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Umbrella Site Technical Position - Geologic Repository Operations Area Design /Rock Mechanics Issues for the Salt Repository Project Investigation (SRP)

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Engineering Branch

Division of Waste Management

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Background

In review of an application for Construction Authorization for a high-level waste geologic repository, the NRC staff is required to make a determination if the site and design meet the technical criteria of 10 CFR Part 60. The NRC staff determination will be based in the answers to, and supporting analyses of, technical questions concerning groundwater flow, geochemical retardation, waste form and waste package, geology and geologic stability, and facility design. During the process of Site Characterization, the Department of Energy (DOE) performs the laboratory and field investigations that develop the information needed to address these basic technical questions.

Investigations needed to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1982 (The Act) has established a schedule for site characterization and selection. Specifically, the Act requires publication of Site Characterization Plans (SCP's) by DOE at an early stage of the process. Subsequent to the receipt of an SCP, the NRC must prepare a formal Site Characterization Analysis (SCA) for each site. Documented site reviews, technical meetings, and site technical position papers will precede and supplement the SCA's. Because of the complexity and long lead times for site characterization investigations, it is essential that activities be organized to make possible an NRC determination of site acceptability. Proper organization necessitates early identification of technical questions (issues) relevant to the specific site. This USTP has as its purpose the establishment of the NRC position as to the essential issues relevant to repository design for the SRP. Future STP's and other NRC documents relevent to repository design will address NRC staff concerns regarding selected issues and acceptable technical approaches for addressing those issues.

In identifying these essential issues, the staff has used a performance analysis approach. In that approach three terms, site issue, performance issue and significant conditions and processes have the special meanings described in the paragraph below.

A Site Issue is a question about a specific site that must be addressed and resolved to complete the licensing assessment of site suitability and/or design suitability in terms of 10 CFR 60. Site issues are not necessarily controversial questions.

A Performance Issue is a broad question concerning the operation and long-term performance of the various components of the repository system. A set of performance issues are derived directly from the performance objectives in 10 CFR 60.

Significant Conditions and Processes (includes potential adverse conditions of 10 CFR 60) are those that must be considered in the assessment of a performance issue and either (1) exist before repository disturbance, (2) could cause future changes, or (3) result from change. They may be of natural (e.g., faulting), repository-induced (e.g., thermal buoyancy), and human induced (e.g., withdrawal of water resources).

In its performance analysis approach, the NRC staff first breaks down the performance objectives of 10 CFR 60 into a set of performance issues corresponding to the individual performance of the various components of the repository system. As developed in NUREG-0960, performance issues for a geologic repository are:

1. How do the design criteria and conceptual design address releases of radioactive materials to unrestricted areas within the limits specified in 10 CFR 60?

2. How do the design criteria and conceptual design accommodate the retrievability option?

3. When and how does water contact the backfill?

4. When and how does water contact the waste package?

5. When and how does water contact the waste form?

6. When, how, and at what rate are radionuclides released from the waste form?

7. When, how, and at what rate are radionuclides released from the waste package?

8. When, how, and at what rate are radionuclides released from the backfill?

9. When, how, and at what rate are radionuclides released form the disturbed zone?

10. When, how, and at what rate are radionuclides released from the far field to the accessible environment?

11. What is the pre-waste emplacement groundwater travel time along the fastest path of radionuclide travel from the disturbed zone to the accessible environment?

12. Have the NEPA Environmental/Institutional/Siting requirements for nuclear facilities been met?

While these performance issues were originally developed for BWIP, upon examination, the staff considers that they also apply to the SRP.

The next step in the performance analysis approach is identification of the significant conditions and processes that bear on assessment of each of the performance issues. Judgment is involved in determining which conditions and processes are considered significant. Knowledge gained from the staffs' review of various related technical data and documents, site visits, technical meetings and research efforts contributed heavily to the particular selection of significant conditions and used in developing of this STP. Questions about the significant conditions and processes as they pertain to the geologic repository operations area design constitute the site issues identified in this position.

Because design has an influence on groundwater flow, the ability to retrieve and release of radionuclides, information on the design parameters collected during site characterization at SRP will be part of the total repository system information needs of the NRC staff required to assess the performance elements. Issues identified in the following section delineate information on the geologic repository operations area design at SRP needed by the NRC staff to assess adequately the performance issues. The sequential order in which issues are identified should not be interpreted as the order of relative importance.

