COMPLIANCE DETERMINATION STRATEGY
RRT 4.3 ASSESSMENT OF COMPLIANCE WITH DESIGN CRITERIA
FOR SHAFTS AND RAMPS

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(i)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(14)
10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)(1)
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.131(b)(10)
10 CFR 60.134
10 CFR 60.137

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analysis (Type 4)

RATIONALE FOR TYPES OF REVIEW:

Acceptance Review (Type 1) Rationale:

This regulatory requirement is considered to be license application-related because, as specified in the License Application content requirements of 10 CFR 60.21(c) and Section 4.3 of the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)," it must be addressed by the DOE in its license application. Therefore, the staff will conduct an Acceptance Review of the license application for this regulatory requirement topic.

Safety Review (Type 3) Rationale:

This regulatory requirement is related to radiological safety, retrievability, containment, and waste isolation. It is a requirement for which compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31(a) (i.e., regulatory requirements in Subparts E, G, H, and I). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with the applicable regulatory requirements.

There are a number of review plan topics that are closely-related for which geologic repository operations area (GROA)-related design reviews will take place. They concern both engineering design and performance. This particular regulatory requirement topic focuses on the review of compliance with the design criteria for shafts, ramps, and boreholes of the GROA set forth, as applicable, in 10 CFR 60.130, 60.131, and 60.134.

In conducting the Safety Review, the descriptions provided in Section 4.1.2 ("Description of the GROA Structures, Systems, and Components: Shafts and Ramps") of the license application, will support the reviews described below. However, it should be noted that the adequacy of GROA shafts, ramps, and boreholes design will eventually be evaluated in the context of compliance with the pertinent performance objectives, and this review strategy should be understood in that context.

The staff concludes that there is a low risk of noncompliance with many of the GROA design criteria for shafts, ramps, and boreholes set forth in 10 CFR Part 60. This conclusion is based on the nature of the Yucca Mountain tuff and the available drilling, boring, excavation, and reinforcement technologies used in underground construction. However, with respect to GROA design criteria regarding sealing set forth in 10 CFR 60.134, the staff has concluded that there may be a high risk of noncompliance with the performance objectives for the GROA, at both the system and subsystem levels, due to Key Technical Uncertainties.

Detailed Safety Review Supported by Analyses (Type 4) Rationale:

The staff considers that there may be a high risk of making a wrong determination of compliance with 10 CFR 60.134 because for the Yucca Mountain site there are Key Technical Uncertainties regarding the performance of the shaft, ramp, and borehole seals; the effects of coupled thermal-mechanical-hydrological-chemical (TMHC) processes; and retrievability of waste. Therefore, predictions regarding: (1) the long term performance of seals for shafts, ramps, and boreholes; (2) the thermal-mechanical-hydrological-chemical response of the host rock, surrounding strata, and groundwater system to thermal loading; and (3) the ability to retrieve high-level radioactive waste, respectively, may vary widely and may lead to inappropriate conclusions concerning compliance with the system and several of the subsystem performance objectives. The staff believes that the risk of non-compliance due to the following Key Technical Uncertainties is sufficient that a detailed Safety Review supported by analyses is justified.

This concern regarding compliance determination with the performance objectives specified below will necessitate analyses above and beyond that required for a Type 3 Safety Review in order to assure that the uncertainties and potential effects on performance have been minimized to the extent practical. It should be noted that the Detailed Safety Reviews for the KTU's identified under items (2) and (3) above will be dealt with under Review Plans 4.4 and 4.5.2, respectively. The thermal loading is expected to affect the shafts, ramps, and exploratory boreholes to a lesser degree than the drifts and emplacement boreholes, however, some input from this Review Plan will be necessary to assure compliance with the Detailed Safety Review of these two KTU's.

Key Technical Uncertainty Topic: Predicting the long term performance of seals for shafts, ramps, and boreholes.

Description of Uncertainty: Review of the post-closure portion of the design for shafts, ramps, and boreholes in 10 CFR 60.134 demands consideration of the performance of seals (and backfill materials), and an evaluation of the impact of repository-generated thermal loads and repeated seismic loads on the long-term performance of these repository features. For example, in order to have confidence in applying current sealing technology to the repository environment, two technical uncertainties relevant to the effectiveness and performance of seals remain to be resolved. These uncertainties are: (1) whether the seals will remain effective over thousands of years (i.e., seal long-term performance); and (2) whether technology exists to effectively install seals such that the intended performance of seals can be achieved.

