COMPLIANCE DETERMINATION STRATEGY
RRT 4.5.2 RETRIEVABILITY OF WASTE

APPLICABLE REGULATORY REQUIREMENTS:

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)(12)
10 CFR 60.21(c)(14)
10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)
10 CFR 60.131(b)(7)
10 CFR 60.132(a)
10 CFR 60.133(c)
10 CFR 60.133(e)(1)
10 CFR 60.133(i)
10 CFR 60.135(b)(3)

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 considered to be license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and 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 is considered to be related to radiological safety, waste retrievability, containment, and 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 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 ability of the U.S. Department

of Energy (DOE) to demonstrate the capability to retrieve any or all of the waste emplaced in the geologic repository. This regulatory requirement topic is also concerned with the alternate plans to store the retrieved waste, should waste retrieval prove to be necessary. The staff's review will evaluate DOE's demonstration of compliance with the general design criteria for the GROA, as they relate to retrievability, set forth in 10 CFR 60.130 and 60.131; the additional design criteria for GROA surface facilities, as they relate to retrievability, set forth in 10 CFR 60.132; the additional design criteria for the underground facility, as they relate to retrievability, set forth in 10 CFR 60.133; and the design criteria for the waste package set forth in 10 CFR 60.135 as they relate to retrievability and thus the GROA design.

In conducting the Safety Review, the descriptions provided in Section 4.1.1 ("Description of the GROA Structures, Systems, and Components: Surface Facilities"), 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 5.1 ("Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting") of the license application, will support the reviews described below. However, it should be noted that the adequacy of the retrieval plans and the GROA design will eventually be evaluated in the context of 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 set forth in 10 CFR Part 60 as they affect waste retrieval plans for operations at the surface. This conclusion is based on the knowledge that past licensees have designed surface facilities to meet NRC's regulations. However, underground retrieval operations of the GROA, if performed, will probably be the first of their kind. The staff expects that some of the technical uncertainties associated with waste retrievability are expected to be reduced during the site characterization phase. However, there may be some aspect or aspects of the GROA design criteria concerning safety and thermal loads set forth in 10 CFR 60.133(c) and 60.133(i) that may not be sufficiently reduced during the site characterization phase and thus 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 level, due to Key Technical Uncertainties.

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

The staff considers that there may be a high potential risk of non-compliance with 10 CFR 60.133(c) and 60.133(i) because, for the Yucca Mountain site, there are several Key Technical Uncertainties. Therefore, predictions regarding: (1) the ability to retrieve high-level radioactive waste; and (2) the thermal-mechanical-hydrological (TMH) response of the host rock, surrounding strata, and groundwater system to thermal loading, 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 of high risk of noncompliance 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.

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" (NRC, 1983).

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 thermo-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 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 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 TMH 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. 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) 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 TMH processes represents a Key Technical Uncertainty complicating the review of DOE's plans and designs for waste retrievability. 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 TMH 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 TMH 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, among others, 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 TMH 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 develops, tests, and provides documentation showing that it has developed an acceptable retrieval procedure and proposes using it in the design of the repository; and

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

Key Technical Uncertainty Topic: Prediction of the thermal, mechanical, and hydrological impact on the host rock surrounding the waste package.

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. One performance objective is that in 10 CFR 60.111(b) concerning the ability to retrieve waste. 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 design or retrieval plans. Many aspects of the GROA 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 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. Kemeny and Cook (1990) have reported that, in the worst-case scenario, some 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 facility.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following three more specific technical uncertainties: (i) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for waste package design; (ii) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for performance assessments; and (iii) extrapolation of short-term laboratory and field test results to predict long-term TMH effects.

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 repository effects of such loads, may not be satisfactory.

The fundamental mechanism of thermal, mechanical, hydrological, and chemical coupling processes are not fully understood at this time. 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 a greater understanding of thermally induced phenomena is gained. Because DOE will need to defend its design and retrieval plan decisions on the level of TMH coupling it chooses to consider in a particular GROA design, including those aspects of TMH coupling it chooses 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 TMH 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 should 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.

The NRC and CNWRA are conducting 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). A TMH coupled code will be developed as part of these studies. This coupled code will be used for independent checking of DOE's performance calculations. If more complicated issues are involved in developing a reliable computer code for the TMH modeling, the staff would consider this KTU to require a Type 5 review.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of the U.S. Department of Energy's (DOE)'s plans for the retrieval of high-level radioactive waste at the geologic repository operations area, the reviewer should determine if the information present in the license application and its references for demonstrating compliance with the applicable regulatory requirements is complete in technical breadth and depth as identified in Section 4.5.2 of regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)." The reviewer should determine that all appropriate information necessary for the staff to review DOE's waste retrieval plans is presented such that the assessments required by the applicable regulatory requirements associated with the retrievability performance objective and other technical criteria can be performed.

