COMPLIANCE DETERMINATION STRATEGY
RRT 4.4 ASSESSMENT OF COMPLIANCE WITH DESIGN CRITERIA FOR THE UNDERGROUND FACILITY

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(7)
10 CFR 60.21(c)(9)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(12)
10 CFR 50.21(c)(14)
10 CFR 60.111(b)(1)
10 CFR 60.112
10 CFR 60.113
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)(7)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.133(a)
10 CFR 60.133(b)
10 CFR 60.133(c)
10 CFR 60.133(d)
10 CFR 60.133(e)
10 CFR 60.133(f)
10 CFR 60.133(g)
10 CFR 60.133(i)
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 topic is license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and the Section 4.4 of the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)," it must be addressed by the U.S. Department of Energy (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 topic is considered to be 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 this regulatory requirement topic.

There are a number of review plan topics that are closely-related for which underground facility 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 GROA design criteria for the underground facility, excluding those man-made elements of the engineered barrier system (EBS). In conducting this review, the descriptions provided in Section 4.1.3 ("Description of the GROA Structures, Systems, and Components: Underground Facility") of the license application, will support the reviews described below. However, it should be noted that the adequacy of GROA design will be evaluated in the context of performance and this review strategy should be understood in that context.

The review of the EBS portion of the underground facility design is the subject of the review called for in Section 5.3 ("Assessment of Compliance with the Design Criteria for the Engineered Barrier System"), of the license application and its attendant review plan. Finally, the confirmation of the design described by the U.S. Department of Energy (DOE) in this section of the license application will be the subject of a plan for performance confirmation program described in Section 8.2 ("Performance Confirmation Program for Structures, Systems, and Components of the GROA") of the license application and its attendant review plan.

The staff concludes that there is a low risk of noncompliance with most of the general design criteria for the GROA and additional design criteria for the underground facility set forth in 10 CFR Part 60. This conclusion is based on standard engineering practice and previous engineering experience. However, with respect to GROA design criteria set forth in 10 CFR 60.133(i), 60.133(c), and 60.134, the staff has concluded that there may be a high risk of noncompliance with the performance objectives 60.111, 60.112, and 60.113 for the underground facility, at both the system and subsystem levels, due to Key Technical Uncertainties.

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

The staff considers that there may be a high potential risk of non-compliance with 10 CFR 60.133(c), 60.133(i), and 60.134, because, for the Yucca Mountain site, there are several Key Technical Uncertainties. Therefore, predictions regarding: (1) the thermal-mechanical-hydrological-chemical response of the host rock, surrounding strata, and groundwater system to thermal loading; (2) the ability to retrieve high-level radioactive waste; and (3) the effectiveness and long-term performance of seals for underground test boreholes, 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 of high risk of noncompliance with the performance objectives specified below will necessitate analysis 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.

Key Technical Uncertainty Topic: Prediction of the thermal-mechanical-hydrological-chemical (T-M-H-C) response of the host rock, surrounding strata, and groundwater system to thermal loads.

Description of Uncertainties: 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 response of the host rock, surrounding strata, and groundwater system. (The performance objectives are those in 10 CFR 60.111, 60.112, and 60.113.) They deal, generally, with the maintenance of safe operating conditions, the ability to retrieve waste for a specified period, and the containment and isolation of wastes after the repository is permanently closed. The rule thus recognizes that an understanding of thermal loads, resulting from the emplacement of nuclear wastes, and corresponding thermomechanical response of the surrounding geologic setting, 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 design. Many aspects of the design, including canister spacing, opening configurations and dimensions, and support requirements, 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 nuclear fuel in the underground facility will generate heat and result in expansion of the rock mass, produce thermal stresses, and cause potential normal and shear displacements of fractures. Kemeny and Cook (1990) have reported that, in the worst-case scenario, 38% waste emplacement boreholes may fail as the repository heats up. Rock failure inside waste emplacement boreholes may cause waste package degradation. The long-term thermomechanical response of the host rock and surrounding strata over the lifetime of the repository is very difficult to predict and thus difficult to account for in the design of the underground facility.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following four more specific technical uncertainties: (1) prediction of thermal-mechanical effects (including seismic effects) on drifts and emplacement boreholes for retrievability; (2) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for waste package design; and (3) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for 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 can be 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 experiences, the use of predictive models to evaluate the possible T-M-H-C coupling 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 an existing model, to predict the likely repository effects of such loads, may not be satisfactory.