Experience on long-term performance of seals is currently lacking. Although available observations of the performance of some seal materials (for example, low permeability cements) seem to indicate that these components may have great durability (Osende, 1985; and Rissler, 1978), it is also uncertain what impact thermal loads and repeated seismic loads will have on their performance. Also, other observations (Roy and Lanton, 1983; and Roy and Lanton, 1986) about deterioration of high quality cement grouts in dam foundations within a decade after installation seem to indicate otherwise. Considerable uncertainty exists related to the installation of seals in the underground excavations (Schaffer and Daemen, 1987). This is especially true concerning the determination of optimum grouting conditions and preferable grouting pressures to seal fractures around the excavations due to construction. It is uncertain how to prevent the fractured zone around the excavations from becoming dominant bypass flow paths around the seals and thereby negating the effectiveness of the seals.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermal-mechanical effects on the performance of seals, including the surrounding rock mass; and (2) prediction of thermal-hydrological effects on the chemical properties of the seal materials.

Performance Objectives at Risk: 60.112 and 60.113(a)(1)

Explanation of Nature of Risk: If the seals for shafts, ramps, and boreholes do not perform as well as intended, it is possible that pathways could exist that would allow water to reach the waste packages and accelerate corrosion of the waste packages putting compliance with 10 CFR 60.113(a)(1) at risk. Accelerated corrosion might produce situations in which the following could occur: containment is not substantially complete; the release of radionuclides is not gradual; and the release rate is too large.

Besides allowing water to reach waste packages, malfunctioning seals might also allow radionuclides to move away from the waste packages in such a fashion as to put the overall system performance objective specified in 10 CFR 60.112 at risk.

It is possible that the net contribution of seals to the overall system performance of the geologic repository may not be significant due to the unsaturated nature of the Yucca Mountain repository site. If future research or field studies by the U.S. Department of Energy (DOE) indicate that these uncertainties regarding seal performance, including the relative effects of thermal loads on the seal performance, can be significantly reduced, or that it can be substantiated that the net contribution of seals to overall system performance is negligible, the review strategy type will be downgraded. If, on the other hand, the Key Technical Uncertainty is not being reduced, and the contribution of the seals is not negligible, then the review strategy type may have to be upgraded.

Description of Resolution Difficulty: The seals for shafts, ramps, and boreholes will not generally be installed until the repository is ready for closure. As a result, a long period of testing and in situ observations of seal components, placement methods, and overall seal performance under a variety of conditions including thermal and repetitive seismic loadings can be evaluated before the final design of the sealing program is necessary. This will result in a reduction in the uncertainty and better understanding of the nature of risk with regard to the long-term seal performance from the initial design and sealing program submitted at the time of the license application. However, the operations period is only a small fraction of time in comparison to the post-closure period, and thus some sort of methodology or conceptual models will still be necessary to allow extrapolation of the available laboratory or field experimental seal data to estimate the long term seal performance after closure of the repository. At the time of license application, extrapolation of uncertain models and test results may be used in design of the seals.

This uncertainty can best be addressed through a comprehensive seal testing program by DOE, in the laboratory as well as in the field, which extends through the period of operations of the repository. The time available during site characterization studies and repository operations is beneficial because that time can be used to adapt the sealing program to the particular geologic setting as well as to the natural and environmental conditions.

Key Technical Uncertainty Topic: Prediction of the thermal-mechanical-hydrological-chemical responses of the host rock, surrounding strata, and groundwater system to thermal loads.

Description of Uncertainty: Section 60.133(i) requires that the underground facility for the GROA be designed so that the performance objectives will be met, taking into account the predicted thermal and thermomechanical responses of the host rock, surrounding strata, and groundwater system. The rule thus recognizes that an understanding of thermal loads caused by the emplacement of nuclear wastes, and the corresponding thermomechanical response is essential to the design of the underground facility. One must also understand the uncertainties associated with predicting the thermal loading and corresponding rock and groundwater responses, so that these uncertainties can be accommodated by the GROA shafts, ramps, and boreholes design. Many aspects of the GROA design, including for shafts, ramps, and boreholes the opening configurations, dimensions, and support requirements, may depend on predictions of heat transfer, and thermally-induced responses such as rock deformations, groundwater flow (both liquid- and vapor-phase transport), and the dissolution and precipitation of mineral species.

The emplacement of spent fuel underground will generate heat and result in the expansion of the rock mass, produce thermal stresses, and cause potential normal and shear displacements of fractures, which could affect the performance of shafts, ramps, and boreholes. For example, Kemeny and Cook (1990) have reported that, in the worst-case scenario, approximately 38 percent of the waste emplacement boreholes may fail as the repository heats up. Rock failure inside waste emplacement boreholes may cause waste package degradation. Although the ramps may be sufficiently far away from the thermal pulse, the lower portions of any additional shafts or boreholes within the repository block will likely be subjected to high thermal stresses. The long-term thermomechanical response of the host rock and surrounding strata over the lifetime of the repository is difficult to predict and thus difficult to account for in the design of the facility.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermomechanical (including seismic load) effects on drifts and emplacement boreholes for retrievability; and (2) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for waste package design and performance assessments.

