2/59

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

1.0 APPLICABLE REGULATORY REQUIREMENTS

10 CFR 60.21(c)(1)(i)
10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(7)
10 CFR 60.21(c)(9)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(12)
10 CFR 60.21(c)(14)
10 CFR 60.111(a,b)
10 CFR 60.112
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.131(b)(10)
10 CFR 60.134
10 CFR 60.137

TYPES OF REVIEW

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

RATIONALE FOR TYPES OF REVIEW

Acceptance Review (Type 1) Rationale

This regulatory requirement topic is considered to be license application-related because, as specified in the License Application content requirements of 10 CFR 60.21(c) and Section 4.3 of the regulatory guide

3/59

"Format and Content for the License Application for the High-Level Waste Repository (FCRG) (Nuclear Regulatory Commission)," 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 related to radiological safety, retrievability, containment, and waste isolation. It is a requirement for which compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31(a) (i.e., regulatory requirements in Subparts E, G, H, and I). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with the applicable regulatory requirements.

A number of review plan topics are closely related for which geologic repository operations area (GROA)-related design reviews will take place. They concern both engineering design and performance. This particular regulatory requirement topic focuses on the review of compliance with the design criteria for shafts, ramps, boreholes, and their seals (SRBS) of the GROA set forth in 10 CFR 60.130, 60.131, 60.134, and 60.137. Some of the regulatory requirements are also applicable to other regulatory requirement topics. Review procedures and acceptance criteria will be developed in this Review Plan for 10 CFR 60.131(b)(9) and 60.134 only. The review procedures and acceptance criteria for other regulatory requirements applicable to this regulatory requirement topic will be developed in Review Plans 4.2, 4.4, and 4.5.2, as appropriate.

In conducting the Safety Review, the descriptions provided in Section 4.1.2 (Description of the GROA Structures, Systems, and Components: Shafts and Ramps) of the license application, will support the reviews described below. However, it should be noted that the adequacy of GROA shafts, ramps, and boreholes design will eventually be evaluated in the context of compliance with the pertinent performance objectives, and this review strategy should be understood in that context. The applicable performance objectives are as set forth in 10 CFR 60.111 and 60.112.

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

Detailed Safety Review Supported by Analyses (Type 4) Rationale

The staff considers that there may be a high risk of making a wrong determination of compliance with 10 CFR 60.134, because for the Yucca Mountain site, there are KTUs regarding the performance of seals for shafts, ramps, and boreholes; the effects of coupled thermal-mechanical-hydrological-chemical (TMHC) processes; and retrievability of waste. Therefore, predictions regarding: (1) the long-term performance of seals for shafts, ramps, and boreholes; (2) thermal-mechanical-hydrological-chemical response of the host rock, and groundwater system to thermal loading; and (3) the ability to retrieve high-level radioactive waste (HLW), 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 noncompliance due to the following KTUs is sufficient that a detailed Safety Review supported by analyses is justified.

This concern regarding compliance determination with the performance objectives specified below will necessitate analyses above and beyond those required for a Type 3 Safety Review in order to ensure that the uncertainties and potential effects on performance have been minimized to the extent practical. It should be noted that the Detailed Safety Reviews for the KTUs identified under items (2), (3), and (4) above will be dealt with under Review Plans 4.4 and 4.5.2, respectively. Only the KTU identified in item (1) above will be addressed herein. Thermal loading is expected to affect shafts, ramps, and exploratory boreholes to a lesser degree than it may affect the emplacement drifts; however, some input from this Review Plan will be necessary to ensure compliance with the Detailed Safety Reviews of these two KTUs.

Key Technical Uncertainty Topic. Predicting the Long-Term Performance of Seals for Shafts, Ramps, and Boreholes.