Generally the USTP's are divided into five technical areas (1.0 groundwater, 2.0 Waste Form/Waste Package, 3.0 Geochemistry, 4.0 Geologic Repository Operations Area Design/Rock Mechanics and 5.0 Geology). The site issues developed under each USTP are numbered and listed by the technical areas designed above.

TECHNICAL POSITION

The issues in this Site Technical Position (STP) are based on the performance objectives of 10 CFR 60 (60.111, 60.112, 60.113) and the design criteria of 10 CFR 60.130-135. Issues relating to pre-permanent closure are found in sections 4.1 and 4.2. These are (1) limiting of radiation doses to personnel to the limits set in 10 CFR 20 and (2) retrievability. Issues relating to the engineered barrier system except for the waste form and waste package are found in Section 4.3, 4.4 and 4.5. Issues related to waste form and waste package are presented under a seperate site technical position (STP No. 2) for convenience of organization. Borehole and shaft seal issues are presented in Section 4.6. It is the position of the NRC staff that based on our current level of knowledge of the SRP, assessment of the technical criteria of 10 CFR Part 60 requires that, at a minimum, the following issues concerning geologic repository operations area design/rock mechanics be addressed.

(NOTE: Issues and subissues under 4.3.3 and 4.6.1 are identical because they are relevant to both 4.3 and 4.6 first tier issues.)

FIRST-TIER SITE ISSUES

4.1 How is the geologic repository operations area designed to maintain radiation dose levels and concentrations of radioactive material within the limits specified in 10 CFR Part 60.111(a)?

4.2 How is the underground facility designed to permit retrieval of waste in accordance with the performance objectives of 10 CFR Part 60.111?

4.3 How is the backfill component of the engineered barrier system designed to meet the release rate requirements (10 CFR 60.113(ii)(b))?

4.4 How is the backfill component of the engineered barrier system designed to prevent the function of the waste packages from being compromised?

4.5 How is the backfill component of the engineered barrier system designed to control releases of radionuclides?

4.6 How does the geologic repository design account for the effects of the disturbed zone, including borehole and shaft seals, in meeting the release rate requirements of 10 CFR 60.112?

4.0 Geologic Repository Operations Area Design/Rock Mechanics

4.1 How is the geologic repository operations area designed to maintain radiation dose levels and concentrations of radioactive material specified in 10 CFR Part 60.111(a)?

4.1.1 What are the restricted and unrestricted areas of the geologic repository operations area?

4.1.2 What provisions are taken in the design to assure that, during normal operations, releases of radioactive material into the air in the restricted area do not exceed limits specified in 10 CFR Part 20.103?

4.1.3 How do the design criteria and design address levels of radiation and releases of radioactive materials to unrestricted areas within the limits specified by 10 CFR Parts 20.105 and 20.106?

4.1.4 How does the design of structures, systems and components important to safety incorporate the design criteria of 10 CFR Part 60.131?

4.1.4.1 How does design of the structures, systems and components important to safety account for natural phenomena and environmental conditions?

4.1.4.2 How does design of the structures, systems and components important to safety account for protection against equipment failure, fires and explosions, accident conditions, utility failures and criticality as required by 10 CFR Part 60.131?

4.1.4.3 How does design account for instrumentation and control systems to monitor and control the behavior of structures, systems and components important to safety for normal and accident conditions as required by 10 CFR Part 60.131?

4.1.4.4 How will inspection, testing, and maintenance be accounted for in the design of structures, systems and components important to safety?

4.1.5 How are surface facilities in the geologic repository operations area designed to meet 10 CFR Part 20 and EPA requirements?

4.1.5.1 How does the design of surface facilities account for radiation control, effluent monitoring and waste treatment as required by 10 CFR Part 60.132?

4.1.6 How does the underground facility design address the requirements for flexibility of design, underground openings and rock excavation as stated in 10 CFR Part 60.133?

4.1.6.1 What are the effects of in situ stresses, anomalies, differential stresses, creep rates, differential creep rates, and temperature on construction of the underground facility and emplacement of waste?

4.1.7 How is the underground facility designed to provide for possible water or gas intrusion into the geologic repository?

4.1.8 How is the underground facility ventilation system designed to restrict releases to limits specified on 10 CFR Part 60.111(a)?