Performance Objectives at Risk 10 CFR 60.111, 10 CFR 60.112, and 10 CFR 60.113.

Explanation of Nature of Risk: The impact of thermal loads on repository performance is a very complex technical issue, depending on many factors, including the magnitude of the thermal loads themselves. For those repository-generated thermal regimes that are within the range of engineering experience, the use of predictive models to evaluate the possible effects of thermal loads on repository performance may be a reasonable approach to demonstrate compliance with Part 60 regulatory requirements. On the other hand, repository-generated thermal regimes that are beyond the range of current engineering experience pose significantly more complex problems. Such thermal regimes, acting over the long time frame of repository performance, may produce effects that involve prediction considerations that are well beyond current engineering practice. For such situations, the use of existing models to predict the likely effects on the repository from such loads, may not be satisfactory.

The fundamental mechanism of thermal, mechanical, hydrological, and chemical coupling processes are not fully understood at this moment. Coupled thermal, mechanical, hydrological, and chemical analytical models or computer codes which can be used to successfully predict the repository thermomechanical and hydrological responses are not available, which makes the prediction of long-term near-field repository behavior difficult.

Description of Resolution Difficulty: Much effort will be required in order to develop a reliable model (and attendant computer code) necessary to understand this Key Technical Uncertainty. However, the staff expects model development/refinement to continue as greater understanding of thermally-induced phenomena is gained. Because DOE will need to defend its shafts, ramps, and boreholes design on the level of TMHC coupling it chooses to consider in a particular GROA design, including those aspects of TMHC coupling it chooses to discount in such decisions, it has been the staff's position that DOE should develop and use a defensible methodology to demonstrate the acceptability of a GROA underground facility design. The staff anticipates that this methodology will include the evaluation and development of "appropriately" coupled models to account for the TMHC processes that are induced by repository generated thermal loads.

The issue of thermal loads on the GROA underground facility was discussed in the NRC's "Staff Technical Position (STP) on Geologic Repository Operations Area Underground Facility Design - Thermal Loads" (Nataraja and Brandshaug, 1992). If DOE chooses a methodology different from that in this STP, the reviewer shall assess if the alternative methodology considers the coupling of thermal-mechanical-hydrological-chemical processes in a manner that is not likely to underestimate the unfavorable aspects of total system performance or to overestimate the favorable aspects of repository performance. As such, the NRC and CNWRA will conduct independent studies to understand and develop an independent capability for reviewing the thermal, mechanical, and hydrological coupling effects on rock joints and fractures (CNWRA, 1993; DECOVALEX, 1993).

Key Technical Uncertainty Topic: Demonstration of compliance with the requirement to maintain the ability to safely retrieve high-level radioactive waste.

Description of Uncertainty: DOE is required to provide a plan that describes how high-level radioactive waste can be safely retrieved and stored. Retrieval of waste canisters on a mass scale from an underground repository has never been attempted or accomplished anywhere. Also, the U.S. program is the only waste management program considering retrieval, thus preventing the benefits of learning from the experience of others. This lack of experience makes retrieval a riskier activity than an activity for which there is experience. The uncertain nature of retrieval is acknowledged in the Statement of Considerations for 10 CFR Part 60, in which it is stated, "...the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation" (Nuclear Regulatory Commission, 1983). Although the retrieval plan will probably have undergone Detailed Safety Review by the DOE, NRC should still perform a detailed review with independent analyses to determine that health and safety will not be adversely affected by what will probably be a largely unproven retrieval system.

Another aspect of this Key Technical Uncertainty is that DOE will have only limited test results available to convince the NRC staff at the time of license application of its ability to retrieve any or all of the inventory of waste. The future conditions during which retrieval would take place, and upon which the retrieval plan is based, will themselves be based on model predictions. Such predictions are bound to have uncertainties, some of which will probably be significant. Examples of uncertain predictions include the effects of coupled thermal-mechanical-hydrological-chemical processes on the waste package, rock, and rock support; the effects of heating on material properties; and the effects of heating and then cooling on strengths and material properties.

In addition to the predictive uncertainties, there will be uncertainties regarding the conduct of the retrieval operation itself. Examples of operational uncertainties include how the possible presence of leaking waste canisters would affect worker health and safety, the ability to cool the repository, and the ability to safely store contaminated material, particularly if large amounts of backfill and/or rock are contaminated. There will likely be uncertainties regarding the conduct of the retrieval operation, which would result in uncertainties regarding the radioactive doses that workers, and even the public, may receive. Because the retrieval operations might rely upon or be affected by the shafts and ramps of the GROA, the uncertainty about retrievability creates uncertainty regarding the design of the shafts and ramps.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermal-mechanical effects on drifts and emplacement boreholes for retrievability and (2) the lack of experience with retrieval operations.