Description of Uncertainty. Review of the post-closure portion of the design for shafts, ramps, and boreholes in 10 CFR 60.134 demands consideration of the performance of seals (and backfill materials) and an evaluation of the impact of repository-generated thermal loads and repeated seismic loads on the long-term performance of these repository features. For example, in order to have confidence in applying current sealing technology to the repository environment, two considerations or factors relevant to the effectiveness and performance of seals remain to be resolved. These uncertainties are: (i) whether the seals will remain effective over the long period of regulatory interest (i.e., long-term seal performance), and (ii) whether technology exists to effectively install seals such that the intended performance of seals can be achieved. There is little experience regarding long-term performance of seals. Although available observations of the performance of some seal materials (e.g., low-permeability cements) seem to indicate that these components may have great durability (Osende, 1985; Rissler, 1978), it is also uncertain what impact thermal loads and repeated seismic loads will have on their performance. Also, other observations (Roy and Langdon, 1983 and 1986) of deterioration of high-quality cement grouts in dam foundations within a decade after installation seem to indicate otherwise. Considerable uncertainty exists regarding the installation of seals in the underground excavations (Schaffer and Daemen, 1987). This uncertainty is especially true regarding 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 created by the excavations from becoming dominant bypass flow paths around the seals and thereby negating the effectiveness of the seals.

It should be noted that this KTU consists of two specific parts: (i) prediction of thermal-mechanical effects on the performance of seals, including the surrounding rock mass; and (ii) prediction of thermal-hydrological effects on the chemical properties of the seal materials.

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

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

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

It is possible that the net contribution of seals to the overall system performance of the geologic repository may not be significant due to the unsaturated and fractured nature of the YM repository site. If future research by the DOE indicates that the uncertainties regarding seal performance, including the effects of thermal and repetitive seismic 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 KTU is not being reduced, and the contribution of the seals is not negligible, then the review strategy type may have to be upgraded.

Description of Resolution Difficulty. The installation of the seals for shafts, ramps, drifts, and boreholes is not generally expected to be completed until the repository is ready for closure (Fernandez and Richardson, 1994). 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 extended evaluation 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. 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.

The uncertainties would best be addressed through a comprehensive seal testing program by the 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 and repository operations can be used to adapt the sealing program to the particular geologic setting, as well as to the natural and environmental conditions. However, it is likely that data and models will be incomplete at the time of license submittal and that the DOE will use engineering judgment and expert opinion to resolve this uncertainty.

The DOE has recently developed a strategy (Fernandez et al., 1994) for sealing exploratory boreholes in unsaturated tuff to satisfy the seal performance requirements in 10 CFR Part 60. This proposed borehole sealing strategy focuses on addressing the following questions: (i) where to seal, relative to the potential repository and geologic setting; (ii) how to seal, relative to the selection of seal materials, geometry, and available technologies to seal exploratory boreholes (including casing removal, borehole wall reconditioning, and seal emplacement); and (iii) when to seal during the stages of repository operation. It has yet to be shown by the DOE whether this same sealing strategy could be applied to seals for shafts and ramps.

From the NRC perspective, uncertainties about extrapolation of short-term data for prediction of long-term performance of seals, including the long-term interaction between seals and the surrounding rock mass, may preclude satisfactory evaluation of the approaches being taken by the DOE and adequate interpretation of DOE results. It is therefore necessary for the NRC to perform selected independent analyses and interpretations to evaluate the DOE predictions. The input for these independent analyses shall be consistent with site characteristics, processes, and events, that are relevant to design of seals.

At present, since methods to address uncertainties associated with the long-term performance of seals are

6/59

still under development, it is difficult to identify the degree to which this KTU can be resolved by DOE activities or understood by NRC or CNWRA research efforts. In addition, heterogeneities in the geology and hydrology at the site will necessarily introduce uncertainty into predictions of seal performance over the period of regulatory interest.

Key Technical Uncertainty Topic. Prediction of the Thermal-Mechanical-Hydrological-Chemical Responses of the Host Rock, Surrounding Strata, and Groundwater System to Thermal Loads.

