of the large volume of the overall rock system being evaluated, that even these methods will yield values that may be considered for practical purposes as point measurements. Available pumping-test or injection-test methods would be used to determine hydraulic conductivity in an array of test holes in the far field. Although the volume of rock tested by pumping a test hole is related to the size of the cone of depression produced by pumping, or the radius of the zone of influence of an injection test, inferences can be made regarding the spatial distribution of hydraulic properties. Also, by installing packers at selected depths in the holes, tests can be made in any of the rock units penetrated. The test holes would, of course, also be used to define the subsurface extent of the rock units and to measure physical rock properties other than hydrologic. The test holes would be cased and completed as piezometers to determine the spatial distribution of static head in the various rock units in the flow system. Water samples from the pumping tests would be used in studies of the geochemical evolution of the water, and to make age determinations if possible. Under certain conditions this information would serve as a check on the hydraulic computation of ground-water velocity.

Available reflection and refraction seismic techniques could provide information on the subsurface extent of rock units, possibly revealing discontinuities and related variations in hydrologic properties. The correlation of down-hole hydraulic test data with information from a variety of borehole geophysical logs would be used to broaden the interpretation of hydraulic properties of the rocks. The construction of a shaft and tunnel at the proposed repository site to perform in situ tests of various properties of the host rock, will provide the opportunity to obtain measurements and data on the hydraulic properties at and above the host-rock horizon. Tests similar to those mentioned earlier could be performed on the pilot test hole that is drilled before the shaft is constructed. Unlike drill cores from conventional holes drilled from the surface, an array of drill cores in the sides of the shaft and other shaft samples would be useful for obtaining a range of laboratory measurements of hydraulic conductivity and porosity and for evaluating the properties of a relatively large rock volume in the vicinity of the shaft. In the host-rock tunnel angle holes could be drilled and tested hydraulically to determine spatial variations in conductivity. These holes together with the shaft and tunnel excavation will provide the opportunity to map the fracture system in three dimensions, and to design large-scale tests to measure the hydraulic properties of the fractures in a relatively large volume of rock in the vicinity of the excavation. Bredehoeft and others (1978) state that theoretically fluid flow through fractured media can be predicted in two ways:

1. By analyzing the flow through a network of fractures whose orientations and aperture sizes are known.
2. By analyzing the fracture system stochastically, using variables such as permeability and porosity that are analogous to those in a granular medium.

They state, however, that the second method of analysis is relatively recent and, as yet, is untested on a field scale.

In addition to the problem of measuring flow in fractured rocks, Bredehoeft and others (1978) also point out that another one is measuring head and permeability in media of low permeability. In situ measurements of this type have not been obtained routinely in the past.

In conclusion, it should be mentioned that the temporal and spatial distribution of the basic parameter values will always require adjustments during the model calibration process. The basis for these adjustments will be a variety of related geologic, hydrologic, geochemical, and geophysical observations, analyses, and interpretations, some of which have been mentioned. These interpretations will supplement the various field measurements of flow properties of the far field and those of the volume of rock in the vicinity of the shaft and tunnel excavation.

It should be stressed that the calculation of ground-water travel time must be based on as many independent or semi-independent methods of measurement as possible. Even though it may not be possible to determine a single, accurate number for travel time, it should be possible generally to determine with confidence the bounds of uncertainty of the estimates.

In view of the difficulties associated with making meaningful measurements of ground-water travel times, a factor of fundamental significance is the selection of a site where geohydrologic conditions are favorable for making the most meaningful measurements. The conditions include structural and stratigraphic simplicity and lithologic homogeneity, which will facilitate the task of extrapolating the most meaningful numbers from the measurements made.

Technical Feasibility of Making Adequate Measurements of Ground-Water Travel Time to Comply with 10 CFR 60

It should be evident from the previous discussion that making an adequate measurement of ground-water travel time for the purposes of complying with 10 CFR 60 cannot be accomplished simply or directly, primarily because of the heterogeneity of ground-water systems and difficulties in making field-scale measurements of the needed parameters.

The feasibility of making an adequate measurement depends on the confidence with which the system's hydrologic characteristics can be modeled. A fundamental consideration in this regard is the selection of a site in a geohydrologic environment whose characteristics can be predicted spatially and temporally with confidence. Field measurements of various types (previously mentioned) would have to be made and a digital flow model developed. The model would be adjusted and calibrated on the basis of a variety of additional observations, analyses, and interpretations of the geology and hydrology, and geophysical and geochemical properties of the system. The calibration process would involve considerable judgement. Finally, the so-called measurement of an average ground-water travel time for the most rapid flow paths to the accessible environment would result from the judgement of the hydrologist conducting the model analysis.

It is feasible, using the general procedure outlined above, to derive adequate measurements of ground-water travel time. The NRC's decision as to the measurement's adequacy would have to be based on a review and evaluation of all aspects of this procedure.

Conclusions and Suggestions for Modifying 10 CFR 60

The present requirement that the geologic setting have pre-waste emplacement ground-water travel times through the far field to the accessible environment of at least 1,000 years is both reasonable and achievable. In many existing environments, actual pre-waste emplacement travel time can be expected to be much greater than that.

Page 35289, Column 3, 60.112 (c): The present statement is not sufficiently meaningful unless it specifies that the ground-water travel time is the average for the most rapid flow paths between the disturbed zone and the accessible environment. It is suggested that the statement read as follows:

"The geologic repository shall be located so that under pre-waste emplacement conditions the average ground-water travel times through the far field to the accessible environment, for the most rapid flow paths, are at least 1,000 years."

Page 35290, Column 2, 60.122 (f) (4): This statement should agree with that on page 35289, Column 3, 60.112 (c), (see modification suggested above), as follows: "Average ground-water travel times, under pre-waste emplacement conditions, for the most rapid flow paths between the underground facility and the accessible environment, that substantially exceed 1,000 years."

Page 35293, Column 3, 60.132, (ii) (A): In view of the difficulty of placing backfill in the drifts of a mine, it is not reasonable to make the general statement that the backfill shall provide a barrier to ground-water movement into and from the underground facility. This may be feasible for specific rock types and conditions, but as a general requirement it would be difficult to comply with. The following is suggested: "To the extent possible, it shall minimize ground-water movement into and from the underground facility."

Item (B): Change "reduce" to "minimize."

Item (C): See comments on Item (A). It is suggested that the statement read as follows: "To the extent possible, it shall minimize ground-water movement within the underground facility."

Reference

Bredehoeft, J. D., England, A. W., Stewart, D. B., Trask, N. J., and Winograd, I. W., 1978, Geologic disposal of high-level radioactive wastes--earth-science perspectives: U.S. Geological Survey Circular 779, 15 p.

NUCLEAR REGULATORY COMMISSION

10 CFR Part 60

Disposal of High-Level Radioactive Wastes in Geologic Repositories

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The NRC is publishing proposed amendments which specify technical criteria for disposal of high-level radioactive wastes (HLW) in geologic respositories. The proposed criteria address siting, design, and performance of a geologic repository, and the design and performance of the package which contains the waste within the geologic repository. Also included are criteria for montoring and testing programs, performance confirmation, quality assurance, and personnel training and certification. The proposed criteria are necessary for the NRC to fulfill its statutory obligations concerning the licensing and regulating of facilities used for the receipt and storage of high-level radioactive waste.

DATE: Comments received after November 5, 1981 will be considered if it is practical to do so, but assurance of consideration cannot be given except for comments received on or before this date.

ADDRESS: Written comments or suggestions on the proposed amendments should be sent to the Secretary of the Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. Copies of comments may be examined in the U.S. Nuclear Regulatory Commission Public Document Room, 1717 H Street NW, Washington, D.C. Comments may also be delivered to Room 1121, 1717 H Street NW, Washington, D.C., between 8:15 a.m. and 5:00 p.m.

FOR FURTHER INFORMATION CONTACT: Frank J. Arsenault, Director of the Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Telephone (301) 427-4350.

SUPPLEMENTARY INFORMATION:

Background

On December 6, 1979 the Nuclear Regulatory Commission (Commission or NRC) published for comment proposed procedures for licensing geologic disposal of high-level radioactive wastes. The licensing procedures were published in final form on February 25, 1981 (46 FR 13971). On May 13, 1980 (45 FR 31393) the Commission published for comment an Advance Notice of Proposed Rulemaking (ANPR) concerning technical criteria for regulating disposal of high-level radioactive wastes (HLW) in geologic respositories. Included with the advance notice was a draft of the technical criteria under development by the staff. The public was asked to provide comment on several issues discussed in the advance notice and to reflect on the draft technical criteria in light of that discussion. The comments received were numerous and covered the full range of issues related to the technical criteria. The tecnhical criteria being proposed here are the culumination of a number of drafts, and were developed in light of the comments received on the ANPR. It is the Commissions's belief that the regulation proposed here is one which is both practical for licensing and this notice provides a flexible vehicle for accommodating comments in that it points out alternatives and calls for comment in a number of critical plans. The Commission has prepared an analysis of the comments which explains the changes made from the ANPR, and intends to publish soon the comments and the analysis as a NUREG document. A draft of this NUREG has been placed in the Commission's Public Document Room for review. In addition, the staff has begun a program to develop guidance as to the methods that it regards as satisfactory for demonstrating compliance with the requirements of the proposed rule.