4.1.9 How does the design permit implementation of a performance confirmation program as specified in Part F of 10 CFR Part 60?

4.2 How is the underground facility designed to permit retrieval of waste in accordance with the performance objectives of 10 CFR Part 60.111?

4.2.1 How does the design account for natural conditions such as in situ stresses, heterogeneities and anomalies in salt formations that affect the ability to retrieve as required by 10 CFR Part 60.111(b)?

4.2.2 How does the design account for geologic repository induced, thermal-hydrological-mechanical-chemical conditions that affect the ability to retrieve as required by 10 CFR Part 60.111(b)?

4.2.2.1 What effect does thermal loading have on creep rates, in situ stresses, heterogeneities and anomalies in the salt formation?

4.2.2.2 If spalling occurs how will it affect the ability to retrieve waste packages?

4.2.2.3 What effect will brime migration and the presence of brime in the geologic repository have on the ability to retrieve waste packages?

4.2.2.4 What effect will water (if any is present) in the underground facility have on the ability to retrieve waste packages?

4.2.2.5 What effect will retrieval have on the ventilation system requirements?

4.2.3 What effect does backfill have on the ability to retrieve (if backfill is emplaced prior to permanent closure)?

4.2.3.1 How will backfill (if any) be remined in order to remove the waste packages?

4.2.3.2 How will waste packages retrieval be affected by changes in backfill properties due to thermal-hydrological-mechanical-chemical processes?

4.2.4 What provisions are contained in the design to assure that, during retrieval, releases of radioactive material into the air in the restricted areas do not exceed limits specified in 10 CFR Part 20.103?

4.3 How is the backfill component of the engineered barrier system designed to meet the release rate requirements (10 CFR 60.113(ii)(b))?

4.3.1 How does the design incorporate the geologic and natural processes which will cause water to contact the backfill?

4.3.1.1 How much, by what means, and from what sources is intrusion of water into the engineered barrier system anticipated?

4.3.2 How does the design incorporate the geologic repository-induced changes on the geologic setting which will cause water to contact the backfill?

4.3.2.1 What effect does the excavation of openings have on rock movement, creep, fracturing and permeabilities in the underground facility, shafts and boreholes?

4.3.2.2 What effects do thermal gradients caused by waste emplacement have on rock movement, creep, fracturing and permeabilities in the underground facility, shafts and boreholes?

4.3.3 How will borehole and shaft seals be designed to meet the release rate requirement to the accessible environment (60.112)?

4.3.3.1 How does borehole and shaft seal design account for changes in characteristics of sealing materials?

4.3.3.2 What effect will construction of the shafts (e.g., rock damaged zone, liner effects), boreholes and in situ testing have on the ability to seal openings?

4.3.3.3 How will placement of borehole and shaft seals be controlled to ensure that the performance objective stated as 10 CFR Part 60.112 is met?

4.3.3.4 How does sealing system design account for rock movement, creep, fracturing, and groundwater chemical interaction?

4.4 How is the backfill component of the engineered barrier system designed to prevent the function of the waste packages from being compromised?

4.4.1 How does the design incorporate the effects of the coupled thermal-hydrological-mechanical-chemical processes on the properties of the backfill component of the engineered barrier system?

4.4.1.1 How does the design incorporate the effects of heat and radiation from the waste packages on the hydraulic conductivity, porosity, and permeability of the backfill component of the engineered barrier system?

4.4.1.2 How does the design incorporate the effects of groundwater flow and chemical composition of the groundwater on the properties of the backfill component of the engineered barrier system?

4.4.1.3 How does the design incorporate the effects of changes in the in situ stress field and of creep on the properties of the backfill component of the engineered barrier system?

4.5 How is the backfill component of the engineered barrier system designed to control releases of radionuclides?

4.5.1 What characteristics of the backfill component of the engineered barrier system will control releases of radionuclides?

4.5.2 How will the placement methods for the backfill component of the engineered barrier system be controlled to ensure that the system will meet the release rate requirements as stated in 10 CFR Part 60.113?

4.5.3 What level of performance is expected for the backfill component of the engineered barrier system in order to meet the release rate requirements stated in 10 CFR Parts 60.112 and 60.113?

4.6. How does the geologic repository design account for the effects of the disturbed zone, including borehole and shaft seals, in meeting the release rate requirements of 10 CFR 60.112?

4.6.1 How will borehole and shaft seals be designed to meet the release rate requirements to the accessible environment (60.112)?