Performance Objective at Risk: 10 CFR 60.111(b)

Explanation of Nature of Risk: Understanding the response of the geologic repository to coupled TMHC processes represents a Key Technical Uncertainty complicating the review of DOE's plans and designs for waste retrievability. At this time it is recognized that the chemical processes may not be important during the operations period. Because waste retrieval operations will necessitate activities in a repository that will be affected by these processes, with uncertain effects, it is reasonable that the impacts of TMHC processes on retrieval are also uncertain, and may put the ability to safely retrieve and store waste at risk. The lack of an adequate understanding of the TMHC processes could lead to a misjudgment of the response of the repository's physical environment, perhaps putting the retrieval performance objective at risk.

The waste emplacement configuration could pose a risk to retrievability and storage, depending on its complexity. It is not yet known whether borehole or room emplacement will be used, or whether emplacement will be horizontal or vertical, or whether single or multiple canisters will be in an emplacement hole, or what the dimensions and mass of a waste container will be, or whether rooms/boreholes will be backfilled. Complicated emplacement schemes in a backfilled repository will probably make it more difficult to retrieve waste than a simpler scheme. Such difficulties or complexities also will make it more difficult to demonstrate that waste can be retrieved. In addition, the heat generated by the waste (which is a function of the waste emplacement configuration) makes it likely that the difficulties and uncertainties in retrieval will be exacerbated as the repository becomes hotter. Retrieval of some, but not all, waste packages may endanger the long-term performance of the remaining waste packages, if those waste packages or their environments are adversely affected during retrieval.

The decision to retrieve will probably not be made lightly, and may be prompted by a situation of leaking waste packages. Even if waste packages are not leaking, the complex process of retrieval raises the possibility of situations that could expose workers to high levels of radiation. With a lack of prior experience, there is uncertainty regarding the ability to retrieve waste and still be in compliance with radiation protection requirements.

<u>Description of Resolution Difficulty</u>: There is a lack of experience with retrieval operations in an underground, heated repository. Thus, previous experience cannot be examined, utilized, or referred to. In addition, the determination of the ability to retrieve waste will be made at the time of license application, but the decision to retrieve would be made later in the operational phase. Therefore, the demonstration and determination of compliance with the retrievability requirement will be partly based on the uncertain results of TMHC models.

However, some of the uncertainty regarding retrievability can be reduced by DOE. For example, the following actions are among those that could reduce this Key Technical Uncertainty:

(1) that DOE designs a simple and straightforward waste emplacement configuration (for example, single canisters in vertical or horizontal holes, or room emplacement with no backfill);

(2) that DOE proposes to use proven retrieval equipment and procedures; and

(3) that the results of site characterization activities demonstrate that site-related complexities do not preclude the ability to retrieve waste.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of the assessment of the U.S. Department of Energy's GROA shafts, ramps, and boreholes design, the reviewer should determine if the information present in the license application and its references for determining compliance with the applicable regulatory requirements is complete in technical breadth and depth as identified in Section 4.3 of the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)."

The descriptions provided in Section 4.1.2 ("Description of the GROA Structures, Systems, and Components: Shafts and Ramps") of the license application will form the basis for the Safety Review of the information contained in Section 4.3 of the license application. Thus, the review of the information contained in Section 4.1.2 will be performed in parallel with the review of the information contained in Section 4.3. Therefore, during the Acceptance Review of Section 4.3, the reviewer should verify from the reviewer of Section 4.1.2 that all appropriate descriptive information of the GROA shafts, ramps, and boreholes design has been provided, as described in Section 4.1.2, and that the information is both internally consistent, and consistent from section-to-section.

The reviewer should determine that all appropriate information necessary for the staff to review the demonstration of compliance with the applicable regulatory requirements is presented such that the assessments required by the regulatory requirements associated with pre- and post-closure performance objectives or other GROA design and technical criteria can be performed. The reviewer should determine that the information in the license application is presented in such a manner that the assumptions, data, and logic leading to a demonstration of compliance with the applicable regulatory requirements are clear and do not require the reviewer to conduct extensive analyses or literature searches. The reviewer should also determine that controversial information and appropriate alternative interpretations and models have been acceptably described and considered.

Finally, the reviewer should determine if DOE has either resolved all the NRC staff objections to the license application that apply to this requirement or provided all the information requested in Section 1.6 of the FCRG for unresolved objections. The reviewer should evaluate the effect of any unresolved issues, both individually and in combinations with others, on (1) the reviewer's ability to conduct a meaningful and timely review and (2) on the Commission's ability to make a decision regarding construction authorization within the three-year statutory period.