The fundamental mechanism of T-M-H-C coupling processes are not fully understood at this time. Coupled thermal, mechanical, and hydrological 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 a greater understanding of thermally-induced phenomena is gained. Because DOE will need to defend its design decisions on the level of T-M-H-C coupling it chooses to consider in a particular GROA underground facility design, including those aspects of T-M-H-C coupling chosen to discount in such decisions, it is 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 T-M-H-C processes that are induced by repository generated thermal loads.

The NRC and CNWRA are conducting independent studies to understand and to develop an independent capability for reviewing the thermal, mechanical (including seismic), and hydrological coupling effects on rock joints and fractures (CNWRA, 1993; DECOVALEX, 1993). An appropriately coupled model which takes into account T-M-H-C coupling effects will be developed or modified as part of these studies. Such a code will be used for independent checking DOE's design and performance calculations.

__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, if necessary. 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." (CFR,1992)

One major aspect of this Key Technical Uncertainty is that there is a lack of experience with retrieval operations in an uncertain physical environment (e.g. elevated temperatures and thermal-mechanical stresses). This means that DOE will not be able to plan retrieval operations based on past experience, but instead will have to design a first-of-a-kind operation. Although the retrieval plan will probably have undergone detailed review by the DOE, NRC should still perform a Detailed Safety 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 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 T-M-H-C 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. Thus, that there are uncertainties regarding the conduct of the retrieval operation, necessarily means that there will be uncertainties regarding the radioactive doses that workers, and even the public, may receive.

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) 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 T-M-H-C processes represents a 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 perations 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 T-M-H-C 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 T-M-H-C processes could lead to a misjudgment of the response of the repository's physical environment, perhaps putting the retrieval performance objective at risk.

There is also uncertainty regarding the waste emplacement configuration, and this poses a risk to retrievability and storage being done safely. It is not clear 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 compliance with the requirement that waste retrievability be maintained. 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.

Description of Resolution Difficulty: 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 T-M-H-C 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) 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) DOE proposes to use proven retrieval equipment and procedures; and

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

The Key Technical Uncertainty regarding the demonstration of the ability to safely retrieve high-level radioactive waste will be reviewed in the Review Plan 4.5.2 ("Assessment of Integrated GROA Compliance with Performance Objectives: Retrievability of Waste"). This Review Plan will complement the review work under the Review Plan 4.5.2.

Key Technical Uncertainty Topic: Predicting the long term performance of seals for the underground test boreholes.

Description of Uncertainty: There will be test boreholes drilled from the underground facility for site characterization and performance confirmation tests. These test boreholes need to be sealed after the tests are completed. Review of the design of post-closure portion of underground test boreholes (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. Some 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). However, 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. It remains uncertain what impact thermal loads and repeated seismic loads will have on their performance. 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.

The issue of postclosure seals in an unsaturated medium is discussed in the NRC staff's "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 chooses a methodology different from that in the STP, the reviewer should assess if the alternative methodology considers sealing in a manner that is not likely to underestimate the unfavorable aspects of seal performance or to overestimate its favorable aspects of seal performance.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following three 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. Such detailed considerations of the Key Technical Uncertainty will be examined in the Compliance Determination Method for Shafts and Ramps Design of the Review Plan.

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 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; the waste package life is less than 300 years; 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 will 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.

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.

The Key Technical Uncertainty regarding the prediction of the long-term performance of seals for the underground test boreholes to ensure that the boreholes will not become preferential pathways will be reviewed in the Review Plan 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps"). The reviewer should coordinate the review of boreholes seals performance with the Review Plan 4.3.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of the assessment of the U.S. Department of Energy's underground facility 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 regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)."

