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March 4, 2002
Contract No. NRC–02–97–009
Account No. 20.01402.951/952/953

U.S. Nuclear Regulatory Commission
ATTN: Mr. Jeffrey A. Ciocco
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TWFN Mail Stop 7 C6
Washington, DC 20555

Subject: Submittal of Intermediate Milestones 01402.951.210, 01402.952.210, and 01402.953.210: Yucca Mountain Review Plan—NUREG Camera Ready

Dear Mr. Ciocco:

Attached are the subject documents, submitted as deliverables under Contract No. NRC–02–97–009. The purpose of these deliverables is to provide an updated version of the Yucca Mountain Review Plan that can be made available for public comment. The three deliverables are combined as a single document.

This submittal incorporates U.S. Nuclear Regulatory Commission (NRC) staff and internal concurrence review comments and responds to direction in Staff Requirements Memorandum COMSECY–02–0001, Public Release of the Yucca Mountain Review Plan Draft Revision 2.

The Yucca Mountain Review Plan will be used as the staff guidance document for reviews of any U.S. Department of Energy license application for the proposed high-level waste repository at Yucca Mountain. It defines areas of review, review methods, acceptance criteria, evaluation findings, and references that the staff will use to prepare a safety evaluation report for any licensing action at Yucca Mountain.

In developing this update to Yucca Mountain Review Plan Revision 1, the Center for Nuclear Waste Regulatory Analyses (CNWRA) worked with the NRC staff to enhance the extent to which the plan is risk-informed and performance-based.

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The CNWRA will continue to support the NRC staff in refinement of the Yucca Mountain Review Plan and in response to any public comments received on it.

Please call me at 210.522.5054 if you have any questions on this deliverable.

Sincerely,

Patrick C. Mackin
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REVISION X

YUCCA MOUNTAIN REVIEW PLAN

Draft Report for Comment

Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
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AVAILABILITY NOTICE

DRAFT NUREG–
REVISION X

YUCCA MOUNTAIN REVIEW PLAN

Draft Report for Comment

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Prepared by
Center for Nuclear Waste Regulatory Analyses

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ABSTRACT

The Yucca Mountain Review Plan provides guidance to evaluate a license application for a geologic repository. The licensing criteria are contained in the U.S. Code of Federal Regulations (CFR) Title 10, Part 63 (10 CFR Part 63), "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada." The Secretary of Energy has recommended the Yucca Mountain site to the President for the development of a nuclear waste repository. The President has notified Congress that he considers Yucca Mountain qualified for construction permit application. The law now gives Nevada the opportunity to disapprove the President's recommendation, and, if it does, then Congress will have an opportunity to act. The U.S. Department of Energy would submit any license application to the U.S. Nuclear Regulatory Commission. The principal purpose of the Yucca Mountain Review Plan is to ensure the quality, uniformity, and consistency of U.S. Nuclear Regulatory Commission staff reviews of the license application and any requested amendments. The Yucca Mountain Review Plan has separate sections for reviews of repository safety before permanent closure, repository safety after permanent closure, the research and development program to resolve safety questions, the performance confirmation program, and administrative and programmatic requirements. Each of these sections supports determining compliance with specific regulatory requirements from 10 CFR Part 63. The regulations and the Yucca Mountain Review Plan are risk-informed, performance-based to the extent practical.

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EXECUTIVE SUMMARY

Disposal of high-level nuclear waste requires a U.S. Nuclear Regulatory Commission license. Part 63 under Title 10 of the U.S. Code of Federal Regulations ("Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada") is the governing rule. U.S. Nuclear Regulatory Commission authority to regulate a high-level waste repository comes from the Atomic Energy Act of 1954, as amended; the Energy Reorganization Act of 1974, as amended; and the Nuclear Waste Policy Act of 1982, as amended. The Yucca Mountain Review Plan is guidance to the staff for review of any license application from the U.S. Department of Energy for a geologic repository for disposal of high-level radioactive waste. The U.S. Nuclear Regulatory Commission has directed the staff to carry out risk-informed and performance-based regulatory programs. 10 CFR Part 63 is risk-informed, performance-based, because risk of health effects to the reasonably maximally exposed individual is the basis for its performance objectives. 10 CFR Part 63 also requires protection of ground water by limiting the radioactivity in a representative volume of ground water and an assessment of repository performance under conditions of human intrusion. The U.S. Nuclear Regulatory Commission will base its licensing decision on whether the U.S. Department of Energy has demonstrated compliance with the performance objectives. Therefore, the Yucca Mountain Review Plan is risk-informed, performance-based.