Description of Uncertainty. Section 60.133(i) requires that the underground facility for the GROA be designed so that the performance objectives will be met, taking into account the predicted thermal and thermal-mechanical (TM) responses of the host rock, surrounding strata, and groundwater system. The rule thus recognizes that to design an underground repository facility and waste packages and to assess the performance of the EBS and the total system, it is necessary to understand the thermal loads caused by the emplacement of radioactive wastes and the corresponding TMHC responses. One must also understand the uncertainties associated with predicting the thermal loading, corresponding jointed rock mass, geochemical, and groundwater responses, and subsequent impact on EBS and total system performance, so that these uncertainties can be accommodated in the underground facility design and the performance assessment of the EBS and the total system. The processes most likely to contribute to uncertainty in predicting the long-term mechanical, geochemical, and hydrological responses of the host rock surrounding the EBS and the long-term performance of the EBS and the total system are: (i) mechanical-effect (including repetitive seismic load) dependent fracture flow in unsaturated fractured rocks; (ii) formation of dryout regions, recondensation of vapor, and condensate dripping through fractures; (iii) time-dependent degradation of rock properties (matrix and fracture) under heated, partially saturated, and stressed conditions; (iv) extrapolation of laboratory fracture flow properties for field-scale application; (v) determination of extent of rewetting of the waste package and the chemistry of the condensed phase; and (vi) dissolution and precipitation of mineral species.

The geomechanical conditions at the YM site are characterized by a highly fractured rock mass with prominent vertical and sub-vertical faults and joints (U.S. Department of Energy, 1988). The fractured rock mass will be perturbed in several ways. First, the construction of the repository changes the state of stress, which, in turn, causes mechanical deformation of the rock, including joint normal and shear deformations. Joint normal and shear deformations have implications regarding the stability of excavations and may also affect fluid flow and solute transport in the jointed rock mass and into the emplacement drifts. Preferential flow paths may change causing change in quantity and location of fluid flow into the emplacement drifts. This is particularly important to the performance of the EBS and the total system. Second, the radioactive waste provides a heat source that is active over an extended period of time. This thermal load induces rock expansion which, in turn, may cause dilation, closure, and shear failure of fractures. The permeability of both matrix and fractures may change accordingly. The thermal load may also cause degradation of the mechanical properties of rock and rock joints. Kemeny and Cook (1990) have reported that about 38 percent of waste emplacement boreholes may experience slabbing failure as the repository heats up to 206 °C. Third, dynamic ground motions due to earthquakes, nearby underground weapons testing, etc., will be superimposed on *in situ*, excavation induced, and thermally induced stresses. The dynamic ground motions, including the cumulative effect of repetitive seismic motions, will cause further dilation, closure, and shear of fractures, which may change the fracture and matrix permeabilities. These perturbations are in addition to the effects of structural deformation and tectonic processes on jointed rock mass properties.

In addition to the causes mentioned above that may induce changes in fracture hydrological properties, it is well recognized that the strengths of intact rock and joints are functions of time, moisture content and stress field (Atkinson, 1984; Jaeger and Cook, 1979; Schotz, 1968; Kie, 1993). Although it is realized that this time-dependent or creep strain of intact hardrock, such as tuff, at room temperature may be insignificant relative to engineering design, fractured rock mass may exhibit significant creep due to joint filling and/or localized high-stress concentration on joint asperities (Pariseau, 1992). The thermal load may significantly increase the creep strain of both intact rock and joints. As a result, the overall strength of the fractured rock mass may significantly deteriorate with time. The effect of this time-dependent rock mass strength degradation will be more pronounced during the preclosure period, but the rock mass surrounding the emplacement drift may still deteriorate after the drifts have been backfilled as the backfill is not expected to provide sufficient support to the rock mass especially at the crown region of the drifts. Furthermore, presence of pore water or water vapor in the rock matrix causes crack nucleation and propagation due to stress corrosion. Laboratory results presented by Althaus et al. (1994) using both saturated and unsaturated granite samples suggest that rock matrix will weaken significantly due to microfracturing. The microfracturing may cause considerable increase in the rock mass permeability.