The technical criteria being set forth here as proposed rulemaking are a result of the Commission's further effort in regulating geologic disposal of HLW by the Department of Energy (DOE). The rationale for the performance objectives and the Environmental Impact Assessment supporting this rulemaking are also being published separately and are available free of charge upon written request to Frank Arsenault at the above address. In developing these criteria we have not reexaminated DOE's programmatic choice of disposal technology resulting from its Generic Environmental Impact Statement, inasmuch as the Commission has expressly reserved until a later time possible consideration of matters within the scope of that generic statement (44 FR 70408). Accordingly, the technical criteria apply only to disposal in geologic respositories and do not address other possible or potential disposal methods. Similarly, in that DOE's current plans call for dispoal at sufficient depth to be in the area termed the saturated zone, these criteria were developed for disposal in saturated media. Additional or alternative criteria may need to be developed for regulating disposal in the unsaturated or vadose zone.

Authority

Sections 202 (3) and (4) of the Energy Reorganization Act of 1974, as amended, provide the Commission with licensing and regulatory authority regarding DOE facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under the Atomic Energy Act and certain other long-term HLW storage facilities of DOE. Pursuant to that authority, the Commission is developing criteria appropriate to regulating geologic disposal of HLW by DOE. The requirements and criteria contained in this proposed rule are a result of that effort.

Relation to Generally Applicable Standards for Radiation in the Environment Established by the Environmental Protection Agency

The Environmental Protection Agency (EPA) has the authority and responsibility for setting generally applicable standards for radiation in the environment. It is the responsibility of the NRC to implement those standards in its licensing actions and assure that public health and safety are protected. Although no EPA standard for disposal of HLW yet exists, these proposed technical criteria for regulating geologic disposal of HLW have been developed to be compatible with a generally applicable environmental standard. Specifically, the performance objectives and criteria speak to the functional elements of geologic disposal of HLW and the analyses required to give confidence that these functional elements will perform as intended.

Disruptive Processes and Events

The NRC's implementing regulations assume that licensing decisions will be based, in part, on the results of analysis of the consequences of processes and events which potentially could disrupt a repository. Thus, throughout the criteria are requirements that the design basis take into account processes and events with the potential to disrupt a geologic repository. If the process or event is anticipated, i.e., likely, then the design basis requires barriers which would not fail in a way that would result in the repository not meeting the performance objectives. Anticipated processes and events would include such items as waste/rock interactions that result from emplacement of the wastes or the gradual deterioration of borehole seals. If the process or event is unlikely, then the overall system must still limit the release of radionuclides consistent with the EPA standard as applied to such events. An example of an unlikely event would be reactivation of a fault within the geologic setting which had not exhibited movement since the start of the Quaternary Period. In general, both likely and unlikely processes and events are expected to be site and design specific and would be identified by DOE in its license application.

Multiple Barriers

The proposed technical criteria were developed not only with the understanding that EPA's generally applicable environmental standard would need to be implemenfed, at least in part, by performing calculations to predict performance, but also with the knowledge that some of those calculations would be complex and uncertain. Natural systems are difficult to characterize and any understanding of the site will have significant limitations and uncertainties. Those properties which pertain to isolation of HLW are difficult to measure and the measurements which are made will be subject to several sources of error and uncertainty. The physical and chemical processes which isolate the wastes are themselves varied and complex. Further, those processes are especially difficult to understand in the area close to the emplaced wastes because that area is physically and chemically disturbed by the heat generated by those wastes.

However, a geologic repository consists of engineered features as well as the natural geologic environment. Any evaluation of repository performance, therefore, will consider the waste form and other engineering factors which are elemental to the performance of the repository as a system. By partitioning the engineered system into two major barriers, the waste package and the underground facility, and establishing performance objectives for each, the Commission has sought to exploit the ability to design the engineered features to meet specific performance objectives as a means of reducing some of the uncertainties in the calculations of overall repository performance.

In addition, the requirements for containment, controlled release rate, and 1,000-year groundwater transit time are three criteria which act independently of the overall repository performance to provide confidence that the wastes will be isolated at least for as long as they are most hazardous.

Containment and Isolation

During the first several hundred years following emplacement of the wastes, both the radiation from and the heat generated by the wastes are attributable mainly to the decay of the shorter-lived nuclides, primarily fission products. At about 1,000 years after emplacement both the radiation from and heat generated by decay of the wastes have diminished by about 3 orders of magnitude. As the decay of the longer-lived nuclides, primarily actinides, begins to dominate, both the radiation from and thermal output of the wastes continue to fall until almost 100,000 to 1,000,000 years after emplacement. By that time both have diminished by about 5 orders of magnitude and both heat and radiation become roughly constant due to the ingrowth of daughter nuclides, primarily Ra-225, Ra-226 and their decay products.

The technical criteria would require the engineered system to be designed so that the wastes are contained within the waste package for the first thousand years following emplacement. Following this period, containment is no longer assumed and the function of the waste package and underground facility is to control the release of radionuclides from the underground facility. By requiring containment during the period when the thermal conditions around the waste packages are most severe, evaluation of repository performance is greatly simplified to considerations of the degree of conservatism in the containment design relative to events and processes that might affect the performance during the containment period.

Although both the radiation from and heat generated by the decay of the wastes have diminished about 3 orders of magnitude during the containment period, the area surrounding the emplaced wastes will not return to temperatures near those before the wastes were emplaced until after about 10,000 years. As mentioned earlier, the thermal disturbance of the area near the emplaced wastes adds significantly to the uncertainties in the calculation of the transport of the radionuclides through the geologic environment. The technical criteria are intended to compensate for uncertainties by imposing further design requirements on the waste package and underground facility, thereby limiting the source term by controlling the release rate.

Role of the Site

The Commission neither intends nor expects either containment to be lost completely at 1,000 years following emplacement or the engineered system's contribution to the control of the release of wastes to cease abruptly at some later time. However, the Commission recognizes that at some point the design capabilities of the engineered system will be lost and that the geologic setting—the site—must provide the isolation of the wastes from the environment, and has translated this requirement into a performance objective for the geologic setting. The Commission also recognizes that isolation is, in fact, a controlled release to the environment which could span many thousands of years, and that the release of radionuclides and the potential exposures to individuals which could result, should be addressed in the evaluation of a repository. A complement to the evaluation of the effects of design basis processes and events which might disrupt the repository is a projection of how the repository, unperturbed by discrete external events, will evolve through the centuries as a result of the geologic processes operating at the site. Hence, an amendment is being proposed to that portion of Subpart B of 10 CFR Part 60 which describes the contents of the Safety Analysis Report of DOE's application for geologic disposal of HLW which would require DOE to project the expected performance of the proposed geologic repository noting the rates and quantities of expected releases of radionuclides to the accessible environment as a function of time.

Retrievability

The licensing procedures of 10 CFR Part 60 were written assuming that there would be a program of testing and measurement of the thermal, mechanical, and chemical properties of the major engineered barriers to confirm their expected performance. The Commission would like to tie the requirement for retievability of the wastes to the expected time needed to execute the performance confirmation program. However, at present it appears to the Commission that neither the specific nature nor the period needed for execution of the performance confirmation program will be certain until construction of the repository is substantially complete; that is, until the actual licensing to receive wastes at a geologic repository. Hence it is difficult at this time to use the performance confirmation program as a basis for establishing a period of retrievability. Nonetheless, DOE is now making critical decisions regarding the design of geologic repositories which will have a direct effect upon how long the optio to retrieve wastes can be maintained, and upon the difficulty which will be encounted in exercising that option, should that be necessary for protection of public health and safety. Therefore, to provide a suitable objective in this regard, the proposed rule sets forth a requirement that the engineered system be designed so that the option to retrieve the waste can be preserved for up to fifty years following completion of emplacement. Thus, the waste package and the underground facility would be designed so that the period of retrievability would not be the determinant of when the Commission would decide to permit closure of the repository. Rather, the Commission would be assured of the option to let the conduct of the performance confirmation program indicate when it is appropriate to make such a decision. In particular, the Commission is concerned that the thermo-mechanical design of the underground facility be such that access can be maintained until the Commission either decides to permit permanent closure of the repository or to take corrective action, which may include retrieval.