Safety Review:

This regulatory requirement topic is limited to assessment of compliance of the GROA shafts, ramps, and boreholes design with the pertinent 10 CFR Part 60 GROA design criteria and performance objectives. The review of these other underground facility elements will be treated in Sections 4.4 ("Assessment of Compliance with Design Criteria for the Underground Facility"), 5.2 ("Assessment of Compliance with the Design Criteria for the Waste Package and its Components"), and 5.3 ("Assessment of Compliance with the Design Criteria for the Engineered Barrier System") of the license application and its attendant review plans. Finally, the assessment of the GROA underground facility design, from the perspective of waste retrievability, will be evaluated in Section 4.5.2 ("Assessment of Integrated GROA Compliance with the Performance Objectives: Retrievability of Waste") of the license application.

The reviewer's objectives during the Safety Review of this regulatory requirement topic are to:

- conduct a preliminary review of the data base, used for demonstrating compliance with the applicable regulatory requirements, to determine data completeness;

- determine whether portions of the data and/or analyses submitted need further detailed review (in addition to those areas requiring detailed Safety Reviews which may arise in the future);

- understand and evaluate DOE's compliance demonstration logic; and

- determine whether any use of expert opinion (in lieu of experiments or analyses) is appropriate.

In conducting the Safety Review, the reviewer should determine if the information presented in the license application and its references is an acceptable demonstration of compliance with all applicable regulatory requirements. At a minimum, the reviewer should determine the adequacy of the data and analyses that are presented in the license application as DOE's supporting information concerning its demonstration that its design for the GROA shafts, ramps, and boreholes meets those design criteria and helps meet the performance objectives specified in 10 CFR Part 60. The review should include consideration of the design that has been presented, and evaluation of the contribution of design to meeting the performance objectives.

The specific aspects of the license application on which a reviewer will focus are described below, and the Acceptance Criteria are identified in Section 3.0 of this review plan. The reviewer should determine whether DOE has demonstrated that the design for GROA shafts, ramps, and boreholes meets the performance objective of 10 CFR 60.111(a) concerning radiation exposure to workers; the performance objective of 10 CFR 60.111(b) concerning retrieval of waste; the GROA design criteria of 10 CFR 60.130; the general design criteria of 10 CFR 131; and the design criteria concerning seals in 10 CFR 60.134. The reviewer will also determine whether DOE has demonstrated that the GROA shafts, ramps, and boreholes design permit the implementation of the performance confirmation program defined in 10 CFR 60.137.

Pertinent design criteria chosen by DOE should also be reviewed for acceptability. The reviewer should determine whether or not DOE has demonstrated that the design bases for the shafts, ramps, and boreholes take into account the results of DOE's site characterization activities.

In presenting the GROA shafts, ramps, and boreholes design, the reviewer should evaluate whether DOE has acceptably described, at a minimum, the following systems:

(1) waste shaft or ramp;
(2) muck shaft or ramp;
(3) ventilation intake shaft or ramp;
(4) ventilation exhaust shaft or ramp;
(5) personnel and material shaft or ramp; and
(6) decommissioning system.

In conducting the Safety Review, the staff will evaluate the adequacy of the following information, as appropriate, for the systems described above:

(1) a description and discussion of the GROA shafts, ramps, and boreholes design including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the GROA shafts, ramps, and boreholes;

(2) a description and analysis of the design and performance requirements for structures, systems, and components (SSC) of the geologic repository shafts, ramps, and boreholes which are important to safety. This analysis shall consider: (i) the margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena;

(3) an identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of license specifications. Special attention shall be given to those items that may significantly influence the final design; and

(4) an identification of those structures, systems, and components of the shafts, ramps, and boreholes which require research and development to confirm the acceptability of design. For structures, systems, and components important to safety and waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

In reviewing Items (1)-(4), above, the staff will confirm that DOE has included the following:

(1) an analysis of the performance of the major structures, systems, and components, to identify those that are important to safety. For the purposes of this analysis, it should be assumed that operations at the GROA will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application; and

(2) an explanation of measures used to support the models used to perform the assessments required in Item 1 above. Analyses and models that will be used to predict future conditions and changes in the geologic setting should be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

For the information described in Item (2), the following should be reviewed for completeness and acceptability:

(a) discussions of data representativeness, including uncertainties associated with extrapolation of data;

(b) variability and uncertainty of data and resultant propagation of errors in models or analyses for which such data was used;

(c) identification of, and justification for, assumptions used in analyses and models;

(d) documentation and validation of models and analyses;

(e) input and output data and interpretations of the data with the basis for interpretation; and

(f) the role of expert judgment, if used, in models and analyses.