The perturbations of the jointed rock mass discussed above affect the joint aperture and the flow of fluids through the fracture depends upon the spatial geometry of this void space. When the two surfaces of a natural joint are in partial contact with one another, this geometry becomes so complex that fluid movement through the joint cannot be approximated as laminar flow between parallel surfaces (Cook, 1992). Furthermore, the fracture permeability is also influenced by the size effect, whose prediction method is unknown at this time (Raven and Gale, 1985; Neuzil and Tracy, 1981; Swan, 1983).

Moreover, opening and closure of certain faults and joints, and the precipitation or dissolution of minerals in the fracture network of the surrounding rock may significantly change the paths for groundwater flowing into the emplacement drifts. This phenomenon is likely to impact the geochemistry of the liquids that come in contact with the waste package and the residence time of such liquids. Thus, the TMHC coupled phenomena will have effects on the permeability of the host rock surrounding the EBS and consequently on the performance of the EBS and the total system. The long-term TMHC response of the host rock and the EBS over the lifetime of the repository is very difficult to predict and thus difficult to account for in the performance assessment of the EBS and the total system.

<u>Performance Objective at Risk</u>. 10 CFR 60.111(b), 10 CFR 60.112, and 10 CFR 60.113(a)(1)

<u>Explanation of Nature of Risk</u>. 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 and the TMHC coupling in the jointed rock mass and the components of EBS. The fractured nature of the surrounding host rock mass, the complex nature of the TMHC response of EBS, and the repository generated thermal regimes that are beyond the range of current engineering experience pose significantly complex problems to demonstrate compliance with 10 CFR Part 60 regulatory requirements. For such situations, the use of existing models to predict the likely TMHC effects on the host rock and the EBS from such loads, may not be satisfactory.

The performance of the EBS and the total system is dependent on the rate at which the waste package environment dries out during the heating period, extent of the dry period, chemistry of the condensate, condensate drainage taking place through fractures, and eventual rewetting during the cooling period. Thus, prediction of moisture redistribution in fractured rock mass near the heat-generating waste package is of critical importance. The fundamental mechanisms of thermal, mechanical, and hydrological coupling processes in jointed host rock and the EBS are not fully understood at this time. Coupled TMHC analytical models or computer codes that can be used to successfully predict the jointed host rock and EBS TMHC responses are not available, which makes the prediction of long-term behavior of host rock and EBS difficult (Ghosh et al, 1994). In conducting a degradation analysis of a system, such as the jointed host rock and the EBS, for which there is no precedent, it is difficult to provide reasonable assurance that the degradation models due to TMHC effects have been adequately considered.

Description of Resolution Difficulty. Much effort will be required to develop reliable models (and attendant computer codes) necessary to understand the phenomena underlying this KTU. There is a high degree of uncertainty related to identification of fast fracture flow paths and prediction of flow through them in the repository environment. The DOE has undertaken a program of laboratory measurements and experiments, field scale tests, and modeling (Management and Operating Contractor, 1994) to evaluate coupled TMHC processes in the jointed rock mass surrounding the EBS and in the EBS to resolve this KTU. The staff expects model development/refinement to continue as a greater understanding of thermally induced phenomena is gained. However, it is likely that data will be incomplete at the time of license submittal and that DOE will use engineering judgment and expert opinion to address this uncertainty.

The uncertainty related to the TMHC effects on the host rock will propagate to the EBS. For example, the opening of the faults and joints and changes in the flow path for intruding groundwaters are likely to impact the geochemistry of the liquids that come in contact with the waste package and the residence time of such liquids. The flow paths will influence the level of the radiation field on the water in the fracture near the waste package which, in turn, will affect the type and production of radiolysis products, pH, solute concentrations, and the potential for the formation of colloids from the iron-rich alloy that is expected to be used for the waste package overpack. Also, the cyclic evaporation/condensation of groundwater in the vicinity of the waste package could affect the concentration of salts in that region (Manaktala and Interrante, 1990; Walton et al., 1993). However, the manner in which these phenomena and processes interact and the temporal and spatial scales over which they occur have considerable uncertainty.