The principal purpose of the Yucca Mountain Review Plan is to ensure the quality and uniformity of staff licensing reviews. Yucca Mountain Review Plan sections present the areas of review, review methods, acceptance criteria, evaluation findings, and references the staff will use for its review. There are sections for an acceptance review, reviews of general information, preclosure repository safety, postclosure repository safety, the research and development program to resolve safety questions, the performance confirmation program, and administrative and programmatic requirements. A summary of the risk-informed, performance-based foundation for each section follows.

An acceptance review is the first screening of the U.S. Department of Energy license application. The application must provide enough information to demonstrate compliance with the regulations. The reviewer will evaluate whether the information is sufficient to support a detailed review, and will assess the schedule for any later U.S. Nuclear Regulatory Commission milestones. The acceptance review does not determine the technical adequacy of the submitted information. U.S. Nuclear Regulatory Commission staff will send the results of the acceptance review, with a projected schedule for the rest of the review, to the U.S. Department of Energy within 90 days of receiving the license application. If the license application fails this minimum standard, the staff will tell the U.S. Department of Energy the application will not support a detailed technical review, and will recommend specific corrective action.

The general information material provides a broad overview of the U.S. Department of Energy engineering design concept for the repository and allows the U.S. Department of Energy to demonstrate its understanding of which aspects of the Yucca Mountain site and its environs influence repository design and performance. More detailed technical descriptions are in the Safety Analysis Report sections of the license application. Notable exceptions are the "Physical Protection Plan" and "Material Control and Accountability" sections. The extent to which the general information incorporates risk-informed, performance-based principles varies.

EXECUTIVE SUMMARY (continued)

The preclosure safety analysis evaluates compliance with performance objectives to limit levels of doses to workers and the public considering acceptable risk levels. 10 CFR Part 63 requires the U.S. Department of Energy to demonstrate compliance using a preclosure safety analysis. A preclosure safety analysis systematically examines the site, the design, the potential hazards, and initiating events and their consequences, and the potential dose consequences to workers and the public. The preclosure safety analysis considers the probabilities and uncertainties associated with potential hazards. The preclosure review will focus on the U.S. Department of Energy demonstration that repository design, construction, and operation will meet the performance objectives (exposure limits). The staff will apply resources proportionately to review high-risk significant systems, structures, and components important to safety.

10 CFR Part 63 requires the U.S. Department of Energy to conduct a performance assessment to demonstrate compliance with postclosure performance objectives. A performance assessment systematically analyzes what can happen, the likelihood, and the consequences. The staff will use risk information to focus on those items most important to performance. The staff will examine the U.S. Department of Energy identification of natural and engineered barriers important to waste isolation. The staff will use risk insights from previous performance assessments for the Yucca Mountain site, detailed process-level modeling efforts, laboratory and field experiments, and natural analog studies. The staff will then evaluate the U.S. Department of Energy scenario analysis. The scenario analysis must consider the risk information from identified barriers and include the identification and screening of features, events, and process and construction of scenarios from the retained features, events, and processes of the Yucca Mountain site. Finally, the performance assessment review will examine information on 14 model abstractions. The abstractions arose from engineered, geosphere, and biosphere subsystems shown to be most important to performance, based on previous performance assessments, knowledge of site characteristics, and repository design. Since it is unlikely each of the model abstractions will have equal risk significance, the staff will focus on those with the greatest risk to repository performance. For the postclosure period, "important to performance" means important to meeting the radiation exposure performance objective. The risk of radiation health effects is the basis for the radiation exposure limit. The postclosure performance objectives also protect ground water by limiting the radioactivity in a representative volume of ground water. Postclosure performance objectives also require an assessment of performance under conditions of human intrusion.

The review of the research and development program for resolving safety questions applies to systems, structures, and components important to safety, and engineered and natural barriers important to waste isolation. The program identifies, describes, and discusses safety features or components that require further information to confirm the adequacy of design. This will be a risk-informed review, because it focuses on those items most important to safety or waste isolation.

The review of the performance confirmation program examines the program of tests, experiments, and analyses the U.S. Department of Energy will conduct to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives in 10 CFR Part 63. A performance confirmation program is unique and results from uncertainties in estimating repository performance over thousands of years. This section is

risk-informed, performance-based because it focuses on parameters and engineered and natural barriers important to performance.

