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COLLEGE OF ENGINEERING

DEPARTMENT OF NUCLEAR ENGINEERING

February 20, 1980

Mr. Kellog Morton
Chief, Research Contracts Branch
Division of Contracts
United States Nuclear Regulatory Commission
Washington, D.C. 20555

RE: NRC Contract No. NRC-04-80-217

Dear Sir:

Attached is a reproducible copy of the panel final report on the technical review of Draft 10 CFR Part 60, Subpart E-technical criteria. Six additional copies are being sent separately to NRC based on telephone instructions from Dr. Larry Doyle, RES. These are being distributed as follows:

Dr. Larry Doyle, RES, - 1 copy
Dr. Craig Roberts, SD - 2 copies
Dr. [illegible]k Martin, WM/LIC - 3 copies

Due to the lateness in receipt of the contract a fiscal report will be delayed and will be submitted as soon as final billings are received from the involved vendors.

Sincerely,

Stanley Davis

Stanley Davis
Panel Chairman

Copies to:

RES
WM/LIC
SD

8007140611

Chapter 1

Introduction

A panel of dist ̓.guished representatives of the scientific community (Appendix A) was convened in Tucson, Arizona on January 9-11, 1980, for the purpose of conducting a technical review of the Nuclear Regulatory Commission (NRC) Draft Regulation 10 CFR Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories Subpart F-Technical Criteria. This does not include that portion of 10 CFR Part 60 relating to canister construction and emplacement which was excluded from review.

This review was sponsored by the NRC under contract through The University of Arizona with Dr. Stanley Davis, Professor of Hydrology and Water Resources, as the Panel Chairman and Director of the review and Dr. James McCray, Adjunct Associate Professor of Nuclear Engineering, as the Associate Chairman.

The panel received several briefings from the NRC and after a question and answer period adhered to a previously planned schedule (Appendix B).

A guidance paper including administrative procedures for the review was distributed by the Panel Chairman (Appendix C). The General Items listed in the checklist of Appendix C were developed by the panel into Chapter 2, "General Comments."

The panel was divided by the chairman into two groups to expedite the review of the Draft 10 CFR Part 60. One group, composed primarily of earth scientists, reviewed the hydrogeologic aspects of the regulation and the other group, primarily engineers, reviewed the engineering and operations parts of the regulation. The complete panel then reviewed the comments of both groups which resulted in Chapter 3, "Specific Issues and Comments," Appendix D, "Specific Comments" and Appendix E, "Annotated Draft Regulation 10 CFR Part 60 Subpart F-Technical Criteria."

In a number of cases the panel was divided in the acceptance or rejection of a comment. Chapter 2 and 3 additionally record the degree of acceptance of each statement when there was a consensus of panel opinion. Those statements, where there was not a panel consensus, are assembled in Appendix F, Significant Conflicting Opinions.

There has been a minimum of editing in the numbered parts of Chapters 2 and 3 and in Appendix D in that these portions were from individual panel input and the particular part was agreed or disagreed to by the panel on a technical basis only. It was decided to publish those parts as they were considered and not try to rewrite them for fear of altering a meaning or interpretation of a panel member.

Chapter 2

General Comments

The objective of this chapter is to provide the panel consensus on a number of important considerations relative to the management and regulation of high level radioactive waste in a deep geologic environment. Most of the comments are directly pertinent to Draft NRC Regulation 10 CFR Part 60. The method of presentation is the subject heading, panel consensus and the panel vote on the comment.

2.1 Intent and Objectives of 10 CFR as Stated

The Nuclear Regulatory Commission is to be commended for realizing the urgency and dire need for this regulation and for taking the initiative to develop it.

The multibarrier concept and the common sense approach to the establishment of performance objectives is a practical way to achieve a viable regulation that maximizes public safety within realistic parameters.

14 Agree 1 Disagree

2.2 Clarity of Expression of 10 CFR Part 60

Most of the draft regulation is clearly presented; however, several parts can lead to confusion. The attempt to define the special use of certain words or phrases in Part 60.3 is a step in the right direction; but, the list of definitions is not complete and this deficiency leads to a lack of clarity in several sections. An example of this is that the differences among the control zone, operations area and exclusion area are not clear.

Such terms as "reasonable assurance," "reasonable evidence" or "reasonable potential" in a regulation make it extremely difficult to interpret by the designer, engineer or the enforcer of the regulation.

Care should be taken to avoid double negatives such as in Part 60.122 (b) (5) (i) and the complex structure of Part 60.122 (c) (2) p 20 and Part 60.122 (c) (3) p 21.

15 Agree 0 Disagree

2.3 Nature of Performance Requirements Specified

10 CFR Part 60, draft rules for deep geologic disposal of high level waste, has to define clearly the performance objectives. The performance objectives currently are represented in two parts.

(1) EPA acceptable risk objectives

(2) NRC performance objectives

It is our understanding that both should be met even if for a particular site one of the above is more stringent than the other. The major difficulty of both objectives is that the performance of materials forming the earth's crust are subject to considerably more uncertainty than fabricated engineered components. Can these uncertainties be reduced to a level that will assure the health and safety of the public and at the same time provide a route by which engineers, and scientists attempting to locate,construct and then operate a deep geologic repository even hope to find,and prove adequately,that the repository will meet those objectives?

The classical method of evaluating the safety of a structure, in the earth's crust, has been to apply conservative engineering experience and destructive testing and through the use of models determine a limiting criteria (failure point). Subsequently a factor of safety could be applied which really, particularly in geotechnical and mining engineering, is a factor of ignorance.

Such methods cannot be applied to many critical components of a repository since we have not sufficient time to measure the response of all the components in a repository,let alone test the geological environment to failure. If conservative criteria based on good engineering practice is relied upon,then the problem is likely to arise that such criteria when coupled will be excessively conservative and disqualify many if not all potential sites. What then is the solution? It is our opinion that the practical alternative lies in the use of uncertainty analysis. This method of analysis allows quantitative statements about both subjective (expert opinion) and objective facts or data, and also allows incorporation of uncertainties of the predictive modeling in a rigorous manner. Perhaps most important it allows for alternatives to be compared and then decisions to be made. It must be emphasized that the only prerequisite is that an acceptable risk criterion in terms of dose or equivalent measure be provided by comparison of alternatives (i.e., surface disposal, do nothing, etc.). This method will prevent arguments except about the technical factors which are significant since those factors which may have no negligible impact can be demonstrated to be insensitive to the overall perceived performance.

Uncertainties in geological performance may be broken down into at least the following types:

(1) Uncertainties in the methods used to determine data

(2) Uncertainties in the basic physical laws - fracture flow laws

(3) Uncertainties in the ability to model physical processes

(4) Uncertainties associated with undetected features.

If we carry out enough tests we may produce substantial scatter from which we may form frequency distribution. Uncertainty should then be combined with such distributions. Point estimates only tell part of our perception of reality. This may sound like a perfectly reasonable approach but what are the consequences of using such an approach in the licensing environment?

1. When an area is naturally characterized there will be substantial uncertainty about the perceived performance of a proposed repository. Thus it is reasonable that the distribution of output of models etc. will be broad (i.e. significant uncertainty). We should ask at that time for DOE to also detail in site specific terms, what they propose to do, if they continue, in order to reduce the critical (or sensitive) uncertainties. Thus, the repository in that stage of licensing will be able to present two performances: that currently perceived and, that it is expected to have as a result of future operations, exploration etc. If the latter cannot satisfy appropriate long term risk objectives then no further action should proceed with that site. Clearly it may be possible through technological understanding to reopen that site since critical technical review would then demonstrate that objectives can be reached.
2. Can consensus be reached? It is our opinion that it can, given knowledge of the data and experience in the particular field in question.
3. Has this process, clearly different from statistics, been used in courts or similar environments? The answer is that there are several case histories where this method has successfully been used in courts.

Finally, while this approach is perhaps apparently cumbersome it forces rigorous and complete statements of knowledge. If this methodology is more clearly specified than we have had the time, and perhaps the ability, to do here, then we believe NRC will have made a major step in the development of repositories. The use of conservative point estimate requirements are not incompatible with this method if the experts are satisfied that there is a very small degree of uncertainty or that the particular factor or objective is insensitive to the overall performance. In the latter cases, the use of conservative engineering judgements is clearly important since sites will substantially reduce the amount of unnecessary investigation and proof on the part of DOE. At the very least it is our opinion this methodology requires serious consideration.

___13___ Agree ___2___ Disagree

2.4 Data Needed to Meet Performance Objectives of 10 CFR 60

Comment: All data needed may not be collected during the candidate site investigation (DOE) and subsequent feasibility site characterization phase (NRC) which are performed prior to application for licensing. Some critical data likely will be collected during the construction and early operational phases.

Data collected on the geologic, seismologic, and hydrologic processes, rock properties, and other aspects for design purposes should utilize the minimum quantified values and not only the statistical average. At least four categories of data are needed to construct a 10,000 yr. geologic repository with a minimum 1,000 yrs. effectiveness for the engineering elements.

Modeling: Forecasting during investigation phase. One should use much of data generated with caution. Does it reflect the minimum geologic/hydrologic etc. set of circumstances that may occur? Any probabilistic analysis should be based on natural conditions/site specific, not a broad state wide/USA base.

Judgement and State of the Art/Experience: Rely strongly on this source of factual data, in addition to modeling/theoretical data generated.

Design: Further quantification of some natural parameters and engineering elements are needed. Is the design workable or are modifications required?

Verification/Tests and Additional Data During Construction and Early Operation: In situ and 'as constructed' data that reflect interaction of geologic and other processes/parameters and site environs dictate modifications to designs from these data.

Good engineering practice/state of the art for exploration, design, construction, and operation of a geologic repository should be defined in 10 CFR 60 coeument.

___10___ Agree ___5___ Disagree

2.5 Suggest Numerical Criteria where Appropriate

Specific numerical criteria generally are appropriate in describing the performance of the repository or its components, providing of course that the numbers represent realistically achievable goals. However, specific numerical criteria are generally inappropriate if they designate the design for a desired performance. For example specifying the length of time a containment canister should retain the waste is appropriate; however, the designation of the intrinsic permeability and effective porosity of the repository horizon are not. The latter should be replaced by time to travel to an appropriate measuring point or perhaps a time distance criteria. Even a velocity of transport would be an improvement, but still less than completely satisfactory. Other numerical criteria, such as population densities are judgement decisions and also probably are appropriate.

Specific discussions of many of the numerical criteria have been addressed in the specific comments.

___14___ Agree ___1___ Disagree

2.6 Exclusion Area - Control Zone

The geologic repository operations area is the area under which the radioactive materials will be placed. If the area is selected according to the geologic and hydrologic criteria specified in the regulations and if the construction of the repository follows the regulations then a control zone provides a fourth level of protection. The statement on page 11 that a control zone "shall at a minimum extend to a horizontal distance of 2 kilometers," therefore, seems to be excessive.

Admittedly, deep excavations immediately adjacent to the operations area should be prohibited, but the extent of the control zone should be established for each site after the characteristics of the site have been determined.

If the site selection process has been followed, the rules of a 2-kilometer control zone should be the maximum rather than the minimum.

This applies also to the depth of the control zone; the 1-kilometer depth should be a maximum rather than a minimum.

__9__ Agree __6__ Disagree

Comments of Disagree:

2.7 Research Needed to Support, Improve, or Identify Technical Criteria

This note excludes consideration of purely site-specific research and research for engineered components:

1. There is a conflict between the requirements (pp. 21, 22) that "the geological repository shall be investigated in sufficient scope and detail, etc.," and the requirement that information be obtained "with minimal adverse effect, etc." As an aid toward resolution of this delemma, R & D should be pursued on network design, worth-of-data, effects of uncertainty in parameter estimation, and in the application of statistical analysis to bound uncertainties.
2. The repository site and its environs are expected to delay possible migration of radionuclides by sorption and other chemical processes. The principal method for calculating delay is through the use of the distribution coefficient, Kd. However, this coefficient is based on over-restrictive assumptions. R & D should be pursued in geochemistry to obtain relationships that have a sounder physical basis than is presently the case.
3. Considerable effort has been devoted toward obtaining numerical solutions of the governing equations for mass transport through porous media. Insufficient effort has been devoted toward determining the validity of the governing equations themselves.

15 Agree 0 Disagree

2.8 How Much Field Work, and Particularly How Much Subsurface Exploration, is Required for Characterization?

The goal of field work is to locate a suitably feasible site/volume of host rock. Surface geology and geophysical investigations may be able to characterize an overall history of a rock mass, homogeneity or average consistency of bedding, and overall bulk properties. But as depth from the surface increases, the ability of geophysical tools confined to the surface to interpret correctly small heterogeneities or properties of specific volumes of rock becomes wholly inadequate.

Surficial investigations in a sedimentary section or one of basalt flows may suggest to the hydrologist possible generalized flow regimes. The very important effects of vertical barriers or vertical communication through faults and open joints can only sometimes be suggested by geophysical means, if at all.

Thus site characterization must involve subsurface penetration. The two somewhat different tasks of site characterization - far field and near field - require different detail and different approaches.

Far field investigations, which for speed, economy, and cost-effectiveness would be performed via boreholes, outcrops/excavations and indirect means would be used to verify, correct, and extend the three-dimensioned visualization of the earth in the area of detailed investigation. Aquifers can be subjected to tests and if relatively uncontaminated waters can be obtained from such aquifers, geochemical analyses can yield apparent water ages and possibly correlations from well to well. Petrologic examination of well cores are integral parts of such correlations. If the well is to characterize unlayered, fractured media - as in a pluton or some metamorphic rocks - standard, proven methods of characterization are not available. Emphasis in such cases is fracture characterization and detection of water-transmitting fractures, and possibly the effect of depth on such fractures. Regardless of the geologic medium, the important factor of stress field can be determined.

From the picture obtained from off-site wells, a specific candidate volume of rock can be selected for feasibility investigations if the system appears to be suitable. A well sunk at the site of a proposed shaft can yield the information outlined above. But here the limitations of well-bore information become critical. A vertical borehole can say little about vertical and near-vertical fractures or fracture systems; a borehole of ~ 20 cm diameter doesn't intersect a representative volume of a fractured rock; and the drilling of the well may introduce contamination that renders impossible unequivocal geochemical interpretation of the waters collected.

Thus for near-field feasibility site characterization, a shaft must be sunk to the candidate host rock and drifts mined within the candidate volume to intersect the expected fracture sets and determine the insitu rock properties. Drifts may be preceded by horizontal boreholes from the shaft at the depth of interest, in the same manner as the shaft was preceded by a vertical borehole. Relatively uncontaminated water samples can be obtained in the underground workings, since the water will be moving towards a sink at one atmosphere pressure for an extended time. Further exploration of the candidate volume can be made via addititional horizontal boreholes from the workings. Drifts will be necessary, depending on the number and spacing of expected fracture sets throughout the length of the candidate volume.

If field information shows homogeneity on the scale deemed important and geochemical, hydrological interpretations are essentially confirmed as more volume is intersected and more data gathered, then the site can be said to be feasible and "characterized."

__15__ Agree __0__ Disagree

2.9 What Part Should Numerical Modeling Have?

Instead of numerical models, we prefer to talk about mathematical models. In principle at least, the past and present state of a system can be surmised from direct or indirect observation. When it comes to future states, there are only three options: (1) speculate; (2) forecast (extrapolate) on the basis of past observations; (3) predict on the basis of physical laws expressed in a physically-based mathematical model. Item (3) is preferred, but it requires a complete understanding of system behavior. In the absence of such understanding, (3) must be used in conjunction with doses of (2) and even (1). In any event, some type of mathematical modeling is indispensable to foresee future events.