As it is now structured, the rule would require in affect that the repository design be such as to permit retrieval of waste packages for a period of up to 110 years. The components of this total period are as follows: the first waste packages to go in the repository are likely to be in place about thirty years before all wastes are in place; thereafter, a 50-year period is required by the rule; finally, a retrieval schedule is suggested of about the same time as the original construction plus emplacement operations—another 30-odd years. Since it is probably not practical to adjust the retrievability design aspects of the repository according to the order of emplacement of the waste packages, the 110-year requirement will apply to all of the waste. The Commission is particularly interested in comments on the degree to which this requirement will govern the thermal and mechanical design of the repository and on whether some shorter period would be adequate or whether there are other ways than an overall retrievability requirement to preserve options before permanent closure. The Commission does not want to approve construction of a design that will foreclose unnecessarily options for future decisionmakers, but it is also concerend that retrievability requirements not unnecessarily complicate or dominate repository design.

The retrievability requirement does not specify the form in which the wastes are to be retrievable or that wastes are "readily retrievable." The requirement is simply that all the wastes be retrievable during a period equal to the period of construction and emplacement. DOE's plans for retrieval are specifically requested as part of its license application and the practicability of its proposal will be considered by the Commission. Waste may be retrieved upon NRC approval of a DOE application or upon order by NRC, or otherwise, where authorized by DOE's license.

Human Intrusion

Some concern has been raised on the issue of human intrusion into a geologic repository. Human intrusion could conceivably occur either inadvertently or deliberately. Inadvertent intrusion is the accidental breaching of the repository in the course of some activity unrelated to the existance of the repository, e.g., exploration for or development of resources. For inadvertent intrusion to occur, the institutional controls, site markers, public records, and societal memory of the repository's existence must have been ineffective or have ceased to exist. Deliberate or intentional intrusion, on the other hand, assumes a conscious decision to breach the repository; for example, in order to recover the high-level waste itself, or exploit a mineral associated with the site.

Historical evidence indicates that there is substantial continuity of information transfer over time. There are numerous examples of knowledge, including complex information, being preserved for thousands of years. This has occurred even in the absence of printing and modern information transfer and storage systems. Furthermore, this information transfer has survived disruptive events, such as wars, natural disasters, and dramatic changes in the social and political fabric of societies. The combination of the historical record of information transfer, provisions for a well-marked and extensively documented site location, and the scale and technology of the operation needed to drill deeply enough to penetrate a geologic repository argue strongly that inadvertent intrusion as described above is highly improbable, at least for the first several hundred years during which time the wastes are most hazardous. Selecting a site for a repository which is unattractive with respect to both resource value and scientific interest further adds to the improbability of inadvertent human intrusion. It is also logical to assume that any future generation possessing the technical capability to locate and explore for resources at the depth of a repository would also possess the capability to assess the nature of the material discovered, to mitigate consequences of the breach and to reestablish administrative control over the area if needed. Finally, it is inconsistent to assume the scientific and technical capability to identify and explore an anomalous heat source several hundred meters beneath the Earth's surface and not assume that those exploring would have some idea of either what might be the cause of the anomaly or what steps to take to mitigate any untoward consequence of that exploration.

The above arguments do not apply to the case of deliberate intrusion. The repository itself could be attractive and invite intrusion simply because of the resource potential of the wastes themselves. Intrusion to recover the wastes demands (1) knowledge of the existence and nature of the repository, and (2) effort of the same magnitude as that undertaken to emplace the wastes. Hence intrusion of this sort can only be the result of a conscious, collective societal decision to recover the wastes.

Intrusion for the purpose of sabotage or terrorism has also been mentioned as a possibility. However, due to the nature of geologic disposal, there seems to be very little possibility that terrorists or saboteurs could breach a repository. Breach of the repository would require extensive use of machinery for drilling and excavating over a considerable period of time. It is highly improbable that a terrorist group could accomplish this covertly.

In light of the above, the Commission adopted the position that commonsense dictates that everything that is reasonable be done to discourage people from intruding into the repository. Thus, the proposed technical criteria are written to direct site selection towards selection of sites of little resource value and for which there does not appear to be any attraction for future societies. Further, the proposed criteria would require reliable documentation of the existence and location of the repository and the nature of the wastes emplaced therein, including marking the site with the most permanent markers practical. However, once the site is selected, marked, and documented, it does no use to argue over whether these measures will be adequate in the future, or to speculate on the virtual infinity of human intrusion scenarios and whether they will or will not result in violation of the EPA standard. Of course, the Commission recognizes that there are alternative approaches to the Human Intrusion question. Accordingly, comment on this and alternative approaches is welcome.

Relation to Other Parts of NRC Regulations

The proposed rule contemplates that DOE activities at a geologic repository operations area may in appropriate cases be licensed under other parts of NRC regulations and would then not be governed by these technical criteria. We note, in this connection, that the scope section of the procedural rule specifically provides that Part 60 shall not apply to any activity licensed under another part. This allows an independent spent fuel storage installation to be licensed under Part 72, even though located at a geologic repository operations area (provided, of course, it is sufficiently separate to be classified as "independent"). Other DOE activities of the geologic repository operations area could be licensed under Parts 30 or 70 if an exemption from Part 60 is determined to be appropriate.

Alternative Approach

In the course of the Commission's deliberation, it becomes evident that in order to have confidence in the ability of a geological repository to contain and isolate the wastes for an extended period of time, the repository must consist of multiple barriers. In view of the uncertainties that attach to reliance on the geologic setting alone, the Commission believes that a repository should consist of two major engineered barriers (waste packages and underground facility) in addition to the natural barrier provided by the geological setting. The Commission is emphasizing these elements to take advantage of the opportunity to attain greater confidence in the isolation of the waste. Having reached these conclusions, the Commission considers next whether or not and to what level of detail the performance criteria for a geological repository should be prescribed. In this regard, the Commission considers the following 3 alternatives:[1]

1. Prescribe a single overall performance standard that must be met. The standard in this case would be the EPA standard;

2. Prescribe minimum performance standards for each of the major elements, in addition to requiring the overall system to meet the EPA standards; and

3. Prescribe detailed numerical criteria on critical engineering attributes of the repository system.

Alternative 3 is considered overly restrictive on the design flexibility and judged to be inappropriate at this stage of technological development. Therefore, this alternative is quickly eliminated as a viable regulatory approach.

Alternative 1 has as its principal advantage the fact that it provides maximum flexibility in apportioning credit for containment and isolation to the several elements of the repository. It also allows the designer to incorporate and apply new technological developments and knowledge from the site characterization phase to the repository design. Notwithstanding some concern over its practicality in the regulatory framework, the Commission cannot at this time eliminate it from further consideration. The Commission is, therefore, specifically requesting the general public, particularly those from the technical communities, to comment on this point. In addition, the Commission requests commentors espousing this alternative to address specifically ways in which the Commission might find reasonable assurance that the ultimate standards

[1] Detailed discussions on the advantages and disadvantages of each of these alternatives are given in Appendix J to Commission Paper SECY-81-287, April 27, 1981, "Rationale for Performance Objectives and Required Characteristics of the Geologic Setting." This appendix is being published separately and is available without charge on request to the Commission's Public Document Room, 1717 H St. NW, Washington, D.C. 20555.

are met without prescribing standards for the major elements of a repository.

In relation to the first and the third alternatives that are briefly discussed above, Alternative 2 appears to offer a reasonable and practical compromise. In addition to retaining the single overall performance standard in Alternative 1 as the final performance objective, this approach establishes the minimum performance objectives for each of the 3 major barriers of the repository. While this approach limits the repository designer's flexibility, it is clear that meeting these minimum design goals would substantially enhance the Commission's confidence that the final EPA standard will be met. Therefore, the Commission prefers a technical rule established upon this approach.

It should be noted that, in the event that the Commission decides to adopt the Alternate 1 approach in the final rulemaking, portions of the proposed rule (e.g., the section on requirements for the geological setting) would have to be further studied and possibly revised. In addition, it is possible that further public comments would have to be sought.

Major Features of the Proposed Rule

1. *Overall Description.* The proposed technical criteria have been written to address the following: performance objectives and requirements for siting, design and construction of the repository, the waste package, confirmation of repository performance, quality assurance, and the training and certification of personnel. As appropriate, these topics are divided in turn to address separately requirements which apply during construction, waste emplacement, and after permanent closure (decommissioning) of the repository. Although the licensing procedures indicate that there would be separate subparts for siting and design requirements, viz. Subparts E and F, respectively (cf. § 60.31(a)(2)), the NRC now believes that the site and design are so interdependent that such a distinction is artificial and misleading. For example, although the requirement to place the underground facility at a minimum depth of 300 meters is clearly a design requirement, it is manifested as a siting requirement since unless the site has a host rock of sufficient thickness at sufficient depth, the above design requirement cannot be met. Hence the proposed Subpart E to 10 CFR Part 60 contains both site and design requirements.