The descriptions provided in Sections 4.1.1 ("Description of the GROA Structures, Systems, and Components: Surface Facilities"), 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 5.1 ("Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting") of the license application will support the Safety Review of the information contained in Section 4.5.2 of the license application. Thus, the review of the information contained in Section 4.1.1, 4.1.2, 4.1.3, and 5.1 will be performed in parallel with the review of the information contained in Section 4.5.2. Therefore, during the Acceptance Review of Section 4.5.2, the reviewer should determine that all appropriate descriptive information necessary for the staff to conduct a Safety Review of the GROA design and plans for waste retrieval and alternative storage of retrieved waste has been provided, as described in Sections 4.1.1, 4.1.2, 4.1.3, and 5.1, 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 presented in the license application is presented in such a manner that the assumptions, data, and logic leading to a demonstration of compliance with the requirement 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 adequately 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 the assessment of compliance with the requirement that the GROA design permit the retrieval of waste, and that there are plans for the alternative storage of waste.

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 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 the performance objective relating to waste retrievability. At a minimum, the reviewer should evaluate the acceptability of the design and the retrieval plans that have been presented, and confirm that the design preserves the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program (10 CFR 60.137) and Commission review of the information obtained from such a program. The review should include a determination of the adequacy of the data and analyses that are presented in the license application as DOE's supporting information concerning its demonstration that its GROA design meets those design criteria and performance objectives specified in 10 CFR Part 60. 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 Safety Review will focus on two areas: (1) the review of the design of the GROA to permit waste retrieval; and (2) review of the design of the GROA to permit the alternate storage of waste should retrieval prove necessary.

As regards the first area of review, the reviewer should determine whether DOE has generally demonstrated that the retrieval plans and the design for the GROA meet the pre-closure performance objective concerning radiation exposure to workers specified in 10 CFR 60.111(a); the waste retrievability requirement set forth in 10 CFR 60.111(b); the general design criteria for the geologic repository operations area, as they relate to retrievability, set forth in 10 CFR 60.130 and 60.131; the additional design criteria for GROA surface facilities, as they relate to retrievability, set forth in 10 CFR 60.132; the additional design criteria for the underground facility, as they relate to retrievability, set forth in 10 CFR 60.133; and the design criteria for the waste package, as they relate to retrievability and thus the GROA design, set forth in 10 CFR 60.135. The reviewer should determine whether the GROA design and the waste retrievability plans will permit the implementation of a performance confirmation program defined in 10 CFR 60.137. The reviewer should also determine if the GROA design and retrieval plans will permit the retrieval of any or all of the emplaced waste on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. (This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.)

Pertinent design criteria chosen by DOE should also be reviewed for adequacy concerning retrieval. The reviewer should determine whether or not DOE has demonstrated that the design bases for the pre-closure features of the GROA design appropriately take into account the results of DOE's site characterization activities. The Safety Review should establish whether or not DOE's design and retrieval plans show that all conditions and events associated with normal operations and those events that can be reasonably expected to occur have been considered.

In conducting the Safety Review, the staff will determine if DOE has submitted demonstration of compliance with the retrievability requirement in the following:

(1) a description and discussion of the retrieval plans and GROA design features that affect retrievability 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 waste retrievability features of the GROA;

(2) a description and analysis of the design and performance requirements for the GROA and a description and analysis of the performance requirements of the retrieval plans 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 SSCIS of the GROA which require research and development to confirm the adequacy of design.

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

(1) an analysis of the design and performance of the major structures, systems, and components (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 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 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.

Models used by the DOE to predict conditions likely to be encountered during retrieval, and the ability to retrieve HLW under those conditions, should be reviewed for completeness and adequacy. Those items to be reviewed should include:

(1) identification and evaluation of environmental parameters used to predict conditions likely to be encountered during retrieval;

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

(3) descriptions of analyses and models used to predict conditions likely to be encountered during retrieval;

(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 retrieval, including comparisons to field tests, in-situ tests, laboratory tests that are representative of field conditions, monitoring data, and natural analog studies.

In reviewing DOE's plans, described above, the reviewer should confirm that DOE has included a description of its plans for the alternate storage of high-level radioactive wastes (HLW). Any plans for the alternate storage of retrieved wastes should be integral with the overall GROA design described above.

The reviewer should assess the adequacy of the retrieval plans and the design of the GROA elements that affect retrievability 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 waste retrievability plans.

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 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., 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.

Finally, the GROA design and retrieval plans need to demonstrate that all SSC are properly integrated. Accordingly, when reviewing the waste retrievability aspects of the GROA 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.

In order to conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, and 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 the NRC staff. Alternatively, when deemed appropriate, confirmatory calculations may be performed using appropriate procedures. Therefore, 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 assure that the retrieval plan for the geologic repository at Yucca Mountain, as presented in the license application, is sufficient in scope and depth.