The descriptions provided in Sections 4.1.2 ("Description of the GROA Structures, Systems, and Components: Shafts and Ramps"), 4.1.3 ("Description of the GROA Structures, Systems, and Components: Underground Facility"), and 4.1.5 ("Interface between Structures, Systems, and Components") of the license application will form the basis for the Safety Review of the information contained in Section 4.4 of the license application. Thus, the review of the information contained in Section 4.1.3 will be performed in parallel with the review of the information contained in Section 4.4. Therefore, during the Acceptance Review of Section 4.4, the reviewer should determine that all appropriate descriptive information necessary for the staff to conduct a Safety Review of the GROA underground facility design has been provided, as described in Section 4.1.3, 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 that apply to this requirement or provided all the information requested in Section 1.6.2 of the FCRG, for unresolved objections. The reviewer should evaluate the effects of any unresolved objections, both individually and in combination with others, on: (1) the reviewer's ability to conduct a meaningful and timely review; and (2) 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 underground facility design with the pertinent 10 CFR Part 60 GROA design criteria. It is not concerned with the assessment of compliance with the design criteria for other elements of the underground facility system, including the engineered barrier system (including the waste package). The review of these other underground facility elements will be treated in Sections 4.3 ("Assessment Compliance with Design Criteria for Shafts and Ramps"), 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 (the review of the GROA underground facility, from the post-closure perspective, will be treated in both Sections 5.2 and 5.3). 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:

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

(2) determine whether data generated are appropriate and 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);

(3) understand and evaluate DOE's compliance demonstration logic; and

(4) 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 underground facility, exclusive of the EBS, meets those design criteria and performance objectives specified in 10 CFR Part 60, that are applicable for the pre-closure period. The review should include consideration of the design that has been presented, and evaluation of the contribution of design to meeting the performance objectives (both pre-closure and post-closure).

The specific aspects of the license application on which the reviewer will focus are described below, and the Acceptance Criteria are identified in Section 3.0 of this review plan. The reviewer should determine if DOE has demonstrated that its design for the GROA underground facility meets the design criteria used to support the pre-closure performance objectives concerning radiation exposure to workers specified in 10 CFR 60.111(a), retrievability of waste specified in 10 CFR 60.111(b), the design criteria for GROA specified in 10 CFR 60.130, the general design criteria for the GROA specified in 10 CFR 60.131, and those additional design criteria for the underground facility specified in 10 CFR 60.133 that are applicable to the underground facility. The reviewer should determine whether GROA underground facility design will permit the implementation of a performance confirmation program defined in 10 CFR 60.137.

Pertinent design criteria chosen by DOE should also be reviewed for adequacy. The reviewer should determine whether or not DOE has demonstrated that the design bases for the pre-closure features of the underground facility take into account the results of DOE's site characterization activities.

In presenting the underground facility design, the reviewer should determine if DOE has described, at a minimum, the following systems:

(1) excavation and ground support systems;
(2) muck handling systems;
(3) ventilation systems;
(4) waste emplacement systems;
(5) waste retrieval systems;
(6) emergency systems;
(7) communication systems;
(8) operational support system;
(9) decommissioning systems;
(10) electrical support systems; and
(11) underground transportation systems;

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

(1) a description and discussion of the underground facility's 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 underground facility;

(2) a description and analysis of the design and performance requirements for the underground facility to identify which structures, systems, and components are important to safety (SSCIS). This analysis should 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 SSCIS 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 should be given to those items that may significantly influence the final design; and

(4) an identification of those structures, systems, and components (SSC) of the underground facility which may require research and development to confirm the adequacy of design. For SSCIS and for the engineered and natural barriers important to waste isolation, DOE should 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 determine that DOE has provided:

(1) an adequate analysis of the design and performance of the SSC, 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 license application; and

(2) an adequate 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 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 and monitoring data.

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

(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 pre-closure and post-closure behavior of the underground facility should be reviewed for completeness and adequacy. 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 how these uncertainties are reflected in

models;

(3) descriptions of analyses and models used in the design of the underground facility;

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

(5) results that are used to support analyses and models of predicted conditions likely to be encountered during the waste emplacement and retrieval, including comparisons to field tests, *in-situ* tests, laboratory tests that are representative field conditions, monitoring data, and natural analog studies.

The Safety Review should establish whether or not DOE's assessment shows that all anticipated processes and events have been considered and analyzed. The Safety Review should also determine whether or not DOE's assessment shows that both the partial and complete filling with groundwater of available void space in the post-closure features of the underground facility have been considered and analyzed.

The underground facility design also needs to demonstrate that all SSC are properly integrated. Accordingly, when reviewing the underground facility 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.