The current state of the art in groundwater modeling is such that models cannot be relied upon to predict system behavior under nonsteady state conditions with any reasonable accuracy over a period exceeding a few years, or at best, a few decades. Since the transport of radionuclides is a nonsteady (transient) process, it is subject to the above restriction. Thus, one should not expect existing models to provide him with reasonably accurate predictions of, say, radionuclide concentrations in different parts of the system at different times.

What, then, can such models do for us ? Here are a few answers:

(A) Indicate possible trends of future system behavior. For example models can help answer questions such as: At what rate will radionuclide concentrations tend to change at various points? What will be the rate of temperature variation at various points? What will be the general flow pattern around the repository? The answers should be interpreted more in a qualitative than quantitative sense.

(B) Indicate extreme behavioral patterns: For example, one could ask, what is the shortest amount of time for the radionuclides to reach a given concentration at a given point, taking into account worst conditions such as no sorption, high permeability, etc.

Various hypothetical scenarios can be investigated, but there is always a danger of interpreting the results of such mathematical games as a reflection of reality.

(C) Perform parametric studies to investigate effect of different parameters and assumptions on model predictions and hypothetical systems behavior. This not only helps gaining insight into the manner in which the system may work, but also provides guidance as to which system properties should be measured in the field, at which locations, and how often.

In general, the models are no better than the assumptions and data which enter into them. Since these are generally uncertain and insufficient, the models will never represent the system adequately. Current practice in reservoir engineering and aquifer hydrology is to update the model every few years, otherwise, the model output tends to diverge from observed behavior. This should speak for itself.

In conclusion, models are extremely useful and important, but should not be relied upon for accurate, or even remotely reliable, predictions into the distant future. They must become part of our engineering arsenal, but should not replace engineering judgement and experience.

___14___ Agree ___1___ Disagree

2.10 How Should the Problem of Natural Resources Be Handled?

Our reaction to your definition of "resource" on page 4 of 10 CFR Part 60 is that it is too limited. Resource is apparently being considered in the context it might be "mined" in the future and consequently impinge on the integrity of the operational zone rather than concern being with economic loss. We concur with the latter for geologic resources but are concerned that the definition is too limited. Natural resource is a more comprehensive term and includes water, biological, agricultural and recreational resources. Although these may be the purview of NEPA we see no reason why they should not be mentioned in a limited fashion.

Further, we have not seen the charter of NRC and would be surprised if the persons developing it restricted it to the effects of ionizing radiation to man. This was the intent in the Atomic Energy Act and as a result of this restriction there were considerable problems at a later date following the "Calvert Cliffs decision." As NRC has ecologists on its staff and has expressed concern for the environment (including antiquities) in other documents, why not insert a single line expressing the concern in 10 CFR Part 60?

It is believed that [iii, pg. 14] is a consideration but it should be only a minor restriction in this section. The insertion of "reasonable potential" is impossible to define, especially for the distant future, eliminating the area (including horizontal and vertical distance from the repository) may be difficult; and last, but not least, this matter is related to site ownership and control and can, to some extent, be mitigated at time of closure.

Excessive restrictions will probably eliminate from site consideration areas that are suitable for HLW disposal. There must be a trade off in site selection. NRC staff is aware of this but will a person in another agency be over restrictive trying to follow 10 CFR Part 60?

Surface resources (e.g., agricultural, recreational) may also have an effect at some future date on the integrity of the repository including monitoring.

___14___ Agree ___1___ Disagree

2.11 How Much Reliance Can Be Placed on Human Institutions for Monitoring Enforcing Exclusion and Remedial Action?

In the short term human institutions can be effective. For the last half of one generation, for the next and, in part, for the third, society will "remember" perceived concerns and the essential control functions will be effectively discharged. Unless the concerns are reinforced by a succession of mishaps, however, the "primitive" concerns become diminished in perceived priority and provision for control administration suffers severely. Experts in political science in numerous recent "hearings" have maintained that not only can priorities within a societal entity change radically within a one or two century period - (five to ten generations), but it is impossible to assure that the basic operational institutions of a given society will not change radically within a one or two century time scale.

It is probably impossible, therefore, to ensure that a society will be able to exercise a consistent and continuing policy of facility control for a period of more than a century or two.

__13__ Agree __2__ Disagree

2.12 How Should the Problem of Accidental Intrusion on the Body of Emplaced Wastes Be Handled?

This scenario contemplates that a few centuries after waste emplacement and repository facility closure when the surface facilities have been decommissioned and the significance of surface "markers" has been forgotten, some human activity, exploratory drilling for mineral resources for example - inadvertently penetrates the storage area, brings to the surface significant quantities of TRU wastes which are unrecognized until after they have become widespread throughout significant segments of the then economy's personnel with disastrous effects. Surface markers - short of a pyramid of Gizeh - are transitory and cannot be relied upon for multi-century sentinel duty. Underground markers, however, should be feasible that would warn any unwary driller or excavator that the site of his operations was highly peculiar at the least and conceivably warn him that it was hazardous as well.

A research project or workshop on the subject would appear to be warranted.

__12__ Agree __1__ Disagree __2__ No Opinion

2.13 What Requirements for Retrievability Should be Specified?

Two aspects to be considered:

1. How easy should retrievability be?
2. How can the desired retrievability be obtained with an acceptable reduction in isolation?

Have to find a balance between two extremes:

Maximum retrievability	Minimum retrievability
Maximum accessibility	Minimum accessibility
Minimum isolation	Maximum isolation

1. What is the desirable "ease of retrievability?"

The importance of isolation dominates all discussions on HLW disposal, so that good arguments are needed to justify retrievability, which necessarily implies some reduction in isolation. A rationale for retrievability is not included in 10 CFR 60 nor in A 60. Retrievability has to be justified, presumably in terms of the likelihood that it might become necessary.

2. How can the desired retrievability be obtained with an acceptable reduction in isolation?

Needed are access to containers, container handling facilities and suface receiving and storage.

Access will require maintaining tunnels, deciding on whether or not to use backfill (in tunnels and boreholes), on type of backfill, deciding on seal construction, deciding on ventilation (heat removal) requirements.

All these factors depend on repository rock type and are influenced by length of time for which retrieval is required and by ease of retrieval required.

Tunnel backfill (emplacement rooms - access tunnels):

- Reduction in physical accessibility (can be designed)
- Reduction in tunnel convergence - any reinforcement will require large convergence (soft ground) or stiff backfill

Tunnel seals: construction and material will affect retrievability as well as type of ioslation accomplished, e.g. compare clay (bentonite) with concrete (steel) plugs.

Container and emplacement method:

- size, weight: affected by accepted thermal load
- backpack: heat effects
- rock movements: heat load, stress, strength, creep

Long term tunnel stability: rock type

- stressfield (in situ; excavation; heat)
- long term strength: deterioration (stress; air; heat)
- supports
- instrumentation-monitoring

Ventilation: requires same access as easy retrievability

- may facilitate retrieval by reducing rock and/or backpack deterioration

__12__ Agree __2__ Disagree __1__ No Opinion

2.14 How Much Reliance Should Be Placed Upon Engineering Design:

Engineering design is involved in construction, operation and maintenance of a geologic repository for both surface and subsurface facilities. The design and construction of both facilities, although certainly site dependent, is well within the state of the art. Two components of the subsurface facility deserve special attention: (a) the waste package and (b) the repository structure and engineered elements. The performance objectives for each component require each, individually, to provide containment of radionuclides for the first 1000 years after closure of the geologic repository. Until closure, with the retrievability requirement as part of the design, observation, monitoring and instrumentation will allow either component to be repaired or replaced as part of a dedicated maintenance program. Until closure heavy reliance can be placed upon engineering design.

The critical concern will be with possible changes in material properties and engineering behavior under conditions of elevated temperatures and aging. With a knowledge of the time-dependent properties, the response of any of the engineered components can be assessed for postulated events. The problem lies in determining the time-dependent properties. Certain amounts of testing will give valuable insight to property changes resulting from elevated temperatures. Changes in properties caused by aging will continue to be a matter of significant concern; however data will have been collected during the operational stage to allow property and performance projection into the future.

At the time of closure the geologic media will never have been tested with respect to its ability to provide adequate retardation of emission of radionuclides to the biosphere. However at the time of closure responses of the geologic media to temperature and groundwater changes will have been measured over time and in space (e.g., use of tracers, etc.). It is conceived that during that time engineering properties in response to the changes will have been measured so that if total failure of the engineered system were assumed to occur anytime during the 1000 yr containment period following closure, the ability of the geologic media to provide adequate retardation can be adequately analyzed.

Thus at the time of closure the engineering design will have proved itself. Data collected up until closure will give adequate credibility to project behavior into the future. A worst case can be assumed, i.e., total failure, with data to assess the ability of the geologic media to provide adequate containment.

___15___ Agree ___0___ Disagree

2.15 Monitoring

Monitoring is discussed in Section 60.13F which states:

Period: From time of site characterization through entire period of institutional control. Presumably the period of institutional control is equivalent to the time of continuation of a civilization capable of monitoring, but this should be spelled out.

Character: to be done in such a way as to have no possibility of the monitoring activity contributing to site and/or repository degradation.

Purpose: to assume that site characterization and operation activities have no adverse effects on site or repository properties which add to repository safety; to follow repository behavior after decommissioning.

This rule is fine as it stands and should remain, with only the minor clarification suggested above.

The difficulties arise in carrying out this rule. Specifically what properties will require monitoring and how will they be measured. Properties will vary from site to site, and with different repository operation strategies. Likewise, monitoring equipment will change and develop during the period of site characterization, development and operation. Thus to specify in the rule the properties to be measured and how would be unduly restrictive. Such matters should be placed in a more easily changeable format, a Reg-guide perhaps.

Important properties and monitoring strategies are discussed in the GAIN report.

A major problem will be the availability and reliability of non-destructive and remote monitoring techniques. Research in this area would be most desirable.

__14__ Agree __0__ Disagree __1__ No Opinion

2.16 General Remarks Concerning Ownership and Control of Repository Site

All materials below (to the center of the earth) and above (to the altitude of commercial airline flights) the repository and a 1000-meter peripheral buffer zone shall be owned directly by the United States government through the Department of Energy or successor agencies. During the period of repository construction and subsequent emplacement of radioactive waste in deep repositories, access to the area including the buffer zone shall be limited to authorized personnel. After closure of the repository and decommissioning of surface structures, but during continued monitoring, access shall be allowed only if monitoring installations are protected against vandalism. All permanent habitations, drilling beyond depths of 100 m, deep mining, and other activities which may compromise the containment or potentially endanger future inhabitants of the area should be banned for ever. Substantial monuments designed to withstand natural weathering and vandalism shall be placed on the site to inform future inhabitants of the potential dangers.

12 Agree 3 Disagree

CHAPTER 3

SPECIFIC ISSUES AND COMMENTS

This chapter has a primary objective of identifying controversial statements in the Draft Regulation 10CFR Part 60 and providing the panel concensus concerning these statements. In addition there is included the panel concensus on a number of important comments relative to deficiencies in the current draft regulation. The method of presentation is a series of statements and the panel vote to support the statements.

3.1 Repository Structure and Engineered Elements

A goal should be for containment of all radionuclides for at least 1000 years after closure of the repository assuming failure of the container and expected dissolution of some of the waste soon after closure.

__14__ Agree __1__ Disagree

3.2 Radionuclide Release Rate

After 1000 years, any radionuclides released fron the repository structure will occur at a release rate that will be as low as reasonably achievable and will in no case be greater than an annual rate of one part in 100,000 of the total activity contained within the geologic reposiotry 1000 years after closure assuming expected processes and reasonably foreseeable events.

__10__ Agree __4__ Disagree __1__ No Opinion

3.3 Design for Retrievability

The design of the waste package and repository structure and the stability of the site shall be such that the option to retrieve the wastes would be available if desired, for a period of ~~1000~~ 100 years after completion of nuclear waste storage. per James McCray

__11__ Agree __4__ Disagree

3.4 Retrieval Time

The repository shall be designed so that retrieval of waste could be accomplished in a period of time not greater than the time for emplacement.

__8__ Agree __6__ Disagree __1__ No Opinion

3.5 Adverse human activities: Subsurface Exploration

Control zone shall not be located where:

(i) There is or has been mining, drilling excavation or subsurface exploration for mineral, hydrocarbon, or water resources which provides a permanent pathway to the biosphere and which may perturb the hydrogeolgic framework in a way which could produce significant migration of radionuclides to the biosphere.

__13__ Agree __2__ Disagree

3.6 Adverse human activities: Flooding

Control zone shall not be located where:

(i) There is reasonable potential for flooding of the operations area as a result of human-made impoundments prior to repository closure.

__13__ Agree __2__ Disagree

3.7 Adverse human activities: Groundwater flow

Control zone shall not be located where:

(i) There is reasonable potential for future large-scale inpoundments in the operations area caused by human activity which may affect the groundwater flow system in such a way as to increase significantly the potential for migration of radionuclides.

__14__ Agree __1__ Disagree

3.8 Adverse human activities: Population

Control zone shall not be located where:

(i) There is a population density of 200 persons per square kilometer or greater.

__12__ Agree __2__ Disagree __1__ No Opinion

3.9 Adverse tectonic conditions: Faulting

A control zone shall not be located where:

(i) There is a fault or fracture zone with the last movement during the Cenozoic age, which has a minimum horizontal displacement on the order of a few hundreds of meters and a vertical displacement extent on the order of a few tens of meters.

12 Agree [illegible] Disagree 1 No Opinion

3.10 Adverse tectonic conditions: Earthquakes

A control zone shall not be located where:

(v) There are concentrations of tectonic microseismic earthquake activity of a Richter magnitude of 3 or greater relative to the regional distribution of earthquakes . . .

11 Agree 4 Disagree

3.11 Adverse hydrologic conditions: Flood Plain

A control zone shall not be located:

(i) delete "within the 500-year flood plain."

14 Agree 1 Disagree

3.12 Adverse Ecosystems or Biota:

Add: A control zone shall not be located where there are unique ecosystems or biota in areas of disturbance of the site.

11 Agree 4 Disagree

3.13 Surface and Subsurface Stability

Candidate area. Unless it can be demonstrated that the requirements of Sections 60.110 and 60.111 will still be met, the candidate area shall meet the following criteria to the extent achievable as determined by reasonable evaluations:

Delete 60.122 (c)(1)(i) in that it is too vague and really impossible to define technically.

13 Agree 2 Disagree

3.14 Groundwater Discharge Locations

Canidate area. Unless it can be demonstrated that the requirements of Sections 60.110 and 60.111 will still be met, the candidate area shall meet the following criteria to the extent achievable as determined by reasonable evaluations:

6.122(c)(1)(iii)

Sparse population at the potential groundwater discharge locations (add: if within 10 km of the site).

12 Agree 3 Disagree

3.15 Vertical and Lateral Continuity

Candidate area. Unless it can be deomnstrated that the requirements of Sections 60.110 and 60.111 will still be met, the candidate area shall meet the following criteria to the extent achievable as determined by reasonable evaluations:

60.122(c)(1)(v) b Substitute: "Vertical continuity of at least 50 meters and lateral continuity which exceeds the lateral dimensions of the repository by at least 20%.

