NUCLEAR REGULATORY COMMISSION

10 CFR PART 60

TECHNICAL CRITERIA FOR REGULATING GEOLOGIC DISPOSAL
OF
HIGH-LEVEL RADIOACTIVE WASTE

AGENCY: Nuclear Regulatory Commission.

ACTION: Advance Notice of Proposed Rulemaking.

SUMMARY: In the December 6, 1979 edition of the Federal Register (44 FR 70408), the Commission published its proposed licensing procedures for the disposal of high-level radioactive wastes (HLW) in geologic repositories. This advance notice is the next stage in the HLW rulemaking process. The notice informs the public and interested parties concerning the status of efforts related to the development of technical criteria to become part of 10 CFR Part 60. It invites public comment on issues related to such development; on the approach being considered, including partitioning of the problem into workable elements and statements of underlying principles and technical considerations. Attached to this notice are draft technical criteria. These criteria are a result of the efforts of the staff to accommodate and include the best thinking which has been made available to the staff from technical experts in the form of technical points, suggestions and criticisms on previous drafts of technical criteria. However, these criteria do not necessarily represent staff positions with respect to rulemaking on this subject.

DATE: Comments must be received by July 14, 1980.

ADDRESS: Written comments or suggestions on the advance notice should be sent to the Secretary of the Nuclear Regulatory Commission, Washington, DC 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, DC 20555.

FOR FURTHER INFORMATION CONTACT:

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SUPPLEMENTARY INFORMATION:

Background

On December 6, 1979, the Nuclear Regulatory Commission published for comment in the Federal Register, proposed regulations for licensing geologic repositories for disposal of HLW (44 FR 70408). The proposed regulations contained only the procedural requirements for licensing: Subparts A, B, C, D, concerning general provisions, licenses, participation by State governments, and records, reports, tests and inspections, respectively. The technical criteria against which a license application will be reviewed were and are still under development. However, the technical and scientific understanding concerning the scope of the technical criteria were regarded as sufficiently developed to enable an appropriate licensing procedure to be established for their implementation. Thus, the Commission was able to propose a procedural rule to establish the necessary regulatory framework for licensing.

Since then the staff of the Commission has made further progress in focusing more sharply on the technical and scientific issues and problems related to licensing geologic disposal of HLW, in partitioning the problem so as to facilitate the development of practicable technical criteria; in articulating principles which might reasonably underlie the technical criteria; and in considering these principles in the identification of approaches to specifying the technical criteria. The Commission seeks comment from all interested parties in order to provide the Commission and its staff the opportunity to obtain public assessment of the general direction being taken in the development of the technical criteria.

The formative work on the technical criteria has been conducted in as public a manner as possible. Numerous drafts of the technical criteria have been developed, and widely circulated to interested agencies, groups, and individuals to obtain input. These drafts, prepared by the licensing staff, have formed the basis for this interaction with outside groups. They started with a fairly diffuse set of principles and ideas and have evolved with an increasing concreteness through 14 staff drafts. Technical reviews of early drafts of the criteria have been conducted by the Keystone Radioactive Waste Review Group and at a workshop held at the University of Arizona. The results of these reviews have been placed in the NRC public document room. Other Federal agencies and groups which have been involved in the review of one or more of the drafts include DOE, EPA, USGS, NRDC, Atomic Industrial Forum, Bureau of Mines, and a host of individual scientists, engineers, and public interest groups.

The technical criteria include specific numerical criteria in certain areas in order to further stimulate the thoughts and commentary of the public. The staff is preparing a document explaining the basis and rationale for these technical criteria. It is anticipated that this document will be available as a NUREG report at the time that the technical criteria are published in

the form of a proposed rule. A working draft of the bases and rationale document has been placed in the NRC Public Document Room for inspection.

Nature of the Problem

To best comprehend regulation of geologic disposal of HLW it is useful to note that such disposal of HLW is separable into five distinct problem areas: lifetime of the repository, physical extent, waste/rock interaction, treatment of uncertainties, and the problem of human intrusion. In turn, each of these areas can be further separated into fairly distinct regimes over which certain aspects or characteristics of the problem area dominate. Each of these regimes then can be treated more-or-less individually, not as specific criteria, but as functional elements addressed by the criteria. What is described below is essentially a matrix for the technical criteria cutting across the five areas above.

1. Lifetime of the Repository

The operational life of a geologic repository for the disposal of HLW quite naturally divides into three periods--the period of construction and emplacement of the wastes; the period during which the short-lived fission products dominate the hazard posed by the wastes; and the long term during which the hazard is dominated by the very long-lived isotopes including the actinides. The technical criteria must reflect the different physical conditions of the repository during these periods and be responsive to the specific nature of the hazard posed by the wastes.

During site selection, the ongoing program is one of probing and testing to find an appropriate site for a repository and develop a compatible design. Construction has not yet begun, and no radiologic hazard is posed. Nonetheless, technical criteria are needed (1) to indicate site features which clearly render a site suitable or unsuitable (site suitability criteria), and (2) to allow a judgment as to whether a proposed

site can accommodate an effective repository design and together provide the protection sought (site acceptability criteria). The nature of the criteria is changed to fit the particular needs of the periods as explained below.

Construction and emplacement of wastes is the next period which the criteria must address. During this period the immediate radiologic hazard is to those who are working at the repository and to a much lesser extent those who reside nearby. (There are also the hazards of construction to workers. Criteria which address these hazards would be expected to follow the regulations of the Mine Safety and Health Administration.) In addition, there is the actual design and construction of the repository to be considered for the long term. But the more proximate problem during this phase is that the construction and emplacement methods used will not compromise the ability of the repository to protect future populations. Thus, the technical criteria directed at this period deal with construction techniques, emplacement techniques, operations procedures, and designs for radiological protection of workers and persons living nearby (accidents).

The third period begins following closure of the repository, and will persist for the time that the relatively short-lived fission products dominate the hazard. During this time there will be a substantial heat output from the wastes which if not properly accommodated by site selection and engineering could compromise the integrity of the repository. In addition, the chemical species and makeup of the emplaced wastes are rapidly changing due to radioactive decay. Criteria applicable to this period will focus on selecting sites and generating designs to accommodate these two major features.

By the time the short-lived fission products no longer dominate the hazard, the wastes are no longer generating significant amounts of heat.

Moreover, the short-lived elements have for the most part decayed away and the chemical properties of the waste have greatly stabilized--generally dominated by the actinides. However, for this final period it would be imprudent to rely on engineering to contain the emplaced wastes; and final protection is achieved by the ability of the geologic setting to inhibit migration of the wastes leached from the waste form in a controlled manner. Properties which affect leaching of the waste and which affect transport of the wastes such as fractures, porosity, sorption, hydraulic gradient, and thermal gradient, and determination of the long-term stability of the geologic setting will dominate the criteria addressed to this period.

2. Physical Extent

A repository also can be divided physically into two broad categories--surface and subsurface. The subsurface can be further divided into the area affected by excavation and emplacement of waste and the broad geologic environment into which the repository is set.

The surface portion is comprised of the surface facilities and operations areas needed to support construction and emplacement of wastes. Generally, the criteria which apply here are those which address the construction and emplacement period.

The criteria which pertain to the broad geologic environment address those geologic and hydrologic features which if too close to the excavated area can produce effects on the integrity of the repository that are not readily understood; and, therefore, lead to doubt that the waste can be safely disposed at the repository. The thrust of these criteria would be to assure that such features are far enough away so that they either present no problem, or the problem they do present can be made tractable.

The last division in the subsurface is the area affected by excavation and emplacement of wastes. It is here that the wastes are emplaced and that the engineering is expected to be used during the first period following closure. It is also here that the construction and emplacement activities must be carried out in a manner which assures that the integrity of the repository is maintained. Hence, criteria applicable to the excavated area address siting, design, operations and the first two periods of concern.

3. Waste/Rock Interaction

The chemical and thermal properties of the wastes undoubtedly will have a significant interaction with the rock unit into which they are emplaced. To assure that the repository will function as planned, siting, designing, emplacement methods, engineering and waste form criteria will be needed to understand, control, and assess the effect of the waste upon its surroundings. These criteria are the complement to the excavated area criteria above. Those criteria are to protect the emplaced wastes from their surroundings; whereas these protect the repository from the effects of waste themselves.