10 CFR Part 63 provides no performance objectives for the administrative and programmatic sections of the Yucca Mountain Review Plan. Existing regulatory programs are the basis for acceptance criteria and review methods in this section. The staff considered the expected operations and associated risks, while taking advantage of opportunities to limit prescriptive requirements. The quality assurance section of the Yucca Mountain Review Plan contains review methods and acceptance criteria to support a review of either a graded or nongraded program. The staff will conduct a risk-informed review for a graded quality assurance program.

1 INTRODUCTION

A U.S. Nuclear Regulatory Commission license is required, under the provisions of the U.S. Code of Federal Regulations (CFR) Title 10, Part 63 (Part 63), "Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada," for disposal of high-level radioactive waste. U.S. Nuclear Regulatory Commission authority to regulate a high-level radioactive waste repository comes from the Atomic Energy Act of 1954, as amended; the Energy Reorganization Act of 1974, as amended; and the Nuclear Waste Policy Act of 1982, as amended.

The Energy Policy Act of 1992 directed the U.S. Environmental Protection Agency to contract with the National Academy of Sciences, to provide advice on the appropriate technical bases for public health and safety standards governing a Yucca Mountain, Nevada, repository. In its report, "Technical Bases for Yucca Mountain Standards" (National Research Council, 1995), the National Academy of Sciences recommended that an individual protection standard, expressed as a limit on individual risk rather than on dose, would provide a reasonable basis for protecting the health and safety of the general public. The Energy Policy Act of 1992 also directed the U.S. Environmental Protection Agency to issue public health and safety standards for Yucca Mountain that "... prescribe the maximum annual effective dose equivalent to individual members of the public and that are consistent with the findings and recommendations made by the National Academy of Sciences in its 1995 report" (National Research Council, 1995). This approach is different from that contained in the U.S. Environmental Protection Agency disposal standards at 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Wastes," that were applied at the Waste Isolation Pilot Plant in New Mexico. In addition, the Energy Policy Act of 1992 directs the U.S. Nuclear Regulatory Commission to modify the technical requirements and criteria contained in original U.S. Nuclear Regulatory Commission generic regulations for disposal of high-level radioactive waste in 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," to be consistent with the U.S. Environmental Protection Agency standards applicable to Yucca Mountain. The U.S. Environmental Protection agency published public health and environmental radiation protection standards for Yucca Mountain, Nevada, at 40 CFR Part 197 on June 13, 2001. The Commission has incorporated these standards into its final 10 CFR Part 63. Any license application for a geologic repository at Yucca Mountain, submitted under 10 CFR Part 63, is to contain "General Information," a Safety Analysis Report, and is to be accompanied by a final environmental impact statement. Any Restricted Data or National Security Information must be separated from unclassified information in any license application. In light of the terrorist attacks of September 11, 2001, the Commission has directed the staff to conduct a comprehensive reevaluation of U.S. Nuclear Regulatory Commission physical requirements. If this effort indicates that U.S. Nuclear Regulatory Commission regulations or requirements warrant revision, such changes would occur through appropriate methods and, if necessary, the Yucca Mountain Review Plan would be revised accordingly.

Although the National Environmental Policy Act of 1969 requires an environmental evaluation for major federal actions that significantly affect the human environment, the Nuclear Waste Policy Act of 1982 requires that the U.S. Nuclear Regulatory Commission adopt, to the extent practicable, the final environmental impact statement prepared by the U.S. Department of Energy. Thus, the U.S. Nuclear Regulatory Commission would prepare an environmental

evaluation only for those areas that it cannot adopt the U.S. Department of Energy final environmental impact statement. U.S. Nuclear Regulatory Commission regulations at 10 CFR 51.109 contain the criteria the U.S. Nuclear Regulatory Commission will use to determine if the final environmental impact statement published by the U.S. Department of Energy can be adopted. The Yucca Mountain Review Plan is not a staff guidance document for an environmental evaluation. The Commission has previously provided its comments on the draft environmental impact statement, the supplemental draft environmental impact statement, and the final environmental impact statement for a potential high-level waste repository at Yucca Mountain to the U.S. Department of Energy.

The U.S. Department of Energy, as the applicant for a license to construct and operate a geologic repository, and to receive, and possess source, special nuclear, or byproduct material, and dispose of such material at a geologic repository operations area at the Yucca Mountain site, which will be permanently closed, is required to provide detailed information on the facilities, equipment, and procedures to be used, and to discuss the effect of proposed operations on public health and safety. This information is to include a final environmental impact statement for the Yucca Mountain site, together with any U.S. Nuclear Regulatory Commission comments on such statement. This final environmental impact statement shall, to the extent practicable, be adopted by the U.S. Nuclear Regulatory Commission in connection with the issuance of a construction authorization and license for a geologic repository. U.S. Nuclear Regulatory Commission staff uses this information to determine whether the proposed activities will meet the applicable regulatory requirements, and thus be protective of public health and safety and the environment. General procedures for the issuance of a license, license amendment, and transfer and renewal of a license, are described in 10 CFR Part 2, Subpart A. 10 CFR Part 2, Subpart J, contains the procedures applicable to proceedings for the issuance of licenses for the receipt of high-level radioactive waste at a geologic repository.