The effect of thermal loads on the GROA host rock mass and EBS was discussed in the NRC "Staff Technical Position (STP) on Geologic Repository Operations Area Underground Facility Design—Thermal Loads" (Nataraja and Brandshaug, 1992). If the DOE chooses a methodology different from that in this STP, the reviewer should assess whether the alternative methodology considers the coupling of TMHC processes in a manner that is not likely to underestimate the unfavorable aspects of repository performance or to overestimate the favorable aspects of repository performance. To ensure that an appropriate method is used, the NRC and the CNWRA will conduct independent studies to understand and develop an independent capability for reviewing the TMHC coupling effects on jointed rock mass and EBS.

The DOE is addressing these various difficulties through ongoing and planned programs involving laboratory experiments (mechanical and hydraulic properties of matrix and fractures, thermal properties of rock and fluids, hydrological properties of waste package); field experiments (fluid flow in unsaturated fractured rock, drying and rewetting of matrix and fractures, TMHC coupling); site characterization (fracture and matrix flow, *in situ* hydrothermal responses, waste package); and modeling (TMHC coupling). From the perspective of the NRC, uncertainties in predicting the hydrological behavior of jointed rock mass under dynamic and thermal conditions may preclude the satisfactory evaluation of the approaches taken by the DOE and adequate interpretation of DOE results regarding spatial and temporal distributions of hydraulic conductivity of jointed rock mass surrounding the EBS and the TMHC response of the EBS. Therefore, it is necessary for the NRC to develop an independent understanding of the phenomena and associated processes relevant to TMHC coupling including repetitive seismic load so that DOE work may be evaluated. Alternatives to DOE concepts and models must be independently developed by the NRC to assess the conservatism of DOE models and bounding conditions.

At present, methods to address uncertainties associated with the prediction of TMHC, including repetitive seismic load, effects on the host rock surrounding the EBS and the EBS are still under development. Thus, it is difficult to identify the degree to which the KTU can be resolved by DOE activities or understood by NRC/CNWRA research effort. In addition, heterogeneities in the geology of the site will necessarily introduce uncertainty into predictions of TMHC effects over the regulatory period of interest.

Key Technical Uncertainty Topic. Demonstration of Compliance with the Requirement to Maintain the Ability to Safely Retrieve High-Level Nuclear Waste.

Description of Uncertainty. The DOE is required to provide a plan that describes how HLW can be safely retrieved and stored. Retrieval of waste package canisters on a mass scale from an underground repository has never been attempted or accomplished. Also, the United States program is the only waste management program considering retrieval; thus the U.S. HLW program participants cannot learn from the experience of others. This lack of experience makes retrieval a riskier activity than one for which there is some experience. The uncertain nature of retrieval is acknowledged in the Statement of Considerations for 10 CFR Part 60, in which it is said, "...the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation" (Nuclear Regulatory Commission, 1983). Although the retrieval plan will probably be developed by the DOE using detailed analyses, the NRC should still perform a detailed review with independent analyses to determine that radiological health and safety will not be adversely affected by what will probably be a largely unproven retrieval system.

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

In addition to the predictive uncertainties, there will be uncertainties regarding the conduct of the retrieval operation itself. Examples of operational uncertainties include how the possible presence of leaking waste packages 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 or rock are contaminated. There will likely be uncertainties regarding the conduct of the retrieval operation, which would result in uncertainties regarding the radioactive doses that workers, and even the public, may receive. Because the retrieval operations might rely upon or be affected by the shafts and ramps of the GROA, the uncertainty about retrievability creates uncertainty regarding the design of the shafts and ramps.