To enable the Commission to reach a finding as to whether the generally applicable environmental standard for disposal of HLW is met and that public health and safety will be protected, a careful and exhaustive analysis of all the features of the repository will be needed. That analysis necessarily must be both qualitative and quantitative although the analysis can and will be largely quantitative during the period that greatest reliance can be placed upon the engineered system. Thereafter, although the issues of concern, and certainly the physics of a repository itself, do not change, the numerical uncertainties begin to become so large that calulations become a weak indicator of expected repository performance.

In sum, the technical criteria perform two tasks. First they serve to guide DOE in siting, designing, constructing, and operating a repository in such a manner that there can be reasonable confidence that public health and safety will be protected. Second, they serve to guide DOE in those same areas in such a manner that there can be reasonable confidence that the analyses, needed to determine whether public health and safety is protected, can be performed.

2. *Performance Objectives.* The design and operation of the repository are prescribed to be such that during the period that wastes are being emplaced and performance assessed, exposure to workers and releases of radioactivity to the environment must be within limits set by the Commission and the EPA. Further, the repository is to be designed so that the option can be preserved to retrieve the emplaced wastes beginning at anytime up to 50 years following completion of emplacement. Following permanent closure, the repository must perform so that releases are within the limits prescribed by the generally applicable environmental standard which will be set by the EPA. Further, the design of the repository must include a waste package and an underground facility, as well as the site, as barriers to radionuclide migration.

The performance of the engineered system (waste package and underground facility) following permanent closure is specified to require containment of the wastes within the waste package for at least 1000 years following closure, when temperatures in the repository are substantially elevated, and control of the release of nuclides to the geologic environment thereafter.

Transuranic waste (TRU) may be disposed of in a geologic repository. Since transuranic waste does not generate significant amounts of heat, there is no advantage to containment for any specified period. Hence, the requirement for TRU waste is simply a controlled release equivalent to that for HLW, provided they are physically separted from the HLW so that they will not experience a significant increase in temperature.

Although a minimum 1,000-year containment and a maximum one part in 100,000 release rate will satisfy these criteria, the Commission considers it highly desirable that wastes be contained as long thereafter as is reasonably achievable, and that release rates be as far below one part in 100,000 as is reasonably achievable.

3. *Siting Requirements.* Although no specific site suitability or exclusion requirements are given in the criteria, stability and minimum groundwater travel times are specified as required site characteristics. ALARA (as low as reasonably achievable) principles have not been applied to the natural features of a site because they are not amenable to modification once a site is chosen. However, the technical criteria do identify site characteristics considered favorable for a repository as well as characteristics which, if present at the site, may compromise site suitability and which will require careful analysis and such measures as may be necessary to compensate for them adequately. The impact of these characteristics on overall performance would be site specific. Thus, the Commission has judged that these should not be made absolute requirements. Presence of all the favorable characteristics does not lead to the conclusion that the site is suitable to host a repository. Neither is the presumption of unsuitability because of the presence of an unfavorable characteristic incontrovertible. Rather, the Commission's approach requires a sufficient combination of conditions at the selected site to provide reasonable assurance that the performance objectives will be achieved. If adverse conditions are identified as being present, they must be thoroughly charaterized and analyzed and it must be demonstrated that the conditions are compensated for by repository design or by favorable conditions in the geologic setting.

The Commission has not included any siting requirements which directly deal with population density or proximity to population centers. Rather, the issue has been addressed indirectly through consideration of resources in the geologic setting. The Commission believes this to be a more realistic approach given the long period of time involved with geologic disposal. Nonetheless, the Commission invites comment on whether population related siting requirements should be included in the final rule and how they might be implemented.

4. *Design and Construction.* In addition to the requirements on designing for natural phenomena, criticality control, radiation protection, and effluent control, the proposed technical criteria require the design of the repository to accommodate potential interaction of the waste, the underground facility, and the site. Requirements are also placed upon the design of the equipment to be used for handling the wastes, the performance and purpose of the backfill material, and design and performance of borehole and shaft seals. Further, there are requirements related to the methods of construction. The Commission believes such requirements are necessary to assure that the ability of the repository to contain and isolate the wastes will not be compromised by the construction of the repository.

The proposed technical criteria would require that the subsurface facility be designed so that it could be constructed and operated in accordance with relevant Federal mining regulations, which specify design requirements for certain items of electrical and mechanical equipment and govern the use of explosives.

These criteria are a blend of general and detailed prescriptive requirements. They have been developed from Commission experience and practice in the licensing of other nuclear facilities such as power plants and fuel cycle facilities. While there are differences in the systems and components addressed by these criteria from those of power plants or fuel cycle facilities, and the criteria have been written to be appropriate for a geologic repository, the proposed criteria represent a common practice based on experience which has shown that the above items need to be regulated. The level of detail of these criteria reflects the Commission's current thinking on how to regulate effectively geologic disposal of HLW. However, the Commission continues to examine other possibilities for promulgating the more detailed of these requirements. Comments are invited on formulations for the design and construction criteria in the rule, perhaps in a more concise form; these may be supplemented, of course, with more details in staff guidance documents such as Regulatory Guides.

5. *Waste Package.* The proposed requirements for the design of the waste package emphasize its role as a key component of the overall engineered system. Besides being required to contribute to the engineered system's meeting containment and controlled release performance objectives, both compatibility with the underground facility and the site and a method of unique identification are required of the waste package. Included in the section of the proposed technical criteria which deals with the waste package are requirements that the waste form itself contained within the package be consolidated and non-pyrophoric.

6. *Performance Confirmation.* The proposed technical criteria include requirements for a program of testing and measurement (Subpart F). The main purpose of this program is to confirm the assumptions, data, and analyses which led to the findings that permitted construction of the repository and subsequent emplacement of the wastes. Further, the performance confirmation program includes requirements for monitoring of key geologic and hydrologic parameters throughout site characterization, construction, and emplacement to detect any significant changes in the conditions which supported the above findings during, or due to operations at the site. Also included in the program would be tests of the effectiveness of borehole and shaft seals and of backfill placement procedures.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Commission hereby certifies that this rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. This proposed rule affects only the Department of Energy, and does not fall within the purview of the Act.

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, the National Environmental Policy Act of 1969, as amended, and sections 552 and 553 of title 5 of the United States Code, notice is hereby given that adoption of the following amendments to Title 10, Chapter I, Code of Federal Regulations is contemplated.

PART 60—DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

1. The authority citation for Part 60 reads as follows:

Authority: Secs. 51, 53, 62, 63, 65, 81, 161b., f., i., o., p., 182, 183, Pub. L. 83–703, as amended, 68 Stat. 929, 930, 932, 933, 935, 948, 953, 954, as amended (42 U.S.C. 2071, 2073, 2092, 2093, 2095, 2111, 2201, 2232, 2233); Secs. 202, 206, Pub. L. 93–438, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846); Sec. 14, Pub. L. 95–601 (42 U.S.C. 2021a); Sec. 102(2)(c), Pub. L. 91–190, 83 Stat. 853 (42 U.S.C. 4332)

2. Section 60.2 is revised to read as follows:

§ 60.2 Definitions.

For the purposes of this Part—

"Accessible Environment" means those portions of the environment directly in contact with or readily available for use by human beings.

"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 and from which the design bases for the engineered system are derived.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Candidate area" means a geologic and hydrologic system within which a geologic repository may be located.

"Commencement of construction" means clearing of land, surface or subsurface excavation, or other substantial action that would adversely affect the environment of a site, but does not include changes desirable for the temporary use of the land for public recreational uses, site characterization activities, other preconstruction monitoring and investigation necessary to establish background information related to the suitability of a site or to the protection of environmental values, or procurement or manufacture of components of the geologic repository operations area.

"Commission" means the Nuclear Regulatory Commission or its duly authorized representatives.

"Containment" means the confinement of radioactive waste within a designated boundary.

"Decommissioning," or "permanent closure," means final backfilling of subsurface facilities, sealing of shafts, and decontamination and dismantlement of surface facilities.

"Director" means the Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards.

"Disposal" means the isolation of radioactive wastes from the biosphere.

"Disturbed zone" means that portion of the geologic setting that is significantly affected by construction of the subsurface facility or by the heat generated by the emplacement of radioactive waste.

"DOE" means the U.S. Department of Energy or its duly authorized representatives.

"Engineered system" means the waste packages and the underground facility.

"Far field" means the portion of the geologic setting that lies beyond the disturbed zone.

"Floodplain" means the lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands and including at a minimum that area subject to a one percent or greater chance of flooding in any given year.

"Geologic repository" means a system for the disposal of radioactive wastes in excavated geoligic media. A geologic repository includes (1) the geologic repository operations area, and (2) the geologic setting.

"Geologic repository operations area" means an HLW facility that is part of a geologic repository, including both surface and subsurface areas, where waste handling activities are conducted.