10 CFR Part 63, a site-specific rule, will be implemented using this site-specific review, the Yucca Mountain Review Plan. The Yucca Mountain Review Plan provides the staff with guidance on the review of a license application for a high-level radioactive waste disposal facility at Yucca Mountain. The staff will also use the Yucca Mountain Review Plan to review requested amendments to the license application and, potentially, applications to amend a construction authorization or license. The principal purpose of the review plan is to ensure quality and uniformity in the U.S. Nuclear Regulatory Commission staff reviews. Although there will only be one application for a potential repository at Yucca Mountain, use of this Yucca Mountain Review Plan will begin in the prelicensing consultative phase of the program. This will allow the U.S. Nuclear Regulatory Commission staff to provide prelicensing consultation consistent with what is needed to make a determination in a licensing review. Each Yucca Mountain Review Plan section provides guidance on what is to be reviewed, the review basis, how the staff review is to be accomplished, what the staff will find acceptable in a demonstration of compliance with the regulations, and the conclusions that are sought regarding the applicable sections in 10 CFR Part 63.

This Yucca Mountain Review Plan is intended to cover only those aspects of the U.S. Nuclear Regulatory Commission regulatory mission that are related to the licensing of a high-level radioactive waste disposal facility. As such, the Yucca Mountain Review Plan helps focus the

staff review on determining if a facility can be constructed and operated in compliance with the applicable U.S. Nuclear Regulatory Commission regulations. The Yucca Mountain Review Plan is also intended to make information about regulatory matters widely available and to improve communications and understanding of the staff review process by the U.S. Department of Energy, interested members of the public, the State of Nevada, affected units of local governments and Indian tribes, and other stakeholders. For review of any amendments, the focus of the review should be on the changes proposed in the amendment. Reviewers should not review other previously accepted actions if they are not part of the amendment, unless the review of the amendment package identifies problems with other aspects of facility operation.

It is important to note that the acceptance criteria laid out in this Yucca Mountain Review Plan are for the guidance of staff responsible for the review of an application for a high-level radioactive waste repository at Yucca Mountain. Review plans are not substitutes for the U.S. Nuclear Regulatory Commission regulations, and compliance with the Yucca Mountain Review Plan is not required. Methods and solutions different from those set out in the Yucca Mountain Review Plan will be acceptable if the U.S. Department of Energy provides a basis for the findings requisite to the issuance or amendment of a license by the U.S. Nuclear Regulatory Commission. To the extent practical, the staff has made the Yucca Mountain Review Plan risk-informed and performance-based. This, coupled with the performance-based regulations, will ensure that the U.S. Nuclear Regulatory Commission review is focused on those aspects most important to the safety of the repository, which still affords the U.S. Department of Energy flexibility in how it chooses to meet the performance-based regulation. It is important to note that although significant focus was placed on developing a risk-informed, performance-based Yucca Mountain Review Plan, the staff also needed to balance that against having a review plan with sufficient detail to support the necessary conclusions. Use of acceptance criteria that are too general and provide no guidance beyond what is specified in a performance-based regulation, would make this review plan less useful, especially given the first-of-a-kind facility to be reviewed and the mandatory 3-year review schedule. The licensing review will use the Yucca Mountain Review Plan in a flexible way. The scope of the review will consider the safety strategy of the U.S. Department of Energy. This approach is consistent with the U.S. Nuclear Regulatory Commission policy regarding risk-informed, performance-based regulations (U.S. Nuclear Regulatory Commission, 1999) in which risk insights, engineering analysis, expert judgment, the principle of defense-in-depth, safety margins, and performance history are incorporated in licensing decisions.