4. Treatment of Uncertainties

If there is to be confidence that wastes disposed in a geologic repository will not pose a significant hazard to the health and safety of future populations, then two factors which pose fundamental difficulties must be addressed satisfactorily. First, geologic disposal is an entirely new enterprise--no experience exists with geologic disposal. Second, there will be no opportunity to observe behavior over the long term--the decisions to close the repository in effect will be a statement of its expected behavior based upon inference, deduction, and extrapolation from

results of tests and experiments carried out for a comparatively short period and upon predictions of future geologic, hydrologic, and climatologic conditions based upon observations of the past. These facts impose very definite constraints as to how confidence is achieved that the expectation of behavior will match actual behavior over the long term. These constraints fairly clearly define the items of uncertainty which arise because qualitative descriptions and models necessarily approximate nature rather than exactly describe or predict nature; uncertainties which arise, because the data used as input to those descriptions and models upon which our understanding of the natural processes in question are based, are the result of tests and measurements which themselves have degrees of uncertainty. Finally, there are uncertainties which arise simply because of the large number of geologic and hydrologic elements which must be identified, measured, and combined to determine the expected behavior of a repository--in fact, the very process of combining those elements compounds the uncertainties associated with them. Thus, criteria are needed to assure that those uncertainties are identified, understood, and compensated. Avoiding potentially adverse features is one way of compensating for uncertainties. Placing constraints on design and performance of components is another. Siting criteria which tend to lead toward relatively geologically simple sites are a third. Finally, developing criteria which address individually the separable aspects (temporal and spatial) of geologic disposal is perhaps the surest means of dealing with uncertainties.

5. Human Intrusions

To this point the discussion has focused upon the processes of nature--how the repository can be expected to behave over the long term.

However, the problem of human intrusions, intentional or inadvertent moots much of the previous discussions since there is no way to reasonably limit the variety of conceivable human activities which might compromise a forgotten repository. The only logical recourse, since engineering against human intrusion is impossible practically,* is to avoid targets, i.e., sites which may invite such intrusion. Mineral resources, water resources, interesting geologic or hydrologic features are sure to attract the developer or the explorer. Shallow repositories would more easily be intruded upon than deep ones. Therefore, what is needed are site suitability criteria which would lead toward uninteresting sites of little resource value, and design criteria which would yield designs that present minimal "targets."

Underlying Principles

The efforts of the Commission staff to develop the technical criteria have been guided by the following principles:

(1) Under Reorganization Plan Number 3 of 1970, the Environmental Protection Agency (EPA) was given the authority under the Atomic Energy Act of 1954 as amended to set the generally applicable standards for radiation in the environment. Such standards represent a broad social consensus concerning the amount of radioactive materials and levels of radioactivity in the general environment that are compatible with protection of the health and safety of the public. This EPA authority extends to the setting of the standard and not to the implementation of such

*Actually, containing the wastes within a canister for the period that the relatively short-lived fission products dominate the hazard does tend to lessen the impact of drilling into the repository by localizing the waste (i.e., keeping the "target" small) and making a smaller quantity available for dispersion during that period should drilling penetrate a waste canister.

standards or to the establishing of requirements concerning how they are to be met. The Commission is bound to implement these standards in its regulations, thus assuring that they will be met by activities authorized by the Commission's licensing decisions. The Commission may not substitute its judgment for that of the EPA, but the Commission may, and must, determine whether particular proposed disposal activities will conform to the EPA standard.

The EPA has published its generally applicable environmental standard for all of the fuel cycle except waste storage and disposal, 40 CFR 190, which expresses the limit in the form of a quantitative dose limit to the individual. The EPA is in the process of developing its HLW standard. The Commission expects this standard (40 CFR 191), to be similar in approach to that followed in 40 CFR 190.

(2) As noted above, although the Commission is bound to implement the EPA HLW standard, it has the authority and discretion to determine how that standard will be achieved. In particular, the Commission must decide how it will develop its regulatory requirements, viz., the technical criteria of 10 CFR Part 60, and carry out its decision process to show that in each particular licensing case, the EPA standard will be met.

(3) In order to establish the technical criteria for meeting the EPA standard and to make individual licensing decisions as to whether such criteria are met, the Commission needs to carry out conservative analyses because of the many uncertainties associated with HLW waste disposal in geologic repositories. These uncertainties arise from the inability, given the present and expected state of science and technology, to determine precisely the degree to which wastes, under credible conditions for the time periods involved, will be contained and isolated.

Further, in order to carry out such analyses the Commission may require measures which may not directly enter into the analyses, but will add to confidence in those analyses, thus adding to the Commission's confidence in the degree to which the EPA standard can be or has been met. Such measures are likely to be aimed at simplifying the problem: such as requiring that precepts of simplicity and stability of the geologic settings govern the site selection process in order to reduce the overall uncertainty and thus render more tractable the problem of demonstrating that the criteria and the EPA standard are met.

(4) Because the scientific and technical problems associated with HLW waste disposal are sufficiently understood, it is possible, even in the absence of an EPA standard, to identify relevant areas of regulation. These are the areas which contribute to: protection of the public health and safety or the environment; the reduction of uncertainty; or the confidence in any decision as to whether the EPA standard and NRC regulations are met.

(5) The natural divisions of the problem in time and space and the separation of the problem of human intrusion from natural events aid in understanding which areas should be regulated, facilitate the analyses which will serve as the decision-bases, and so will increase confidence in regulating and licensing decisions.

(6) The analyses and requirements must reflect a degree of examination and control which corresponds to the importance to safety of any given technical area. Thus, the technical criteria must address not only questions of site suitability, but--to the extent possible--address questions of site/facility acceptability.

Considerations

In the course of developing technical criteria a number of considerations have arisen. The Commission believes that the program to develop the technical criteria for HLW disposal in geologic repositories would benefit from comment on them:

(1) Systems Approach. The term "systems approach" relates to the set of natural and engineered barriers which would function to contain and isolate the waste from the biosphere for the periods of time required, to increase the degree of the Commission's confidence that indeed such containment and isolation would be achieved, or to permit appropriate and conservative analyses to be performed which would form the decision bases.

It is evident that for a geologic repository, the geologic setting must be one barrier. In considering whether there should be other barriers, a key question which needs to be answered is whether it is prudent, in view of the nature of the problems and the uncertainties involved, to rely on the geologic setting alone to accomplish the functions stated above. The state-of-the-art in the earth sciences is such that all of the uncertainties associated with these functions cannot be resolved through consideration of the geologic setting.

It is appropriate, therefore, to consider how engineering--in the broadest sense of anything used to effect a purpose--might be used to compensate for, reduce, or eliminate at least some of the uncertainties inherent in reliance on the geologic setting alone. Engineering can be used to narrow the extent of geologic processes which need to be considered in the rulemaking and licensing processes; that is, engineering can be used to bound and/or diminish the importance of certain geologic processes. Engineering also can be used to make the containment of emplaced waste as

insensitive as possible to potential changes in the geologic environment. For example, the use of buffering materials to retain radionuclides is one possible way to compensate for uncertainties in the sorption capabilities of a particular medium and site.

In light of these considerations, therefore, the Commission staff believes that it is reasonable to couple a prudently and cautiously selected geologic setting (natural barrier) with a set of engineered barriers capable of performing or assisting the performance of the functions stated above. Further, the Commission staff believes that sites which are relatively easily understood and can be expected to be stable for long times, are the most desirable; and that engineered systems which are compatible with and make the least adverse impacts upon the geologic and hydrologic characteristics of the site will contribute most to the performance of the overall disposal system. Similarly, to the greatest extent possible, the performance of engineered systems should be insensitive to changes in those characteristics and should provide a high degree of protection by themselves.

Given the nature of the problems, as discussed earlier, the Commission staff has identified the following as composing the set of three primary barriers of the waste disposal system: the geologic setting; the design and configuration of the repository, including the waste emplacement scheme and engineered barriers; and the waste package.

(2) Use of Minimum Performance Standards for Major Regulatory Elements. Determining the expected evolution of a geologic repository in time is the key to understanding the consequences of emplacing wastes in a repository. Such expectation of the effects of pertubations and changes, both natural and man-caused to the hydrologic environment, serves to identify

the kinds of events, including institutional failures, which might cause a radioactive release to the biosphere. Assessment of such events that reasonably can be assumed to occur and their likely consequences permits the identification of the "credible" events which should be considered in the design of the repository and evaluated in rulemaking and licensing decisions: identification of these "credible" events permits development of performance requirements for both the natural and engineered barriers to assure that such events are avoided where possible or their consequences mitigated when these performance requirements are met. Such describes the deterministic approach the Commission staff has been taking in the development of the performance requirements for HLW disposal in geologic repositories, and defense-in-depth approach to provide assurance and confidence that the EPA standard can be met.

(3) The Nature of the Major Regulatory Elements. The regulatory elements selected should be either important to safety, that is, contain and isolate the waste from the biosphere for the periods of time required, or contribute to confidence in the functioning of the repository system or individual components. As discussed above, the repository is conceived as a system of multiple barriers, both natural and engineered. The two most important attributes of the natural barrier are that the site should be geologically simple and stable so that the site can be easily understood and so that there can be confidence that the ability of the site to contain and isolate the wastes will remain viable for long times.