"Geologic setting" or "site" is the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste.

"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.

"HWL facility" means a facility subject to the licensing and related regulatory authority of the Commission pursuant to Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974 (88 Stat. 1244).[1]

"Host rock" means the geologic medium in which the waste is emplaced.

"Important to safety," with reference to structures, systems, and components, means those structures, systems, and components that provide reasonable assurance that radioactive waste can be received, handled, and stored without undue risk to the health and safety of the public.

"Indian Tribe" means an Indian tribe as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93–638).

"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.

[1] These are DOE "facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such act (the Atomic Energy Act)" and "Retrievable Surface Storage Facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive wastes generated by (DOE), which are not used for, or are part of, research and development activities."

"Medium" or "geologic medium" is a body of rock characterized by lithologic homogeneity.

"Overpack" means any buffer material, receptacle, wrapper, box or other structure, that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

"Public Document Room" means the place at 1717 H Street NW., Washington, D.C., at which records of the Commission will ordinarily be made available for public inspection and any other place, the location of which has been published in the Federal Register, at which public records of the Commission pertaining to a particular geologic repository are made available for public inspection.

"Radioactive waste" or "waste" means HLW and any other radioactive materials other than HLW that are received for emplacement in a geologic repository.

"Site" means the geologic setting.

"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 borings, 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 respository, but does not include preliminary borings and geophysical testing needed to decide whether site characterization should be undertaken.

"Stability" means that the nature and rates of natural processes such as erosion and faulting have been and are projected to be such that their effects will not jeopardize isolation of the radioactive waste.

"Subsurface facility" means the undergound portions of the geologic repository operations area including openings, backfill materials, shafts and boreholes as well as shaft and borehole seals.

"Transuranic wastes" or "TRU wastes" means radioactive waste containing alpha emitting transuranic elements, with radioactive half-lives greater than five years, in excess of 10 nanocuries per gram.

"Tribal organization" means a Tribal organization as defined in the Indian Self-Determination and Education Assistance Act (Public Law 93–638).

"Underground facility" means the undergound structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

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

"Waste form" means the radioactive waste materials and any encapsulating or stabilizing materials, exclusive of containers.

"Waste package" means the airtight, watertight, sealed container which includes the waste form and any ancillary enclosures, including shielding, discrete backfill and overpacks.

3. Section 60.10 is revised to read as follows:

§ 60.10 Site characterization.

(a) Prior to submittal of an application for a license to be issued under this part the DOE shall conduct a program of site characterization with respect to the site to be described in such application.

(b) Unless the Commission determines with respect to the site described in the application that it is not necessary, site characterization shall include a program of in situ exploration and testing at the depths that wastes would be emplaced.

(c) As provided in § 51.40 of this chapter, DOE is also required to conduct a program of site characterization, including in situ testing at depth, with respect to alternative sites.

(d) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

(2) As a minimum the location of exploratory boreholes and shafts shall be selected so as to limit the total number of subsurface penetrations above and around the underground facility.

(3) To the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for repository construction and operation or where large unexcavated pillars are planned.

(4) Subsurface exploratory drilling, excavation, and in situ testing before and during construction shall be planned and coordinated with repository design and construction.

4. Paragraphs (c)(1), (c)(3), and (c)(13) of § 60.21 are revised to read as follows:

§ 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 facility design and performance. The description of the site shall identify the limits of the accessible environment with respect to the location of the geologic repository operations area.

(i) The description of the site shall also include the following information regarding subsurface conditions in the vicinity of the proposed underground facility—

(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 permeable anomalies;

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

(D) The bulk hydrogeologic properties and conditions;

(E) The bulk geochemical properties; and

(F) The anticipated response of the bulk 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, and meteorology of the sits;

(B) Analyses to determine the degree to which each of the favorable and adverse conditions, if present, has been characterized, and the extent to which it contributes to or detracts from isolation.

(C) An evaluation of the expected performance of the proposed geologic repository noting the rates and quantities of expected releases of radionuclides to the accessible environment as a function of time. In executing this evaluation DOE shall assume that those processes operating on the site are those which have been operating on it during the Quaternary Period and superpose the perturbations caused by the presence of emplaced radioactive waste on the natural processes.

(D) An analysis of the expected performance of the major design structures, systems, and components, both surface and subsurface, that bear significantly on the suitability of the geologic repostory for disposal of radioactive waste assuming the anticipated processes and events and natural phenomena from which the design bases are derived. 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.

(E) An explanation of measures used to confirm 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 confirmed by using field tests, in situ tests, field-verified laboratory tests, monitoring data, or natural analog studies.

* * * * *

(3) 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 and conditions that may result from anticipated operational occurrences, including those or natural origin; (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; and (iii) 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 radionuclide containment and isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

* * * * *

(13) An identification and evaluation of the natural resources at the site, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the site to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscovered deposits, shall be conducted for the disturbed zone and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The [illegible] of net value shall take into [illegible] current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

* * * * *

5. Paragraph (a)(2) of § 60.31 is revised to read as follows:

§ 60.31 Construction authorization.

* * * * *

(a) * * *

(2) The site and design comply with the criteria contained in Supart E.

* * * * *

6. Paragraph (a)(2) of § 60.51 is revised to read as follows:

§ 60.51 License amendment to decommission.

(a) * * *

(2) a detailed description of the measures to be employed—such as land use controls, construction of monuments, and preservation of record—to regulate or prevent activities that could impair the long-term isolation of emplaced waste within the geologic repository and to assure that relevant information will be preserved for the use of future generations. As a minimum, such measures shall include—

(i) Identification of the geologic repository operations area by monuments that have been designated, fabricated, and emplaced to be as permanent as is practicable; and

(ii) Placement of records of the location of the geologic repository operations area and the nature and hazard of the waste in the archives of local and Federal government agencies, and archives elsewhere in the world, that would be likely to be consulted by potentional human intruders.

* * * * *

7. New Subpart E, "Technical Criteria," Subpart F "Performance Confirmation," Subpart G, "Quality Assurance" and Subpart H, "Training and Certification of Personnel" are added to 10 CFR Part 60.

Subpart E—Technical Criteria

Sec.

60.101 Purpose and nature of findings.
60.102 Concepts.

Performance Objectives

60.111 Performance objectives.
60.112 Required characteristics of the geologic setting.

Subpart E—Technical Criteria

§ 60.101 Purpose and nature of findings.

(a)(1) Subpart B of this part prescribes the standards for issuance of a license to receive and possess source, special nuclear, or byproduct material at a geologic repository operations area. In particular, § 60.41(c) requires a finding that the issuance of a license will not constitute an unreasonable risk to the health and safety of the public. The purpose of this subpart is to set out performance objectives and site and design criteria which, if satisfied, will support such a finding of no unreasonable risk.

(2) While these performance objectives and criteria are generally stated in unqualified terms, it is not expected that complete assurance that they will be met can be presented. A reasonable assurance, on the basis of the record before the Commission, that the objectives and criteria will be met is the general standard that is required. For § 60.111, and other portions of this subpart that impose objectives and criteria for repository performance over long times into the future, there will inevitably be greater uncertainties. Proof of the future performance of engineered systems and geologic media over time periods of a thousand or many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period and hazards involved, that the outcome will be in conformance with those objectives and criteria.

(b) Subpart B of this part also lists findings that must be made in support of an authorization to construct a geologic repository operations area. In particular, § 60.31(a) requires a finding that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a repository of the design proposed without unreasonable risk to the health and safety of the public. As stated in that paragraph, in arriving at this determination, the Commission will consider whether the site and design comply with the criteria contained in this subpart. Once again, while the criteria may be written in unqualified terms, the demonstration of compliance may take uncertainties and gaps in knowledge into account, provided that the Commission can make the specified finding of reasonable assurance as specified in paragraph (a) of this section.

§ 60.102 Concepts.

(a) *The HLW facility.* NRC exercises licensing and related regulatory authority over those facilities described in section 202 (3) and (4) of the Energy Reorganization Act of 1974. Any of these facilities is designated an *HLW facility.*

(b) *The geologic repository operations area.*

(1) This part deals with the exercise of authority with respect to a particular class of HLW facility—namely a *geologic repository operations area.*

(2) A *geologic repository operations area* consists of those surface and subsurface areas that are part of a geologic repository where radioactive waste handling activities are conducted. The underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals, is designated the *underground facility.*

(3) The exercise of Commission authority requires that the geologic repository operations area be used for *storage* (which includes *disposal*) of *high-level radioactive wastes (HLW).*

(4) HLW includes irradiated reactor fuel as well as reprocessing wastes. However, if DOE proposes to use the geologic repository operations area for storage of *radioactive waste* other than HLW, the storage of this radioactive waste is subject to the requirements of this part. Thus, the storage of *transuranic-contaminated waste (TRU),* though not itself a form of HLW, must conform to the requirements of this part if it is stored in a geologic repository operations area.