4.6.1.1 How does borehole and shaft seal design account for changes in characteristics of sealing materials?

4.6.1.2 What effect will construction of the shafts (e.g., rock damaged zone, liner effects), boreholes and in situ testing have on the ability to seal openings?

4.6.1.3 How will placement of borehole and shaft seals be controlled to ensure that the performance objective stated as 10 CFR Part 60.112 is met?

4.6.1.4 How does the sealing system design account for rock movement, fracturing, creep, and groundwater chemical interaction?

4.6.2 How does the design incorporate the effects of thermal loading on the geomechanical properties of the rock in the disturbed zone?

Discussion

The rationale for each issue is described in the subsequent discussion. In the discussion, the broadest issues, i.e., those that would appear in the first tier of a hierachy of issues and sub-issues (logic tree) are related directly to the performace issues that are listed in the Background section above. Other issues are related by technical argument to the issue(s) directly above in the logic tree.

4.1 How is the geologic repository operations area designed to maintain radiation dose levels and concentrations of radioactive material within the limits specified in 10 CFR Part 60.111(a)?

10 CFR Part 60 contains design criteria incorporating the standards for protection against radiation (10 CFR 20) for the operational period of the repository. These include criteria for both the restricted and unrestricted areas of the geologic repository operations area. DOE should identify those structures, systems and components which are important to safety. The natural and induced geologic conditions and their effects on operation and performance of the geologic repository operations area should be considered.

4.1.1 What are the restricted and unrestricted areas of the geologic repository operations area?

To apply 10 CFR Part 20 - Standards for Protection Against Radiation, as specified in 10 CFR Part 60.111(a) and .131(a), it is necessary to determine the boundaries of the restricted and unrestricted areas based on the design for the geologic repository operations area.

4.1.2 What provisions are taken in the design to assure that, during normal operations, releases of radioactive materials into the air in the restricted area do not exceed limits specified in 10 CFR Part 20.103?

10 CFR Part 60.131 requires that the geologic repository operations area shall be designed to maintain radiation doses, levels and concentrations of radioactive material in air in restricted areas within the limits specified in 10 CFR Part 20.103. The requirement applies to the restricted area during normal operations only.

4.1.3 How do the design criteria and design address levels of radiation and releases of radioactive materials to unrestricted areas within the limits specified by 10 CFR Parts 20.105 and .106?

10 CFR Part 60.111(a) and 60.131(a) applies limits on levels of radiation and release of radioactive material in the unrestricted areas of the geologic repository operations area by 10 CFR Parts 20.105 and 106. The design for the geologic repository operations area should identify how levels and releases will be kept below those specified in Part 20 during normal operations of the facility.

4.1.4 How does the design of structures, systems and components important to safety incorporate the design criteria of 10 CFR Part 60.131?

10 CFR Part 60.131(a) requires that the geologic operations area be designed to maintain radiation doses, levels and concentrations within the limits specified in 10 CFR Part 20. The dispersal of radioactive contamination must be monitored and controlled.

4.1.4.1 How does design of the structures, systems, and components important to safety account for natural phenomena and environmental conditions?

10 CFR Part 60.131(b) requires that structures, systems, and components important to safety be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

4.1.4.2 How does design of the structures, systems, and components important to safety protect against equipment failure, fires, and explosions, accident conditions, utility failures, and criticality as required by 10 CFR Part 60.131?

10 CFR 60.131(b) requires that the structures, systems, and components important to safety be designed to (1) withstand dynamic effects of equipment failure, (2) protect against fires and explosions, (3) be capable of responding to emergencies, (4) ensure that utility service systems can function under normal and accident conditions, and (5) ensure that nuclear criticality is not possible.

4.1.4.3 How does design account for instrumentation and control systems to monitor and control the behavior of structures, systems, and components important to safety for normal and accident conditions as required by 10 CFR Part 60.131?

10 CFR Part 60.131(b) requires that the design of structures, systems, and components important to safety be designed to include provisions for

intrumentation and control systems to monitor and control behavior over anticipated ranges for normal and accident conditions.

4.1.4.4 How will inspection, testing, and maintenance be accounted for in the design of structures systems and components important to safety?

10 CFR Part 60.131(b) requires that structures, systems, and components important to safety are designed to permit periodic inspection, testing and maintenance.