It should be noted that this KTU consists of two specific parts: (i) prediction of TM effects on shafts, ramps, and emplacement drifts for retrievability; and (ii) 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 TM processes represents a specific part of the TMHC KTU that complicates review of DOE 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 to conclude that the impacts of TM 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 TM 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 scheme, and this uncertainty poses a risk to retrievability and storage being done safely. It is not clear whether emplacement drifts will be backfilled during the operations period. Complicated emplacement schemes in a backfilled repository will probably make it more difficult to retrieve waste than would a simpler scheme. Such difficulties or complexities will also 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 jeopardize 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 not be made lightly. It may be prompted, for example, by early-time performance problems such as waste packages corroding faster than anticipated. However, even if waste packages are not significantly degraded, 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 or utilized. 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 the DOE. For example, the following actions are among those that could reduce this KTU:

- The DOE designs a simple and straightforward waste emplacement configuration (for example, emplacement with no backfill prior to permanent closure);
- The DOE develops, tests, and provides documentation showing that it has developed an acceptable retrieval procedure and proposes using it in the repository design documentation; and
- The results of site characterization show that site-related complexities do not preclude the ability to retrieve waste.

The DOE is addressing these various difficulties through ongoing planning activities (pre-retrieval considerations, normal retrieval operations, abnormal retrieval conditions and operations, retrieval equipment considerations, and retrieval ventilation considerations) (TRW Environmental Safety Systems, Inc., 1994a; b). From the NRC perspective, uncertainties regarding the ability to conduct the planned retrieval operation may preclude satisfactory evaluation of the DOE retrievability plan.

2.0 REVIEW STRATEGY

2.1 Acceptance Review

To determine if this section of the DOE license application is acceptable for docketing, the staff will determine if the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before receipt of the license application, the staff will have conducted prelicensing reviews of the DOE program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these prelicense application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate the significance of any unresolved objection to license application submittal to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

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

2.2 Compliance Reviews

2.2.1 Safety Review

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

In conducting the Safety Review, the staff should determine if the information presented in the license application and in its references is an acceptable demonstration of compliance with all applicable

12/59

regulatory requirements. At a minimum, the staff should determine the adequacy of the data and analyses presented in the license application to demonstrate that the design for GROA shafts, ramps, boreholes, and their seals meets those design criteria.

The staff should evaluate if the DOE has acceptably described, at a minimum, the following systems:

(1) Waste shafts or ramps
(2) Muck shafts or ramps
(3) Ventilation intake shafts
(4) Ventilation exhaust shafts
(5) Personnel and material shafts or ramps
(6) Decommissioning systems.

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

(1) Conduct a preliminary review of the data base used to demonstrate compliance with the applicable regulatory requirements for each structure, system, and component (SSC), important to safety to determine data completeness

(2) Determine if portions of the data and/or analyses submitted need further detailed review (in addition to those areas requiring detailed Safety Reviews that may arise in the future)

(3) Understand and evaluate the DOE compliance demonstration logic

(4) Determine if any use of expert opinion (in lieu of experiments or analyses) is appropriate.