1.1 Conduct of The Yucca Mountain Licensing Review

1.1.1 Licensing Review Philosophy

Since passage of the Atomic Energy Act of 1954, the U.S. Nuclear Regulatory Commission has been engaged in a continuing process of interpreting and applying the Agency's basic responsibilities to protect public health and safety, assure the common defense and security, minimize danger to life or property, and provide adequate protection from the risks involved in the commercial use of Atomic Energy Act radioactive materials. These terms are not defined in the Atomic Energy Act of 1954, nor are they self-explanatory. The underlying regulatory philosophy used by the U.S. Nuclear Regulatory Commission in fulfilling its regulatory mission

can be found in the "U.S. Nuclear Regulatory Commission Strategic Plan" (U.S. Nuclear Regulatory Commission, 2000) which embodies the principle that the licensee is responsible for the safe operation of a nuclear facility.

The following three principles are important in implementing the U.S. Nuclear Regulatory Commission regulatory mission:

- The U.S. Nuclear Regulatory Commission does not select sites or designs, or participate with licensees or applicants in selecting proposed sites or designs. (However, the Nuclear Waste Policy Act of 1982 requires prelicensing consultation between the U.S. Nuclear Regulatory Commission and U.S. Department of Energy;

- U.S. Nuclear Regulatory Commission role is not to monitor all licensee activities, but to oversee and audit them. The U.S. Nuclear Regulatory Commission should evaluate whether a license application meets the applicable regulations based on a review of what is in the application. Reviews using staff audit calculations should be performed in very limited situations, such as where there are unique proposals involving new methods or assumptions. Otherwise, the U.S. Nuclear Regulatory Commission staff should review the application to ensure that assumptions are justified, methods used are acceptable and applicable over the range presented, models are properly applied, and results are acceptable. Staff can and should do quick, bounding calculations and performance assessments, and confirmatory analyses using process-level models; however, in-depth, detailed analyses can be limited to a very few applications. Figure 1-1 shows the relationship of the level of detail to licensing reviews and inspections during the preclosure period; and

- The three outcomes available to the U.S. Nuclear Regulatory Commission at the conclusion of a licensing review are: (i) grant the license; (ii) grant the license subject to conditions agreed by the licensee; or (iii) deny the license. Other than rejecting an applicant or licensee proposal, the U.S. Nuclear Regulatory Commission has no power to compel a licensee to come forward with, or prepare, a different proposal.

The U.S. Nuclear Regulatory Commission regulatory role in any licensing action is to apply the applicable regulations and guidance, and to review applications for proposed actions to determine if compliance with regulations has been achieved. The burden of proof is on the applicant or licensee to show that the proposed action is safe, to demonstrate that regulations are met, and to ensure continued compliance with the regulations.

In conducting its reviews, the U.S. Nuclear Regulatory Commission is evaluating whether the licensee has demonstrated that its proposed approach meets the codified requirements, not seeking scientific precision (i.e., the licensee having to present a complete understanding and answers for all issues that could be raised concerning a proposal, including those not related to health and safety). U.S. Nuclear Regulatory Commission staff should examine whether applicant and licensee proposals are acceptable. If a proposal meets the applicable regulations, the U.S. Nuclear Regulatory Commission staff has no basis for requiring something different or additional. To do so would be imposing a requirement on a licensee beyond what is required in the regulations. Imposing specific requirements on a licensee, consistent with the