Analyses and models used by the DOE to predict behavior of the GROA shafts, ramps, and boreholes should be reviewed for completeness and acceptability. The items to be reviewed should include:

(1) identification and evaluation of design parameters used to meet design criteria;

(2) description of uncertainties in parameters and of how these uncertainties are reflected in models;

(3) descriptions of analyses and models used in the design of the shafts, ramps, and boreholes; and

(4) description of uncertainties in analytical models and how such uncertainties affect predicted results.

The GROA design also needs to demonstrate that all structures, systems, and components important to safety are properly integrated. Accordingly, when reviewing the GROA shafts, ramps, and boreholes design, the reviewer will rely on the information contained in Section 4.1.5 ("Description of the GROA Structures, Systems, and Components: Interfaces Between Structures, Systems, and Components") of the license application to ensure that the necessary design and operating interfaces are addressed.

The reviewer should also assess the adequacy of the design of the shafts, ramps, and boreholes for the control of radiation exposures and radiation levels, and releases of radioactive material, in effluent, to workers. The reviewer will determine if a reasonable effort has been made to maintain radiation exposures and radiation levels, and releases of radioactive material, in effluent, "as low as is reasonably achievable" (ALARA) as required by 10 CFR Part 20. Those design enhancements that are necessary for the implementation of ALARA need to be identified as part of the shafts, ramps, and boreholes design.

DOE's demonstration of compliance with the applicable regulatory requirements concerning radiation protection for workers is expected to consist of the following: (1) identification of conditions and events, associated with normal repository operations and those events that can be reasonably expected to occur prior to permanent closure (such as those events referred to in American Nuclear Society Standard, ANSI/ANS-57.9-1984, as Design Events I, II, and III), that could lead to the intake of radioactive materials by, or radiation exposures to workers; (2) estimation of the probabilities (numerical or qualitative) that these conditions and events may occur, and determination of the regulatory limits for the estimated conditions and events; (3) analyses of the source terms (quantities, concentrations, and specifications of potential releases and direct radiation exposures and levels) that are expected to occur for the applicable conditions and events; (4) identification and analyses of receptors (locations and work characteristics of individuals potentially exposed); (5) use of models to determine potential radiological impacts within the restricted area; and (6) planning and design considerations used to meet the criteria of 10 CFR Part 20.

The NRC staff's evaluation of compliance will also consist of six steps, paralleling the steps in DOE's demonstration of compliance. The specific aspects of the license application on which a reviewer will focus are discussed below, and the Acceptance Criteria are identified in Section 3.0 of this Review Plan. The scope of this review plan includes:

(1) identification of the conditions and events, associated with normal operations and those conditions and events that can be reasonably expected to occur prior to permanent closure, that could lead to the intake of radioactive materials by, or radiation exposures to workers during the pre-closure period. DOE is expected to use event tree analyses, fault tree analyses, and similar methods to identify repository conditions potentially leading to radiological impacts on workers. The NRC staff will review DOE's submittal, but will not independently develop its own identification of repository conditions;

(2) estimation of the probabilities (numerical or qualitative) that these conditions and events may occur, and determination of the regulatory limits for the estimated conditions and events. The NRC staff will review DOE's submittal, but will not independently develop its own probability estimates. The NRC staff will independently confirm that the proper regulatory limits have been applied to the potential radiological impacts of the applicable repository conditions and events;

(3) analyses of the source terms (quantities, concentrations, and specifications of potential releases and direct radiation exposure levels) that are expected to occur for applicable conditions and events. DOE's analyses of the source terms are expected to include the quantities and rates of discharges of radioactive materials to, and radiation fields for workers associated with the pre-closure period, as a result of those conditions and events that can be reasonably expected to occur prior to permanent closure. Analyses of the source terms are also expected to include any items intended to control or monitor radiological exposure as a result of those conditions and events that can be reasonably expected to occur prior to permanent closure that affect the concentration and exposure limits specified in 10 CFR Part 20. The NRC staff expects DOE's source term analyses to include estimates of the quantities of radionuclide releases and the field strengths associated with pre-closure repository activities. The NRC staff will review DOE's analyses of source terms, but will not independently develop its own estimates;

(4) identification and analyses of receptors (locations and work characteristics of individuals who are potentially exposed) for each potential release and radiation exposure. DOE's identification and analyses of receptors is expected to be based on projections of facility design, planned schedules, work conditions within the repository and on DOE's plans for reducing potential exposures to ALARA for the conditions and events that can be reasonably expected to occur prior to permanent closure. Thus, different receptor

analyses may be developed for various conditions and events that can be reasonably expected to occur at the repository. The NRC staff will review DOE's identification and analyses of receptors, but will not independently develop its own analyses;