The three most important attributes of the engineered barriers must be their compatibility with the geologic and hydrologic characteristics of the site so that the engineered barriers will have the least adverse

impact on the site's ability to retain the emplaced wastes; their insensitivity to any changes in the site characteristics so that there can be confidence in the predicability of their performance over time; and their ability to complement the performance of the site so as to increase confidence in overall repository performance to supplement the performance of the site--where possible--to increase the overall margin of safety.

(4) Adequacy of Favorable and Unfavorable Site Characteristics to Impose Proper Technical Restrictions. Consideration of site characteristics is important to the development of technical requirements for HLW disposal from several aspects. The first relates to question of site suitability, that is, to the potential of a site to serve as the location for a repository. Unfavorable site characteristics are identified to eliminate from consideration sites which would not be acceptable under any circumstances for a HLW geologic repository or which would present insuperable difficulties in terms of understanding the geology and hydrology of the site or would introduce or compound uncertainties which would affect negatively confidence in any licensing decisions. Favorable site characteristics are identified where the likelihood of a site/facility combination (repository) being acceptable is greater or which would contribute to increased understanding of the geology and hydrology, permit uncertainties to be better handled, and increase confidence in any licensing decisions. However, neither kind of site suitability characteristics say anything about the ultimate acceptability of the repository system as a means to safely contain and isolate the wastes for the time required with the degree of confidence necessary to a licensing decision. Criteria by which the acceptability of the site/facility combination can be assessed are needed for this determination.

Specifically, this second aspect relates to questions of whether or not, given the present state-of-the-art in the earth sciences, it is possible to identify on a generic basis site characteristics the presence of which at an otherwise suitable site would render the site/facility combination unacceptable for HLW disposal. The question of general site acceptability criteria is an open one in the sense that the staff has not identified to date such criteria. Should general site acceptability criteria not be developed, it will be necessary to determine the site acceptability question on a case-by-case basis.

(5) Codification of Models in Licensing Process. The question of whether regulations should codify models to be used in licensing disposal of HLW or whether the criteria should only allow the use of models is a controversial one. In considering these questions the staff recognizes that it is necessary to: (a) Use descriptions (models) of the behavior of geologic processes and of the repository and of the consequences associated with that behavior; (b) acknowledge that these descriptions are approximations to nature and as such introduce uncertainties into the process; (c) recognize that for the foreseeable future, the "old" models, in which there is the greatest confidence because of their "proven" use appear to be as qualitative as they are quantitative; (d) consider that the judgment of the appropriateness of these models for their intended purpose will be supported largely through expert opinion; (e) confront and explore fully these uncertainties and their ramifications including "uncertainties" arising from differences in expert opinion; (f) judge the acceptability of the consequences of events in the light of these uncertainties; and (g) assure that the judgment itself will be detailed in the public record

If one views the realization of our understanding in geologic disposal from successively more nearly complete and accurate qualitative descriptions of the observed phenomenon in question through more precise and semi-quantitative and quantitative approximations where uncertainties are better understood and can be treated mathematically, to an elegant theory embodied in a mathematical description which represents a culmination of human thought, the present state of modeling for geologic repositories is closer to qualitative than quantitative. This fact does not make whatever understanding we have less valid--we know what we know. Rather this means that neither the process by which the technical criteria should be developed nor the process by which a licensing decision should be made should rely solely on quantitative calculations and assessments. It means that when analytical techniques are used, care must be taken not to apply those techniques outside their established region of validity. Finally, it means that confidence in a licensing finding is inextricably linked to uncertainty; and the validity of any licensing finding is linked to the means by which uncertainty is uncovered, explored, and treated.

There are a number of considerations that need to be taken into account before establishing whether qualitative/quantitative models will be codified in the regulations or their use merely permitted: (1) if modeling is used as the primary decision tool then demonstration of whether the geologic setting at a particular site can fulfill the stated purpose of the geologic barrier relies fundamentally on the predictive power of the particular transport model appropriate to that site; (2) the less stable the site geologically and hydrologically, the less reliable the transport model as a description of the steady-state; (3) the more complex with respect to geologic and climatology processes, the poorer

the model is as an approximation to nature and the greater the uncertainty of any prediction; (4) the more complex the site or less stable the site, the greater the difficulty in modeling long-term behavior at the interface between the geologic barrier and the set of engineered barriers; (5) the lack of empirical data on the performance of engineered barriers or the inability to obtain credible data may preclude the development or use of credible quantitative models in the showing that either the uncertainties are addressed properly in the performance standards or the performance standards are met in a particular licensing action. In light of these considerations, the staff's thought has been not to require modeling to be the primary decision tool to determine the capability of the geologic repository to contain and isolate waste from the biosphere. The staff believes, however, that quantitative models can be used to compare sites and designs.

In sum, the staff considers the following to be a reasonable position with respect to the use of models:

Technical criteria must be developed through a rulemaking process in which the logic and factual basis is clearly articulated and can withstand challenge. Hence, where appropriate, quantitative models should be used to develop technical criteria. However, because of the limitations discussed above, it is desirable to specify technical criteria associated with the regulatable elements in such a manner as not to predicate their technical justification on the results of quantitative modeling, except in those instances where quantitative modeling can contribute to their technical justification. Where quantification is not possible, without meaning, incomplete or ambiguous, the process must rely on expert opinion to provide insight and alternatives. This process is particularly

appropriate to the development of criteria for which neither direct experience nor recourse to experimental verification exists to provide the basis for the criteria. Through expert opinion in public proceedings, and the exercise of judgment by the Commission, a satisfactory if imprecise margin of safety for site characteristics and engineering design can be realized. This is particularly important where quantitative modeling and experimental verification alone cannot be used to establish a sound record. When these qualitative and semiquantitative considerations are combined with quantitative models to develop a scheme for comparison, the staff believes the result will lead to a sound regulation and to sound licensing decisions.

(6) Retrievability. Selection of a suitable site for a geologic repository for HLW disposal and the design, construction and operation of a repository is a new human enterprise. In undertaking such a venture for the first time, it is reasonable to expect that, whatever the care exercised and however advanced the techniques, mistakes will occur, improved technologies developed, better designs created, and operational procedures improved. It is reasonable, therefore, to assume that it might be desirable to postpone any irreversible (or not easily reversible) decisions until the maximum amount of reasonably obtainable information about how well the repository is functioning and can be expected to function to contain and isolate the waste for the periods of time required is at hand. The staff believes that it may be desirable to maintain the option to retrieve the wastes for a period of time after the last waste is emplaced and is developing criteria to require it. The draft technical criteria contain a requirement that the repository be designed to preserve the option to retrieve the wastes for a period of years following emplacement. This option, however, is not without impact, particularly in the areas of

repository design and waste emplacement. However, it would allow monitoring and taking corrective actions if required, including removal of the wastes, before the repository is sealed.

(7) Human Intrusion Problem. For geologic repositories, the human intrusion problem is not a simple or straightforward extension of natural events and may require different standards as well as a different approach. Simply stated, human intrusion cannot be prevented: In spite of all efforts to avoid sites which may prove attractive to humans, there may be deliberate or inadvertent intrusion. In the former instance, it is reasonable to assume that the intruder has access to information which makes it attractive to intrude. For example, the intruder may know of the location and contents of the repository itself and may regard the HLW as a resource of some value. How should such an intrusion be regarded as an event to be considered in the design of the repository? That is, should attempts be made to protect future generations from the deliberate intruder? What are the consequences of intrusion to the intruder? To the general population? In the latter instance, where the event is one of inadvertent (accidental) intrusion other questions occur. Did the intrusion occur beyond the time that it is reasonable to expect that knowledge of the existence of the repository is known? What is a reasonable period of time? What steps in repository design and enforcement can be taken to mitigate the consequences of an accidental intrusion? Is one kind of intrusion more likely than the other? Are the consequences of inadvertent intrusions different from those for deliberate intrusions? The human intrusion issue is a difficult one that is far from having been resolved.

Questions: In particular, we are seeking comment on the following questions.

(1) Does the list of considerations above clearly, adequately and fully identify the relevant issues involved in disposal of HLW?

(2) Would a rule structured along the lines of the referenced draft rule reasonably deal with issues in an appropriate manner?

(3) In light of the fact that EPA has the responsibility and authority to set the generally applicable environmental standard for radiation in the environment from the disposal of HLW, with what factors/issues should an NRC environmental impact statement on technical criteria deal?

(4) What are the environmental impacts of criteria constructed in accordance with the above cited principles? What alternative criteria exist and what are their impacts?