Finally, the reviewer should assess the adequacy of the underground facility design for the control of radiation exposures and radiation levels, and releases of radioactive material 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 (*Code of Federal Regulations*, Title 10, "Energy"). Those design enhancements that are necessary for the implementation of ALARA need to be identified as part of the GROA underground facility 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 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 conditions and events, associated with normal repository 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 trees analyses, fault trees 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., source terms, expected conditions and events, 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 the GROA. 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 underground facility, 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, to ensure that confirmation on the assessment of compliance with the design criteria for the underground facility in the license applications sufficient in scope and depth to provide needed information to resolve 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 are listed in Table 4.4-1.

Detailed Safety Review Supported by Analysis:

A *Detailed Safety Review Supported by Analysis* will be needed for evaluation of the Key Technical Uncertainty regarding the prediction of the thermal-mechanical-hydrological-chemical (T-M-H-C) response of the host rock, surrounding strata, and groundwater system to thermal loading. This will ensure that the DOE has adequately demonstrated compliance with the information requests described in Section 2.2.1 (see "Safety Review"). Activities performed in the *Detailed Safety Review* will help to assure that DOE has acceptably addressed this Key Technical Uncertainty so that they do not lead to non-compliance with the overall system and several of the subsystem performance objectives.

With respect to demonstrating compliance with the thermal loads design requirement for the underground facility, the reviewer will determine if DOE has submitted information that describes its design decisions on the level of T-M-H-C coupling it chooses to consider in underground facility design, including those aspects of T-M-H-C coupling it chooses to discount. The staff anticipates that this methodology would include the evaluation and development of "appropriately" coupled models to account for the T-M-H-C processes that are induced by repository-generated thermal loads. The "Staff Technical Position (STP) on Geologic Repository Operations Area Underground Facility Design: Thermal Loads" --NUREG-1466 (Nataraja and Brandshaug, 1992) offers guidance to the DOE on development of appropriately coupled models, in an iterative approach, to account for processes that are induced by repository-generated thermal loads. The reviewer will assess if DOE has:

(1) applied the methodology described in NUREG-1466 providing an example of an acceptable approach for demonstrating compliance with 10 CFR 60.133(i); and

(2) developed, to the extent practical, detailed predictive models to predict the thermal and thermomechanical response of the host rock, surrounding strata, and groundwater system to thermal loading.

In addition, at the reviewer's discretion, independent analyses of DOE's prediction of T-M-H-C effects on underground facility performance may be conducted. It is anticipated that these analyses will be based on one or more of the following:

(1) descriptions and models used by DOE;

(2) the staff's independent interpretations of DOE's data and descriptions; and

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

If DOE has not demonstrated a detailed understanding of coupled T-M-H-C effects, the reviewer should determine if DOE has:

(1) developed models that approximate coupled behavior in a manner that is not likely to underestimate the unfavorable aspects or overestimate the favorable aspects of repository performance; and

(2) presented plans for in-situ and laboratory monitoring and testing, and for additional model development/refinement, as may be appropriate to confirm the adequacy of the analytical results used to support the license application.

For the Key Technical Uncertainties concerning: (1) predicting the effectiveness and long-term performance of seals for shafts, ramps, and boreholes; and (2) demonstration of the ability to retrieve high-level radioactive waste, a *Detailed Safety Review and Analysis* will also be required. However, the evaluation of these Key Technical Uncertainties will be addressed in Review Plans 4.3 ("Assessment Compliance with Design Criteria for Shafts and Ramps") and 4.5.2 ("Assessment of Integrated GROA Compliance with the Performance Objectives: Retrievability of Waste"), respectively, of the License Application Review Plan.

RATIONALE FOR REVIEW STRATEGY:

In view of the complexity of the key technical uncertainty addressed above, it is appropriate that NRC conduct the following independent activities: (1) develop the licensing tools and technical bases necessary to judge the adequacy of DOE's license application, (2) assure sufficient independent understanding of the basic physical processes taking place at the geologic repository, and (3) maintain an independent but limited confirmatory research capability under NRC auspices.