(c) *Areas adjacent to the geologic repository operations area.* Although the activities subject to regulation under this part are those to be carried out at the geologic repository operations area, the licensing process also considers characteristics of adjacent areas. First, there is to be an area within which DOE is to exercise specified controls to prevent adverse human actions. Second, there is a larger area, designated the *geologic setting* or *site* which includes the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste from the accessible environment. The geologic repository operations area plus the geologic setting make up the *geologic repository.* Within the geologic setting, particular attention must be given to the characteristics of the host rock as well as any rock units surrounding the host rock.

(d) *Stages in the licensing process.* There are several stages in the licensing process. The *site characterization* stage, though begun before submission of a license application, may result in consequences requiring evaluation in the license review. The *construction stage* would follow, after issuance of a construction authorization. A *period of operations* follows the issuance of a license by the Commission. The period of operations includes the time during which *emplacement* of wastes occurs; and any subsequent period before permanent closure during which the emplaced wastes are *retrievable;* and *permanent closure,* which includes final backfilling of subsurface facilities, sealing of shafts, decontaminating and dismantling of surface facilities. Permanent closure represents the end of active human activities with the geologic repository operations area and engineered systems.

(e) *Containment.* Early during the repository life, when radiation and thermal levels are high and the consequences of events are especially difficult to predict rigorously, special emphasis is placed upon the ability to contain the wastes by waste packages within an engineered system. This is known as the *containment period.* The *engineered system* includes the waste packages as well as the underground facility. A *waste package* includes:

(1) The *waste form* which consists of the radioactive waste materials and any associated encapsulating or stabilizing materials.

(2) The *container* which is the first major sealed enclosure that holds the waste form.

(3) *Overpacks* which consist of any buffer material, receptable, wrapper, box or other structure, that is both within and an integral part of a waste package. It encloses and protects the waste form so as to meet the performance objectives.

(f) *Isolation.* Following the containment period special emphasis is placed upon the ability to achieve isolation of the wastes by virtue of the characteristics of the geologic repository. *Isolation* means the act of inhibiting the transport of radioactive material to the accessible environment in amounts and concentrations within limits. The *accessible environment* means those portions of the environment directly in contact with or readily available for use by human beings.

Performance Objectives

§ 60.111 Performance objectives.

(a) *Performance of the geologic repository operations area through permanent closure.*—(1) *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 any generally applicable environmental standards established by the Environmental Protection Agency.

(2) *Retrievability of waste.* The geologic repository operations area shall be designed so that the entire inventory of waste could be retrieved on a reasonable schedule, starting at any time up to 50 years after waste emplacement operations are complete. A reasonable schedule for retrieval is one that requires no longer than about the same overall period of time than was devoted to the construction of the geologic repository operations area and the emplacement of wastes.

(b) *Performance of the geologic repository after permanent closure.*—(1) *Overall system performance.* The geologic setting shall be selected and the subsurface facility designed so as to assure that releases of radioactive materials from the geologic repository following permanent closure conform to such generally applicable environmental radiation protection standards as may have been established by the Environmental Protection Agency.

(2) *Performance of the engineered system.*—(i) *Containment of wastes.*[3] The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. This requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW.

(ii) *Control of releases.*[3]

(A) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the total annual curie release as prescribed by this paragraph.

(B) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.

(3) *Performance of the geologic setting.*—(i) *Containment period.* During the containment period, the geologic setting shall mitigate the impacts of premature failure of the engineered system. The ability of the geologic setting to isolate wastes during the isolation period, in accordance with paragraph (b)(3)(ii) of this section, shall be deemed to satisfy this requirement.

(ii) *Isolation period.* Following the containment period, the geologic setting, in conjunction with the engineered system as long as that system is expected to function, and alone thereafter, shall be capable of isolating radioactive waste so that transport of radionuclides to the accessible environment shall be in amounts and concentrations that conform to such generally applicable environmental standards as may have been established by the Environmental Protection Agency. For the purpose of this paragraph, the evaluation of the site shall be based upon the assumption that those processes operating on the site are those which have been operating on it during the Quaternary Period, with perturbations caused by the presence of emplaced radioactive wastes superimposed thereon.

§ 60.112 Required characteristics of the geologic setting.

(a) The geologic setting shall have exhibited structural and tectonic stability since the start of the Quaternary Period.

(b) The geologic setting shall have exhibited hydrogeologic, geo-chemical, and geomorphic stability since the start of the Quaternary Period.

(c) The geologic repository shall be located so that pre-waste emplacement groundwater travel times through the far field to the accessible environment are at least 1,000 years.

Ownership and Control of the Geolocghic Repository Operations Area

§ 60.121 Requirements for ownership and control of the geologic repository operations area.

(a) *Ownership of the geologic repository operations area.* The geologic repository operations area shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use. These lands shall be held free and clear of all encumbrances, if

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[3] The Commission specifically seeks comment on whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases. In particular, the Commission has considered whether the technical criteria should explicitly require containment to be for "as long as is reasonably achievable" and the release rate to be "as low as is reasonably achievable." Comments should address the merits of such a requirement, how to best frame it, and the practicality of its implementation.

significant, such as: (1) rights arising under the general mining laws; (2) easements for right-of-way; and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Establishment of controls.* Appropriate controls shall be established outside of the geologic repository operations area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the site or engineered system's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

Additional Requirements for the Geologic Setting

§ 60.122 Favorable conditions.

Each of the following conditions may contribute to the ability of the geologic setting to meet the performance objectives relating to isolation of the waste. In addition to meeting the mandatory requirements of § 60.112, a geologic setting shall exhibit an appropriate combination of these conditions so that, together with the engieered system, the favorable conditions present are sufficient to provide reasonable assurance that such performance objectives will be met.

(a) The nature and rates of tectonic processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(b) The nature and rates of structural processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(c) The nature and rates of hydrogeological processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(e) The nature and rates of geomorphic processes that have occurred since the start of the Quarternary period are such that, when projected they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(f) A host rock that provides the following groundwater characteristics— (1) low groundwater content; (2) inhibition of groundwater circulation in the host rock; (3) inhibition of groundwater flow between hydrogeologic units or along shafts, drifts, and boreholes; and (4) groundwater travel times, under pre-waste emplacement conditions, between the underground facility and the accessible environment that substantially exceed 1,000 years.

(g) Geochemical conditions that (1) promote precipitation or sorption or radionuclides; (2) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; and (3) inhibit the transport of radionuclides by particulates, colloids, and complexes.

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

(i) 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.)

(j) Any local condition of the disturbed zone that contributes to isolation.

§ 60.123 Potentially adverse conditions.

The following are potentially adverse conditions. The presence of any such conditions may compromise site suitability and will require careful analysis and such measures as are necessary to compensate for them adequately pursuant to § 60.124.

(a) *Adverse conditions in the geologic setting.*

(1) Potential for failure of existing or planned man-made surface water impoundments that could cause flooding of the geologic repository operations area.

(2) Potential, based on existing geologic and hydrologic conditions, that planned cnstruction of large-scale surface water impoundments may significantly affect the geologic repository through changes in the regional groundwater flow system.

(3) Potential for human activity to affect significantly the geologic repository through changes in the hydrogeology. This activity includes, but is not limited to planned groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage facilities, or underground military activity.

(4) Earthquakes which have occurred historically that if they were to be repeated could affect the geologic repository significantly.

(5) A fault in the geologic setting that has been active since the start of the Quaternary Period and which is within a distance of the disturbed zone that is less than the smallest dimension of the fault rupture surface.

(6) Potential for adverse impacts on the geologic repositroy resulting from the occupancy and modification of floodplains.

(7) 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 affect the performance of the geologic repository through changes in the regional groundwater flow.

(8) Expected climatic changes that would have an adverse effect on the geologic, geochemical, or hydrologic characteristics.

(b) *Adverse conditions in the disturbed zone.* For the purpose of determining the presence of the following conditions within the distrubed zone, investigations should extend to the greater of either its calculated extent or a horizontal distance of 2 km from the limits of the underground facility, and from the surface to a depth of 500 meters below the limits of the repository excavation.

(1) Evidence of subsurface mining for resources.

(2) Evidence of drilling for any purpose.

(3) Resources that have either greater gross value, net value, or commercial potential than the average for other representative areas of similar size that are representative of and located in the geologic setting.

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

(5) Evidence of dissolutioning of soluble rocks.

(6) The existence of a fault that has been active during the Quaternary Period.

(7) Potential for creating new pathways for radionuclide migration due to presence of a fault or fracture zone irrespective of the age of last movement.

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

(9) More frequent occurrence of earthquakes or earthquakes of higher

magnitude than is typical of the area in which the geologic setting is located.