DRAFT TECHNICAL CRITERIA FOR
10 CFR PART 60
DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES
IN GEOLOGIC REPOSITORIES

SUBPART E - TECHNICAL CRITERIA

§ 60.2 Definitions (to be inserted as appropriate into subpart A)
§ 60.101 Purpose
§ 60.111 Performance Objectives
§ 60.121 Site and Environs Ownership and Control
§ 60.122 Siting Requirements
§ 60.132 Design Requirements
§ 60.133 Waste Package and Emplacement Environment
§ 60.135 Retrieval of Waste
§ 60.137 Monitoring Programs

SUBPART F - PHYSICAL PROTECTION

SUBPART G - QUALITY ASSURANCE

§ 60.171 Quality Assurance Program

SUBPART H - CRITERIA FOR PERSONNEL TRAINING

SUBPART I - EMERGENCY PROGRAMS

§ 60.2 Definitions.

For the purpose of this part --

"Accessible Environment" - means those portions of the environment directly in contact with or readily available for use by human beings. It includes the earth's atmosphere, the land surface, surface waters, and the oceans. It also includes presently used aquifers which have been designated as underground sources of drinking water under the Environmental Protection Agency's proposed rule 40 CFR Part 146.

"Aquifer" - means a distinct hydrogeologic unit that readily transmits water and yields significant quantities of water to wells or springs.

"Barrier" - means any material or structure which prevents or substantially delays movement of radionuclides from the radioactive wastes towards the accessible environment.

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

"Container" - means the first major sealed enclosure that holds the waste form.

"Containment" - means keeping radioactive waste within a designated boundary.

"Confining unit" - means a distinct hydrogeologic unit which neither transmits ground water readily nor yields significant quantities of water to wells or springs.

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

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

"Disposal" - means permanent emplacement within a storage space with no intent to retrieve for resource values.

"Expected processes and events" - means those natural processes or events that are likely to degrade the engineered elements of the geologic repository during a given period after decommissioning. As used in this part, expected processes and events do not include human intrusion.

"Floodplain" - means the lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands 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 geologic media. A geologic repository includes (1) the geologic repository operations area, and (2) all surface and subsurface areas where natural events or activities of man may change the extent to which wastes are effectively isolated from the accessible environment.

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

"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.

"HLW 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).

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

"Hydrogeologic unit" - means any soil or rock unit or subsurface zone that has a distinct influence on the storage or movement of ground water by virtue of its porosity or permeability.

"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.

"Intrinsic permeability" - means a measure of the relative ease with which a porous medium transmits a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the fluid.

"Isolation" - means segregation of waste from the accessible environment within acceptable limits.

"Overpack" - means any additional, receptacle, wrapper, box or other structure which becomes an integrated part of a waste package and is used to enclose a waste container for purposes of providing additional protection or meeting the requirements of an acceptance criteria.

"Packaging" - means the container, and any overpacks, and their contents excluding radioactive materials and their encapsulating matrix, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for absorbing mechanical shock, external fittings or handling devices, neutron absorbers or moderators and other supplementary equipment.

"Stability" - means the rate of natural processes affecting the site during the recent geologic past are relatively low and will not significantly change during the next 10,000 years.

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

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

"Underground facility" - means the civil engineered structure, including backfill materials, but not including seals, in which waste is emplaced.

"Waste form" - means the radioactive waste materials and any associated encapsulating or stablizing materials.

"Waste package" - means the physical waste form, its container and any ancillary enclosures, including its shielding, packing, and overpack.

§ 60.101 Purpose

(a) This subpart states the performance objectives to be achieved and the technical criteria to be met by the Department of Energy in order for the Commission to make the findings called for in Subpart B.

(b) The Commission will apply the technical criteria in this subpart in making findings that the activities authorized by a license, or any amendment thereof, will not constitute unreasonable risk to the health and safety of the public.

(c) The Commission will also apply the technical criteria in this subpart, insofar as they may be pertinent, in making determinations with respect to the issuance of a construction authorization.

(d) Omissions in the General Design Criteria do not relieve an applicant from the requirement of providing the necessary safety features in the design of a specific facility.

(e) The requirements and conditions in subsequent sections assume that disposal will be in saturated media. The Commission does not intend to exclude disposal in the vadose zone or any other method by promulgating these criteria; however, different criteria may need to be developed to license other disposal methods.

§ 60.111 Performance Objectives

(a) Overall Repository Performance

(1) Radiation exposure or releases during operation

The Department of Energy shall design and operate the geologic repository operations area to provide reasonable assurance that radiation exposures and releases of radioactive materials are within the limits set forth in Part 20 of this Chapter.

(2) Releases After Decommissioning

The Department of Energy shall provide reasonable assurance that after decommissioning the geologic repository will isolate radioactive wastes to such a degree that quantities and concentrations of radioactive waste in the accessible environment will conform to such generally applicable environmental standards as may have been established by the Environmental Protection Agency.

(3) Retrievability

The Department of Energy shall design the geologic repository operations area so that the radioactive waste stored there can be retrieved for a period of 50 years after termination of waste emplacement operations, if the geologic repository operations area has not been decommissioned. If during this period a decision is made to retrieve the wastes the Department shall insure that wastes could be retrieved in compliance with Part 20 of this Chapter and in about the same period of time as that during which they were emplaced.

(b) Required Barriers

In the design and construction of a geologic repository, the Department shall utilize (1) an engineered system including waste packages and an underground facility, and (2) the geologic environment.

(c) Performance of Required Barriers and Engineered Systems

(1) Waste Packages*

The Department shall design waste packages so that there is reasonable assurance that radionuclides will be contained for at least the first 1,000 years after decommissioning and for as long thereafter as is reasonably achievable given expected processes and events as well as various water

*Paragraphs 60.111(c)(1) and 60.111(c)(2) apply only to HLW.

flow conditions including full or partial saturation of the underground facility.

(2) Underground Facility

The Department shall design the undergrourd facility to provide reasonable assurance of the following:

(i) An environment for the waste packages that promotes the achievement of Paragraph 60.111(c)(1) above under conditions resulting from expected processes and events.

(ii) Containment of all radionuclides for the first 1,000 years after decommissioning of the geologic repository operations area and as long thereafter as is reasonably achievable, assuming expected events and processes and that some of the waste dissolves soon after decommissioning.

(3) Overall Performance of the Engineered System After Containment

The Department shall design the engineered system to provide reasonable assurance that:

(i) Starting 1,000 years after decommissioning of the geologic repository operations area, the radionuclides present in HLW will be released from the underground facility at an annual rate that is as low as reasonably

achievable and is in no case greater than an annual rate of one part in one hundred thousand of the total activity present in HLW within the underground facility 1,000 years after decommissioning assuming expected processes and events.

(ii) Starting at decommissioning radionuclides present in TRU waste will be released at a rate that is as low as reasonably achievable and is in no case greater than one part in one hundred thousand of the total activity present in TRU waste within the underground facility at the time of decommissioning assuming expected processes and events.

(4) Performance of the Geologic Environment

(i) The Deparment shall provide reasonable assurance that the degree of stability exhibited by the geologic environment at present will not significantly decrease over the long term.

(ii) The Department shall provide reasonable assurance that the site exhibits properties which promote isolation and that their capability to inhibit the migration of radionuclides will not significantly decrease over the long term.

(iii) The Department shall provide reasonable assurance that the hydrologic and geochemical properties of the host rock and surrounding confining units will provide radionuclide travel times to the accessible environment of at least 1,000 years assuming expected processes and events.

§ 60.121 Site and Environs Ownership and Control

(a) Ownership and Control of the Geologic Repository Operations Area

The Department shall locate the geologic repository operations area in and on lands that are either acquired lands under the jurisdiction and control of the Department or lands permanently withdrawn and reserved for its use. The Department shall hold such lands free and clear of all significant encumbrances (including rights arising under the general mining laws, easements for right-of-way, and all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise).

(b) Establishment of a Control Zone

The Department shall establish a "Control Zone" surrounding the geologic repository operations area. The Department shall exercise such jurisdiction and control with respect to surface and subsurface estates in the control zone as may be necessary to prevent adverse human actions that could significantly reduce the ability of the natural or engineered barriers to isolate radioactive materials from the accessible environment. The

Department's rights may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) Long-Term Control

The Department shall identify the geologic repository operations area by the most permanent markers and records practicable. The markers shall be inscribed in several languages as well as English. In addition, the Department shall deposit records of the location of the geologic repository operations area and the nature and hazard of the waste in the major archives of the world. For the purpose of demonstrating compliance with § 60.111 (Performance Objectives), the Department shall assume that other institutional controls will not persist for more than one hundred years.

§ 60.122 Siting Requirements

(a) General Requirements

(1) The Department shall select the site and environs so that they are not so complex as to preclude thorough investigation and evaluation of the site characteristics that are important to demonstrating that the performance objectives of §60.111 will be met.

(2) The Department shall investigate and evaluate the natural conditions and human activities that can reasonably be

expected to affect the design, construction, operation, and decommissioning of the geologic repository operations area. The natural conditions include geologic, tectonic, hydrologic, and climatic process. The Department shall evaluate the stability of the geologic repository and the isolation of radionuclides after decommissioning.