11 Agree 4 Disagree

3.16 Nonpotable water

60.122(c)(2) Control Zone . . . the control zone shall meet the following criteria in addition to the criteria of Section 60.122(b)(1):

Delete (vii) "Nonpotable water quality in the host rock and surrounding confining units."

15 Agree 0 Disagree

3.17 Host Rock Criteria

60.122(c)(3) Repository horizon:

Comment: Panel agrees that there are major problems in (i) and (ii). For example, fractured rock is different than non-fractured rock and extreme values of intrinsic permeabilities may be equally as important as average values. The requirement of effective porosity less than one percent of the total volume is of little value. The requirement in (iii) of a minimum depth of 300 meters seems without scientific explanation.

14 Agree 1 Disagree

3.18 Extent of investigation

60.122(d) Site Evaluation

(1) Candidate Site Investigations

. . . It is expected that the horizontal extent of these investigations could be on the order of 100 kilometers from the geologic repository operations area; however, in some geologic settings this could be much less (i.e., on the order of 25 kilometers). The investigations shall emphasize obtainment of information that bears on these conditions which may affect the geologic repository during the next 10,000 years...

13 Agree 2 Disagree

3.19 Site Hydrologic Investigation

60.122(d)(1)(i) Active Natural Processes and Conditions

d Delete in total and replace by the following:

The ultimate goal of the hydrogeologic investigations will be to obtain data needed to identify all possible pathways of groundwater flow from the repository to the land surface and, neglecting possible geochemical interaction with host rock, to calculate the rates of flow along such pathways, under existing and anticipated boundary conditions, including future thermal effects of decay heat from the waste repository. However, the initial goal will be to obtain such information as will be needed for the "go-no-go" decision on construction and location of a pilot shaft. To the extent possible, data needed to satisfy both the initial and ultimate goals shall be obtained by measurement techniques that will not adversely affect the long-term performance of the geological repository. Calculation and measurement should include"

1 Water level data to obtain distribution of hydraulic head in three dimensions.

2 Groundwater ages.

3 Regional and local water balances.

4 Near-surface (2 to 3 meters below land surface) temperature distributions.

5 Current and possible future events and/or processes that could affect groundwater flow.

12 Agree 3 Disagree

3.20 Data Analysis

60.122(d)(2) Synthesis and Analysis of Data

This section requires substantial extension. It should include detailed comments on the following:

A. A requirement to state the logical flow of investigations and the nature of assumption in

(1) The data variability

(2) The existing uncertainties in measurement techniques

(3) The existing uncertainities in models and analysis techniques

(4) The expected reduction in uncertainities in both models and data as specific investigations proceed

B. Consideration of post decommissioning scenarios i.e., backfill performance, sealing etc. must be considered.

_15_ Agree _0_ Disagree

3.21 Safety Verification

60.122(d)(3) Verification

A minimum set of requirements should be established relative to a site safety verification program.

_14_ Agree ____ Disagree _1_ No Opinion

3.22 Requirements for Design, Fabrication, Construction, Testing and Operation of a Repository - 60.132

(1) General Comment: This is a too inclusive section of the regulation. Certainly Design Fabrication and Construction should be a separate section with more specificity of requirements. A system of stepwise approvals for characterization of the design and construction should be specified. The testing, final licensing and operation of the repository could specify key technical requirements in a separate section.

_9_ Agree _1_ Disagree _3_ No Opinion

3.23 Overall Facility

60.132(a)(12) Ventilation Systems

There are two quite different problems that must be faced here; the normal ventilation of the underground work areas and the added requirement that the system be capable of handling radioactive effluents. The uranium-thorium content of the host rock should be determined early for if it is significant then the radiological effluent control requirements must be applicable to the construction phase as well as to the emplacement phase. If the U-Th content is negligible so that Radon & Thoron can be ignored, then the radiological effluent control measures need apply only to the emplacement operations and then only to the accident mode in which a waste package is ruptured in handling.

It must be kept in mind that as long as the ventilation systems operate they provide open pathways to the storage areas and should be treated with the same precautions as are the ingress-egress systems.

This area should be referred to a team of ventilation experts that possess expertise both in mine ventilation - (U & Th preferred) - and in radioactive material processing facility design.

15 Agree 0 Disagree

3.23 Surface Facilities

60.132(2)(b)(3) Retrieval of waste

Delete and replace with:

It is desirable that surface facility structures shall be designed and constructed to facilitate the safe retrieval of emplaced wastes and shall contain facilities to inspect, repair, decontaminate and reconfigure waste packages as necessary to facilitate their shipment off site. It shall be shown that surface storage could be modified in a timely manner to meet the needs for retrieval of the waste.

14 Agree 1 Disagree

3.24 Monitoring Programs - 60.137

General Comment: This section should be more explicit as to what is required. As a minimum there should be a requirement for a monitoring plan to be approved as part of the site characterization requirements.

13 Agree 2 Disagree

3.25 Decommissioning - 60.141

General Comment: Consideration should be given to developing subsurface marking of site.

12 Agree 2 Disagree 1 No Opinion

3.26 SUBPART F-PHYSICAL PROTECTION

This subpart is inadequate. It should be greatly expanded to more detail.

12 Agree 2 Disagree 1 No Opinion

Chapter 4

Conclusions

The following discussion contains some general conclusions drawn from the workshop by the chairman, Stanley N. Davis. Although the statements probably do not reflect the exact thinking of all members of the group, an attempt is made to express the general reaction of the group to the draft copy of 10 CFR 60. Comments and conclusions concerning specific parts of the document or certain philosophical issues are contained in the body of this workshop report and will not be repeated here.

Participants of the workshop were, first of all, impressed with the importance of the task which is addressed in 10 CFR 60 and also with the difficulty of wording the document so that it is specific enough to be useful but on the other hand flexible enough to allow nuclear repositories to be constructed in a variety of geologic media. Although the participants took exception to many specific numbers proposed, they were in agreement that, where possible, numbers should be used rather than broad generalities. These numbers, however, should be based on sound scientific and engineering prinicples.

The greatest uncertainties amongst the participants related to the extent and nature of the controls which should be placed on access to the repository area and on various types of land and resource development which might be allowed after closure of the repository. The inability to predict future social and political conditions is obviously the origin of most of the uncertainties expressed.

Although it was not an item of general discussion, several participants indicated that a number of additional groups might profitably review 10 CFR 60. Some of these groups might be smaller to increase the efficiency of discussion and writing. Other groups might be the same size as the present review group. This size, however, appeared to be about the maximum size for a useful interchange of ideas on a semi-formal basis.

Finally, the members of the workshop were appreciative of the helpful flow of information from the NRC representatives. The short orientation talks and the continued input of information were essential during the deliberations. Future review groups for 10 CFR 60 should make sure they have a similar opportunity to interact with the NRC. Critical decisions and final deliberations should, of course, be handled in executive sessions where views fully independent of the NRC can be developed, as was the case in the present workshop.

APPENDIX A

Panel Participants

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AGENDA

REVIEW PANEL

10CFR Part 60 (Draft #10)

Doubletree Inn, Tucson, Arizona
January 9, 10, and 11 1980

Wednesday, January 9 - Ironwood Room

9:00 - 9:15	Opening remarks and announcements - Stanley N. Davis
9:15 - 9:30	General Orientation, Larry White, Division of Waste Management, NMSS, NRC
9:30 - 9:45	Licensing Procedures, Pat Comella for Siting Standards, SD, NRC
9:45 -10:40	Technical and Regulatory Approach in 10CFR Part 60, L. White, Section Leader, High-level Waste Management, NMSS, NRC
10:40 -	Completion of prepared NRC Orientation
10:40 -11:00	Coffee Break
11:00 -12:15	Major technical issues will be outlined briefly and the review panel will be subdivided into appropriate working groups.
12:15 - 1:30	Lunch - Redwood Room
1:30 - 3:00	Ironwood Room, Parlor 131, Parlor 907. Panel will meet initially together to continue discussion of work outline. Separate working groups will meet about 2:00 p.m. to organize and review assignments.
3:00 - 3:20	Coffee Break - Ironwood Room
3:20 - 4:00	Ironwood Room. Panel will meet as a group to further consider major questions, resolve areas of overlap among working groups, and ask questions of the NRC representatives.
4:00 - 5:00	Panel will meet as a group in executive session.

Thursday, January 10 - Redwood Room

9:00 - 9:45	Initial meeting of entire group for general discussion with NRC representatives.
9:45 -10:30	Working groups Redwood Room, Parlor 131, Parlor 907
10:30 -10:45	Coffee Break - Redwood Room
10:45 -12:15	Working groups - group rooms
12:15 - 1:30	Lunch - Salon H
1:30 - 3:00	Working group - group rooms
3:00 - 3:15	Coffee Break - Redwood Room
3:15 - 4:15	Working groups - group rooms
4:15 - 5:00	Executive session of entire panel - Redwood Room

Friday, January 11 - Redwood Room

9:00 - 9:45	Redwood Room - Initial meeting of entire group
9:45 -10:30	group ro ms - Completion of rough-draft reports of each working , roup
10:30 -12:15	group rooms - Final Completion of rough-draft reports
12:15 - 1:30	Lunch - Basswood Room
1:30 - 3:00	Redwood Room - Reports of working groups
3:00 - 3:20	Coffee Break
3:20 - 4:00	Closing remarks J. Martin, C. Roberts, and S. Davis
4:00 - 4:30	Executive session

Guidance for Review
Draft Report Outline

Abstract

Panel Objective

The NRC expects DOE to characterize several sites (3 to 5) in different geologic media before selecting any one site for construction of a repository. The NRC envisions site characterization that may include sinking of exploratory shafts, construction of exploratory drifts, drilling and in situ experiments.

The objective of this review is for a panel of experts in the various disciplines associated with the siting of high-level nuclear waste repositories to perform a technical review of a draft NRC Regulation 10CFR Part 60 entitled "Disposal of High-Level Radioactive Wastes in Geologic Repositories."

Comments will be made on the scope of in situ investigations and the types of tests that may be performed for establishing design parameters and assessing geologic conditions with regard to assessing for field performance in retarding radionuclide transport. Comments may be made on techniques that may be used to identify and screen sites and to make preliminary assessments on site suitability to identify most promising nondestructive geotechnical investigation procedures and monitoring systems.

Scope of Work

Proposed work will provide technical support to the NRC Waste Management Research Program.

This effort is a peer review of the draft technical requirement for licensing contained in the Advance Notice of Rulemaking (10CFR60 Subparts E through I). Comments will be focused on the technical requirements of Subpart 1, par 60.111 performance objectives, par 60.122 dealing with the site selection and evaluation process (primarily the geologic, hydrogeologic, geochemical, and environmental pathways aspects), par 60.132 dealing with the design, construction and operation of a repository.

Panel Organization

to be issued later

Part I - General Comments

Comments of a general nature will comprise Part One of the report. Majority views and dissenting views will be expressed and identified as such. A consensus will also be so designated whenever it exists. Recommendations will be provided on required steps for evaluation of issues which the panel was not able to resolve. The panel's overall conclusions regarding the document's efficacy plus any other matters requiring address, will be included.

Points to be Addressed by Peer Group

1. The intent and clarity of expression of portions of the Advance Notice of Rulemaking (10CFR60 Subparts E through 1), will be considered.
2. Peer comment is sought on the NRC approach of specifying numerical as opposed to qualitative performance requirements.

3. Given the uncertainties in the assessment of the overall performance of a repository, the NRC proposes setting minimum performance requirements for major parts of the system, i.e., the waste package, repository design, and the site. (This review primarily addresses the site) Comment is sought on this approach.
4. Comment is sought on whether or not there should be exclusion criteria in siting repositories, and, if so, what should these criteria be and what should be the exclusion distance.
5. With regard to the performance objectives (keyed to research needs), what types of data or information would be useful to support them? Also, what considerations should be taken into account in refining these performance objectives?
6. Which of the numerical criteria are complete? If some are not complete, what additional criteria would you recommend? Numerical values will be suggested where possible.
7. What research is needed: a) to support the technical criteria, b) to improve the criteria, or c) to identify any criteria required but not indicated?
8. Panel recommendations are desired relative to investigation and testing to be conducted during site characterization, e.g.,
   a. Necessity of sinking shafts (question as to whether the DOE 3-5 sites need to be looked at below the surface prior to selection).
   b. Extent of exploration of sites at depth (how much and how deep).
   c. Types of in situ information needed and the methods of obtaining information.

Part II - Specific Comments

Part two will address subpart E, par 60.111, 60.122 and 60.132 on an item by item basis.

Comments addressing specific items in 10CFR60 will be identified by number of the specific item addressed,

e.g., 60.122, siting

(a) General Technical Requirement

(1) Comments on this item here

Where there is disagreement with an item in the draft of 10CFR60, reasons shall be stated and alternatives specified. This statement will be supported by cited research, or by other professional criteria, such as "accepted professional practice." Majority views and dissenting views will be so identified, and a consensus will be so designated. Recommendations will be provided on required steps for both interim and long-term resolution of issues not resolved by the panel.

CHECK-LIST OF SOME ITEMS

FOR STUDY AND COMMENT

General Items

1. Intent and objectives as stated.
2. Clarity of expression.
3. Nature of performance requirements specified.
4. Need for exclusion area around site.
5. If exclusion needed, what areas should be specified.
6. Data needed to meet performance objectives.
7. Suggest numerical criteria where appropriate.
8. Research needed to support technical criteria.
9. Research needed to improve criteria.
10. Research needed to identify criteria which have not been included.
11. How much field work, and particularly how much subsurface exploration is required for site characterization?
12. What part should numerical modeling have?
13. How should the problem of natural resources be handled?
14. How much reliance can be placed on human institutions for monitoring, enforcing exclusion, and remedial action?
15. How should the problem of human intrusion (accidental or intentional) be handled?
16. What requirements for retrievability should be specified?
17. How much reliance should be placed on engineering design?
18. What are the long-term monitoring requirements?
19. Who should have site ownership and control?

Site Characterization and Repository Design

For each proposed requirement, the following questions should be asked:

1. Is the technology developed to enable the work to be completed?
2. Are proposed quantitative values proposed realistic?
3. If not, what values should be used?
4. Is the status of our knowledge sufficient to set the required quantitative values?
5. If given values are not reasonable, could the probabilities of events or measurements of natural parameters be expressed in terms of probabilities?
6. What type of modeling should be required? (stress distribution, heat flow, ground-water flow, radionuclide transport)

APPENDIX D

Annotated Draft
Regulation 10 CFR
Part 60

10 CFR Part 60
DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTES IN GEOLOGIC REPOSITORIES

SUBPART E - TECHNICAL CRITERIA

SUBPART F - PHYSICAL PROTECTION

SUBPART G - QUALITY ASSURANCE

SUBPART H - CERTIFICATION OF PERSONNEL

SUBPART I - EMERGENCY PROGRAMS

60.3 Additions - Definitions

As used in this part:

(a) " Aquifer" - means a distinct hydrogeologic unit which readily transmits water and yields useful quantities of water to wells or springs.

(b) "Candidate area" - means the area which envelopes the geomorphic, geologic, tectonic, biologic and hydrologic, framework and human activities potentially affecting and affected by the repository.