(5) use of models to determine potential radiological impacts on workers. The NRC staff expects DOE's estimates of impacts to include: (a) anticipated concentrations of each radionuclide during the pre-closure period and the contribution of each to the radiation dose; (b) calculations and explanations of the measures used to support the shielding and airborne concentration models used to determine exposures; (c) annual whole body individual and collective doses determined to be attributed to the pre-closure period; and (d) details specified in Section 8.4 of the FCRG, and the requirements specified in 10 CFR 60.131(a). The NRC staff will review DOE's use of models to determine potential radiological impacts, but will not independently develop its own determinations; and

(6) planning and design considerations used to meet the criteria of 10 CFR Part 20 for workers. The NRC staff expects DOE's planning and design considerations to include: (a) design criteria and plans for pre-closure activities, e.g. expected functions and handling scenarios; (b) planning and design objectives for the pre-closure period, e.g. limits of radiation exposure, shielding objectives, containment integrity, and maintaining exposures ALARA; and (c) planning and design bases for the pre-closure period, e.g., codes or standards used for design, shielding codes used, calculational methods applied, and safety procedures. The NRC staff will review DOE's plans and design considerations, but will not independently develop its own planning and design parameters.

In order to conduct an effective safety review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data such as the results of research activities being conducted by the NRC's Office of Nuclear Regulatory Research, in addition to that provided by the DOE in its license application. At the reviewer's discretion, independent analyses of results of DOE's models or analyses may be performed using data, descriptions, and models available to NRC staff. Alternatively, when deemed appropriate, confirmatory calculations may be performed using appropriate procedures. Moreover, the reviewer should focus on additional data or information which can refine knowledge of the facilities design and operations related to compliance with the design criteria. The reviewer should perform, as necessary, any reviews needed to confirm the adequacy of the methodologies proposed to assure compliance with the design criteria and performance objectives for GROA facilities. Also, the reviewer should have available specific documents (design drawings, reports, planning documents, and procedures) bearing on this topic, that were commissioned by NRC, DOE, and others. These documents should be available to the reviewers in anticipation of the license application submittal and review.

The reviewer should also use any additional data and knowledge that can refine the assessment of compliance with the design criteria for the post-closure features of the shafts, ramps, and boreholes, and should perform, as necessary, additional analyses to confirm the resolution capabilities of the methodologies. It is incumbent upon the reviewer to have acquired a body of knowledge regarding these and other critical considerations in anticipation of conducting the review, so as to ensure that the assessment of compliance with the design criteria for the post-closure features of the shafts, ramps, and boreholes is sufficient, in scope and depth, to provide the information required to resolve the concerns.

As part of the Safety Review, the reviewer may choose to refer to additional information and analyses contained in other sections of the license application. The information in this section of the license application may be cross-referenced to information and analyses in those license application sections listed in Table 4.3-1.

Detailed Safety Review Supported by Analysis:

A Detailed Safety Review will be needed for evaluation of the Key Technical Uncertainty regarding assessing the design and long-term performance of seals for shafts, ramps and boreholes. This will ensure that DOE has adequately demonstrated that the design of shafts, ramps, and boreholes meets the design criteria of 10 CFR 134. Activities performed in this Detailed Safety Review will help to assure that DOE has adequately addressed the Key Technical Uncertainty regarding sealing so that it does not contribute to non-compliance with the performance objectives related to overall system performance and the engineered barrier system.

For the Key Technical Uncertainty concerning TMHC processes and how they affect seals, a Detailed Safety Review will also be required. However, the evaluation of the TMHC Key Technical Uncertainty will be addressed in Review Plan 4.4 ("Assessment of Compliance with Design Criteria for the Underground Facility") of the License Application Review Plan. For the Key Technical Uncertainty concerning retrievability and how it affects shafts, ramps, and boreholes design, a Detailed Safety Review will also be required. However, the evaluation of the retrievability Key Technical Uncertainty will be addressed in Review Plan 4.5.2 ("Assessment of Integrated GROA Compliance with the Performance Objectives: Retrievability of Waste") of the License Application Review Plan.

As regards the seals, the reviewer will assess the adequacy of DOE's evaluation of the degree to which the shafts, ramps, boreholes, and their seals may be preferential pathways for the movement of groundwater to contact the waste packages, as specified in 10 CFR 60.134(b)(1). DOE's evaluation should show that groundwater movement through the sealed or backfilled shafts, ramps, and boreholes is less than or equal to that which occurs in the absence of such openings. DOE's evaluation of the design of seals should also demonstrate that, following permanent closure, the seals do not become pathways that compromise the geologic repository's ability to meet the performance objectives, per 10 CFR 60.134(a). In addition, DOE must demonstrate that the materials and placement methods for seals for shafts, ramps, and boreholes must reduce to the extent practicable radionuclide migration through existing pathways, as specified in 10 CFR 60.134(b)(2). Factors which should be considered are methods of construction of seals, dimensions and properties of the resulting disturbed zone, materials and placement methods for seals, and the amount and pressure differentials of the fluids that could flow through the seals. Also, if the seals for shafts, ramps, and boreholes are made much less permeable than the adjacent geologic media, any potential negative effects of lower permeability zones in the presence of higher permeability zones of the geologic setting should be investigated.