(i) The Department shall conduct investigations on the order of 100 kilometers horizontal radius from the geologic repository operations area,

(ii) The Department shall emphasize those natural conditions active anytime since the start of the Quaternary Period in their investigations.

(iii) The Department shall emphasize the first 10,000 years following decommissioning in their prediction of changes in natural conditions and the performance of the geologic repository.

(3) The Department shall conduct investigations that adequately characterize and provide representative and bounding values for those human activities and natural events and conditions that may affect any of the following:

(i) The design, construction, operation, and decommissioning of the geologic repository operations area.

(ii) Demonstration of the stability of the geologic repository after decommissioning.

(iii) Demonstration of the isolation of radionuclides from the accessible environment after decommissioning.

(4) The Department shall evaluate reasonably likely future variations in the site characteristics which may result from natural processes, human activities, construction of the repository, or waste/rock/water interactions.

(5) The Department shall conduct the site investigations in such a manner as to obtain the required information with minimal adverse effects on the long-term performance of the geologic repository.

(6) The Department shall validate analyses and modeling of future conditions and changes in site characteristics using field tests, in situ tests, field-verified laboratory tests, monitoring data, or natural analog studies.

(7) The Department shall continuously verify and assess any changes in site conditions which pertain to whether the performance objectives will be met.

(8) The Department shall perform a resource assessment for the region within 100 km of the site using available information. The Department shall include estimates of both known and undiscovered deposits of all resources that (1) have been or are being exploited or (2) have not been exploited but are exploitable under present technology and market conditions. The Department shall estimate undiscovered deposits by reasonable inference based on geologic and geophysical information. The Department shall estimate both gross and net value of resource deposits. The estimate of net value shall take into account development, extraction and marketing costs.

(9) The Department shall determine by appropriate analyses the extent of the volume of rock within which the geologic framework, ground-water flow, ground-water chemistry, or geomechanical properties are anticipated to be significantly affected by construction of the geologic repository or by the presence of the emplaced wastes, with emphasis on the thermal loading of the latter. In order to do the analyses required in this paragraph, the Department shall at a minimum conduct investigations and tests to provide the following input data:

(i) The pattern, distribution and origin of fractures, discontinuities, and heterogeneities in the host rock and surrounding confining units;

(ii) The presence of potential pathways such as fractures, discontinuities, solution features, unsealed faults, breccia pipes, and other permeable anomalies in the host rock and surrounding confining units.

(iii) The in situ determination of the bulk geomechanical properties, pore pressures and ambient stress conditions of the host rock and surrounding confining units;

(iv) The in situ determination of the bulk hydrogeologic properties of the host rock and surrounding confining units;

(v) The in situ determination of the bulk geochemical conditions, particularly the redox potential, of the host rock and surrounding confining units;

(vi) The in situ determination of the bulk response of the host rock and surrounding confining units to the anticipated thermal loading given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass.

As a minimum, the Department shall assume that the volume will extend a horizontal distance of 2 kilometers from the limits of the repository excavation and a vertical distance from the surface to a depth of 1 kilometer below the limits of the repository excavation.

(b) Potentially Adverse Conditions

The following paragraphs describe human activities or natural conditions which can adversely affect the stability of the repository site, increase the migration of radionuclides from the repository, or provide pathways to the accessible environment. The Department shall demonstrate whether any of the potentially adverse human activities or natural conditions are present. The Department shall document all investigations.

The presence of any of the potentially adverse human activities or natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives. The conditions and activities in this section apply, unless otherwise stated, to the volume of rock determined by the Department in Paragraph 60.122(a)(8) above.

(1) Potentially Adverse Human Activities

(i) There is or has been conventional or in situ subsurface mining for resources.

(ii) Except holes drilled for investigations of the geologic repository, there is or has been drilling for whatever purpose to depths below the lower limit of the accessible environment.

(iii) There are resources which are economically exploitable using existing technology under present market conditions.

(iv) Based on a resource assessment, there are resources that have either higher gross or net value than the average for other areas of similar size in the region in which the geologic repository is located.

(v) There is reasonable potential that failure of human-made impoundments could cause flooding of the geologic repository operations area prior to decommissioning.

(vi) There is reasonable potential based on existing geologic and hydrologic conditions and methods of construction for construction of large-scale impoundments which may affect the regional ground-water flow system.

(vii) There is indication that present or reasonably anticipatable human activities can significantly affect the hydrogeologic framework. Human activities include

ground-water withdrawals, extensive irrigation, subsurface injection of fluids, underground pumped storage facilities or underground military activities.

(2) Potentially Adverse Natural Conditions - Geologic and Tectonic

(i) There is evidence of extreme bedrock incision since the start of the Quaternary Period.

(ii) There is evidence of dissolutioning, such as karst features, breccia pipes, or insoluble residues.

(iii) There is evidence of processes in the candidate area which could result in structural deformation in the volume of rock such as uplift, diapirism, subsidence, folding, faulting, or fracture zones.

(iv) The geologic repository operations area lies within the near field of a fault that has been active since the start of the Quaternary Period.

(v) There is an area characterized by higher seismicity than that of the surrounding region or there is an area in which there are indications, based on correlations of earthquakes with tectonic processes and features, that seismicity may increase in the future.

(vi) There is evidence of intrusive igneous activity since the start of the Quaternary Period.

(vii) There is a high and anomalous geothermal gradient relative to the regional geothermal gradient.

(3) Potentially Adverse Natural Conditions - Hydrologic

(i) There is potential for significant changes in hydrologic conditions including hydraulic gradient, average pore velocity, storativity, permeability, natural recharge, piezometric level, and discharge points. Evaluation techniques include paleohydrologic analysis.

(ii) The geologic repository operations area is located where there would be long term and short term adverse impacts associated with the occupancy and modification of floodplains. (Executive Order 11988).

(iii) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity to create large-scale impoundments that may affect the regional ground-water flow system.

(iv) There is a fault or fracture zone, irrespective of age of last movement, which has a horizontal length of more than a few hundreds of meters.

(4) Potentially Adverse Natural Conditions - Geochemical

The rock units between the repository and the accessible environment exhibit low retardation for most of the radionuclides contained in the radioactive waste.

A presumption that the geologic repository will not meet the performance objectives can be rebutted upon showing that the presence of the potentially adverse condition does not adversely affect the performance of the geologic repository. In order to make this showing, the Department shall first demonstrate that :

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

(2) The effect of the potentially adverse human activity or natural condition on the geologic framework, ground-water flow, ground-water chemistry and geomechanical integrity has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural condition;

(3) The effect of the potentially adverse human activity or natural conditon is compensated by the presence of favorable characteristics in Paragraph 60.122(c) of this Section; and

(4) The potentially adverse human activity or natural condition can be remedied during construction, operation, or decommissioning of the repository.

(c) Favorable Characteristics

Each of the following characteristics represent conditions which enhance the ability of the geologic repository to meet the performance objectives. Candidate areas and sites which exhibit as many favorable characteristics as practicable are preferred.

The Department shall demonstrate the degree to which each favorable characteristic is present. The Department shall fully document all investigations. The Department shall perform evaluations to demonstrate to what extent the favorable characteristic contributes to assuring the stability of the site and/or the isolation of the waste by restricting the access of groundwater to the waste, the rate of dissolution of the waste, or the migration of radionuclides from the geologic repository. The Department shall use conservative analyses to demonstrate the significance of the favorable characteristics. The Department shall include evaluation of the degree to which the

favorable characteristic has been adequately characterized, given the degree of resolution achieved by the investigations.

The specific favorable characteristics are the following:

(1) The Department shall select the site so that to the extent practicable the candidate area --

(i) exhibits demonstrable surface and subsurface geologic, geochemical, tectonic, and hydrologic stability since the beginning of the Quaternary Period; and

(ii) contains a host rock and surrounding confining units that provide:

(a) long ground-water residence times and long flow paths between the repository and the accessible environment;

(b) inactive ground-water circulation within the host rock and surrounding confining units, and little hydraulic communication with adjacent hydrogeologic units due to ground-water characteristics such as low intrinsic permeability and low fracture permeability of the rock mass; and

(c) geochemical properties, such as reducing conditions which result in low solubility of radionuclides, and near-normal pH, or a lack of complexing agents.