(c) "Container" - means the first major sealed enclosure which holds the waste form.

( ) "Control zone" -----define

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

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

(f) "Disposal" - means emplacement within a storage space with no intent to retrieve from the geologic repository.

(g) "Effective porosity" - means the ratio of the volume of interconnected pore space through which fluid flow occurs to the total bulk volume of the sample.

( ) "Exclusion area" -----define.

(h) "Expected processes" - means those natural forces or degradations of the engineered elements of the geologic repository, which can be identified and projected at the time of disposal.

(i) "Geologic repository" - means a system for the disposal or long term storage of radioactive wastes in excavated geologic media. A geologic repository includes the surrounding operations and exclusion areas.

(j) "Geologic repository operations area" - means the facilities that are part of a geologic repository, including both surface and subsurface areas, where waste handling and emplacement activities are conducted.

(k) "High-level radioactive waste" or "HLW" - means (1) uranium and/or thorium irradiated as a fuel or blanket material in a nuclear reactor, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such wastes have been converted.

(l) "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).

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

(n) "Hydrogeologic unit" - means any soil or rock unit or zone which has a distinct influence on the storage or movement of groundwater by virtue of its porosity or permeability.

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

(p) "Isolation" - means segregation of waste from the biosphere to the extent required by the EPA standard (40 CFR Part 191).

(_) "Operations area"-----define.

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

(r) "Reasonably foreseeable" - means a cumulative probability of occurrence greater than about one chance in 100 over _a_ 10,000 year period.

(s) "Repository horizon" - means the portion of the host rock and surrounding rock units that will be affected by construction or operation of the repository.

(t) "Repository structure" - means the engineered structure including backfill materials in which high level waste is emplaced.

( ) "Release rate" ----- define.

(u) "Resource" - means presently identifiable mineral or hydrothermal deposits which are of value and which are either unique in their occurrence or are widely used elsewhere at a significant rate when compared to the total volume of the known reserve.

(v) "Site" - means the geographic unit which is owned and controlled by the Department and includes natural geological, hydrological, and geochemical barriers which retard the movement of radionuclides from the waste to the biosphere.

(w) "Structures, systems, and compnents important to safety" - means those elements of a geologic repository, the failure of which could result in (a) the release of radioactive materials to the biosphere in excess of 10 CFR Part 20, or
(b) a substantial reduction in the safety margin provided for the protection of public and employee safety.

(x) "Very unlikely" - means a cumulative probability of occurrence of less than about one chance in 100 in a period over 10,000 years.

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

( ) "Reasonable assurance" - means the considered judgment of experts in the field after full study of the posed case.

( ) "Reasonable potential" -----define.

( ) "Reasonably foreseeable" -----define.

( ) "Long term" -----define.

60.101 Purpose and Scope

This subpart states the performance objectives to be achieved and the technical criteria to be met by the Department in order for the Commission to make the findings called for in Subpart B. This subpart was developed for deep geologic continental disposal of radioactive waste. It is not intended to be applied to alternative concepts of geologic disposal.

The technical criteria specified in this subpart are intended to compensate for uncertainty and to reduce risk by extensive reliance on conservative readily demonstrable measurements and calculations. Although they are conservative, the criteria purposely allow the application of latitude and judgment. The variability of factors to be considered in establishing a geologic repository does not permit, in some cases, detailed engineering standards or specifications to be established. Nevertheless, the Commission in this subpart has sought to identify those factors, investigations, and evaluations it considers important in determining the acceptability of a geologic repository with allowance for site-specific information and case-by-case application.

Because of the importance to the site of long-term performance, extensive siting criteria are included in this subpart. They were developed to avoid potentially adverse situations which are difficult to assess with regard to long-term performance. Also, reevaluations of the criteria are called for at each licensing stage to further assess site suitability.

The criteria attempt to establish a balance between regulating the individual components of a geologic repository and regulating the geologic repository as a system. Multiple and redundant components to isolate waste or substantially inhibit radionuclide movement are required to compensate for uncertainties in assessing the long-term performance of the geologic repository system. Yet, allowances and deviations from specific criteria are permitted, if it can be shown through appropriate analyses that they are warranted and that the performance objectives can still be conservatively achieved. It is expected that compliance with this subpart will involve the use of both probabalistic and deterministic analyses giving due consideration to the uncertainties inherent in such analyses.

The requirements in this subpart will probably be applied in a conservative manner taking into account the lack of experience in HLW disposal and the uncertainties in assessments. Because of the lack of experience and the uncertainties involved in establishing a geologic repository, investigations and evaluations not specifically required in this subpart may be required in individual cases.

60.110 General Requirements

(a) Major Elements

A geologic repository shall include at least the following major elements which retard migration of radionuclides: (1) waste packages, (2) a repository structure, and (3) the site and its environs.

(b) Overall Repository Performance

(1) The geologic repository shall be designed and operated so that radiation exposures and releases of radioactive materials comply with all applicable environmental and safety standards including the standards established by the U. S. Environmental Protection Agency (40CFR Part 191).

(2) Releases of radioactive materials to the biosphere from the geologic repository following closure shall comply with the generally applicable environmental standards established by the U. S. Environmental Protection Agency (40 CFR Part 191).

60.111 Performance Objectives

The performance objectives presented here apply to the long-term performance of the major elements of a geologic repository.

(a) Waste Packages*

Each waste package shall be designed to provide reasonable assurance of containment of radionuclides for at least the first 1000 years after closure of the geologic repository and as long thereafter as is reasonably achievable. Conditions in the vicinity of the waste packages resulting from expected processes and reasonably foreseeable events as well as various flow conditions including full or partial saturation at any time after closure should be assumed.

(b) Repository Structure and Engineered Elements

The repository structure shall be designed to provide reasonable assurance of the following:

(1) An in-situ environment for the waste packages which promotes the achievement of Section 60.111 (a) above under conditions resulting from expected processes and reasonably foreseeable events.

(2) Containment of all radionuclides for at least the first 1,000 years after closure of the geologic repository assuming expected processes and reasonably foreseeable natural events including failure of the container and expected dissolution of some of the waste within the repository structure soon after closure. No human disruption should be assumed.

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*Sections 60.111(a) and 60.111(b)(1) apply only to HLW. Criteria for other forms of waste including TRU waste are being developed and will be incorporated as appropriate.

(3) The waste packages and repository structure shall be designed to provide reasonable assurance that after the initial period of radionuclide containment, at least the first 1,000 years after closure, any radionuclides released from the repository structure will occur at a rate of release that will be as low as reasonably achievable and will in no case be greater than an annual rate of one part in one hundred thousand of the total activity contained within the geologic repository 1,000 years after closure assuming expected processes and reasonably foreseeable events.

(c) Site Performance

(1) The site and environs shall be chosen to provide reasonable assurance that their capability to inhibit the migration of radionuclides, will not change over the long term.

(2) The site and environs shall be chosen to provide reasonable assurance that the degree of stability exhibited at present will not change over the long term.

(d) Retrievability

The design of the waste package and repository structure and the stability of the site shall be such that the option to retrieve the wastes would be available if desired for a period of 100 years after the nuclear waste emplacement phase. If during this period a decision is made to retrieve the wastes, the geologic repository shall be such that the wastes could be retrieved in a time not greater than the same period of time during which they were emplaced. This would correspond to the operational period of geologic repository.

(e) Demonstrations of Compliance

At each step in the licensing process, the applicant shall demonstrate compliance with the performance objectives stated above. The applicant's analyses, and the NRC staff's evaluations of these analyses, shall be consistent with the level of information available at each step in the licensing process.

60.121 Site and Environs Ownership and Control

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

The geologic repository operations area shall be situated in and on lands that are either acquired lands under the jurisdiction and control of the U. S. Department of Energy or lands permanently withdrawn or reserved for public use. The Department shall hold such lands under its jurisdiction and control, free and clear of all significant encumbrances (including rights arising under the general minimg laws, mineral and ground water rights, easements for right-of-way, and all other rights arising under lease, rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise). The Department shall control such lands to assure appropriate safeguards and radiation protection.

(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 biosphere. The Department's rights may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws, ground water and mineral rights. The control zone shall at a minimum extend to a horizontal distance to a boundary at which the temperature gradient is ten percent of that at the boundary of the operations area at the time of maximum heat generation within the repository and all of the vertical distance below the surface of repository excavation to ensure that natural or human activities do not compromise the ability of the site to meet the requirements of Sections 60.110 and 60.111.

(c) Long-term control

The Department shall implement long-term controls over the geologic repository operations area and control zone to prevent potential human disruptions to the geologic repository. For the purposes of demonstrating compliance with Section 60.110 and 60.111, these controls shall not be assumed to persist for more than one hundred years.

60.122 SITING

(a) General Requirement

The site and environs shall have characteristics that will facilitate design and construction or fabrication of the engineered elements, operation, and closure of the geologic repository to maximize protection of public health and the environment for an extended period of time.

(b) Adverse Conditions (that militate strongly against the site) The following criteria shall be met within the control zone as determined by reasonable evaluations.**

(1) Adverse human activities. Control zone shall not be located where:

(i) There is or has been mining, drilling, excavation, or subsurface exploration for mineral, hydrocarbon, or water resources which provides a permanent pathway to the biosphere and which may perturb the hydrogeologic framework in a way which could produce significant migration of radionuclides to the biosphere.

(ii) There are economically attractive biological, mineral, hydrocarbon, geothermal and recreational resources.

(iii) There is reasonable potential for future subsurface exploration for mineral, hydrocarbon, or geothermal resources based on reconnaissance-level or detailed investigations.

(iv) There is reasonable potential for flooding as a result of failure of human-made impoundments prior to repository closure.

Comment (iv) and (v) Recommend apply to area only where facilities are located - not whole area.

(v) There is reasonable potential for future large-scale impoundments caused by human activity which may affect the groundwater flow system in such a way as to increase significantly the potential for migration of radionuclides.

**Exceptions to individual criteria may be granted if the Department can demonstrate that the requirements of Sections 60.110 and 60.111 will still be clearly met.

(vi) There is a population density of 200 persons per square kilometer* or greater.

(vii) There is reasonable potential that near-by human activities such as water wells, excavations, construction or explosions will have a significant adverse affect on the performance of the geologic repository.

(2) Adverse geologic conditions. A control zone shall not be located where:

(i) Surface geologic processes such as mass wasting, erosion, weathering, channel incision and avulsion, sea level fluctuations, or glaciation could reasonably be expected to increase significantly the potential for radionuclide transport from the geologic repository.

(ii) There is dissolutioning occurring at a rate which could adversely affect the performance of the geologic repository.

(iii) There are thermal barrier(s) which may significantly reduce the capacity of the rock to conduct heat away from the geologic repository and hence significantly increase the likelihood of radionuclide release to unacceptable levels.

(3) Adverse tectonic conditions. A control zone shall not be located where:

(i) Processes such as uplift, channel incision and avulsion, folding, faulting, fracturing, or other structural deformations could reasonably be expected to increase significantly the potential for radionuclide transport by breaching the engineered elements or by providing a hydrologic pathway.

(ii) There has been faulting due to deep geologic causes at depths greater than 1 kilometer since the start of the Quaternary Period.

(iii) There is a cenozoic fault or fracture zone, of the cenozoic age of last movement, which has as a minimum horizontal displacement on the order of a few hundred meters and a vertical displacement on the order of a few tens of meters.

(iv) Fractures or faults are oriented relative to the attitude of existing principal stresses such that potential changes in the stress field due to natural processes or human activity could reasonably be expected to result in future movement.

(v) There are concentrations of tectonic earthquake activity of a magnitude of 3 or greater relative to the regional distribution of earthquakes, or there are indications that earthquake activity may be concentrated in the future based on either the distribution and rate of occurrence of earthquakes or tectonic and structural information.

(vi) There is reasonable evidence of active volcanic vents during the past one million years.

(vii) There is a high and anamolous geothermal heat flux* with respect to the regional geothermal heat flux.

(viii) There is detectable active diapirism of an extent which may adversely affect performance of the geologic repository.

(4) Adverse hydrologic conditions. A control zone shall not be located:

(i) Where there is evidence suggesting a reasonable potential for the formation of a large-scale impoundment by natural causes during the operation of the repository.

(ii) Within an area of potential flooding.

(iii) In a hydrologic environment that has been shown to have a reasonable potential for significant increase in the rate of hydrologic transport from the excavation to the biosphere.

(5) Adverse geochemical conditions. A control zone shall not be located where:

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*Gradients vary owing to changes in thermal conductivity and the boundary conditions.

(i) There is no medium between the excavation and the biosphere that does not significantly inhibit migration of radionuclides by sorption or reaction in event of failure of the engineered elements of repository.

(ii) There is a reasonable likelihood of a change in groundwater chemistry that would significantly decrease the retention of radionuclides by sorption or reaction compared to existing groundwater chemistry. (Assuming that existing groundwater chemistry is acceptable)

(6) Adverse Ecosystems or Biota. A control zone shall not be located where there are unique ecosystems or biota in areas of disturbance of the site.

(c) Favorable Conditions

The characteristics of the geologic repository operations area and surrounding candidate area shall not be so complex as to preclude a thorough evaluation of those siting factors that are important to demonstrating that the requirements of Sections o0.110 and 60.111 will be met.

(1) Candidate area. Unless it can be demonstrated that the requirements of Sections 60.110 and 60.111 will still be met, the candidate area shall meet the following criteria to the extent achievable as determined by reasonable evaluations.

(i) Surface and subsurface geologic, tectonic, and hydrologic stability since the beginning of the Quaternary Period.

(ii) A location amenable to the safe transportation and handling of the wastes.

(iii) Sparse population at the potential groundwater discharge locations if within 10 Km of the site.

(iv) Sparse hydrocarbon and mineral resources and no extensive water resources.

(v) A host rock and surrounding confining units that function as natural elements which retard radionuclide migration. The following characteristics generally enhance the ability of a rock unit to function as a retarding element:

a. relatively low intrinsic permeability of the rock mass, including low fracture permeability

b. vertical continuity of at least 50 meters and lateral continuity which exceeds the lateral dimensions of the repository by at least 20%

c. high geochemical retardation factors - ability to retard migration of dissolved waste by solution and/or by promoting reducing conditions

d. relatively inactive ground water circulation

e. long groundwater flow paths prior to entering discharge areas or potable aquifers

f. capability to withstand or compensate for reasonably foreseeable natural events such as earthquakes, faulting, fracturing, or folding without breaching the multiple and redundant barriers.

(2) Control zone. Unless it can be demonstrated that the requirements of Sections 60.110 and 60.111 will still be met, the control zone shall meet the following criteria in addition to the criteria of Section 60.122(b)(1):

Comment
Define "adequately"

(i) Ability of the rocks to dissipate adequately heat generated by the waste.

(ii) Ability of rocks to maintain geomechanical stability under influences of the thermal load or other waste/rock/water interactions.

(iii) Characteristics that permit effective sealing of shafts, drifts, and bore holes.

Comment
More specific. How does one demonstrate lack of potential

(iv) Little potential for future groundwater intrusion or increased circulation of groundwater in the host rock.

(v) Conditions that prevent significant upward groundwater flow between hydrostratigraphic units or along shafts, drifts, and bore holes.

(vi) Horizontal or downward potential gradients in the host rock and surrounding confining units away from the nearest potential hazard areas.