In conducting the Detailed Safety Review, the reviewer should rely on relevant research results being conducted through the NRC's Office of Nuclear Regulatory Research regarding the design criteria related to design, construction, and performance of seals for shafts, boreholes, ramps, and drifts associated with a geologic repository at Yucca Mountain (e.g., Akgun and Daemen, 1990; Sharpe and Daemen, 1991; Greer and Daemen, 1991; Ran and Daemen, 1991; Crouthamel and Daemen, 1991; Fuenkajorn and Daemen, 1991; and Adisoma and Daemen, 1988).

With respect to demonstrating compliance with the seals design requirement for the shafts, ramps, and boreholes, the reviewer will assess if DOE has applied the methodology described in the NRC staff "Technical Position on Postclosure Seals, Barriers, and Drainage System in an Unsaturated Medium" (Gupta and Buckley, 1989). This Staff Technical Position (STP) offers guidance to the DOE on sealing and drainage concepts for a geologic repository in an unsaturated medium. If DOE has used a methodology different than that recommended in the STP, the reviewer will assess if the alternative methodology considers sealing in a manner that is not likely to underestimate the unfavorable aspects of seal performance or overestimate its favorable aspects, in the context of design and analyses.

In addition, at the reviewer's discretion, independent analyses of DOE's seal designs may be performed. It is anticipated that these analyses will be based on one or more of the following:

(1) Descriptions and models used by DOE

(2) Staff's independent interpretations of DOE's data and descriptions

(3) Independent models developed or obtained by the NRC, using staff's interpretations of DOE's data and descriptions.

The analyses should focus on model sensitivity, resolution, and capabilities of different models; the degree to which the separate techniques can provide independent assessment of various features of concern; and the degree to which the techniques provide information which either corroborates or contradicts results of other techniques.

As part of the review strategy, the reviewer should be aware of the review of the performance confirmation plan. The evaluation of the seals at the time of license application will take place without the results of the performance confirmation program, which will be implemented during construction and operation of the repository. The reviewer of the seals should make sure that the performance confirmation plan provides for obtaining data that could be used in evaluating seal design and performance in the future, after license application.

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Date of Analysis: July 14, 1993

RATIONALE FOR REVIEW STRATEGY:

Not applicable.

APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(1)(i)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(14)
10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)(1)
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.131(b)(10)
10 CFR 60.134
10 CFR 60.137

Type 3:

10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)(1)
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)

10 CFR 60.131(b)(10)
10 CFR 60.134
10 CFR 60.137

<u>Type 4</u>:

10 CFR 60.111
10 CFR 60.112
10 CFR 60.134

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TABLE 4.3-1. Sections of the License Application that may support the review of the "Assessment of Compliance with the Design Criteria for Shafts and Ramps" section of the License Application.

License Application Section	*Section Title*
1.1	General Description of the Facility
3.1	Description of Individual Systems and Characteristics of the Site: 3.1.5 Integrated Natural System Response to the Maximum Design Thermal Loading
4.1	Description of the GROA Structures, Systems, and Components: 4.1.1 Surface Facilities 4.1.2 Shafts and Ramps 4.1.3 Underground Facility
4.2	Assessment of Compliance with Design Criteria for Surface Facilities
4.4	Assessment of Compliance with Design Criteria for the Underground Facility;
4.5.1	Assessment of Integrated GROA Compliance with the Performance Objectives: Protection against Radiation Exposures and Releases of Radioactive Material to Unrestricted Areas;
4.5.2	Assessment of Integrated GROA Compliance with the Performance Objectives: Retrievability of Waste
5.1	Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting
5.2	Assessment of Compliance with the Design Criteria for the Waste Package and its Components
5.3	Assessment of Compliance with the Design Criteria for the Post-closure Features of the Underground Facility
5.4	Assessment of Compliance with the Engineered Barrier System Performance Objectives
6.1	Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
6.2	Assessment of Compliance with the Individual Protection Requirements
6.3	Assessment of Compliance with the Groundwater Protection Requirements
8.2	Performance Confirmation Program for the Structures, Systems, and Components of the Geologic Repository Operation Area;
8.3	Performance Confirmation Program for the Engineered Barrier System