(2) The Department shall select the site so that to the extent practicable the volume of rock--

(i) possesses the favorable characteristics described above;

(ii) possesses a geologic framework that permits effective sealing of shafts, drifts, and boreholes, and that permits excavation of a stable subsurface opening, and the emplacement of waste at a minimum depth of 300 meters from the ground surface;

(iii) possesses ground-water flow characteristics that--

(a) result in a host rock with very low water content;

(b) prevent ground-water intrusion or circulation of ground water in the host rock;

(c) prevent significant upward ground-water flow between hydrogeologic units or along shafts, drifts, and boreholes;

(d) result in low hydraulic gradients in the host rock and surrounding confining units;

(e) result in horizontal or downward hydraulic gradients in the host rock and surrounding confining units; and

(f) result in ground-water residence times under ambient conditions, between the repository and the accessible environment, that exceed 1000 years.

(iv) possesses geomechanical properties that provide stability during construction, operation, and under the influences of thermal load or other waste/rock/water interactions;

(v) possesses a low population density;

(vi) possesses a combination of meteorological characteristics (especially prevailing wind flow direction) and population distribution such as to assure that a radiological exposure of the population, which is within the limits of Part 20 of this chapter; and

(vii) is in an area where climatic change is not expected to have an adverse impact on the geologic, tectonic, or hydrologic characteristics.

§ 60.132 Design requirements

(a) General design requirements

The requirements in this section apply to surface and subsurface facilities.

(1) Compliance with mining regulations

The Department shall design, construct and operate the surface and subsurface facilities to comply with all applicable Federal and state mining regulations including Subchapters D, E, and N of 30 CFR Part 57 as applicable.

(2) Identification of structures, systems, and components important to safety

The Department shall identify by appropriate analyses those systems, structures and components that are important to safety.

(3) Protection against natural phenomena and environmental conditions

(i) The Department shall design and locate structures, systems, and components important to safety to accommodate the effects of and to be compatible with site characteristics and environmental conditions associated with normal operation, maintenance and testing at any time prior to decommissioning.

(ii) The Department shall design and locate structures, systems and components important to safety to withstand the most severe of natural phenomena that are likely to occur at the site including seismic, meteorologic and hydrologic events without loss of capability to perform their safety function.

(4) Protection against dynamic effects of equipment failure and similar events

The Department shall design and locate structures, systems and components important to safety to resist dynamic effects that could result from equipment failure, missile impacts, the dropping of crane loads in transit, and similar events and conditions.

(5) Protection against fires and explosions

(i) The Department shall design and locate structures, systems, and components important to safety to minimize the potential for impairment of their ability to perform their safety functions during fires or explosions.

(ii) To the extent practicable, the Department shall design the geologic repository to incorporate noncombustible and heat resistant materials.

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

(iv) The Department shall design the geologic repository to include provisions to protect personnel from either the operation of, or the failure of the fire suppression systems.

(6) Inspection, testing, and maintenance

The Department shall design and locate structures, systems and components important to safety to permit periodic inspection, testing, and maintenance, as appropiate, to ensure their continued functioning and readiness.

(7) Emergency capability

(i) The Department shall design and locate structures, systems, and components important to safety to assure safe storage of radioactive waste, prompt termination of operations and evacuation of personnel during an emergency.

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

(8) Utility services

(i) The Department shall design each utility service system to provide for the meeting of safety demands under normal and abnormal conditions. The Department shall design utility services and distribution systems important to safety to include redundant systems to the extent necessary to maintain, with adequate capacity, the ability to perform safety functions assuming a single failure.

(ii) The Department shall design emergency utility services to permit testing of the functional operability and capacity, including the full operational sequence, of each system for transfer between normal and emergency supply sources, and the operation of associated safety systems.

(iii) The Department shall make provisions so that in the event of a loss of the primary electric power source

or circuit, reliable and timely emergency power is provided to instruments, utility service systems, and operating systems including the security central alarm station, in amounts sufficient to allow safe conditions to be maintained with all safety devices essential to safety functioning.

(9) Radiological Protection

(i) The Department shall design structures, systems, and components for which operation, maintenance, and required inspections could involve radiological exposure to personnel to include means to control external and internal radiation exposures within the limits specified in Part 20 of this Chapter. This includes the means to:

(a) Prevent the accumulation of radioactive material in those systems to which access by personnel is required;

(b) Minimize the time required to perform work in the vicinity of radioactive components, such as by providing sufficient space for ease of operation and designing equipment for ease of repair and replacement; and

(c) Provide shielding to assure that exposures to personnel in accessible areas are within the limits of Part 20.

(ii) The Department shall design the geologic repository to include means to--

(a) Provide appropriate radiation protection systems and programs for all areas and operations where personnel may be exposed to levels of radiation or airborne radioactive materials significantly above background levels to insure that exposures are within the limits of Part 20;

(b) Control and monitor the spread of contamination;

(c) Control access to areas of high radiation or potential contamination; and

(d) Warn workers by a radiation alarm system of significant increases in radiation levels in normally accessible areas and of excessive radioactivity released in effluents. The Department shall design such systems with redundancy and in situ testing capability.

(10) Criticality control

The Department shall design all systems for processing, transporting, handling, storage, retrieval, emplacement, and isolation of radioactive waste to insure that a nuclear criticality accident is possible only if at least two unlikely, independent and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. Demonstration of criticality safety under normal and accident conditions shall be by calculation of the effective multiplication factor (k_{eff}). This value 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.

(11) Instrumentation and control systems

The Department shall provide instrumentation and control systems to monitor and control the behavior of engineered systems that are important to safety over anticipated ranges for normal operation, for abnormal operation and for accident conditions. The Department shall design the systems with sufficient redundancy to assure that adequate margins of safety are maintained.

(b) Additional design requirements for surface facilities

The requirements in this section apply only to the design of surface facilities.

(1) Compliance with Part 72

If the geologic repository includes surface facilities that would be required to comply with 10 CFR Part 72, were they to be geographically removed from the site, the Department shall design, construct and operate those surface facilities to conform with 10 CFR Part 72.

(2) Facilities for retrieval of waste

The Department shall design and construct surface facilities to facilate safe and prompt retrieval of wastes including facilities to inspect, repair, decontaminate, and store retrieved wastes prior to their shipment off site. Surface storage capacity of all emplaced waste is not required, but must be sufficient to handle waste backlogs prior to shipment offsite.

(3) Ventilation

The Department shall design surface facility ventilation system(s) supporting waste transfer, inspection, decontamination, processing and/or packaging to assure that occupational exposures and releases of gases and airborne radioactive particulate materials during normal operations do not exceed the limits identified in Part 20 of this chapter.

(4) Radiation control and monitoring

(i) Effluent control

The Department shall design the surface facilities to minimize the release of radioactive materials in effluents of any form, during normal operations.

The Department shall monitor the systems provided to guard against the release of radioactive materials.

The Department shall insure that the monitoring systems are provided with alarms which are periodically tested.

The Department shall design and construct facilities to assure treatment of contaminated effluents as necessary to ensure that the concentrations and total quantities of radioactive materials in effluents are maintained within the limits of Part 20 of this chapter.

(ii) Effluent monitoring

The Department shall design effluent monitoring systems to adequately measure the amount and concentration of radionuclides in any effluent to assure that radioactive materials are maintained within the limits of Part 20 of this Chapter.

(5) Waste treatment

The Department shall design radioactive waste treatment facilities to process all site generated wastes.

(6) Consideration of decommissioning

The Department shall design and construct surface facility structures to facilitate decommissioning.

(c) Additional design requirements for subsurface facilities

The requirements in this section apply only to subsurface facilities.

(1) Underground facility

The Department shall design the underground facility as an underground civil engineered structure that satisfies requirements for structural performance, control of groundwater movement and control of radionuclide transport. The Department shall design the facility to provide for safe operation during construction, emplacement, and retrieval of waste and to assure compliance with §60.111 (Performance Objectives).

(2) Waste isolation engineering

(i) The Department shall demonstrate that the underground facility includes those engineered features that are needed to limit radioactive releases after decommissioning to levels that are as low as reasonably achievable. The Department shall include an identification and a comparative evaluation of alternatives to the major

design features that are provided to enhance radionuclide retardation and containment.

(ii) The Department shall design the underground facility such that the orientation, geometry, layout, and depth of the underground excavation in addition to any engineered barriers provided as part of the underground facility are optimized for that site. The Department shall use as optimization criteria the performance objectives in § 60.111, (c)(2), (c)(3).

(iii) The Department shall design the underground facility so that the effects of disruptive events will not propagate through the facility.

(iv) To assure that shafts and boreholes do not act as preferential pathways for ground-water or radionuclide migration, the Department shall design shaft and borehole seals such that--

(a) The shafts and boreholes are sealed along their entire length as soon after they have served their operational purpose as is practicable;

(b) The sealed shafts and boreholes provide a barrier to radionuclide migration which is at least

equivalent to the barrier provided by the undisturbed rock;

(c) There is effective sealing to the rock contact and the adjacent zone of disturbed rock surrounding boreholes and shafts; and

(d) The shaft and borehole seals can accommodate potential variations of stress, temperature, and moisture, and to provide for radionuclide retardation.