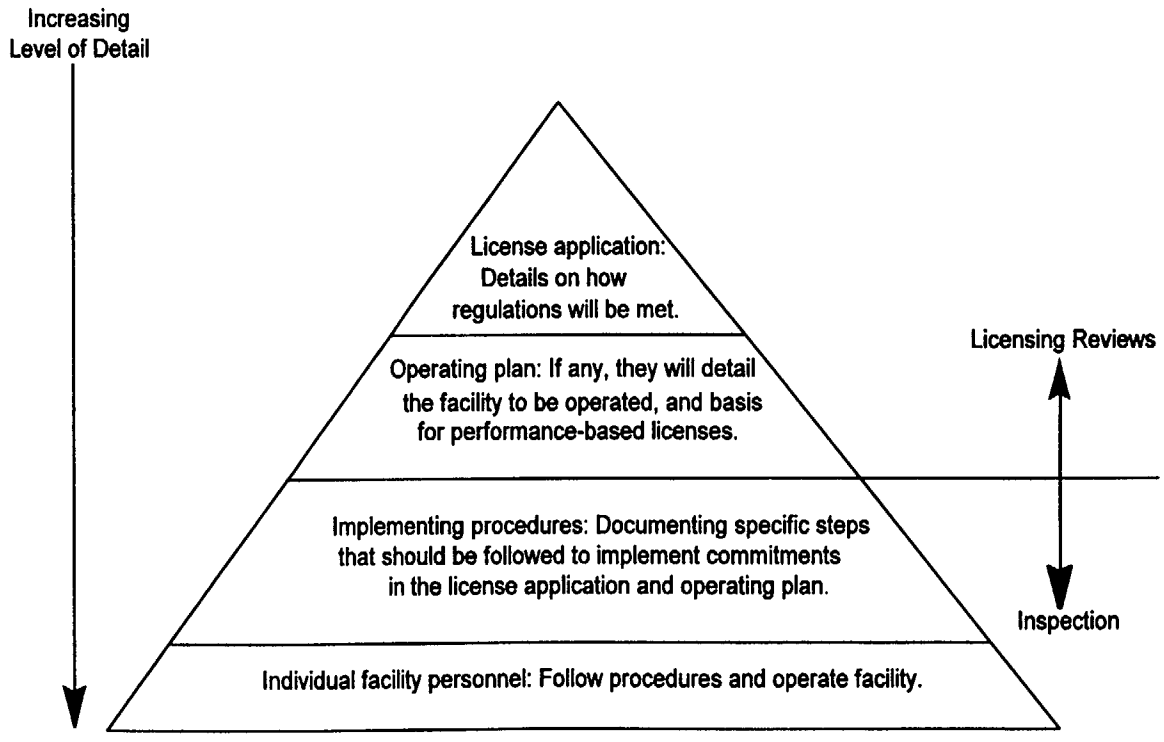

Figure 1-1. Schematic of U.S. Nuclear Regulatory Commission Licensing and Inspection Process and Applicability to Licensing Documents

regulation, is done through the issuance of an order, with hearing rights, according to 10 CFR Part 2.

In no instance should a reviewer determine that alternatives that are less protective than those proposed by the applicant are acceptable. U.S. Nuclear Regulatory Commission staff should submit requests for additional information when more information is needed to justify a proposal. In the high-level radioactive waste program, it is appropriate to inform the U.S. Department of Energy, during prelicensing meetings, when regulatory requirements are at risk of not being met.

1.1.2 Format and Content of Documents

Correspondence and documents for each of the licensing review milestones should be logically organized and contain adequate information to convey the U.S. Nuclear Regulatory Commission position and requirements simply, clearly, and concisely. Procedures for conducting and documenting the acceptance review are presented in Chapter 2 of the Yucca Mountain Review Plan. Requests for additional information should be focused, brief, and clear. A request for additional information should include three parts:

- A statement of the issue

  This presents a summary of the identified deficiency and the regulatory requirement.

- A discussion of the basis for the information request

  This provides an explanation of why the existing information is inadequate.

- The action needed to resolve the issue

  This defines the information needed to address the deficiency without specifying how the U.S. Department of Energy is to obtain the information. The staff must be careful, when describing the action needed, not to assume U.S. Department of Energy responsibility to make and then defend its safety case.

Requests for additional information related to the technical adequacy of the license application should state all relevant problems and issues to be resolved before approval in a manner that is clear, concise, and consistent with the regulations and good engineering practice. A request for additional information is considered primarily an exchange through which the staff elicits the information necessary for it to determine if the applicant has demonstrated compliance with the regulations. U.S. Nuclear Regulatory Commission staff may provide further supporting information, depending on the complexity of the request.

During the technical review, some requests for additional information may be related to an apparent failure to meet regulatory requirements. In this case, the request for additional information should identify the specific section of the regulations, or other supporting documents, (e.g., regulatory guides, standard review plans, the U.S. Nuclear Regulatory Commission technical reports, the American Society of Mechanical Engineers/American Society

for Testing and Materials codes, or techniques accepted by the scientific community) that relate to the issue. In this type of item, it is expected that supporting information will be provided both from a technical and a regulatory perspective.

Requests for additional information should be numbered sequentially, with the numbering for an individual request for additional information remaining constant through the course of the licensing review. The cover letter transmitting the requests for additional information will include a schedule for the applicant to provide responses and the dates of the remaining milestones. The letter will also reiterate the statement from the acceptance review that failure to respond within the specified time frame may be grounds for denial of the application, in accordance with 10 CFR 2.108(a).