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 GROA pre-closure performance objective for waste retrievability. 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. Examples of such documents include analyses and experiments sponsored by DOE (e.g., DOE, 1988; DOE, 1990; SNL, 1987a and 1987b) and NRC (Kendorski et al., 1984; NRC, 1989). Specific topics with which the reviewer should become familiar include the following:

(1) the stability of grouted rock bolt and shotcrete support systems over decades-long periods and at high (greater than 200° F) temperatures (see Kendorski et al., 1984);

(2) the technology for overcoring emplacement boreholes for retrievability as discussed in the Site Characterization Plan Conceptual Design Report (see SNL, 1987a, Appendix E);

(3) the performance of retrieval equipment under high temperatures;

(4) the ventilation requirements for cooling heated emplacement rooms and drifts;

(5) the prototype demonstration of retrieval operations;

(6) techniques to locate emplaced canisters;

(7) the performance of rock under high temperature; and

(8) the degradation of waste package under *in-situ* conditions.

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 the license application sections listed in Table 4.5.2-1.

Detailed Safety Review Supported by Analysis:

A Detailed Safety Review will be needed for evaluation of the Key Technical Uncertainties regarding: (1) the demonstration of ability to retrieve high-level radioactive waste; and (2) the prediction of the thermal-hydrologic-mechanical-chemical behavior of the host rock, surrounding strata, and groundwater system to thermal loads. 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 these Key Technical Uncertainties so that they do not lead to non-compliance with the performance objective concerning any waste retrieval operations that might be necessary.

For the Key Technical Uncertainty concerning the prediction of the thermal-mechanical-hydrological-chemical response of the host rock, surrounding strata, and groundwater system to thermal loads, a Detailed Safety Review will also be required. However, the evaluation of this Key Technical Uncertainty will be addressed in Review Plan 4.4 ("Assessment Compliance with Design Criteria for Underground Facility") of the License Application Review Plan.

As regards the Key Technical Uncertainty regarding waste retrievability, the reviewer will assess the adequacy of DOE's plans and designs that would permit the waste retrieval option. Specific review activities should include detailed reviews of those parts of the retrieval plans and GROA design for which there will probably be more uncertainty. For example, a detailed review should be conducted of any experience with retrieval operations that DOE cites in the license application. The experience should be examined to its depth, breadth, and applicability to Yucca Mountain. Another example of a specific review activity is that detailed reviews should be made of the models and scenarios used to predict the conditions under which retrieval would be accomplished. Specifically, the TMH models should be reviewed in detail because of their uncertainty and the impact of TMH processes on potential retrieval operations. A final example is that a detailed review should be conducted of the retrieval plans that would be used in the case of leaking waste canisters. Such a condition could make retrieval harder to accomplish because of possible radiation exposure and clean up of contaminated materials. In conducting the Detailed Safety Review, the reviewer should be aware of all the items concerning retrievability listed in the preceding section for the review strategy for the Safety Review concerning retrievability.

In addition, at the reviewer's discretion, independent analyses of DOE's waste retrievability design 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) 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.

RATIONALE FOR REVIEW STRATEGY:

Not Applicable.

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Date of Analysis: July 9, 1993

APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

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)(12)
10 CFR 60.21(c)(14)
10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)
10 CFR 60.131(b)(7)
10 CFR 60.132(a)
10 CFR 60.133(c)
10 CFR 60.133(e)(1)
10 CFR 60.133(i)
10 CFR 60.135(b)(3)

Type 3:

10 CFR 60.111
10 CFR 60.112
10 CFR 60.113(a)
10 CFR 60.131(b)(7)
10 CFR 60.132(a)
10 CFR 60.133(c)
10 CFR 60.133(e)(1)
10 CFR 60.133(i)
10 CFR 60.135(b)(3)

Type 4:

10 CFR 60.111(b)
10 CFR 60.133(c)
10 CFR 60.133(i)

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.]

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Sandia National Laboratories, "Final Report of Core Drill Conceptual Design Study for Retrieval of Radioactive Waste Disposed in a Geologic Repository," Albuquerque, New Mexico, SAND84-7100, September 1987b. [Prepared for the U.S. Department of Energy/Office of Civilian Radioactive Waste Management.]

Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada," Office of Nuclear Material Safety and Safeguards, NUREG-1347, August 1989.

Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Wastes in Geologic Repositories:

Technical Criteria [Final Rule]," *Federal Register*, Vol. 48, No. 120, June 21, 1983, pp. 28194-28229.

Nuclear Regulatory Commission, "Format and Content For the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition in effect.]

U.S. Department of Energy, "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada," Office of Civilian Radioactive Waste Management, 9 vols., Report DOE/RW-0199, December 1988.

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TABLE 4.5.2-1. Sections of the License Application that may support the assessment of "Integrated GROA Compliance with the Performance Objectives - Retrievability and Alternative Storage of Waste" 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 4.1.5 Interfaces 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
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;
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
7.1	Plans for Conduct of Normal Activities
8.2	Performance Confirmation Program for the Structures, Systems, and Components of the Geologic Repository Operation Area
11.0	Emergency Planning