The specific aspects of the license application on which a reviewer will focus are described below, and the Acceptance Criteria are identified in Section 3.0 of this review plan. The staff should determine if the DOE has demonstrated that the design for GROA shafts, ramps, and boreholes meets the performance objective of 10 CFR 60.111(a) concerning radiation exposure to workers (Review Plan 4.5.1); the performance objective of 10 CFR 60.112 concerning the post-closure releases of radioactive material to the accessible environment; the GROA design criteria of 10 CFR 60.130; the general design criteria of 10 CFR 131; and the design criteria concerning seals in 10 CFR 60.134. The staff will also determine if the DOE has demonstrated that the GROA shafts, ramps, and boreholes designs permit implementation of the performance confirmation program defined in 10 CFR 60.137 and the performance objective of 10 CFR 60.111(b) concerning the retrievability of waste. The staff will emphasize tracing the identification in the LA of the applicability of pre- and post-closure implications on the design of SRBS. Shafts, ramps, and boreholes are not part of the underground facility as per 10 CFR 60.2, and, as a result, are not directly subject to the provisions of 10 CFR 60.133. On the other hand, sections of 10 CFR 60.133, specifically 60.133(a), (b), (c), (d), (e), (f), (g), and (i), address safety features that are not addressed in 10 CFR 60.131, 60.134, and 60.137 but may be necessary to ensure that shafts, ramps, and boreholes satisfy their performance objectives. Inasmuch as 10 CFR 60.130 requires that provisions be made for such safety features that are necessary to achieve the performance objectives for a specific facility, the design of shafts, ramps, and boreholes shall be reviewed against the specified sections of 10 CFR 60.133 to determine compliance with 10 CFR 60.130.

The staff should determine if the DOE has demonstrated that the design bases for the shafts, ramps, and boreholes take into account the results of the DOE site characterization activities. Pertinent design criteria chosen by the DOE should also be reviewed for acceptability.

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

(1) A description and discussion of the design of each GROA shaft, ramp, and borehole system, including: (i) the principal design criteria and their relationships 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 the DOE proposes to apply to the design and construction of the GROA shafts, ramps, boreholes, and seals;

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

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

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

In reviewing Items (1) through (4), above, the staff will confirm that, for each system identified, the LA has included the following:

(a) An analysis of the performance of the major SSCs 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 performed at the maximum capacity and rate of receipt of radioactive waste stated in the application; and

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

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

(i) Discussions of data representativeness, including uncertainties associated with extrapolation of data

(ii) Variability and uncertainty of data and resultant propagation of errors in models or analyses for which such data were used

(iii) Identification of, and justification for, assumptions used in analyses and models

(iv) Documentation and validation of models and analyses

(v) Input and output data and interpretations of the data with the basis for interpretation

(vi) The role of expert judgment, if used, in models and analyses.

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

(i) Identification and evaluation of design parameters used to meet design criteria

(ii) Description of uncertainties in parameters and of how these uncertainties are reflected in models

(iii) Descriptions of analyses and models used in the design of the shafts, ramps, and boreholes

(iv) Description of uncertainties in analytical models and how such uncertainties affect predicted results.

The GROA design also needs to demonstrate that all structures, systems, and components important to safety are properly integrated. Accordingly, when reviewing the GROA shafts, ramps, boreholes, and seals design, the staff 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.

For the regulatory requirements relevant to description and information, [e.g., those of 10 CFR 21(c)], the evaluation of compliance will consist of a review of site characteristics, processes, and events. The procedural steps for determination of compliance with 10 CFR 60.111(a) are in Review Plan 4.2; those for 60.111(b) are in Review Plan 4.5.2; and those for 60.131(a)(1-6) are in Review Plan 4.2. The procedures for 60.131(b)(1-8) are in Review Plan 4.4. For the regulatory requirements relevant to design for which methodologies have been well established [e.g., those of 10 CFR 60.131(b)(9)], the evaluation of compliance will consist of three steps; (i) review of site characteristics, processes, and events; (ii) review of design bases, criteria and requirements, and engineering specifications; and (iii) selected focused safety reviews. The provisions of 10 CFR 60.131(b)(10) do not apply, because shaft conveyance will not be used at the proposed repository. For the regulatory requirements relevant to engineering design (e.g., those of 10 CFR 60.134), the evaluation of compliance will consist of four steps: (i) review of site characteristics, processes, and events, (ii) review of design bases, criteria and requirements, and engineering specifications, (iii) review of analysis and design process and methodology, and (iv) selected focused safety reviews. The procedures for 10 CFR 60.137 are in Review Plan 4.4.