(3) Repository horizon. The host rock and surrounding confining units of the repository horizon shall meet the criteria of Sections 60.122(b)(1) and 60.122(b)(2) above. Unless it can be demonstrated that the requirements of Sections 60.110 and 60.111 will still be met, the host rock and

surrounding confining units of the repository horizon shall also meet the following criteria:

Comment
Panel agrees that there are problems with these- Example (1) Fractured rock different from non-fractured. (2) Extreme values may be as equally important as average. (3) Item (ii) as stated is not of value.

(i) Average vertical and horizontal intrinsic permeabilities of the rock mass on the order of $\underline{1 \times 10^{-12} cm^2}$.*

(ii) Effective porosity less than one percent* of the total volume.

Comment
Why 300 meters?

(iii) A minimum depth of 300 meters.*

(c) Site Evaluation

The feasibility site investigation shall be conducted to provide those data needed to determine the site parameters which are used for the safe design, construction, and operation of the engineered elements of the geologic repository and for assessment of the long-term performance of the geologic repository. The characteristics of the geologic repository operations areas shall be investigated in sufficient scope and detail to assure that the requirements of Sections 60.110 and 60.111 will be met.

Comment
See general
Items-Survey 6

(1) Candidate site Investigations Investigations conducted during preapplication site selection, feasibility site characterization and other stages of the development of the geologic repository shall be conducted to obtain required information with minimal adverse affect on the long-term performance of the geologic repository.

*Comment particularly sought.

The feasibility investigations shall be conducted taking into account reasonably likely extremes in the variation of site conditions which could result from present or potential future events or processes. The investigations shall also be conducted to approximate the conditions to which the site may be subject by the presence of radioactive wastes.

The area to be investigated shall include those geologic, hydrologic and climatologic conditions and processes and human activities which can reasonably be considered to affect the long-term isolation of radionuclides and the safe design, construction and operation of geologic repository operations area. The investigations shall becom : significantly more detailed with increasing proximity to the control zone, geologic repository operation area and repository horizon. It is expected that the horizontal extent of these investigations could be on the order of 100 kilometers from the geologic repository operations area; however, in some geologic settings this could be much less (i.e. on the order of 25 Km).

The investigations shall emphasize obtainment of information that bears on those conditions which may affect the geologic repository during the next 10,000 years. Regarding past geologic, climatologic and hydrologic processes, the emphasis shall be on any processes which were active at anytime since the start of the Quaternary Period.

(i) Active Natural Processes and Conditions.
Investigations shall be conducted to identify and evaluate those natural and active processes which may adversely affect the stability of the site or negate the ability of the site and environs to function as a major element which retards migration of radionuclides. The natural processes to be investigated are those that may affect groundwater geochemistry, groundwater flow, hydrogeologic geometry and geomechanical integrity.

The following are minimum requirements:

a. Investigations of geologic conditions including:

1. Topography, geomorphology, physiography, stratigraphy, lithology/petrology, geologic structures, geophysical measurements, geomechanical properties, geochemical properties, natural resources and the extent and distribution of subsurface discontinuities and heterogeneities.

2. Surface and near surface static and dynamic foundation properties.

3. In situ and laboratory geomechanical tests of the repository horizon zone of shaft which measure rock stress/strain field, rock strength, and variations in geomechanical properties with time due to potential future natural processes and waste/rock interactions.

4. In situ and laboratory thermal tests to simulate rock response in the range and duration of temperatures which could result from the emplacement of waste.

b. In situ and laboratory geochemical tests to measure the subsurface geochemical conditions at the site and in its environs including geochemical retardation factors, oxidation potential, acidity, solubility, chemical compositions of rocks and fluids; variations in geochemical conditions at the site due to waste/rock interactions and changes in site geochemical conditions due to potential variations in natural processes; and the geochemical compatibility of the waste form and other engineered elements with the repository horizon.

c. Investigation of tectonic conditions including tectonic history and ancient stress patterns, plate-tectonic interpretations, contemporary stress field, faults, fractures, earthquake activity, possible correlation of earthquake activity with tectonic structures (seismotectonic) diapirism, isostatic movements, and volcanism.

d. The ultimate goal of the hydrogeologic investigations will be to obtain data needed to identify all possible pathways of groundwater flow from the repository to the land surface and, neglecting possible geochemical interaction with host rock, to calculate the rates of flow along such pathways, under existing and anticipated boundary conditions, including future thermal effects of decay heat from the waste repository. However, the initial goal will be to obtain such information as will be needed for the "go" - "no-go" decision on construction and location of a pilot shaft. To the extent possible, data needed to satisfy both the initial and ultimate goals shall be obtained by measurement techniques that will not adversely affect the long-term performance of the geological repository. Calculation and measurements should include:

1. Water level data to obtain distribution of hydraulic head in 3-D.
2. Groundwater ages
3. Regional and local water balances
4. Near-surface (2 to 3 meters below land surface) temperature distributions
5. Current and possible future events and/or processes that could affect groundwater flow.

e. Investigations of meteorologic and climatologic conditions including characteristics of extreme events and past variations.

(ii) Human Activities. Investigations shall be conducted to identify and evaluate those human activities which may adversely affect the stability of the site or negate the ability of the site and environs to function as a major element which retards migration of radionuclides, or provide pathways to the accessable environment.

The following are minimum requirements:

Investigations of the past and present activities of man including population distributions, transportation routes, military activities, surface and subsurface explosive storage and blasting, subsurface waste disposal, subsurface penetrations such as minings, borings, exploration activities, surface and subsurface water use.

(iii) Interactions with Engineered Elements Investigations shall be conducted to identify and evaluate those interactions which may adversely affect the ability of the site and environs to function as a major element which retards the migration of radionuclides. The following are minimum requirements:

a. In situ and laboratory tests to measure the effectiveness of sealing of shafts, boreholes, and drifts with respect to both the migration of fluids and radionuclides and stability of the rock mass.

b. In situ and laboratory tests of subsurface excavation techniques which measure the degree of disruptions to the excavated rock surfaces.

(2) Synthesis and Analysis of Data. Data collected from the required investigations shall be synthesized and analyzed to describe the present natural framework and any potential changes to that framework.

(i) Analytic Approach.
The analysis should:

a. Correlate and interpret data to identify conditions and active processes.

b. Reconstruct past natural conditions, processes, and human activities in order to assess potential perturbations to existing conditions and presently active processes.

c. Validate and verify developed concepts and analytic models using analogues of natural processes, field tests, in-situ tests, field verified laboratory tests, and monitoring results.

d. Predict future conditions and changes based upon validated and verified concepts and models.

e. Identify and characterize the potential natural events and conditions which if not considered in the design of the engineered elements could result in failure of the geologic repository to meet the requirements of Sections 60.110 and 60.111.

(ii) Required Evaluations. The Department shall evaluate at least the following natural processes or conditions and human activities:

a. Human Activities.

i. Past, present or potential human activities, including accidental conditions, near-by explosions, subsurface construction, and land use.

ii. The potential effects of exploration for or recovery of resources.

iii. Possible intentional or accidental human intrusion of the geologic repository.

iv. The potential effects of pre-existing subsurface penetration both identified and undetected.

v. Potential human activities which may influence tectonic, geologic, hydrologic conditions.

b. Geologic Processes and Conditions. The effects of past, present or potential geologic processes and present conditions including:

i erosion and deposition

ii mass wasting

iii channel incision, avulsion and capture

iv glaciation

v sea level change

vi uplift, subsidence and faulting

vii seismic conditions - earthquake probability

viii distributor of faults and fractures

ix diapirism and volcanism

x stratigraphic and sedimentologic conditions and variability

xi geochemical and geomechanical conditions and variability

c. Tectonic Processes.

i. The effects of faults and fractures as preferential pathways.

ii. The creation of faults and fractures.

iii. The movement of faults.

iv. The effects of vibratory ground motion.

v. The effects of diapirism.

vi. The effects of vulcanism.

d. Hydrologic Processes.

The effects of groundwater movement and potential changes to groundwater movement which could result from natural processes.

e. Waste Emplacement.

The thermal, geomechanical, radiological, and chemical effects of the emplacement of waste.

(3) Verification

Comment
Should be expanded and more specific.

The Department shall implement a site safety verification program to continuously verify and assess any factors which may pertain to the site suitability findings.

60.132 Requirements for the Design, Fabrication, Construction, Testing, and Operation of a Repository

Comment
1. Separate construction section.
2. Need step-wise approvals for characterization stage.

Pursuant to the provisions of Subpart B an application for a license must include the principal design criteria for a facility. The principal design criteria shall establish the necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components important to safety.

These general design criteria establish minimum requirements for the principal design criteria for geologic repositories for the disposal of high-level radioactive wastes. They are considered to be generally applicable and are intended to provide guidance in establishing the principal design criteria.

The development of these general design criteria is not yet complete. For example, some of the definitions need further amplication. Also, some of the specific design requirements for structures, systems, and components important to safety have not as yet been suitably defined. Their commission does not relieve an applicant from considering these matters in the design of a specific facility and from satisfying the necessary safety requirements.

There may be facilities for which the general design criteria are not sufficient and for which additional criteria must be identified and satisfied in the interest of public health and safety. Also there may be facilities for which the fulfillment of some of the general design criteria may not be necessary or appropriate. For facilities such as these, departures from the general design criteria must be identified and justified.

(a) Overall Facility

Criteria in this section provide requirements which pertain to the entire facility.

(1) Overall requirement

Comment
Needs more specificity.

The design, fabrication, construction, testing, and operation of a repository shall conform with the performance objectives specified in Section 60.111 of this subpart.

(2) Determining structures, systems, and components important to safety.

This determination shall be based on an analysis of repository performance and shall consider the range of environments and conditions that are determined to be reasonably likely to exist during the time frames for which containment is necessary.

(3) Protection against natural phenomena

Structures, systems and components important to safety shall be designed and located to withstand the effects of natural phenomena such as earthquakes, tornadoes, and floods without loss of capability to perform their safety functions.

(4) Protection against environmental conditions

Structures, systems and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operations, maintenance, testing, and postulated accidents.

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

Structures, systems and components important to safety shall be appropriately protected against dynamic effects that may result from equipment failure, operating error and from other similar events and conditions, such as missiles and the dropping of crane loads in transit.

(6) Protection against fires and explosions

(i) Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the potential for and the effects of fires and explosions, and any impairment of their capability to perform their safety functions under conditions involving fires and explosions.

(ii) Noncombustible and heat resistant material shall be used wherever practical throughout the facility.

(iii) Explosion and fire detection, alarm, and appropriate suppression systems with sufficient capacity and capability shall be provided and designed to minimize the adverse effects of fires and explosions on structures, systems, and components important to safety.

(iv) The design of the facility shall include provisions to protect against adverse effects to operating personnel which might result either from the operation or from the failure of the fire suppression systems.

(7) Inspection, testing, and maintenance

Structures, systems and components important to safety shall be designed and located to permit periodic inspection, testing, and maintenance as appropriate to ensure their continued functioning and readiness.

(8) Emergency capability

Structures, systems and components important to safety shall be designed and located to assure capability for safe termination of operations and evacuation of personnel during an emergency. The design shall assure capability for use of onsite facilities and services, and shall facilitate the use of available offsite services such as fire, police, medical and ambulance service and other services as may aid in recovery from emergencies. Provision should be made for rapid sealing of compartments of the facility.

(9) Utility services

(i) Onsite utility service system shall be designed to provide for meeting safety demands under both normal, extreme environmental and accident conditions. The design of the onsite utility service system shall include redundant systems to the extent necessary to maintain, with adequate capacity, the ability of the onsite utility service system to perform safety functions assuming a single failure.

(ii) Onsite utility backup systems shall be designed to permit testing to (1) ensure adequate reliability and capacity to service safety related systems during normal and emergency conditions, and (2) to ensure operability in transferring from normal to emergency supply sources.

(10) Radiation control

(i) The design of the facility shall provide for control of access to the facility and to areas of potential high radiation within the facility.

(ii) The facility shall be designed so that radiation and the spread of contamination can be monitored and controlled.

(iii) Monitoring and sampling systems shall be provided as necessary for determining the quantity and nature of the radioactive material released in effluents.

Comment

Need emergency action requirements.

(iv) Radiation alarm systems shall be provided to warn facility personnel of significant increases in radiation levels in normally accessible spaces and of excessive radioactivity released in effluents. Such systems shall be designed with redundancy and with in situ testing capability.

(11) Criticality control

See specific comments

All systems shall be designed to ensure that no nuclear criticality accident can occur unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety.

(12) Ventilation systems

See specific comments

Ventilation systems shall be designed and appropriately tested to ensure their operability during normal and abnormal conditions. To accomplish this objective, these systems shall be designed to meet the following requirements:

(i) The proper ventilating air flow direction in each area shall be maintained under operating and accident conditions.

(ii) The ventilation system shall accommodate changes in operating conditions, such as variations in temperature and humidity. The system shall be capable of safely controlling releases of radioactive substances and other potentially hazardous substances both under normal conditions and postulated accidents. Any releases in effluent gases shall be as low as reasonably achievable.

(iii) The continuity of necessary ventilation shall be assured by means of redundant equipment, fail-safe control systems, or other provisions.

(iv) Ventilation systems supporting underground excavation and waste emplacement operations shall be separate to the extent practicable and shall be separated automatically by bulkheads in emergency situations.

(13) Instrumentation and control systems

Comment
Needs more
specificity

Instrumentation and control systems shall be provided to monitor variables and operating systems that are important to safety over anticipated ranges for normal operation, for abnormal operation and for accident conditions.

(14) Separation of underground excavation, construction, and waste emplacement operations

Excavation and construction operations and activities shall be separate from waste transport and emplacement operations.

(15) Radioactive materials handling systems

Systems for handling, transporting, and emplacing radioactive wastes shall be designed to reduce to as low as reasonably possible the potential for events which could adversely affect (i) the capability for retrieval of the waste; (ii) the performance of waste packages; and (iii) the health and safety of operators.

(16) Sharing of structures, systems, and components

Structures, systems and components important to safety shall not be shared between the repository facility and a facility of another type unless it is shown that such sharing will not impair the capability of the shared structures, systems, and components to perform their safety functions.

(b) Surface Facilities

Criteria in this section provide requirements which pertain only to the surface facilities.

(1) Decommissioning

Surface and subsurface facilities shall be designed, fabricated, and constructed to facilitate their eventual decommissioning.

(2) Waste management operations

The design of surface facilities for the handling, temporary surface storage, repackaging, overpacking, treatment, or chemical alteration of waste shall satisfy the general design criteria of 10 CFR Part 72 for licensing of Independent Spent Fuel Storage Installations as appropriate.

(3) Retrieval of waste

It is desirable that surface facility structures shall be designed and constructed to facilitate the safe retrieval of emplaced wastes and shall contain facilities to inspect, repair, decontaminate, and reconfigure waste packages as necessary to facilitate their shipment off site. It shall be shown that surface storage could be modified in a timely manner to meet the needs for retrieval of the waste.

(c) Subsurface Facilities and Interconnections

Criteria in this section provide requirements which pertain only to the subsurface facilities and interconnections.

(1) Engineered structures, systems, and components

(i) Engineered structures, systems, and components shall protect the waste packages from environments and mechanical forces that the waste packages are not designed to withstand.

(ii) The facility design shall incorporate structures, systems, and components which increase potential radionuclide retardation or otherwise enhance containment of the waste.