4.1.5 How are surface facilities in the geologic repository operations area designed to meet 10 CFR Part 20 and EPA requirements?

10 CFR Part 60.132 requires that the surface facilities of the geologic repository operations area are designed to ensure that EPA and 10 CFR 20 standards are met.

4.1.5.1 How does design of surface facilities account for radiation control, effluent monitoring, and waste treatment as required by 10 CFR Part 60.132?

10 CFR Part 60.132 requires that surface facilities provide for radiation and effluent control and monitoring and prevent releases exceeding the levels stated in 10 CFR 20 and the EPA standard.

4.1.6 How does the underground facility design address the requirements for flexibility of design, underground openings and rock excavation as stated in 10 CFR Part 60.133?

Underground facility design must be flexible enough to accommodate site specific conditions. Consideration must be given to construction methods and the design of underground openings to limit the potential for creating a preferential pathway for groundwater or radioactive waste migration.

4.1.6.1 What are the effects of in situ stresses, anomalies, differential stresses, creep rates, differential creep rates, and temperature on construction of the underground facility and emplacement of waste?

Natural conditions at the repository horizon must be considered to insure safe waste emplacement. The effects of natural conditions on construction may include requirements for overexcavation to allow for creep closures prior to placement, increased extraction ratio for gassy conditions and increased ventilation capacity to allow for worker and equipment efficiency. Other effects may be identified during repository development which will require design changes to accomodate safe waste emplacement. The range of probable effects resulting from natural conditions needs to be identified.

4.1.7 How is the underground facility designed to provide for possible water, gas, or brime intrusions into the geologic repository?

Intrusion of water, gas, or brime may have a detrimental effect on the construction and operation of the underground facility, and therefore effect the ability of the geologic repository to meet the performance objectives of 10 CFR 60.

4.1.8 How is the underground facility ventilation system designed to restrict releases of radioactive materials to limits specified in 10 CFR Part 60.111(a)?

The underground facilities ventilation system must control the release of radioactive particulates and gases to within the limits specified in 10 CFR Part 20. 10 CFR Part 60.133(g) requires that the ventilation system function during normal and accident conditions and the ventilation of excavation and waste emplacement areas be separate.

4.1.9 How does the design permit implementation of a performance confirmation program as specified in Part F of 10 CFR Part 60?

As part of the design, a system must be developed for assessing how closely actual performance compares with the performance predicted during design. The design should allow the instrumentation system to monitor repository performance without interference from repository operations. The performance confirmation program should gather information on the response and interactions between the geologic media and waste form for comparison to baseline data and expected responses.

4.2 How is the underground facility designed to permit retrieval of waste in accordance with the performance objectives of 10 CFR Part 60.111?

As required by 10 CFR Part 60.111(b) retrieval of the waste is an option that must be maintained for a period of up to 50 years after the initiation of waste placement or until a performance confirmation is completed and accepted by NRC. The design criteria and design for the geologic repository must allow for the retrievability option as required by 10 CFR Part 60.133(c).

4.2.1 How does the design account for natural conditions such as in-situ stresses, heterogeneities and anomalies in salt formations that affect the ability to retrieve as required by 10 CFR Part 60.111(b)?

The natural conditions of salt will dictate many of the design details. The amount of fracturing, heterogeneity, anisotropic properties, anomalous zones, interbedding, ambient temperature, and other geologic conditions will affect storage room and emplacement hole dimensions, creep rates and retrieval equipment. The design criteria should address how the adverse siting conditions, if present, will affect the ability to retrieve.

4.2.2 How does the design account for geologic repository induced, thermal-hydrologic-mechanical-chemical conditions that affect the ability to retrieve as required by 10 CFR Part 60.111(b)?

The excavation and development of a geologic repository operations area results in changes in the existing natural conditions. Stress gradients will develop around the openings. As repository excavation proceeds, the stresses throughout the geologic repository area will be redistributed. Stability of the rock mass is dependent on the magnitude of the stress components, the rock mass strength, thermal loading and the orientation and geometry of the excavations. The stress conditions at retrieval will be a function of excavation techniques and excavation sequence. The effect of creep on room and hole closure and of differential creep on canister orientation must be considered. Floor heave and differential creep may change the location and orientation of the waste package. Relocating the canister prior to retrieval may be required.