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

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

As part of the Safety Review, the staff may choose to refer to additional information and analyses contained in other sections of the license application. The information in this section of the license application may be cross-referenced to information and analyses in those license application sections listed in Table 2.2.1-1.

2.2.2 Detailed Safety Review Supported by Analysis

A Detailed Safety Review Supported by Analysis will be needed for evaluation of the KTU regarding assessing the design and long-term performance of seals for shafts, ramps, and boreholes. This safety review will ensure that the DOE has adequately demonstrated that the design of shafts, ramps, and boreholes meets the design criteria of 10 CFR 60.134. Activities performed in this Detailed Safety Review will help to ensure that the DOE has adequately addressed the KTU regarding sealing so that it does not contribute to noncompliance with the performance objectives related to overall system performance and the engineered barrier system.

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

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

Table 2.2.1-1 Sections of the license application that may support the review of the "Assessment of Compliance with the Design Criteria for Shafts and Ramps" Section of the License Application.

License Application Section	*Title*
1.3	Schedules for Planned Research and Development, Seal Placement, and Seal Material Selection
1.6	Site Characterization Program Review
1.7	Statement of Compliance with the Performance Objectives of 10 CFR Part 60 and Summary of PA Results
2.4	Requirements for Further Technical Information
2.5	Radioactive Material
2.6	License Specifications
3.1	Description of Individual Systems and Characteristics of the Site
3.2.1.5	Structural Deformation
3.2.1.6	Historical Earthquakes
3.2.1.8	Occurrence of More-Frequent/Higher Magnitude Earthquakes
3.2.1.14	Geomechanical Properties

License Application Section	*Title*
3.2.2.1	Nature and Rate of Hydrogeologic Processes
3.2.2.5	Flooding
3.2.2.6, 3.2.2.9	Changes to Hydrologic Conditions
3.2.2.10	Complex Engineering Measures
3.2.2.12	Perched Water Bodies
3.2.3.2	Geochemical Conditions
4.1.2	Description of the Structures, Systems, and Components of the SRBS
4.2	Assessment of Compliance with Design Criteria for Surface Facilities
4.4	Assessment of Compliance with Design Criteria for the Underground Facility
4.5.1	Assessment of Integrated GROA Compliance with the Performance Objectives: Protection against Radiation Exposures and Releases of Radioactive Material to Unrestricted Areas
7	Conduct of Repository Operations
8	Performance Confirmation Program
10	Quality Assurance
11	Emergency Planning

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

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

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

(i) Descriptions and models used by the DOE;

(ii) Staff's independent interpretations of the DOE data and descriptions;

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

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

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

RATIONALE FOR REVIEW STRATEGY

Not Applicable

Contributing Analysts

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APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW

Type 1:

10 CFR 60.21(c)(1)(i)
10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(7)
10 CFR 60.21(c)(9)

10 CFR 60.21(c)(11)
10 CFR 60.21(c)(12)
10 CFR 60.21(c)(14)
10 CFR 60.111(a,b)
10 CFR 60.112
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)
10 CFR 60.131(b)(10)
10 CFR 60.134
10 CFR 60.137

<u>Type 3</u>:

60.21(c)(1)(i)
10 CFR 60.21(c)(1)(ii)(A)
10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(7)
10 CFR 60.21(c)(9)
10 CFR 60.21(c)(11)
10 CFR 60.21(c)(12)
10 CFR 60.21(c)(14)
10 CFR 60.111(a,b)
10 CFR 60.112
10 CFR 60.130
10 CFR 60.131(a)
10 CFR 60.131(b)(1)
10 CFR 60.131(b)(2)
10 CFR 60.131(b)(3)
10 CFR 60.131(b)(4)
10 CFR 60.131(b)(5)
10 CFR 60.131(b)(6)
10 CFR 60.131(b)(8)
10 CFR 60.131(b)(9)

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

Type 4:

10 CFR 60.111(a,b)
10 CFR 60.112
10 CFR 60.134

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