(iii) The facility design shall incorporate, to the extent practicable, engineered structures, systems, and components which are not likely to adversely affect potential radionuclide retardation.

(iv) The facility design shall incorporate, to the extent practicable, engineered structures, systems, and components, which are compatible with the emplacement or retrieval environment.

(2) Subsurface excavation

(i) The methods used for excavation shall be selected and controlled in conformance with the objective that these activities will not enhance a preferential pathway for groundwater or radioactive waste migration, nor increase the migration rate through existing pathways.

(ii) Excavations shall be designed and constructed to minimize the potential for deleterious rock movement and fracturing, to reduce potential stress fields and radial fracturing beyond the smooth excavation face and to facilitate repository sealing.

(iii) Pillar and opening dimensions shall be selected to limit subsidence of overburden and rock formations to levels which will not adversely affect the containment capabilities of the site. The determination of appropriate pillar and opening dimensions shall consider the thermomechanical response of the emplacement medium to waste emplacement and specific site features which could affect repository structural performance and waste retrievability.

(3) Support structures and systems for excavation

Support structures and systems for excavations shall be designed to (1) assure the stability of excavations during the operating and retrieval phases under normal, extreme environmental and accident conditions, (2) reduce the potential for adverse effects caused by rock movement and subsidence over the long-term after the repository is sealed, and (3) permit adequate sealing of the repository.

(4) Water control systems

Engineered systems shall be designed to control potential groundwater, surface water, and service water intrusion. These systems shall be of appropriate capacity and capability to handle accidental or unexpected water intrusion which could adversely affect systems important to safety and on waste retrieval operations.

(5) Heat loading

The facility shall be designed such that the heat loading generated by the wastes will not cause the rock mass to respond in such a manner as to significantly adversely affect the performance of the engineered structures, systems, and components described in (1), (3), and (4) above and the waste packages or otherwise significantly affect the performance of the repository, considering both natural or engineered characteristics for the repository.

(6) Shaft seals and borehole seals

All shafts and boreholes shall be sealed insofar as possible to prevent water transport along the shafts and boreholes along the seal contact and the adjacent disturbed section of rock.

(i) Seals shall be of a design whose performance has been evaluated by analysis and testing under field conditions and confirmed by a minimum of in situ tests at the site of the geologic repository.

(ii) Seals shall be designed to provide an effective barrier to fluid and radionuclide migration for the long term <u>insofar as possible</u> equal to or greater than that of the undisturbed section of rock through which the borehole or shaft passes.

60.133 <u>Waste Package and Emplacement Environment</u>

(a) <u>General Requirements</u>

(1) The waste packages shall be designed and fabricated to assure that the requirements of Sections 60.110 and 60.111 will be met. To demonstrate that the waste package meets the requirements in Section 60.111 the Department shall, at a minimum, do the following:

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

(ii) Provide reasonable assurance that the in-situ chemical, physical, and nuclear properties of the waste package and 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, explosion hazards, thermal loads, and synergistic interactions;

(iii) Provide reasonable assurance that the in-situ chemical, physical, and nuclear properties of the waste package and 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 limted to, evaluation of the following factors: solubility, oxidation/reduction reactions, corrosion, gas generation, thermal effects, mechanical strength, stress, radiolysis, radiation damage, nuclide retardation, leaching, explosion hazards, thermal loads, and synergistic interactions.

(2) The waste packages shall be designed and fabricated to promote safe handling during transportation, handling, emplacement, and retrieval.

(3) The waste packages shall be tested, as appropriate, to assure that the requirements of Section 60.133(a)(1) and 60.133(a)(2) will be met.

(b) Waste Form Requirements

Unless it can be demonstrated that the requirements of Section 60.111 will still be met, the waste form shall meet the following criteria:

(1) Solidification. All liquid radioactive wastes shall be converted to a dry solid and placed in a sealed container before transfer to the repository.

(2) Stabilization. Finely divided waste forms shall be stabilized (for example, by incorporation into a solidifying matrix) so as to limit the production and availability of respirable fines due to any accident condition, to as low as reasonably achievable.

(3) Free Liquids. Waste packages containing free liquids shall not be accepted.

(4) Combustibiles. All solid or solidified radioactive waste classified as combustible shall be reduced to a noncombustible form or the original combustible wastes and their associated packaging shall be such that:

(i) A fire and/or explosion involving a waste package shall not unduly affect the repository or the health and safety of the repository operating personnel.

(ii) A fire and/or explosion involving a single package cannot spread to other packages.

(5) Explosive, Pyrophoric, and Toxic Materials. There shall be no explosive or pyrophoric materials or conditions in the radioactive waste, nor shall there be quantities of chemically toxic wastes which could compromise either the operation or long-term performance of the repository.

(c) Container and Packaging Design Requirements. Unless it can be demonstrated that the requirements of Section 60.111 will still be met, the container shall meet the following acceptance criteria:

(1) Physical Dimensions and Weight. The physical dimensions and weight of the container and its contents shall be such that handling of the material at the repository can be performed safely. Consideration shall also be given to the techniques and equipment required to retrieve the waste package.

(2) Mechanical Strength, Heat Resistance and Fabrication. The container and packaging shall be designed and fabricated to the specification of existing codes and standards which are applicable to containers of a similar type and function.

(3) Materials of Construction and Corrosion Control. The materials used to fabricate the container and packaging shall meet the specifications of existing codes and standards which are applicable to containers of similar type and function.

(4) Mechanical Handling. The waste package shall include features and devices which promote safe lifting and movement of the package and its contents. These features and devices shall be such that they do not provide a means of easily damaging the container should a handling accident occur.

(5) Surface Contamination. The amount of removable radioactive surface contamination on the exterior of the package shall be such that exposure to operational personnel will not exceed the values recommended in applicable radiation protection standards and codes of practice.

(6) Unique Identification. A label or other means of permanent identification shall be attached to each container. The label shall not impair the integrity of the container and shall be permanently attached in such a way that labels and descriptions will be legible at least to the end of the retrievable storage period. Each label shall be permanently attached in such a way that labels and descriptions will be legible at least to the end of the retrievable storage period. Each label shall contain the specific information needed to match the container with its permanent written records.

60.135 Retrieval of Waste

A repository shall be designed, fabricated, constructed, tested, and operated in conformance with the objective that all waste packages can be retrieved mechanically intact and satisfactorily free of contamination at any time during the storage period and for a period of 100 years after storage [para 60.111(d)].

Any provisions for retrieval of waste shall not significantly impair the capabilities of the repository for isolating the wastes.

60.137 Monitoring Programs

The department shall initiate a system of monitors during site characterization. The system of monitors shall be maintained and supplemented, as appropriate, throughout the period of institutional control. The system of monitors shall be designed to verify that the requirements of Section 60.110 and the performance objectives of Section 60.111 are being achieved.

(a) Monitoring systems shall not adversely affect the natural and engineered elements of the geologic repository.

(b) Monitoring systems shall be established at a candidate site to obtain baseline information on those parameters and natural processes pertaining to the safety of the site and perturbations at the site that may be caused by site characterization activities.

Comment

Should be more specific on what to monitor.

(c) Monitoring systems shall be established at the site of the geologic repository to monitor changes from baseline condition of parameters which could affect the performance of the site's natural or engineered barriers to radionuclide migration during construction, operation, and after closure.

60.141 Decommissioning

Decommissioning of the repository includes the decontamination, dismantlement, and disposal of contaminated surface facility structures as well as the closure and sealing of all pentrations into the repository. The scope of decommissioning activities and requirements will be determined by technical criteria and license conditions at the time of closure.

(a) Technical Requirements

(1) Permanent records shall be maintained in the archives of the United States Government which accurately identify repository location, layout, waste types and characteristics, and waste locations within the repository.

(2) The location of the repository shall be marked using the most practicable permanent markers. These markers shall be inscribed in English, French, German, Russian and Spanish.

Comment

What about subsurface marking?

SUBPART F - PHYSICAL PROTECTION

60.161 Safeguards

(a) The repository and repository security program shall be designed to protect against potential acts of sabotage and diversion of radioactive materials.

(b) Provision shall be implemented to control and provide a record of waste form thermal and radiation characteristics prior to shipment to a Federal repository. An inventory control and accountability system shall be established at the repository to verify waste type with shipping records to preclude acts of sabotage or substitution. Records shall be maintained of these waste characteristics and their location within the repository and shall be maintained for a period specified by the appropriate regulation or license condition.

Comment

This subpart should be greatly expanded to more detail.

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) A quality assurance program based on the criteria in Appendix B of Part 50 of this chapter shall be implemented. The quality assurance program shall provide control over activities affecting the quality of structures, systems, and components to the extent consistent with their importance to safety. The requirements of the quality assurance program shall apply to such activities as siting, exploring, designing, fabricating purchasing, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, monitoring, repairing and modifying.

(c) In addition to the requirements of subsection (b) above, personnel who perform activities affecting quality shall be certified in accordance with #60.181 of this part.

(d) The personnel responsible for the implementation of the quality assurance program shall be independent from those organizations having direct responsibility for site exploration and repository design, construction, operation and closure and have sufficient authority and access to the highest levels of Department management required to insure the success of the quality assurance program.

(e) Quality assurance programs shall be developed for each phase of repository development including site exploration, site characterization, repository construction, operation and closure, prior to the beginning of those activities. The issuance of determinations, authorizations, licensing, and amendments by the Commission will be contingent upon the Department showing the adequacy of the quality assurance programs which occur prior to any such issuance.

60.172 Quality Assurance Records

In addition to the requirements of section 60.171 above quality assurance records necessary to assure long term public safety shall be maintained from the beginning of the quality assurance through the duration of repository permits or licenses.

Provisions shall also be made to maintain indefinitely those records deemed to be required for the retrieval of waste.

SUBPART H - CERTIFICATION OF PERSONNEL

60.181 Personnel Requiring Certification

(a) The provisions of this subpart apply to any individual who performs or supervises activities affecting quality.

(b) No person shall perform the functions affecting quality unless:

(1) certified by the Department pursuant to this subpart, or

(2) under the direction and presence of certified personnel as part of certification training.

60.182 Personnel Certification Program

(a) In accordance with subpart B, the required submittals of the Department shall include programs for certification of personnel who perform activities affecting quality. The information submitted shall be in sufficient detail for the Commission to make a reasonable finding that the implemented program results in certified personnel competent to operate and inspect the facility in a safe manner.

(b) The employee and employee supervisor certification program shall include:

(1) prerequisite professional or technical qualifications,
(2) physical and mental health requirements,
(3) formal instruction and operating practice,
(4) written examination and operating tests,
(5) requalification training and testing.

(1) prerequisite professional qualifications,

(2) formal instruction,

(3) written examination,

(4) equipment training and testing as appropriate,

(5) requalification training and testing

(d) Records shall be maintained for all certified personnel through the closure of the repository as evidence that the certification program as approved by the Commission has been implemented.

SUBPART I - EMERGENCIES AND EMERGENCY PROGRAMS

60.191 Purpose

Subpart B required programs for coping with radiological emergencies as part of a license application. This subpart establishes the minimum requirements for such emergency programs. The information submitted shall be in sufficient detail for the Commission to make a reasonable finding that the implementing program will adequately protect site personnel and protect the public health and safety in the event of a radiological emergency.

60.192 <u>Content of Emergency Plans</u>

(a) The emergency plans shall contain the elements set forth in section II, III, and IV of Appendix E to 10 CFR Part 50 "Licensing Production and Utilization Facilities."

(b) The emergency plan shall describe the provisions to augment monitoring systems to insure the accurate and rapid measurement of radiological releases both in the repository/repository site and releases off-site. Provisions for the rapid analyses and communication of the analyses to responsible officials shall also be described.

SPECIFIC COMMENTS ON
10 CRF 60

1. p. 1

60.3 Additions - Definitions

The following definitions need to be added to clarify the regulation:

(1) Long term- means the period of time beyond 1000 years after closure of the repository.

(a) 1000 years has been selected for this definition in that it is the period beyond which the major barrier remaining is hydrogeologic.

(2) Reasonable Assurance - means that there is significant evidence that an event will or will not occur.

(a) This ties the term reasonable assurance to a specific event in which the probability of occurance may or may not be the same in all cases.

2. p. 5 60.101 Purpose and Scope

"Variability of factors to be considered... does not permit detailed engineering standards or specifications to be established."

The above can be circumvented by giving specifications in terms of objectives to be accomplished.

Leave statement out.

3. p. 9

60.111 (d) Retrievability

One reason for the 50 years is the possibility that continued monitoring might be advisable if not indeed required. Since one of the principal uncertainties centers around the thermal effects caused by the HLW heat generation why not make the time period 100 years instead of 50 years. At 50 years the head load will still be some 30% of that at the close of operations while at 100 years it will be down to some 10% which would be essentially negligible.

4. p. 9-10 Retrievability

While considerations of retrieval may be governed by reprocessing factors and also monitoring consideration, the prime consideration in terms of health and safety is that waste can be retrieved if emergency considerations such as inflow of unacceptable hydrological conditions are encountered. Such considerations force engineered barriers from excavation portions of a repository to be designed.

One hundred years. This should be specified in terms of the operational life of the repository, thus "One hundred years after the operational (work emplacement phase) term is completed"

5. p. 11 60.121(a)

..."Control of the U.S. Department of Energy or lands permanently withdrawn or reserved for public use." Suggest ..."Control of the Department or lands permanently withdrawn from public or private use..."

6. p. 11

60.121 (b)

Would it not be feasible to make the generic 2km more site specific by stipulating that the boundaries of the control zone be determined as the distance at which the thermal gradient under maximum heat load would be say 10% of its value at the boundary of the operations zone?

7. p. 12 60.121(c)

Why limit long-term control to not more than one hundred years? Why not much longer? (no suggested time but at least until it can be demonstrated that potential emission of radionuclides is less than established by EPA standards).

8. p. 12 60.121(b)

Why limit the control zone to a ... "vertical distance from the surface to a depth of 1 kilometer...?" Why not all distance below?

9. p. 13 (b)(1)(i)

Abandoned mines, drill holes, etc. at specific sites should not be cause for elimination of sites from consideration. These contribute strongly to the knowledge of what is there and, in fact, if an existing excavation could be made suitable, that would save millions (billions?) of excavation dollars and several years time.

10. p. 13 (b)(1)(i)

With respect to the effect of drill holes and shafts or leaks, this is soluble. The experience with containment of underground nuclear explosions at NTS is especially relevant. That experience could also be useful in designing a means for emergency sealing of the repository. There will be some security classification problems with obtaining these data, but those may be workable.

11. p. 13 (ii)

Adverse human activities

Current: "...control zone shall not be located where: There are mineral, hydrocarbon, or geothermal resources."

Suggested change: "There are economically attractive mineral, hydrocarbon, geothermal, biological and recreational resources."

12. p. 13

General Requirement

Add to statement "...to maximize protection of public health and the environment for an extended period of time."

13. p. 13

60.122 Siting

(1) (b) (1) (i) "There is or has been mining, drilling excavation or subsurface exploration for ----"

(a) This is a control zone prohibition. There are so many places where there has been drilling, mining etc. that it may rule out good sites.

(b) Recommen. that it be modified as follows:

"There is or has been mining, drilling, excavation or subsurface exploration for mineral, hydrocarbon, or water resources which provides a permanent pathway to the biosphere <u>and</u> which may ----"

14. p 14

Adverse human activities (v)

Suggested change - delete

Page 14. Adverse human activities (vi)

Delete: "a population center of 5000 persons or more or"

15. P. 15 Section 60.122

Add to (iii) And hence significantly increase the likelihood of radionuclide migration to unacceptable levels.