(v) The Department shall place emphasis on multicomponent borehole and shaft seals and use materials that are compatible with the rock properties and other in situ conditions.

(vi) The Department shall design the underground facility to include engineered barriers which protect the waste package from (1) natural events and processes, (2) in situ stresses, (3) chemical attack, and (4) groundwater contact. The Department shall determine the location of the barriers by proper engineering analysis and in situ testing. The Department shall include in the design--

(a) Engineered barriers where shafts could provide access for ground water to enter or leave the underground facility;

(b) Creation of a near-field waste package environment which favorably controls chemical reactions affecting the performance of the waste package or other engineered barriers;

(c) Creation of an emplacement environment which reduces the potenial for creep deformation in the rock and deformation of waste packages; and

(d) Backfill materials as a barrier to ground-water movement into the repository. The Department shall select backfill materials to provide for (1) adequate placement and compaction in underground openings, (2) seals to reduce and control ground-water movement, (3) adsorption of radionuclides, and (4) preservation of favorable properties in the presence of anticipated rise of rock temperatures.

(vii) Thermal and thermomechanical response of the rock

(a) The Department shall design the underground facility to assure that the predicted thermal and thermomechanical response of the rock could not adversely affect the performance of the natural or engineered barriers to radionuclide migration.

(b) The Department shall conduct in situ monitoring of the thermomechanical response of the geologic repository until decommissioning to assure that the thermomechanical response of the natural and engineered features are within design limits. Should these limits be exceeded, the NRC shall be notified and informed of any needed changes or actions.

(3) Design to facilitate retrieval of waste

The Department shall design the underground facility to facilitate retrieval of waste in accordance with §§60.111(a)(3). To accomplish this the Department shall design the underground facility to assure structural stability of openings and minimize ground-water contact with the waste packages and design an emplacement environment that otherwise promotes waste recovery without compromising the ability of the geologic repository to meet the performance objectives.

(4) Design of openings

(i) The Department shall design subsurface openings to assure stability throughout the construction, operation, and retrieval periods. If support systems and structures are required for stability, the Department shall design them to be compatible with long-term deformation characteristics of the rock and to allow for subsequent placement of backfill.

(ii) The Department shall design openings to minimize the potential for deleterious rock movement or fracturing of overlying or surrounding rock. The Department shall optimize opening design, including shape, size, orientation, spacing and support materials with respect to natural stress conditions, deformation characteristics of the host rock under thermal loading, and the nature of weaknesses or structural discontinuities present at the location of the opening.

(5) Lining of Subsurface Excavations

The Department shall line subsurface excavations in areas that require:

(i) A positive control of water or gas inflow from aquifers or other porous zones;

(ii) support for zones of weak or fractured rock;

(iii) anchorage for equipment or hardware.

(6) Shaft conveyances used in waste handling

(i) The Department shall consider shaft conveyances as a system important to safety.

(ii) The Department shall design hoists with mechanical geared lowering devices that preclude cage free fall.

(iii) The Department shall design hoists with a reliable cage location system that provides direct signals from all levels in the shaft. The Department shall design and construct final unload points which are controlled and verified by local position detectors.

(iv) The Department shall design shaft loading and unloading systems with a reliable system of interlocks that will fail safely upon malfunction. The Department shall include in the design two independent indicators to indicate whether waste packages are in place, grappled, and ready for transfer.

(7) In situ testing and design verification

(i) During the early or developmental stages of construction an area the Department shall excavate and reserve an

area for in situ testing of borehole and shaft seals, backfill, and thermal effects and waste-rock interaction. The Department shall initiate the testing as early as is practicable and continue as long as necessary to demonstrate that performance is within design limits.

(ii) The Department shall insure that the contact between lining and the rock surrounding subsurface excavations does not jeopardize repository containment by providing a preferential pathway for ground-water or radionuclide migration.

(iii) During repository construction and operation the Department shall conduct a continued program of surveillance, testing, measurement, and geologic mapping to ensure that design parameters are verified and to provide additional data to confirm the isolation and containment characteristics of the seals and the underground facility. The Department shall measure and monitor changes in subsurface conditions on a regular basis.

The Department shall, as a minimum, make measurements of rock deformations and displacement, changes in rock stress and strain, water inflow into subsurface areas, changes in ground-water locations and conditions, host rock pore water pressures, and host rock thermal and

thermomechanical response as a result of development and operations of the geologic repository. The Department shall compare such measurements and observations with original design bases and assumptions and if significant differences exist the Department must determine modifications to design or construction methods and report to the Commission the recommended changes.

(9) Compacted Backfill Test Section

To verify performance requirements intended in the design the Department shall establish, before any backfill placement is initiated, a program for placement, sampling, and testing of the backfill section. If the result of testing and observations made at the test section are different from the original design intent then the Department must analyze the need for changes and report the recommended changes to the Commission.

(10) Water control during operations

(i) The Department shall provide water control systems which are of sufficient capability and capacity to minimize the potentially adverse effects of ground water or service water (including that supporting excavation) intrusion on structures systems and components important to safety, waste emplacement operations, the performance

of waste packages as engineered barrier to radionuclide migration, or effect retrieval capability.

(ii) The Department shall design the water control systems to monitor and control the quality and quantity of water flowing into or from the repository.

(iii) The Department shall provide water control storage capability, modular designs, or other provisions to assure unexpected inrush or flood can be controled and contained.

(iv) The Department shall construct water control systems to control water from waste emplacement areas and shall keep those systems separate from the systems controlling water in the excavation areas.

(v) If aquifers or water bearing structures are encountered during construction then the Department must use pre-grouting in advance of excavation.

(d) General design requirements for construction

The requirements in this section include general design criteria which are important for construction.

(1) Site Development and Excavation Sequence

(i) The Department shall plan the exploratory program so that construction takes advantage of exploratory boreholes, shafts, and excavations in order to minimize the total number of penetrations within the geologic repository operations area.

(ii) The Department shall coordinate the design of the geologic repository with site characterization activities to assure that boreholes necessary for site characterization are located at future positions of shafts or large unexcavated pillars.

(iii) If critical host rock and other site specific design assumptions cannot be verified from boreholes, geophysical measurements, and/or an exploratory shaft and initial excavation, then the Department must establish a pilot program to further characterize the entire volume to be occupied by the underground facility and to verify critical host rock and site specific design assumptions prior to design finalization and waste emplacement.

(iv) The Department shall design the subsurface facilities with sufficient flexibility to ensure that designs are compatible with specific site features encountered

during pilot development and excavation, and to facilitate the use of tests and monitoring system outputs.

(2) Construction Management Program

The Department shall establish a construction management program which is sufficient to assure that construction activities do not adversely affect the suitability of the site or jeopardize the containment capabilities of the underground facility. The Department shall include in the program means to assure that the underground facility is excavated and constructed as designed.

(3) Excavation techniques

The Department shall assure that methods used for excavation will neither create a preferential pathway for ground water or radioactive waste migration, nor increase the potential for migration through existing pathways. The Department shall use to the extent practicable mechanical excavators, boring machines and other nonblasting methods. If blasting is required for excavation, the Department must use methods specifically designed for each phase of the work that minimize fracturing of the surrounding rock. In this program the Department may include the use of pilot bores and tunnels and delay systems designed to minimize the amount of explosives detonated simultaneously. If blasting is utilized

the Department must utilize controlled perimeter blasting such as the smooth blasting or preshearing techniques and cushion.

(4) Control of explosives

If explosives are used, the Department must meet the provisions of 30 CFR Part 57.6 as minimum safety requirements for storage, use and transportation. The Department shall use electrical detonation. If the rock contains open joints or fractures the Department must use cartridge or packaged explosives only.

(5) Support structures

If temporary support structures are used the Department must assure that they do not impair the placement of permanent structures or the ability of the repository to contain wastes by adversely affecting the ability to seal excavated areas.

(e) Records and Reporting Requirements

(1) Identification and reporting of adverse features or conditions.

(a) If any feature listed under §§60.122(b) (Adverse Conditions) is encountered during excavations then the Department must report it to the Commission within 5 days. The Department must analyze the effect of such features or conditions report as required in §§60.122(b).

(2) Construction and mapping records

The Department shall maintain and preserve records which provide a complete, documented history of the repository construction.

The Department shall include in the records the following--

(i) surveys of underground excavations and shafts located with respect to readily identifiable surface features or monuments;

(ii) materials encountered;

(iii) geologic maps and profiles;

(iv) locations and amount of seepage;

(v) details of equipment, methods, progress and sequence of work;

(vi) construction problems;

(vii) anomalous conditions encountered;

(viii) instrument locations, reading, and analysis;

(ix) location and description of support systems;

(x) location and description of dewatering systems; and

(xi) details of seals used, methods of emplacement, and location.

The Department shall perform and plot surveys and geologic mapping as the work progresses.