The content of the safety evaluation report will be based on the guidance provided in the Yucca Mountain Review Plan. If there are limits and restrictions imposed as a condition of approval and agreed to by the U.S. Department of Energy, they will be specified as conditions or technical specifications in the safety evaluation report and the license. The technical reviewer should notify the licensing project manager as soon as practical when potential license conditions are identified. The format for the safety evaluation report will follow the structure of the Yucca Mountain Review Plan. The safety evaluation report will describe what information the staff reviewed, provide the technical basis for the staff conclusion regarding compliance, and state an evaluation finding. It is expected that substantial information from the U.S. Nuclear Regulatory Commission issue resolution status reports will be incorporated in the safety evaluation report. The findings that have been made as a result of the detailed review will be stated in the safety evaluation report at the conclusion of each section. If there are limiting conditions that will be imposed, they will be highlighted for inclusion in the license. In all cases, the limiting conditions that are enumerated in the license will be identified in the safety evaluation report.

1.2 General Review Procedure

A licensing review is not intended to be a detailed evaluation of all aspects of facility operations. Specific information about implementation of the program outlined in an application is obtained through the U.S. Nuclear Regulatory Commission review of procedures and operations done as part of the inspection function. A definition of the differences between licensing reviews and inspections is shown in Figure 1-1. If a positive determination on a license is made, changes to existing licensed activities and conditions require the issuance of an appropriate license amendment. An application for such an amendment should describe the proposed changes in detail, and should discuss the likely consequences of any environmental and health and safety impacts. Amendment requests should be reviewed using the appropriate sections of this document for guidance.

In conducting any review, the staff will rely on the approach described in Section 1.1 to ensure the efficient and effective use of resources. This approach will involve preparing a draft safety evaluation report that identifies where the U.S. Department of Energy has not provided sufficient information to make a regulatory conclusion. These gaps will then serve as the basis for staff requests for additional information. As needed, the U.S. Nuclear Regulatory Commission staff and the U.S. Department of Energy will interact on the response to the

questions through either conference calls or public meetings. These interactions should help ensure that the U.S. Department of Energy responds to the requests for additional information in as complete a manner as possible, and that the responses do not result in additional requests for additional information. This process should allow the staff to conduct its review in a manner that should limit a majority of its review to one round of requests for additional information. While the U.S. Department of Energy is addressing the requests for additional information, the staff may publish the draft safety evaluation report as the safety evaluation report, to allow the hearing to begin on those issues where the staff has reached a regulatory conclusion. This should allow Atomic Safety and Licensing Board to begin to address hearing issues as early in the process as possible.

The steps of the application review are described in the following sections.

1.2.1 Acceptance Review Objectives

The staff shall conduct an acceptance review of the application to determine the completeness of the information submitted. This review requires a comparison of the submitted information with the information specified in 10 CFR 63.21. The application will be considered complete for docketing if the information provided is complete, reflects an adequate reconnaissance and physical examination of the regional and site conditions, and provides appropriate analyses and design information to demonstrate that the applicable acceptance criteria will be met. The staff shall complete the acceptance review and transmit the results to the applicant within 3 months of the receipt of the application, along with a projected schedule for the remainder of the review. In this transmittal, the staff shall identify any additional information needed to make the application complete. Detailed technical questions, although not required, can be included if they are identified during the acceptance review.

1.2.2 Detailed Review Objectives

After completion of the acceptance review, the staff shall conduct a detailed technical review of the application. The results of this review and the basis for acceptance or denial of the requested licensing action are documented by the U.S. Nuclear Regulatory Commission staff in its safety evaluation report. Based on the mandatory 3-year time frame given in the Nuclear Waste Policy Act of 1982, the U.S. Nuclear Regulatory Commission staff will conclude its review after receipt of the application. During the course of this review, the staff will publish its safety evaluation report, and possibly one or more supplements. As the U.S. Nuclear Regulatory Commission staff review is conducted, the safety evaluation report and supplements will provide the staff with conclusions of its reviews, along with open items, confirmatory items, and license conditions.

Open items are items that remain outstanding at the time of publication of the safety evaluation report. For these items, the staff has not completed its review and reached a final position. They, therefore, are considered open.

In the staff review, those items that are essentially resolved to the staff's satisfaction, but for which certain confirmatory information has not yet been received, are called confirmatory items. In these instances, the U.S. Department of Energy may have committed to provide confirmatory

information. The staff would need such information before it could close the open item. Unlike open items, not all confirmatory items[1] will need to be resolved before licensing. Some may require information from construction activities before they can be closed. The staff will track these items through its inspection process.