The environment at the time of retrieval, (e.g., the presence of steam), will influence the type of equipment used, the configuration of geologic repository openings, ventilation requirements, and safety measures.

4.2.2.1 What effect does thermal loading have on creep rates, in situ stresses, heterogeneities and anomalies in the salt formation?

The thermal load imposed by the emplacement of waste will create a thermal gradient in the rock mass. The limits and magnitude of the gradient need to be defined along with resultant thermal expansion and stress changes.

The creep rates determined in laboratory tests and limited in situ testing are related to temperature by an exponential function. Creep rates at the elevated temperature expected at the time of retrieval could be nearly an order of magnitude above those at ambient temperature.

The thermal load may adversely impact the heterogeneities and anomalies in salt. The shear zones, gas pockets, and brine pockets in the salt formation were formed under a particular set of thermal and mechanical conditons. The changes in response to the thermal loading need to be defined to ensure stability of openings as required by 10 CFR 60.133(i).

4.2.2.2 If spalling occurs how will it affect the ability to retrieve waste packages?

Spalling may occur in the form of roof falls, pillar slabbing, or floor heave. Interbeds of clay or anhydrite may be release places in distressed zones around a repository opening. The extent of spalling will affect retrieval time, equipment, worker safety, and the ability to relocate a waste package for retrieval. The design criteria for underground openings requires that the retrievability option be maintained and the potential for rock movement be minimized as stated in 10 CFR Part 60.133(e).

4.2.2.3 What effect will brine migration and the presence of brine in the geologic repository have on the ability to retrieve waste packages?

Brine pockets within the salt formation will move under a thermal gradient toward the heat source. The quantity and condition of the collected brine in repository openings needs to be identified and controlled as required by 10 CFR 60.133 (d). The impact of brine migration on the thermal-mechanical properties of the salt formation must be considered Quantity of brine concentration may also effect waste package integrity. If brine is present and steam is produced, the effect of steam in the emplacement rooms upon retrieval should also be considered.

4.2.2.4 What effect will water (if any is present) in the underground facility have on the ability to retrieve waste packages?

Groundwater may begin to resaturate the waste emplacement rooms when they are sealed off. Retrieval would necessitate re-entry of the room. The effects of water in the emplacement rooms upon retrieval should be considered.

4.2.2.5 What effect will retrieval have on the ventilation system requirements?

Ventilation requirements during retrieval will be a function of rock temperature, backfill conditions and time allowed for precooling. Depending on the magnitude of retrieval, the ventilation capacity of the confined air circuit may need to be enlarged for retrieval. The rock temperature at various times in the retrieval period needs to be defined in terms of the ventilation capacity required for retrieval. The retrieval environment, including temperature, humidity, and air quality will directly affect the type of equipment and the measure taken to keep equipment in operation. Elevated temperatures may preclude the presence of workers leading to a need to cool repository rooms to allow men to work or for remote-controlled equipment. Temperature levels and resultant equipment requirements for retrieval need to be identified.

4.2.3 What effect does backfill have on the ability to retrieve (if backfill is emplaced prior to permanent closure)?

The presence of backfill may affect all of the operations necessary to retrieve the waste. Equipment systems, ventilation systems, excavation equipment, and repository facilities will need to consider the backfill during design. Equipment and excavation systems must identify how the increased temperatures will affect their ability to retrieve. Handling and storing backfill during retrieval operations should be considered in the repository design.

4.2.3.1 How will backfill be remined in order to remove the waste packages?

Remining of backfill may require advanced technology to assure proper equipment operation and worker safety. Under the conditions presently expected during retrieval, remining the backfill may require a remote-controlled excavation system. The system must be sensitive to changes in waste package location and to the possibility of brine pockets in the backfill. The system for remining the backfill and appropriate design criteria for the equipment should be identified.

4.2.3.2 How will waste package retrieval be affected by changes in backfill properties due to thermal-hydrological-mechanical-chemical processes?

The ability of the excavation equipment to remine the backfill will depend on an accurate assessment of the backfill physical properties at the time of retrieval. Groundwater resaturation, possible brine migration, consolidation, and thermal effects on the backfill may require different handling procedures at the time of retrieval than when placed. The limits of the expected changes and their effects on the retrieval systems require identification.

4.2.4 What provisions are taken in the design to assure that, during retrieval, releases of radioactive material into the air in the restricted areas do not exceed limits specified in 10 CFR Part 20.103?