(3) Retention of cores and logs

The Department shall retain on site, until decommissioning, all cores from all exploratory borings drilled during site selection, site characterization, construction, and operation. The Department shall store the cores in durable boxes housed in a weatherproof building. The Department shall arrange the cores to be readily available for inspection. The Department shall store in the same area logs of the borings, including geophysical logs.

(f) General design requirements for subsurface operation

The requirements of this section apply during repository operations.

(1) If concurrent excavation and emplacement of wastes are planned, then the Department must design the repository in modules which are sufficiently separated to assure that

excavation activities could not impair emplacement operations or adversely affect retrieval.

(i) If interconnections are provided, the Department shall design each module to be sealed and isolated from all other modules in the event of an accident and so that waste can be safely retrieved if necessary.

(ii) The Department shall separate ventilation systems supporting excavation and waste emplacement.

(iii) The Department shall coordinate excavation rates and emplacement rates and schedules to assure physical separation of activities and further assure that handling and emplacement operations are not adversely affected by the excavation activities.

(2) Ventilation

(i) The Department shall design ventilation system(s) which are capable of controlling the transport of radioactive particulates and gases within and from the subsurface facility. The Department shall design and test the ventilation system to assure that radiological exposures during operations will not exceed the limits of 10 CFR Part 20.

(ii) The Department shall design ventilation systems to permit occupancy of all areas as required either for normal operations, cessation of operations, or for maintaining the facility in a safe condition.

(iii) The Department shall design the ventilation system(s) to be capable of accommodating changes in operating conditions such as variations in temperature and humidity.

(iv) The Department shall design the ventilation system(s) to protect against the intake and accumulation of radioactive materials and hazardous substances.

(v) The Department shall design ventilation system(s) for under normal and accident conditions.

(vi) The Department shall design the ventilation system to assure by means of redundant equipment, fail safe control systems or other provisions, the continuity of ventilation.

(3) Waste handling and emplacement

(i) The Department shall design the systems used to handle, transport, and emplace radioactive wastes to have positive, fail safe designs to preclude impairment

of the performance of the waste packages as a barrier to radionuclide migration and to minimize radiological hazards.

(ii) The Department shall design the handling systems for emplacement and retrieval operations to minimize the potential for operator error.

(iii) The Department shall demonstrate that the handling equipment and systems for emplacement and retrieval operations are effective under in situ conditions prior to the start of waste emplacement operations.

(iv) The Department shall inspect any holes that are bored to receive waste prior to waste emplacement, to assure the absence of adverse conditions that could jeopardize the integrity of the waste package.

(4) The Department shall determine by analysis the specifications of waste loading and waste spacings. The Department shall make the analysis prior to receipt of waste. The Department shall include in the analysis--

(i) Effects of the design of the geologic repository on the thermal and thermomechanical response of the host rock;

(ii) The characteristics of the site and the host rock that affect the thermal response of the host rock;

(iii) Site and host rock features that affect the thermo-mechanical response of the seals and underground facility, including but not limited to: behavior and deformational characterictics of the host rock, the presence of insulating layers, aquifers, faults, orientation of bedding planes and the presence of discontinuties in the host rock;

(iv) The effect of temperatures and stresses on the performance of the waste packages and other engineered barriers; and

(v) The extent to which fracturing of the host rock occurs during temperature increase and decrease cycles.

§ 60.133 Waste Package and Emplacement Environment

(a) General Requirements

The Department shall insure that waste packages are designed and fabricated to so that the performance objectives of §§ 60.111 will be met. To demonstrate that the waste package meets these objectives, the Department at a minimum, shall do the following--

(1) Perform comparative evaluation of several candidate waste form and packaging combinations considering the proposed emplacement environment to optimize the waste package performance;

(2) Provide reasonable assurance that the in situ chemical, physical, and/or nuclear properties of the waste package and/or its interactions with the emplacement environment will not compromise the function of the waste packages. Supporting analyses shall include, but not be limited to, evaluation of the following factors: solubility, oxidation/reduction reactions, corrosion, gas generation, thermal effects, mechanical strength, mechanical stresses, radiolysis, radiation damage, nuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions;

(3) Provide reasonable assurance that the in situ chemical, physical, and/or nuclear properties of the waste package and/or its interactions with the emplacement environment will not compromise the function of the site or engineered elements of the geologic repository. The supporting analyses shall include, but not be limited to, evaluation of the following factors: solubility, oxidation/reduction reactions, corrosion, gas generation, thermal effects, mechanical strength, stress, radiolysis, radiation damage, nuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions;

(4) Design and fabricate the waste packages to promote safe handling during transportation, handling emplacement, and retrieval; and

(5) Test the waste packages, as appropriate, to ensure that the requirements of paragraphs 60.133(a)(1) and 60.133(a)(2) of the Performance Objectives are met.

(b) Waste Form Requirements

The Department shall accept waste for disposal only if it meets the following criteria--

(1) Solidification. All liquid radioactive wastes must have been converted to a dry solid and placed in a sealed container before transfer to the repository;

(2) Stabilization. Finely divided waste forms must have been stabilized (for example, by incorporation into an encapsulating matrix) to limit the production and availability of respirable fines during any accident condition to a level as low as is reasonably achievable;

(3) Free Liquids. The Waste package must contain no free liquids;

(4) Combustibles. All combustible radioactive wastes must have been reduced to a noncombustible form unless the associated packaging is such that a fire involving a single package will not--

(i) Compromise the integrity of other packages;

(ii) Result in radiation exposures or releases of radioactive materials in excess of permissible levels; and

(iii) Adversely affect any safety related structures, systems, or components.

(5) Explosive, Pyrophoric, and Toxic Materials. The Department shall insure that there are no explosive or pyrophoric materials in the radioactive waste, nor are there chemically toxic wastes that could compromise either the operation or performance of the repository or adversely affect operator safety.

(c) Container and Packaging Design Requirements. Containers shall meet the following criteria--

(1) Physical Dimensions and Weight. Each container has been designed and fabricated to permit safe handling at the repository during operations and if necessary, during retrieval prior to repository decommissioning;

(2) Codes and Standards. The container and packaging shall be designed, fabricated, and tested, to the maximum extent practical, in accordance with generally recognized codes and standards[1] except as authorized by the Commission upon demonstration by the Department that this would result in hardship or unusual difficulties without a compensating increase in the level of quality and safety;

(3) Surface Contamination. The amount of removable radioactive surface contamination on the exterior of the package is such that exposure to operational personnel will not exceed the values in Part 20 of this chapter; and

(4) Unique Identification. A label or other means of permanent identification must be provided for each container. The identification shall not impair the integrity of the container and shall be permanently applied in such a way that the information will be legible at least to the end of the retrievable storage period. Each container identification shall match the container with its permanent written records.

[1]Regulatory guides describing generally acceptable codes and standards for containers of similar type and function will be issued.

§ 60.135 Retrieval of Waste

The Department shall design and construct the geologic repository operations area to permit retrieval of all waste packages, mechanically intact, if retrieval operations begin within 50 years after all of the waste has been emplaced and if the geologic repository has not been decommissioned. The design of the geologic repository operations area shall provide for retrievability of the waste within a period of time that is about the same as that in which it was emplaced.

§ 60.137 Monitoring Programs

The Department shall initiate a system of monitors during site characterization. The Department shall maintain and supplement these monitors, as appropriate, throughout the period of institutional control. The Department shall design the monitoring systems to verify that the performance objectives of Section 60.111 are being achieved.

The Department shall design, construct and operate the monitoring systems so that--

(a) They do not adversely affect the natural and engineered elements of the geologic repository;

(b) They provide baseline information on those parameters and natural processes pertaining to the safety of a candidate site that may be caused by site characterization activities; and

(c) They monitor changes from baseline condition of parameters which could affect the performance of a geologic repository operations area's natural or engineered barriers to radionuclide migration during construction, operation, and after decommissioning.

SUBPART F - PHYSICAL PROTECTION

(Reserved)

SUBPART G - QUALITY ASSURANCE

§ 60.171 Quality Assurance Program

(a) As used in this part, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

(b) The Department shall implement a quality assurance program based on the criteria in Appendix B of Part 50 of this chapter. The quality assurance program shall apply to all activities affecting

the safety-related functions of those structures, systems, and components that prevent or mitigate events that could cause unreasonable risk to the health and safety of the public. These activities include exploring, designing, fabricating purchasing, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, monitoring, repairing and modifying.

SUBPART H - CRITERIA FOR PERSONNEL TRAINING

(Reserved)

SUBPART I - EMERGENCIES AND EMERGENCY PROGRAMS

(Reserved)

Dated at Washington, D.C. this 5th day of May, 1980.

For the U.S. Nuclear Regulatory Commission

Samuel J. Chilk
Secretary of the Commission