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

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

(12) Potential for changes in hydrologic conditions that would significantly affect the migration of radionuclides to the accessible environment including but not limited to changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.

(13) Conditions in the host rock that are not reducing conditions.

(14) Groundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could affect the solubility and chemical reactivity of the engineered systems.

(15) Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered system.

(16) 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.

(17) Geomechanical properties that do not permit deisign of stable underground openings during construction, waste emplacement, or retrieval operations.

§ 60.124 Assessment of potentially adverse conditions.

In order to show that a potentially adverse condition or combination of conditions cited in § 60.123 does not impair significantly the ability of the geologic repository to isolate the radioactive waste, the following must be demonstrated:

(a) The potentially adverse human activity or natural condition has been adequately characterized, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(b) The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural condition; and

(c)(1) The potentially adverse human activity or natural condition is shown by analysis in paragraph (b) of this section not to affect significantly the ability of the geologic setting to isolate waste, or

(2) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics cited in § 60.122, or

(3) The potentially adverse human activity or natural condition can be remedied.

Design and Construction Requirements

§ 60.130 General design requirements for the geologic repository operations area.

(a) Sections 60.130 through 60.134 specify minimum requirements for the design of, and construction specifications for, the geologic repository operations area. Requirements for design contained in §§ 60.131 through 60.133 must be considered in conjunction with the requirements for construction in § 60.134. Sections 60.130 through 60.134 are not intended to contain an exhaustive list of design and construction requirements. Omissions in §§ 60.130 through 60.134 do not relieve DOE from providing safety features in a specific facility needed to achieve the performance objectives contained in § 60.111. All design and construction criteria must be consistent with the results of site characterization activities.

(b) Systems, structures, and components of the geologic repository operations area shall satisfy the following:

(1) *Radiological protection.* The structures, systems, and components located within restricted areas shall be designed to maintain radiation doses, levels, and concentrations of radioactive material in air in those restricted areas within the limits specified in Part 20 of this chapter. These structures, systems, and components shall be designed to include—

(i) Means to limit concentrations of radioactive material in air;

(ii) 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;

(iii) Suitable shielding;

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

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

(vi) A radiation alarm system to warn of increases in radiation levels, concentrations of radioactive material in air, and of increased radioactivity released in effluents. The alarm system shall be designed with redundancy and in situ testing capability.

(2) *Protection against natural phenomena and environmental conditions.*

(i) The structures, systems, and components important to safety shall be designed to be compatible with anticipated site characteristics and to accommodate the effects of environmental conditions, so as to prevent interference with normal operation, maintainence and testing during the entire period of construction and operations.

(ii) The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the site will not result, in any relevant time period, in failure to achieve the performance objectives.

(3) *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 that could result from equipment failure, such as missle impacts, and similar events and conditions that could lead to loss of their safety functions.

(4) *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 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.

(5) *Emergency capability.*

(i) The structures, systems, and components important to safety shall be designed to maintain control of radioactive waste, 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.

(6) *Utility services.*

(i) Each utility service system shall be designed so that essential safety functions can be performed under both normal and emergency 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) The emergency utility services shall be designed to permit testing of their functional operability and capacity. This will include the full operational sequence of each system when transferring between normal and emergency supply sources, as well as the operation of associated safety systems.

(iv) Provisions shall be made so that, if there is a loss of the primary electric power source or circuit, reliable and continued emergency power is provided to instruments, utility service systems, and operating systems, including alarm systems. This emergency power shall be sufficient to allow safe conditions to be maintained. All systems important to safety shall be designed to permit them to be maintained at all times in a functional mode.

(7) *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.

(8) *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.

(9) *Instrumentation and control systems.* Instrumentation and control systems shall be designed to monitor and control the behavior of engineered systems important to safety over anticipated ranges for normal operation and for accident conditions. The systems shall be designed with sufficient redundancy to ensure that adequate margins of safety are maintained.

(10) *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.

§ 60.131 Additional design requirements 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 site, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility. The surface facilities shall be designed so as to permit inspection, repair, and decontamination of such wastes and their containers. Surface storage capacity is not required for all emplaced waste.

(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.

(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 and emergency operations. The facilities shall be designed to provide protection against radiation exposures and offsite releases as provided in § 60.111.

(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 decommissioning.

§ 60.132 Additional design requirements for the underground facility.

(a) General criteria for the underground facility.

(1) The underground facility shall be designed so as to perform its safety functions assuming interactions among the geologic setting, the underground facility, and the waste package.

(2) The underground facility shall be designed to provide for structural stability, control of groundwater movement and control of radionuclide releases, as necessary to comply with the performance objectives of § 60.111.

(3) 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 enhance containment and isolation of radionuclides to the extent practicable at the site.

(4) The underground facility shall be designed so that the effects of disruptive events such as intrusions of gas, or water, or 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) *Separation of excavation and waste emplacement (modular concept).* If concurrent excavation and emplacement of wastes are planned, then:

(1) The design shall provide for such separation of activities into discrete areas (modules) as may be necessary to assure that excavation does not impair waste emplacement or retrieval operations.

(2) Each module shall be designed to permit insulation from other modules if an accident occurs.

(d) *Design for retrieval of waste.* The underground facility shall be designed to—

(1) Permit retrieval of waste in accordance with the performance objectives (§ 60.111);

(2) Ensure sufficient structural stability of openings and control of groundwater to permit the safe conduct of waste retrieval operations; and

(3) Allow removal of any waste packages that may be damaged or require inspection without compromising the ability of the geologic repository to meet the performance objectives (§ 60.111).

(e) *Design of subsurface openings.*

(1) Subsurface openings shall be designed to maintain stability throughout the construction and operation periods. If structural support is required for stability, it shall be designed to be compatible with long-term deformation, hydrologic, geochemical, and thermomechanical characteristics of the rock and to allow subsequent placement of backfill.

(2) Structures required for temporary support of zones of weak or highly fractured rock shall be designed so as not to impair the placement of permanent structures or the capability to seal excavated areas used for the containment of wastes.

(3) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock over the long term. The size, shape, orientation, and spacing of openings and the design of engineered support systems shall take the following conditions into considerations—

(i) natural stress conditions;

(ii) deformation characteristics of the host rock under normal conditions and thermal loading;

(iii) The kinds of weaknesses or structural discontinuities found at various locations in the geologic repository;

(iv) Equipment requirements; and

(v) The ability to construct the underground facility as designed so that stability of the rock is enhanced.

(f) *Rock excavation.* The design of the underground facility shall incorporate excavation methods that will limit damage to and fracturing of rock.

(g) *Control of water and gas.*

(1) Water and gas control systems shall be designed to be of sufficient capability and capacity to reduce the potentially adverse effects of groundwater intrusion, service water intrusion, or gas inflow into the underground facility.

(2) Water and gas control systems shall be designed to control the quantity of water or gas flowing into or from the underground facility, monitor the composition of gases, and permit sampling of liquids.

(3) Systems shall be designed to provide control of water and gas in both waste emplacement areas and excavation areas.

(4) Water control systems shall be designed to include storage capability and modular layouts that ensure that unexpected inrush or flooding can be controlled and contained.

(5) If the intersection of aquifers or water-bearing geologic structures is anticipated during construction, the design of the underground facility shall include plans for cutoff or control of water in advance of the excavation.

(6) If linings are required, the contact between the lining and the rock surrounding subsurface excavations shall be designed so as to avoid the creation of any preferential pathway for groundwater or radionuclide migration.

(h) *Subsurface ventilation.* The ventilation system shall be designed to—

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

(2) Permit continuous occupancy of all excavated areas during normal operations through the time of permanent closure;

(3) Accommodate changes in operating conditions such as variations in temperature and humidity in the underground facility;

(4) Include redundant equipment and fail safe control systems as may be needed to assure continued function under normal and emergency conditions; and

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

(i) *Engineered barriers.*

(1) Barriers shall be located where shafts could allow access for groundwater to enter or leave the underground facility.

(2) Barriers shall create a waste package environment which favorably controls chemical reactions affecting the performance of the waste package.

(3) Backfill placed in the underground facility shall be designed as a barrier.

(i) Backfill placed in the underground facility shall perform its functions assuming anticipated changes in the geologic setting.

(ii) Backfill placed in the underground facility shall serve the following functions:

(A) It shall provide a barrier to groundwater movement into and from the underground facility.

(B) It shall reduce creep deformation of the host rock that may adversely affect (*1*) waste package performance or (*2*) the local hydrological system.

(C) It shall reduce and control groundwater movement within the underground facility.

(D) It shall retard radionuclide migration.

(iii) Backfill placed in the underground facility shall be selected to allow for adequate placement and compaction in underground openings.

(j) *Waste handling and emplacement.*

(1) The systems used for handling, transporting, and emplacing radioactive wastes shall be designed to have positive, fail-safe designs to protect workers and to prevent damage to waste packages.