The retrieval option may possibly require additional provisions if it is necessary to handle contaminated material in the underground facility caused by package failure. Consideration should be given to such problems and what effects these events would have on controlling radioactive material in the restricted area.

4.3 How is the backfill component of the engineered barrier system designed to meet the release rate requirements (10 CFR 60.113 (ii)(b))?

10 CFR 60.113 requires that the release of radionuclides from the engineered barriers to the geologic setting be gradual over a long period of time. Backfill design will be significantly affected by the role of the backfill in mitigating radionuclide releases.

4.3.1 How does the design incorporate the geologic and natural processes which will cause water to contact the backfill?

Salt is by nature a material with fracture healing properties. However, fracturing can occur which allows for the introduction of fresh water from overlying aquifers into the salt horizon. All factors should be considered in identifying the natural geologic factors that could cause water to enter the underground facility.

4.3.1.1 How much, by what means, and from what sources is intrusion of water into the engineered barrier system anticipated?

The greatest risk for a repository in salt is the potential for dissolution of the host salt rock and backfill as a consequent of water ingress.

Intrusion of water into the engineered barrier system can be gradual or sudden and occur in any quantity. Sources of water intrusion could include unidentified boreholes, brine and/or gas pockets, dissolution zones, and groundwater. Potential water intrusions and their impact on geologic repository operations should be addressed.

4.3.2 How does the design incorporate the geologic repository-induced changes on the geologic setting which will cause water to contact the engineered barrier system periphery?

High priority should be assigned in the design activities to maintain appropriate seperation between salt and ground water flow. Excavation of a geologic repository, applied thermal loads, and the construction of vertical shafts and boreholes may enhance the flow of groundwater into the repository system. Changes in the natural conditions which may contribute to groundwater inflow should be identified and their impacts assessed.

4.3.2.1 What effect does the excavation of geologic repository openings have on rock movement or fracturing and permeabilities in the underground facility, shafts and boreholes?

The excavation of geologic repository openings will change the in situ stress conditions in the geologic repository operations area and surrounding strata. In the repository horizon little fracturing of pure salt will be expected. However, in surrounding strata the change in stress may create fractures and open existing fractures thus enhancing permeability. In addition, the intersection of anomolous zones in salt may create a high permeability pathway. Increased permeability and its effect on inflows need to be identified.

4.3.2.2 What effects do thermal gradients caused by waste emplacement have on rock movement or fracturing and permeabilities in the underground facility, shafts and boreholes?

The response of the underground facility and geologic setting to thermal loads should be defined in terms of fracture frequency and fracture opening. Expansion of geologic materials may initially close some fractures. Subsequent cooling may result in the realization of some unrecoverable strains and resultant permeability enhancement. The effects of thermal loading on fractures in the underground facility and on brine and gas pockets and interbeds in the geologic setting must be addressed, as required by 10 CFR Part 60.133(i), to assess how water could contact the engineered barrier system.

4.3.3 How will borehole and shaft seals be designed to meet the release rate requirements to the accessible environment (60.112)?

Construction of shafts and boreholes in salt alters the geologic setting and can create potential pathways for groundwater flow and migration of radionuclides. Since these pathways could adversely affect the isolation capabilities of the repository, the NRC has required in 10 CFR Part 60.134(a) that boreholes and shafts be sealed at permanent closure of the facility. Seal system characteristics should be based on the performance DOE will require of the seal system.

4.3.3.1 How does borehole and shaft seal design account for changes in characteristics of sealing materials?

The compatibility of the physical and chemical characteristics of the seal material to the salt and other evaporite strata is an important consideration in seal design. Aspects of the geologic setting should not have a detrimental affect on the integrity of the seal material. If the seal is not designed properly, salt dissolution could occur or seal material set-up time may be retarded due to infiltration of brine. Incompatability could result in seal deterioration by chemical attack causing seal system failure. Differential creep could cause shearing of the seal system. Therefore, to meet the requirements of 10 CFR Part 60.134(b), the effect of the geologic setting on seal properties must be addressed.

4.3.3.2 What effect will construction of the shafts (e.g., rock damaged zone, liner effects), boreholes and in situ testing have on the ability to seal openings?

Construction of shafts, borehole drilling, and exploratory testing will change the rock characteristics surrounding the openings. Potential effects are rock damage by excavation and stress redistribution around the opening. The effect of these phenomena on the ability to seal the openings should be assessed.