16. P. 15 (Sec 3) (ii)

Adverse tectonic conditions. A control zone shall not be located where there has been faulting since the start of the Quaternary Period (two million years B.P.).

Difficulty with statement:

"Faulting" is a geometric description, not a genetic term. Faults need not be related to tectonic activity. Also, "microfaults" are almost ubiquitous in nature and are no cause for alarm.

Suggested Statement:

A control zone shall not be located where there has been faulting due to deep geologic causes at the depths greater than one kilometer since the start of the Ouaternary Period.

Supporting Arguments:

Faulting has been caused by ground water pumping (see Holzer, Davis, and Lofgram on the Picacho Fault in 1979 issue of Jour. Geoph. Research) and other near-surface natural and artificial phenomena. These surficial faults, in many places, would not compromise the integrity of a repository.

17. p. 15 (Sec 3) (iii)

Adverse tectonic conditions. A control zone shall not be located where there is a fault or fracture zone, irrespective of age of last movement, which has a minimum horizontal extent on the order of a few [illegible]d of meters and a vertical extent on the order of a few tens of meters.

Difficulty with statement:

Certain metamorphic rocks may be perfectly satisfactory as media for repositories or may be underneath good repository rocks. These metamorphic rocks could easily be filled with major faults (perhaps Precambrian) which have been completely cemented for hundreds of millions of years.

p. 15 (continued)

Alternative statement:

A control zone shall not be located where there is a fault or fracture zone with the last movement during the Cenozoic age which has a minimum horizontal displacement on the order of a few hundreds of meters and a vertical displacement on the order of a few tens of meters.

18. p. 15 (Sec 3) (i)

Until the underground openings are built, a high assurance that no faults exist will be impossible. Counter examples in the tunneling industry are everywhere.

Also, many, if not most, hard rocks contain cracks, joints and fractures. These probably cannot be avoided. Therefore it may not be wise to introduce arbitrarily quantitative restrictions on the control zone such as those in sub-paragraphs (ii) and (iii).

19. p. 16 60.122(b)(3)(iv)

Principal stress magnitudes and directions will be difficult to characterize - it can be done - but the influence of changing stresses on initiating fault movement will be extremely difficult to assess.

20. p. 16 60.122 (b)(3)(v)

Adverse tectonic conditions

A control zone shall not be located where there are concentrations of earthquake activity, etc.

Difficulty with statement:

Most minor earthquake concentrations are made of earthquakes too small to feel and of no structural consequence. Without reference to energy released per volume of rock and other factors, this statement is not too useful.

Suggestion:

Eliminate this statement entirely or specify an earthquake magnitude

Supporting arguments:

Earthquake swarms can be caused by artificial crustal loading (as by reservoirs) and by fluid injection in oil fields and waste disposal operations (see work on "Denver earthquakes," and by Bredehoft and others on the Rangely Oil Field in Colorado.) Neither of the foregoing poses a direct hazard to repositories. Furthermore, the hazards from even major earthquakes should not be significant in deep repositories (see literature-search report by Savannah River Laboratory).

21. P. 16 60.122 (b)(3)(vi)

(vi) A control zone shall not be located where there is reasonable evidence of volcanism since the start of the Quaternary Period (two million years B.P.)

Difficulty with statement:

The "evidence of volcanism ..." may be a layer of volcanic ash several hundred kilometers from a volcanic vent.

Suggested statement:

A control zone shall not be located where there is reasonable evidence of active volcanic vents during the past one million years.

Argument for new statement:

Volcanic rocks can extend far beyond the vents from which they originate. No reason exists to exclude an area from consideration as a repository site just because Pleistocene volcanic rocks are present. In fact, ash and tuff generally have a high ion exchange capacity which could retard radionuclide migration; lava flows will serve to protect underlying materials from erosion; and subsurface intrusions, such as dikes, will form hydrogeologic barriers for migration of water. Thus, volcanism most commonly would have a positive effect on repository safety.

22. p. 18 60.122 (b)

Add

(6) Adverse Ecosystems or Brota

A control zone shall not be located where there are unique ecosystems or brota in the areas of disturbance of the site.

23. P. 17, 60.122(b)(4)"Adverse hydrologic conditions" - locations unacceptable

Original statement: Par. (i) specifies no "reasonable potential for significant changes" in components of transport equations; Par. (ii) specifies not in a "500-year*" flood plain; and Par. (iii) specifies no reasonable potential for lake formation.

Disagreement: end result should be specified, not the components of an equation as in (i). The "500-year" flood plan is difficult to define and protection can be engineered. In (iii) the lake impoundment is undesirable only if it may change the ground water flow system, which statement is redundant with a properly-stated (i).

Alternative suggested:

" (4) Adverse hydrologic conditions. A control zone shall not be located

" (i) Within an area of potential flooding.

" (ii) Where there is evidence suggesting a reasonable potential for the formation of a large-scale impoundment by natural causes during the operation of the repository.

" (iii) In a hydrologic environment that has been shown to have reasonable potential for significant increase in the rate of hydrologic transport from the excavation to the biosphere."

24. P. 17-18 60.122 (b)(5)

"Adverse geochemical conditions" - locations unacceptable

Original statement: Par. (i) states that the host rock must "significantly [geochemically] inhibit migration Par (ii) states a number of 'shall nots' about the water itself.

Disagreement: In (i), there should be a naturally-sorptive barrier somewhere between the repository and the biosphere, if the original calculations require it. The host rock itself need not, of necessity, be that barrier -- cf. "pure" dome salt. However, there is a question of philosophy here as to what geochemistry is supposed to be -- is it to be a barrier of the quality of the engineered barrier and the impermeability of the host rock? If the answer is "yes", then some rock types may be impermissible because of their probable low sorptivity.

In (ii), the end result should be specified, not the potential factors that could affect transport. In passing, note that sub-seabed disposal in seawater (35,000 ppm NaCl equivalent) is stated to be a good prospect because of the sorptivity of the overlying clays.

Alternative suggested:

If geochemistry is to be a factor on the level of the engineered barrier, include (i). If geochemistry is not to be assured to be on that level, (i) may be too strong.

Substitute for (5)

(5) Adverse geochemical conditions. A control zone shall not be located where:

(i) There is no medium between the excavation and the biosphere that does not significantly inhibit migration of radionuclides by sorption or reaction in the event of failure of the engineered elements of the repository.

(a) There is a reasonable likelihood of a change in groundwater chemistry that would significantly decrease the retention of radionuclides by sorption or reaction compared to the existing groundwater chemistry." [assuming that existing groundwater chemistry is acceptable]

25. p. 18 60.122(C)(1)(i)

on stability since Quatenary -

Disagreement: implied equivalence of beginning Quarternary Period with 2×10^6 yrs B.P.

Suggestion: Choose either beginning of Quarternary (or whatever is proper stratigraphic term - is it now Holocene?) or 2×10^6 years. Possibly tie to most recent USGS pronouncement i.e. terminology.

26. p. 18 60.122(C)(1)

Introduction to criteria necessary to a candidate area

Disagreement - none

Comment: Criteria as listed appear to be absolute: But - such as geologic stability since beginning of Quarternary (sub sec i), for example, cannot be found anywhere. Thus, statement that criteria to be met "to the extent achievable" is extremely important and should not be lost.

What is a "reasonable evaluation?"

27. p. 18 60.122(C) Favorable conditions

General statement that regional characteristics should be simple enough to permit analysis of site.

Disagreement-None

Suggest this is an extremely important concept which should be retained and perhaps restated elsewhere for emphasis.

Simplicity - so that the analysis is transparent - is necessary for public acceptance. If reviewing groups, environmental panels, for example, like that now examining WIPP for the state of New Mexico can be led easily through the calculations leading to the selection of that site, it will make the general acceptability of the site more likely.

28. p. 18 60.122 (e)(1)(iii)

Sparse population at potential ground water discharge locations

Disagreement: Lack of specificity

1. Do you mean only ground water discharge locations or radio-nuclide discharge locations ?

2. Present discharge locations or discharge locations at time of potential nuclide discharge? If latter how will one decide what future population distribution will be?

Comment: NRC decide on intent and rewrite

29. p. 19 60.122(c)(1)(v) d & e Appears redundant

p. 19 60.122 C. 1 iv

Comment: This lack of extensive subsurface water resources will eliminate Hanford.

30. 60.122 C 1 v

"A host rock [and surrounding confining units] that function...."

Comment: Implication that host rock will be surrounded by confining unit is very limiting. Some plutons may not be surrounded - some potential rocks may be surrounded by aquifers - i.e. Hanford.

Comment: Are these meant to be as restrictive as they are written?

31. p. 19 60.122 C. 1 v

Characteristics enhancing retardation

Comment - attributes a - i seem something of a laundry list and has some redundancies and irrelevancies - to wit.

a. Why intrinsic? - just permeability ok

b. OK

c. Combining with (h) to say "ability to retard migration of dissolved waste by sorption and/or by promoting reducing candidates

d. Ok - includes (e), and (g)

e. delete

f. OK

g. delete

h. delete

i. OK

32. p. 20

60.122 (Siting); (c) Favorable Conditions; (2) Control Zone (continued)

potential hazard areas (nearest biospheric boundary; nearest usable aquifer). Assurance must be provided that the hydraulic gradient is not going to be reversed, or even significantly altered, in the future.

The hydraulic gradient must be such as to insure, that piston-type flow along the shortest flow path will not cause hazardous contitions, given maximum possible release rate at reposit.

33. p. 20

60.122 (Siting); (c) Favorable Conditions; (2) Control Zone

(i) Ability of the rock to adequately dissipate heat generated by the waste.

Disagreement: This is confusing and misleading.

(a) What does "adequately" mean? The degree of dissipation should be tied in with the purpose of keeping temperature, or its gradients, low. Which is it, T^o or ΔT^o? Is there an absolute ΔT^o? How does this relate to the rock and waste material?

(b) It is well known that one effective way to dissipate heat in a porous material is via advection (see review paper by Witherspoon et al.,). However, advection is facilitated by large permeabilities and hydraulic gradients; the latter is obviously not desirable. What then will control the "ability of the rock to... dissipate heat?"

Alternative suggested: Require heat dissipation prior to enplacement of waste underground; limit the statement to conductive heat dissipation. Define "adequately" precisely.

(ii) Ability of rocks to maintain geomechanical stability....

Disagreement: This does not specify e . ect of mechanical disturbances on permeability. Must require that rock permeability be not increased substantially as a result of excavation, drilling, rock bolting, etc. Otherwise, the rules in (3) may be violated after site has been approved.

Alternative: None immediately - requires discussion.

(v-vi) Conditions that do not permit significant upward groundwater flow... horizontal or downward flow gradients and surrounding confining units.

Disagreement: If conditions do not permit upward flow but do permit downward flow, the only factor creating such conditions is an existing downward hydraulic gradient. This point needs clarification.

Alternative suggested: The repository should be located within a zone in which the existing hydraulic graident is away from the nearest

34. p. 21

60.122 (Siting); (c) Favorable Conditions); (3) Repository Horizon

(i) Average vertic and horizontal intrinsic permeabilities of the rock mass on the or er of 1 x 10 $^{-12}$ cm^2.

Disagreement: I disagree on several grounds.

(a) It is not clear what "average permeability" means in relation to fractured rocks. The statement talks about "rock mass:" Is this the intact rock, or does it include fractures? Assuming that fractures are included (otherwise the statemer makes no sense at all) experience indicates that the permeability at a given site depends strongly on the scale of the experiment. A packer test over a short hole segment may yield a very different value than over a large hole segment; a test including a large underground gallery will yield still a different value. Obviously, the larger the sample of rock tested, the closer one is to an "average" permeability value.

On the other hand, tests conducted at different sites (say different boreholes, galleries) will also show a variation in k (permeability) which may be substantial. Here, one should talk about an "average" k over all the sites, and there is a question about this should be computed. The most recent trend is to use kregeng and assume that the "average" is the geometric (rather than arithmetic) mean (Neuman: statistical characterization of aquifer heterogeneities, GSA special paper, to appear: Preprint available).

(b) I do not believe in the utility of specifying numbers (such as 1 x 10^{12} cm^2) unless one clearly states how the permeability is to be measured. As stated earlier, the measured value depends on the method and scale of test. Furthermore, a permeability in itself does not tell us much about flow: Only a combination of k (intrinsic permeability), ϕ_e (effective porosity), and Δh (hydraulic gradient) are of importance.

35. p. 21

60.122 (Siting); (c) Favorable Conditions; (3) Repository Horizon

(3) If 10^{-12} cm^2 refers to the intact rock mass, it is too high. Alternative suggested: More discussion is needed about the definition of "average" k; its usefullness; methods of measurement; scale of rock mass to be tested. Until then, I suggest that the limit be put on seepage velocity, $q_s=q/\phi_e$ (q= darcy velocity), not on k.

(ii) Effective porosity less than one percent of the total volume

Disagreement: There are advantages to having a large effective porosity:

(1) Seepage velocity, q_s, relates to specific flux, q, as obtained from Darcy's law (the re-called darcy velocity) via the relationship $q_s=q/\phi_e$ where ϕ_e= effective porosity; thus, the larger is ϕ_e under a given hydraulic gradient and for a given permeability, the smaller is q_s. Some refer to q_s as "true velocity." (Bear, J., Dynamics of flow through porous media, Elgenier, 1972).

(2) The larger the porosity, the larger the surface area of contact between groundwater and solid rock. The larger the contact area, the more opportunity there is for sorption of radionuclides to rock surface, and thus, for the retardation of their movement (Freeze and Cherry, Groundwater, 1979).

(3) The requirement of low ϕ_e precludes the use of certain very low permeable rock having a large ion exchange and sorptive capacity, such as clay, mudstone, shale, and other argillaceous materials.

Alternative suggested: Effective porosity should not be limiting factor, but large valves are preferable. Low permeability considerations should take preference over porosity considerations.

(iii) A minimum depth of 300 meters

Disagreement: Rationale unclear. Also, suppose one proposes a site at the bottom of a mountain range: The depth below the peak may be significant, but lateral distance from biosphere can be small. Will this be acceptable?

35 (cont.) p. 21

60.122 (Siting); (c) Favorable Conditions; (3) Repository Horizon (cont.)

Alternative Suggested: Provide rationale; Avoid specifying exact depth limitations. Instead, talk about consequences of a given siting/design.

(vii) Nonpotable water quality in the host rock and surrounding confining units.

Disagreement: Rationale unclear; Overly restrictive. If the host rock does not act as an aquifer (a condition which must always be satisfied), why should the quality of its water be of concern outside of its effect on radionuclide transport?

Alternative suggested: Omit entirely.

36. p. 22 Under (c) site evaluation

The site investigation shall be

Consider clarifying the site investigation at this phase of the studies for a geologic repository. For example, the "feasibility" site investigations in contrast to the "candidate" site investigations performed previously by DOE.

37. p. 22 Under (1) Investigations

Investigations conducted during preapplication phase of candidate site selection, feasibility site characterization, and other stages of the development - - -. Protecting the site from an excessive and/or adverse amount of subsurface openings (holes) may require "worth-of-data" studies.