(2) The handling systems for emplacement and retrieval operations shall be designed to minimize the potential for operator error.

(k) *Design for thermal loads.*

(1) The underground facility shall be designed so that the predicted thermal and thermomechanical response of the rock will not degrade significantly the performance of the repository or the ability of the natural or engineered barriers to retard radionuclide migration.

(2) The design of waste loading and waste spacings shall take into consideration—

(i) Effects of the design of the underground facility on the thermal and thermomechanical response of the host rock and the groundwater system;

(ii) Features of the host rock and geologic setting that affect the thermomechanical response of the underground facility and barriers, including but not limited to, behavior and deformational characteristics of the host rock, the presence of insulating layers, aquifers, faults, orientation of bedding planes, and the presence of discontinuities in the host rock; and

(iii) The extent to which fracturing of the host rock is influenced by cycles of temperature increase and decrease.

§ 60.133 Design of shafts and seals for shafts and boreholes.

(a) *Shaft design.* Shafts shall be designed so as not to create a preferential pathway for migration of groundwater and so as not to increase the potential for migration through existing pathways.

(b) *Shaft and borehole seals.* Shaft and borehole seals shall be designed so that:

(1) Shafts and boreholes will be sealed as soon as possible after they have served their operational purpose.

(2) At the time of permanent closure sealed shafts and boreholes will inhibit transport of radionclides to at least the same degree as the undisturbed units of rock through which the shafts or boreholes pass. In the case of soluble rocks, the borehole and shaft seals shall also be designed to prevent groundwater circulation that would result in dissolution.

(3) Contact between shaft and borehole seals and the adjacent rock does not become a preferential pathway for water.

(4) Shaft and borehole seals can accommodate potential variations of stress, temperature, and moisture.

(5) The materials used to construct the seals are appropriate in view of the geochemistry of the rock and groundwater system, anticipated deformations of the rock, and other in situ conditions.

(c) *Shaft conveyances used in radioactive waste handling.*

(1) Shaft conveyances used to transport radioactive materials shall be designed to satisfy the requirements as set forth in § 60.130 for systems, structures, and components important to safety.

(2) Hoists important to safety shall be designed to preclude cage free fall.

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

(4) Hoist loading and unloading systems shall be designed with a reliable system of interlocks that will fail safely upon malfunction.

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

§ 60.134 Construction specifications for surface and subsurface facilities.

(a) *General requirement.* Specifications for construction shall conform to the objectives and technical requirements of §§ 60.130 through 60.133.

(b) *Construction management program.* The construction specifications shall facilitate the conduct of a construction management program that will ensure that construction activities do not adversely affect the suitability of the site to isolate the waste or jeopardize the isolation capabilities of the underground facility, boreholes, shaft, and seals, and that the underground facility is constructed as designed.

(c) *Construction records.* The construction specifications shall include requirements for the development of a complete documented history of repository construction. This documented history shall include at least the following—

(1) Surveys of underground excavations and shafts located via readily identifiable surface features or monuments;

(2) Materials encountered;

(3) Geologic maps and geologic cross sections;

(4) Locations and amount of seepage;

(5) Details of equipment, methods, progress, and sequence of work;

(6) Construction problems;

(7) Anomalous conditions encountered;

(8) Instrument locations, readings, and analysis;

(9) Location and description of structural support systems;

(10) Location and description of dewatering systems; and

(11) Details, methods of emplacement, and location of seals used.

(d) *Rock excavation.* The methods used for excavation shall be selected to reduce to the extent practicable the potential to create a preferential pathway for groundwater or radioactive waste migration or increase migration through existing pathways.

(e) *Control of explosives.* If explosives are used, the provisions of 30 CFR 57.6 (Explosives) issued by the Mine Safety and Health Administration, Department of Labor, shall be met, as minimum safety requirements for storage, use and transport at the geologic repository operations area.

(f) *Water control.* The construction specifications shall provide that water encountered in excavations shall be removed to the surface and controlled in accordance with design requirements for radiation control and monitoring (§ 60.131(c)).

(g) *Waste handling and emplacement.* The construction specifications shall provide for demonstration of the effectiveness of handling equipment and systems for emplacement and retrieval operations, under operating conditions.

Waste Package Requirements

§ 60.135 Requirements for the waste package and its components.

(a) *General requirements of design.* The design of the waste package shall include the following elements:

(1) *Effect of the site on the waste package.* The waste package 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. 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.

(2) *Effect of the waste package on the underground facility and the natural barriers of the geologic setting.* The waste package 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 performance of the underground facility or the geologic setting. 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) *Waste form requirements.* Radioactive waste that is emplaced in the underground facility shall meet the following requirements:

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

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

(3) *Combustibles.* All combustible radioactive wastes must have been reduced to a noncombustible form unless it can be demonstrated that a fire involving a single package will neither compromise the integrity of other packages, nor adversely affect any safety-related structures, systems, or components.

(c) *Waste package requirements.* The waste package design shall meet the following requirements:

(1) *Explosive, pyrophoric, and chemically reactive materials.* The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials that could interfere with operations in the underground facility or compromise 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 impair the structural integrity of waste package components (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of package perforation.

(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 package. The identification shall not impair the integrity of the package and shall be applied in such a way that the information shall be legible at least to the end of the retrievable storage period. Each package identification shall be consistent with the package's permanent written records.

Performance Confirmation Requirements

§ 60.137 General requirements for performance confirmation.

The geologic repository operations area shall be designed so as to permit implementation of a performance confirmation program that meets the requirements of Subpart F of this part.

Subpart F—Performance Confirmation

§ 60.140 General requirements.

(a) The performance confirmation program shall ascertain whether—

(1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review; and

(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure are functioning as intended and anticipated.

(b) The program shall have been started during site characterization and it will continue until permanent closure.

(c) The program will include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The confirmation program shall be implemented so that:

(1) It does not adversely affect the natural and engineered elements of the geologic repository.

(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository.

(4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action.

§ 60.141 Confirmation of geotechnical and design parameters.

(a) During repository construction and operation, a continuing program of surveillance, measurement, testing, and geologic mapping shall be conducted to ensure that geotechnical and design parameters are confirmed and to ensure that appropriate action is taken to inform the Commission of changes needed in design to accommodate actual field conditions encountered.

(b) Subsurface conditions shall be monitored and evaluated against design assumptions.

(c) As a minimum, measurements shall be made of rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into subsurface areas, changes in groundwater conditions, rock pore water pressures including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository.

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

(e) In situ monitoring of the thermomechanical response of the underground facility shall be conducted until permanent closure to ensure that the performance of the natural and engineering features are within design limits.

§ 60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

§ 60.143 Monitoring and testing waste packages.

(a) A program shall be established at the repository for monitoring the condition of the waste packages. Packages chosen for the program shall be representative of those to be emplaced in the repository.

(b) Consistent with safe operation of the repository, the environment of the waste packages selected for the waste package monitoring program shall be representative of the emplaced wastes.

(c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.

(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure.

Subpart G—Quality Assurance

§ 60.150 Scope.

(a) As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that the repository and its subsystems or components will perform satisfactorily in service.

(b) Quality assurance is a multidisciplinary system of management controls which address safety, reliability, maintainability, performance, and other technical disciplines.

§ 60.151 Applicability.

The quality assurance program applies to all systems, structures and components important to safety and to activities which would prevent or mitigate events that could cause an undue risk to the health and safety of the public. These activities include: exploring, site selecting, designing, fabricating, purchasing, handling, shipping, storing, cleaning, erecting, installing, emplacing, inspecting, testing, operating, maintaining, monitoring, repairing, modifying, and decommissioning.

§ 60.152 Implementation.

DOE shall implement a quality assurance program based on the criteria of Appendix B of 10 CFR Part 50 as applicable, and appropriately supplemented by additional criteria as required by § 60.151.

§ 60.153 Quality assurance for performance confirmation.

The quality assurance program shall include the program of tests, experiments and analyses essential to achieving adequate confidence that the emplaced wastes will remain isolated from the accessible environment.

Subpart H—Training and Certification of Personnel

§ 60.160 General requirements.

Operations that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety must also be certified in such operations.

§ 60.161 Training and certification program.

The DOE shall establish a program for training, proficiency testing, certification and requalification of operating and supervisory personnel.

§ 60.162 Physical requirements.

The physical condition and the general health of personnel certified for operations that are important to safety shall not be such as might cause operational errors that could endanger the public health and safety. Any condition which might cause impaired judgement or motor coordination must be considered in the selection of personnel for activities that are important to safety. These conditions need not categorically disqualify a person, so long as appropriate provisions are made to accomodate such defect.

Dated at Washington, D.C. this 2nd day of July, 1981.

Samuel J. Chilk,

Secretary of the Commission.

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