4.3.3.3 How will placement of borehole and shaft seals be controlled to ensure that the performance objective stated as 10 CFR Part 60.112?

The placement techniques used in sealing shafts and boreholes could be a controlling factor in seal performance. Reliability must be obtained in the methods and equipment used to install the seal materials. The reproducibility of results using these methods and equipment must be demonstrated, through field testing of emplacement methods and monitoring the performance of the emplaced seals.

4.3.3.4 How does the sealing system design account for rock movement, fracturing, creep, and groundwater chemical interaction?

Rock mass instabilities could cause shearing of the seal system in shafts and boreholes. Effects of deformation on the seal materials and seal system should be assessed.

The compatibility of the chemical characteristics of the seal material, the groundwater, and the host rock is an important consideration in seal design. Incompatibility could result in seal deterioration by chemical attack which could result in failure of the seal system.

4.4 How is the backfill component of the engineered barrier system designed to prevent the function of the waste packages from being compromised?

The engineered barrier system includes the material surrounding the waste package. How water moves through the part of the engineered barrier system surrounding the waste package will affect the performance of the waste package and therefore, release rates from the geologic repository.

4.4.1 How does the design incorporate the effects of coupled thermal-hydrological-mechanical-chemical processes on the properties of the backfill component of the engineered barrier system?

Changes to the engineered barrier system components will occur due to the combined processes caused by waste emplacement. The impact of the anticipated changes on the backfill must be addressed in the design as required by 10 CFR Part 60.113.

4.4.1.1 How does the design incorporate the effects of heat and radiation from the waste package on the hydraulic conductivity, porosity, and permeability of the backfill component of the engineered barrier system?

Heat from the waste packages will increase in temperature of the surrounding material. The material temperature will increase to a maximum and then gradually decrease. The effects of thermal loading on the hydrologic characteristics of the backfill must be assessed.

Temperature variations may also change the state of stress in the backfill. The effects of stress on the hydrologic characteristics of the backfill must be addressed. Radiation from the waste package can adversely affect the properties of the backfill. Changes in characteristics could cause release rates of radionuclides through the backfill which exceed those specified in 10 CFR 60.113.

4.4.1.2 How does the design incorporate the effects of groundwater flow and the chemical composition of the groundwater on the properties of the backfill component of the engineered barrier system?

Channeling in the backfill from groundwater flow in the underground facility after permanent closure could affect the engineered barrier system performance by allowing more water to contact the waste package. This may result in greater releases of radionuclides through the engineered barrier system than was originally designed for. Alterations due to chemical interactions with the groundwater could adversely affect the performance of the backfill.

4.4.1.3 How does the design incorporate the affects of change in the in situ stress field and of creep on the properties of the backfill component of the engineered barrier system?

Changes in the in situ stress field and the effects of creep may adversely affect the properties of the backfill component of the engineered barrier system. The impact of changes on the properties of backfill should be addressed in the design as required by 10 CFR Part 60.113.

4.5 How is the backfill component of the engineered barrier system designed to control releases of radionuclides?

As stated in 10 CFR Part 60.113, the performance objectives of the engineered barriers are to limit the radionuclide release from a geologic repository. Before a license can be granted, there must be reasonable assurance that these objectives will be met.

4.5.1 What characteristics of the backfill component of the engineered barrier system will control releases of radionuclides?

To comply with the performance objectives for the engineered barrier system as stated in 10 CFR Part 60.112 and 60.113, it will be necessary to determine the characteristics of the materials used in the backfill. It should be shown how these characteristics will limit releases of radionuclides.

4.5.2 How will placement methods for the backfill component of the engineered barrier system be controlled to ensure that the system will meet the release rate requirements as stated in 10 CFR Part 60.113?

Placement of engineered barrier system components can be a controlling factor in their performance. Proper control of placement must be maintained to assure the expected in situ characteristics of the engineered barrier system components will meet the performance objective of 10 CFR Part 60.113.

4.5.3 What level of performance is expected for the backfill component of the engineered barrier system in order to meet the release rate requirements stated in 10 CFR Parts 60.112 and 60.113?

Because performance of the engineered barrier system is based on meeting the EPA standard, it is important to establish what the performance levels will be expected for each engineered barrier system component. By establishing what is expected with respect to performance, design criteria can be developed to meet those objectives.