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Date of Analysis:	July 12, 1993

APPLICABLE REGULATORY REQUIREMENT FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(7)
10 CFR 60.21(c)(9)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(12)
10 CFR 50.21(c)(14)
10 CFR 60.111(b)(1)
10 CFR 60.112
10 CFR 60.113
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)(7)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.133(a)
10 CFR 60.133(b)
10 CFR 60.133(c)
10 CFR 60.133(d)
10 CFR 60.133(e)
10 CFR 60.133(f)

10 CFR 60.133(g)
10 CFR 60.133(i)
10 CFR 60.134
10 CFR 60.137

Type 3:

10 CFR 60.111(b)(1)
10 CFR 60.112
10 CFR 60.113
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)(7)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.133(a)
10 CFR 60.133(b)
10 CFR 60.133(c)
10 CFR 60.133(d)
10 CFR 60.133(e)
10 CFR 60.133(f)
10 CFR 60.133(g)
10 CFR 60.133(i)
10 CFR 60.134
10 CFR 60.137

Type 4:

10 CFR 60.111(b)(1)
10 CFR 60.112
10 CFR 60.113
10 CFR 60.133(i)
10 CFR 60.133(c)
10 CFR 60.134

REFERENCES:

American Nuclear Society, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," American National Standards Institute, La Grange Park, Illinois, ANSI/ANS-57.9-1984, 1984.

Center for Nuclear Waste Regulatory Analyses, "Task 9: DECOVALEX Modeling, Project Plan for Seismic Rock Mechanics Project (Revision 3)," Center for Nuclear Waste Regulatory Analyses, San Antonio, Texas, February 1993. [Prepared for the U.S. Nuclear Regulatory Commission.]

Code of Federal Regulations, "Standards for Protection Against Radiation," Part 20, Chapter I, Title 10, "Energy."

Code of Federal Regulations, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Part 60, Chapter I, Title 10, "Energy," 1992.

DECOVALEX, "Mathematical Models of Coupled H-T-M Processes for Nuclear Waste Repositories (Draft Report of Phase I)," Royal Institute of Technology, Stockholm, Sweden, February 1993.

Gupta, D. C. and J. T. Buckley, "Technical Position on Postclosure Seals, Barriers, and Drainage System in an Unsaturated Medium", Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, NUREG-1373, August 1989.

Kemeny, J., and N. Cook, "Rock Mechanics and Crustal Stresses," in R.K. McGuire, ed., "Demonstration of a Risk-Based Approach to High-Level Waste Repository Evaluation," Electrical Power Research Institute, Palo Alto, California, EPRI NP-7507 (NA.910813.0004), 1990.

Nataraja, M.N. and T. Brandshaug, "Staff Technical Position on Geologic Repository Operations Area Underground Ground Facility Design -- Thermal Loads," Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, NUREG-1466, December 1992.

Osende, J, "The Durability of Cement Grouts," *Fifteenth Congress on Large Dams Transactions*. pp.759-766, Q. 58, R. 43, Volume 3, , Lausanne, Switzerland, International Commission on Large Dams, Paris, June 1985.

Rissler, A, "*Determination of the Water Permeability of Jointed Rock*," English Edition of Vol. 5, Institute for Foundation Engineering, Soil Mechanics, Rock Mechanics and Water Ways Construction. Aachen, F.R.G.: RWTH (University), 1978.

Roy, D.M. and C.A. Lanton, "*Characterization of Cement-Based Ancient Building Materials in Support of Repository Seal Materials Studies*," Office of Nuclear Waste Isolation. BMI/CNWI-523. Columbus, Ohio: Battelle Memorial Institute, 1983.

Roy, D.M. and C.A. Lanton, " *Ancient Concrete Studies as Analogs of Cementitious Sealing Materials for a Tuff Repository*," Materials Research Laboratory. Unnumbered Technical Report. University Park, Pennsylvania: Pennsylvania State University, 1986.

Schaffer, A. and J.J.K. Daemen, "*Experimental Assessment of the Sealing Effectiveness of Rock Fracture Grouting*," U.S. Nuclear Regulatory Commission NUREG/CR-4541. Washington, D.C.: NRC March, 1987.

TABLE 4.4-1. Sections of the License Application that may support the Review of Assessment of Compliance with the Design Criteria for the Pre-Closure Features of the Underground Facility" Section of the License Application.

License Application Section	Section Title
	Design
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
4.1.5	Interface Between Structures, Systems, and Components
4.2	Assessment Compliance with Design Criteria for Surface Facilities
4.3	Assessment Compliance with Design Criteria for Shafts and Ramps
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
	Performance
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
5.4	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