Quantify minimal adverse affect -

38. p. 22 (c) Site Evaluation

under (1) Investigations

Area to be investigated - "It is expected that the horizontal extent of these investigations may be on the order of 100 km. from the geological repository operational area."

Disagree with 100 km as generally the inferred size of area to probably require investigation

Alternative Suggestion: ---these investigations could be (may be) on the order of 100 km from the geologic repository operations area; however in some geologic settings this horizontal extent of investigation could be much less -- on order of 25 km.

Support - Geologic frameworks, major fault control boundaries, etc. Limit size of area requiring (appropriate) for investigation.

39. p. 23 under (1) Investigations of

(since the start of the Quarternary Period)
During the past two millions years. (B.P.)

Original - The investigations shall emphasize obtainment of information that bears on those conditions which may affect the geologic repository during the next 250,000 years.

Suggest - during the next 10,000 years.

Arguments - Heat generated will be near ambient temperature of rock - -according to paper of White, Bell, Rohrer (1979) p. 9. -- in 10,000 years.

Toxicity released approaches An Ore Body at 1,000 years. Therefore 10,000 years is the time period during which major hazard exists and also the period over which forecasting of geologic and other processes can be done with some reliability.

40. P. 23

(i) Active Natural Process and Conditions
Add "and Conditions"
The discussion that follows involves both process and conditions

41. p. 24 - Under Active Natural Processes

3 In situ and laboratory geomechanical tests of the repository horizon (insert and zone of shaft)

--"and variations in geomechanical properties (insert "with time" due to potential future natural processes and waste/rock interactions.

42. P. 24 60.122 (d)(1)(a)

The following are minimum requirements:

(a) Investigations of geologic conditions including.

(1) Investigation of geomorphic conditions including rates of erosion, potential for mass wasting, channel and network rejuvenation, past evidence of glaciation and its effects, and effects of former climatic, hydrologic, sea level and tectonic changes (Quaternary history).

(2) Investigation of geologic structures and tectonic conditions as on page 25.

(3) Investigation of stratigraphic and sedimentorgic conditions including the extent and distribution of subsurface discontinuities and heterogeneities such as porosity permeability and mineralogical variations.

(4) Investigations of petrologic conditions and geochemical and geomechanical properties and variability including items 2,3,4 and page 24, 25

(5) Investigations of economic geology including the presence of mineral deposits.

43. p. 24 Under Investigations

(a) Investigations at geologic conditions including,

1. topography, physiography, stratigraphy, lithology/petrology, geologic structures, geophysical measurements, geochemical properties,

Suggest - Add:/petrology and geophysical measurements

Arguments - Petrology covers more detailed analysis at rocks than broad term lithology.

Geophysical measurements as gravity or magnetic surveys may infer geologic conditions of importance at depth - that must be investigated-- as well as more insight into fault/structural features.

44. p. 24 60.122(d)(1)(i) a 4

How will it be possible to conduct "...thermal tests to measure rock response...(for)... the duration of temperatures...?"

Measure rock response for duration is clearly impossible. Thus replace measure with "simulate." The question of far field thermal effects must also be simulated.

Note: It should be emphasized in my opinion that no validated models exist which enable deformation of a rock mass to be coupled with hydraulic conductivity. Such a task may be impossible and may remain an important large residual uncertainty.

45. p. 25

Under Investigations

c Investigation of tectonic conditions including tectonic history, plate tectonic interpretations, stress field, faults, fractures, earthquake activity, possilbe correlation of earthquake activity with tectonic structures, diapirism isostatic movements, and volcanism.

Inserts modify meaning

tectonic history and ancient stress pattern

contemporary stress field

possible correlation of earthquake activity with tectonic structures (seismotectonics),

Arguments:

Need to understand ancient stress pattern - cause of faulting as basis for interpretating contemporary stress pattern and whether ongoing stresses could conceivably cause recurring movement. Earthquakes do not necessarily correlate with known fault(s).

46. p. 25

Site Evaluation, minimum requirements, sub-section d, investigations of hydrologic conditions.

Replace sub-section d by the following:

d The ultimate goal of the hydrogeologic investigations will be to obtain data needed to identify all possible pathways of groundwater flow from the repository to the land surface and, neglecting possible geochemical interaction with host rock, to calculate the rates of flow along such pathways, under existing and anticipated boundary conditions, including future thermal effects of decay heat from the waste repository. However, the initial goal will be to obtain such information as will be needed for the "go" - "no-go" decision on construction and location of a pilot shaft. To the extent possible, data needed to satisfy both the initial and ultimate goals shall be obtained by measurement techniques that will not adversely affect the long-term performance of the geological repository. Calculation and measurements should include:

1. Water level data to obtain distribution of hydraulic head in 3-D.
2. Groundwater ages
3. Regional and local water balances
4. Near-surface (2 to 3 meters below land surface) temperature distributions
5. Current and possible future events and/or processes that could affect groundwater flow.

47. p. 27 (iii)a

In situ and laboratory tests to measure the efficiency of sealing of shafts, boreholes, and drifts with respect to both the migration of fluids and radionuclides.

Needs broadening:

Additions/clarification

Alternative suggestions:--to measure the effectiveness of sealing of shafts, boreholes, drifts and drifts with respect to both the migration of fluids and radionuclides and stability of the rock mass.

Support - Include stability of site mass with time

48. p. 27 - (iii) b

" which measure the degree of disruptions to the excavated rock surfaces."

- can only measure superficially, i.e., contour
- laboratory tests would require rock sampling, probably more destructive than careful blasting

49. (2)(i)a. & b.

Active processes and natural processes are not well defined. Presumably they are the same or similar to "Expected processes" given in the definitions (pg 2), or is it? That definition limits processes which will affect the engineered facility only. I think we are talking of a much broader term i.e., all geologic processes which are present in the area such as erosion, deposition, earth quakes, regional ground-water movement, etc. They are specified in the section just preceeding, but on Pg. 23 "Active Natural Processes" is also tied to the effect on the engineered facility.

In effect you are asking that all natural geologic processes be identified and analysed to determine the affect of that process on the depository. I think what is intended is the effect of these processes on the geologic barriers e.g., the ground water flow system and stability of the rock mass.

50. p. 28 (2) (i) c Validate and verify concepts and analytic models using natural analogues, etc.

No analogues exist for the type of situation you are trying to validate and varify. I see great difficulty in the requirement. You have a rather unique situation which will not be similar to existing structures. Because of the "tight" host rock, preterbation resulting from . .ns activities will be slow and difficult to monitor.

Research needs to be conducted in underground cavities in "tight" rocks; most research to date has been of situations where large quantities of water have been a problem.

51. p. 29 (2) (ii) a. iv Effects of pre-existing subsurface penetration, both identified and undetected.

How do you make a reasonable guess as to the undetected (unknown?) penetration? From past exploration activities? From possible mineral resources of the region which could be in the region and reasonably could have been explored? How do you take into account changes in exploration equipment?

52. p. 29 60.122 (d)(2)(ii) b

b Replace with: Geologic Process and Conditions

The effects of past, present or potential geologic processes and present conditions including:

The effects of past, present or potential geologic processes and present conditions including:

- i erosion and deposition
- ii mass wasting
- iii channel incision, avulsion and capture
- iv glaciation
- v sea level change
- vi uplift, subsidence and faulting
- vii seismic conditions - earthquake probability
- viii distributor of faults and fractures
- ix diapirism and volcanism
- x stratigraphic and sedimentologic conditions and variability
- xi geochemical and geomechanical conditions and variability

53. 60.122 pg 30

(1) - (3) Verification

(a) This subsection is extremely important in the regulatory effort. It should be spelled out what a site safety verification program requires.

(b) Recommend a special study to determine a minimum required site safety verification program.

54. p. 31 60.132

The entire section is broad and conceptual. Upon review the section tends to set a philosophy of design rather than give quantitative guidance. T.. all I do not think that the section should strive to give absolutes.

55. P. 32 60.132 (a) (2)

The determination of structures, systems and components that are important to safety seems to me to be involved with the system itself. For example if a valve is critical to the safe operation then it must be designed with built in strength and back up systems to withstand possible adverse conditions but would not be determined to be critical based on "an analysis of repository performance..." Wording would improve intent of section.

56. p. 32-35

This section should contain statements of the level of protection required against each of the effects. These should not be engineering specifications on components but should be consistent with other performance criteria such as the EPA criteria.

57. P. 34 ara. (8) Emergency Capability

This should include means for rapidly sealing compartments of the facility. The experience of the Defense Nuclear Agency in sealing underground explosions is relevant.

58. p. 36 60.132 (11) Criticality Control

This section is applicable only to the storage of spent fuel elements and criticality can only occur even then if the facility were to become flooded. The waste package should probably be "poisoned" so that criticality could not occur even if flooding did.

59. P. 36-37 60.132-7

Ventilation during the operational phase of a repository is vital to the health and safety. Consideration should be given to the location of vent shafts with respect not only to operation but a trade off must also be made in relationship to the best location from the stand point of the hydraulic regime i.e.,downstream of potential gradients, etc.

Ventilation should be separate for excavation and waste storage not only under normal conditions but under emergency conditions.

The use of words such as proper [item (i) page 37] is vague.

60. P. 39 Section 60.132-9

Add Decommissioning

This is left out

Consideration of the operational design in its entirety should consider, decommissioning of all subsurface facilities.

61. P. 38 60.132 (a) (14)

Restate to read "Excavation and construction operations and activities will be separate from waste transport and emplacement operations.

62. P. 39 60.132-9

(1) - (b) Retrieval of Waste

(a) This subsection requires that surface facility structures be designed and constructed to facilitate the safe retrieval of emplaced wastes----.

(b) What is the rationale for this requirement?

(c) Recommend that this statement be modified as follows:

"It is desirable that surface facilities shall be designed ---- off site. It shall be shown that surface storage could be modified in a timely manner to meet the needs for retrieval of the waste.

63. P. 39 60.132 b (3)

The regulation should keep in mind that the waste packages may well be of two different kinds, encapsulated chemical process wastes and packaged spent fuel elements. The retrieval can also be required for two quite different reasons. The first reason for removal is true retrieval with intent to transfer to another repository because of a decision that the repository in question gives evidence of unsatisfactory long term performance. The second reason for removal would be the reclamation of the packaged materials. This would be unlikely as far as the encapsulated chemical process wastes are concerned at least for a century or two but the reclamation of the spent fuel elements is highly probable and that on a fairly short time scale.

The last sentence, "Such storage----- to require retrieval," should be striken.

64. p. 40 (c)(1)(i) and (ii)

2. Subsurface excavations

General

In my opinion the wording is too restrictive since some excavation or stress relief phenomenon will occur. The point should be made that this deformation and hence potentially increased permeability should be minimized to the extent possible. As an example, even smooth wall blasting will cause some excavation fractures though it will be substantially less than produced by conventional drilling and blast methods of development. This item is a matter of urgent in situ research since the available knowledge of fracture hydraulic conductivity is minimal for all the potential rock mass types currently being considered in the U.S.A.

In summary these sub sections should be reworded.

65. P. 41 60.132-11

(ii) Excavation design and constructions

Stressing can not be suppressed

"Radial" fracturing is not the main stability concern

Design should optimize the stressfield around the opening, i.e., minimize the development of potential leakage-migration.

- compressive stresses can be optimized to reduce permeability around opening
- design: - opening shape (input variable)
- in situ stress (input from site characterization)

66. P. 41 60.132-11 (iii)

Repository extraction ratios----

The determination of appropriate extraction ratios

Disagreement: the term extraction ratio suggest a mine design method which I do not consider appropriate for a repository design

Replace by: Pillar and opening dimensions shall be----

Surface subsidence is one of the easiest elements to monitor maximum surface subsidence can and should be specified, e.g., in terms of max subsidence as a function of opening dimensions.

67. p. 42 60.132(c)(5)

There are primarily three factors which heat will influence.

1. Near field thermal effects - waste package performance and retreval
2. Near field thermal effects around the immediate vicinity of subsurface openings. - pathways long term
3. Far field effects. The extensive massive loading say 75 kw/acre etc. in some times of rock could theoretically under specific conditions have subtracted effects on hydraulic properties of the rock mass. I know of at least one study which indicated the possibility of a significant tensile zone 800 ft from the surface.

68. P. 42 60.132 (c) (5)

Suggest rewording "The facility shall be designed such that the heat loading generated by the wastes will not cause the rock mass to respond in such a manner so as to significantly adversely affect..."

69. P. 42 60.132 (c)

(6) Shaft seals and borehole seals

"in-situ tests <u>at the site</u> "

It would seem preferable to minimize penetrations, hence such test requirements should <u>not</u> justify any additional penetrations.

There are strong arguments for absolutely minimizing the number of penetrations, because no experience to date indicates that penetrations can be sealed to the point where release paths are equivalent to those through "solid" rock.

70. P. 42-43 60.132 (c)

(6) Shaft seals and borehole seals

Specification is subject to maximum release rate as per EPA - can this be given as a performance objective?

(ii) Would imply that half or less of the total release is through the penetrations

71. P. 49 60.135 <u>Retrieval of Waste</u>

The 50 year period seems so arbitrary that it would be difficult to sustain in a intervenor confrontation. Would a better approach be that suggested earlier, viz. that closure be definitely postponed until the spent fuel reclamation situation is resolved and until monitoring gives no great promise of further-developing the base of data and understanding. A possible choice of time after closure might then be the time for decay of the heat load to some level below which change due to thermal effects becomes acceptably small.
See revision of 60.111 (d)

72. P. 52 60.161 Safeguards 60.135-4

This subpart (SUBPART F) needs to be greatly expanded to define requirements on the Department.

73. General

Clarity of the regulation might be improved if in sections such as "Monitoring", "Physical Protection", etc...the sections would be structured in phases such as "Site Characterization Phase", "Construction Phase", "Operations Phase", and "Decommissioning Phase."

Significant Conflicting Opinions

The intent of this Appendix is to provide more detail on technical positions on which the panel could not reach a consensus.

1. Control Zone

The control zone shall extend to a boundary at which the temperature gradient is ten percent of that at the boundary of the operations area at the time of maximum heat generation within the repository and all of the vertical distance below the surface of the repository excavation.

_6_ Agree _6_ Disagree _3_ No Opinion

Comments on Disagreement:

a. Seems that temperature gradient should not be the only criterion; if there is no ground water migration then it would be.

b. Should be defined on the basis of heat flux and not temperature gradient.

c. Rationale for the ten percent is not clear and I would want to see calculations to satisfy the radii requirement.

d. Heat load as a function of time cannot now be specified. We have no information about waste composition or age at time of emplacement.

2. Adverse Tectonic Conditions

A control zone shall not be located where there has been faulting due to deep geologic causes at depths greater than 1 kilometer since the start of the Quaternary Period of the order of a magnitude of 3 or greater.

_7_ Agree _7_ Disagree _1_ Unclear

Comments on Disagreement:

a. Do not mix faulting with earthquake generation. Recommended the following earthquake statement be included:

There is evidence of the clustering of present day earthquakes caused by geologic forces at depths greater than 1 kilometer. Earthquakes to be considered are only those with a magnitude on the Richter scale of more than 3.

b. What is meant by faulting of magnitude 3? Why 1 kilometer?

c. Recommended the following be inserted after Quarternary Period:

"With associated mic.--eismicity on" and deleting the word "of".

d. I oppose arbitrary prohibitions.