Finally, the last category of items in the staff review will be called license conditions. These items will be incorporated into the license, if issued. These conditions are what the staff believes are needed to ensure that the applicable requirements are met during facility operation. A license condition may be in the form of a condition in the body of the license, or an operating condition, placed in the "Technical Specifications," which outline the operational limits of the facility, and are appended to any issued license. It is important to note that any license condition must be based on a commitment made by the U.S. Department of Energy in its application. U.S. Nuclear Regulatory Commission staff cannot unilaterally impose a condition on the U.S. Department of Energy without first getting a U.S. Department of Energy commitment to such a condition. Otherwise, imposition of any condition on the U.S. Department of Energy requires an order under 10 CFR Part 2, Subpart B, "Procedures for Imposing Requirements by Order, or for Modification, Suspension, or Revocation of a License, or for Imposing Civil Penalties."

1.3 Developing a Risk-informed, Performance-Based Yucca Mountain Review Plan

The Yucca Mountain Review Plan incorporates the following four principles:

- The U.S. Nuclear Regulatory Commission defends its licensing decision, while the U.S. Department of Energy defends its safety case in the Yucca Mountain license application;
- The Yucca Mountain Review Plan implements 10 CFR Part 63, a performance-based and site-specific rule;
- The Yucca Mountain Review Plan will be consistent with the applicable regulations and the review that the staff needs to complete to make the necessary findings on safety; and

[1]Confirmatory items are used during a licensing process to identify items for which a licensee needs to provide additional confirmatory information but which do not prevent the licensing action from proceeding. Closed pending issues, which were defined during the formal high-level waste prelicensing issue resolution process established between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy, were those issues for which the U.S. Nuclear Regulatory Commission staff had confidence that the U.S. Department of Energy proposed approach, together with any U.S. Department of Energy agreements to provide additional information (through specified testing, analysis, etc.) acceptably addressed the staff questions such that no information beyond that provided, or agreed to, would likely be required at the time of initial license application. Closed pending items do not presuppose whether the U.S. Nuclear Regulatory Commission considers the U.S. Department of Energy license application to meet the acceptance criteria provided in this review plan.

Introduction

- The Yucca Mountain Review Plan incorporates the more than 15 years of knowledge gained about the Yucca Mountain site and design during the prelicensing period and will avoid the imposition of unnecessarily prescriptive acceptance criteria.

To support review of the "U.S. Department of Energy Safety Analysis Report," these principles are reflected in five major Yucca Mountain Review Plan sections: (i) repository safety before permanent closure; (ii) repository safety after permanent closure; (iii) research and development program to resolve safety questions; (iv) performance confirmation program; and (v) administrative and programmatic requirements. Subordinate chapters include this introduction, a chapter providing guidance for the conduct of the acceptance review, and a chapter that supports review of compliance with general information requirements in 10 CFR Part 63. The structure of the Yucca Mountain Review Plan is presented in Figure 1-2.

The preclosure and postclosure safety reviews will focus on whether the "U.S. Department of Energy Safety Analysis Report" demonstrates, with reasonable assurance for preclosure and reasonable expectation for postclosure periods, that the corresponding performance objectives at 10 CFR Part 63 will be met. U.S. Nuclear Regulatory Commission staff is using a total system approach for both the preclosure and postclosure safety reviews that takes advantage of the knowledge of the site and design that has accumulated during the prelicensing period and the rapid growth in preclosure safety analysis and performance assessment capabilities. These improvements in capability include the results of performance assessment work by the U.S. Nuclear Regulatory Commission and industry, and reviews of the U.S. Department of Energy performance assessments for Yucca Mountain. This total system approach facilitates integration of the technical disciplines required to review the Yucca Mountain license application. The Yucca Mountain Review Plan uses existing U.S. Nuclear Regulatory Commission guidance from other regulatory programs that is applicable to the construction and operation of a geologic repository, modifying it as necessary for consistency with the risk-informed, performance-based philosophy. The approaches used to develop each of the major Yucca Mountain Review Plan sections are described in the following six subsections.

Chapter 2, "Acceptance Review," provides the procedure for conducting the acceptance review of the license application. Risk-informed, performance-based principles are not incorporated. The review verifies only that the information in the license application is complete, and therefore does not require a risk-informed, performance-based approach.

1.3.1 Developing a Risk-Informed, Performance-Based Review Plan for General Information

Any license application for a geologic repository at Yucca Mountain, submitted under 10 CFR Part 63, is to contain "General Information," a Safety Analysis Report, and is to be accompanied by a final environmental impact statement. (Review guidance for the final environmental impact statement is not included in the Yucca Mountain Review Plan.)

Chapter 3, "General Information," reviews the requirements specified in 10 CFR 63.21(b). The intent of providing general information in the license application is twofold. First, it allows the U.S. Department of Energy to provide an overview of its engineering design concept for the repository (Section 3.1). Second, it allows the U.S. Department of Energy to demonstrate its

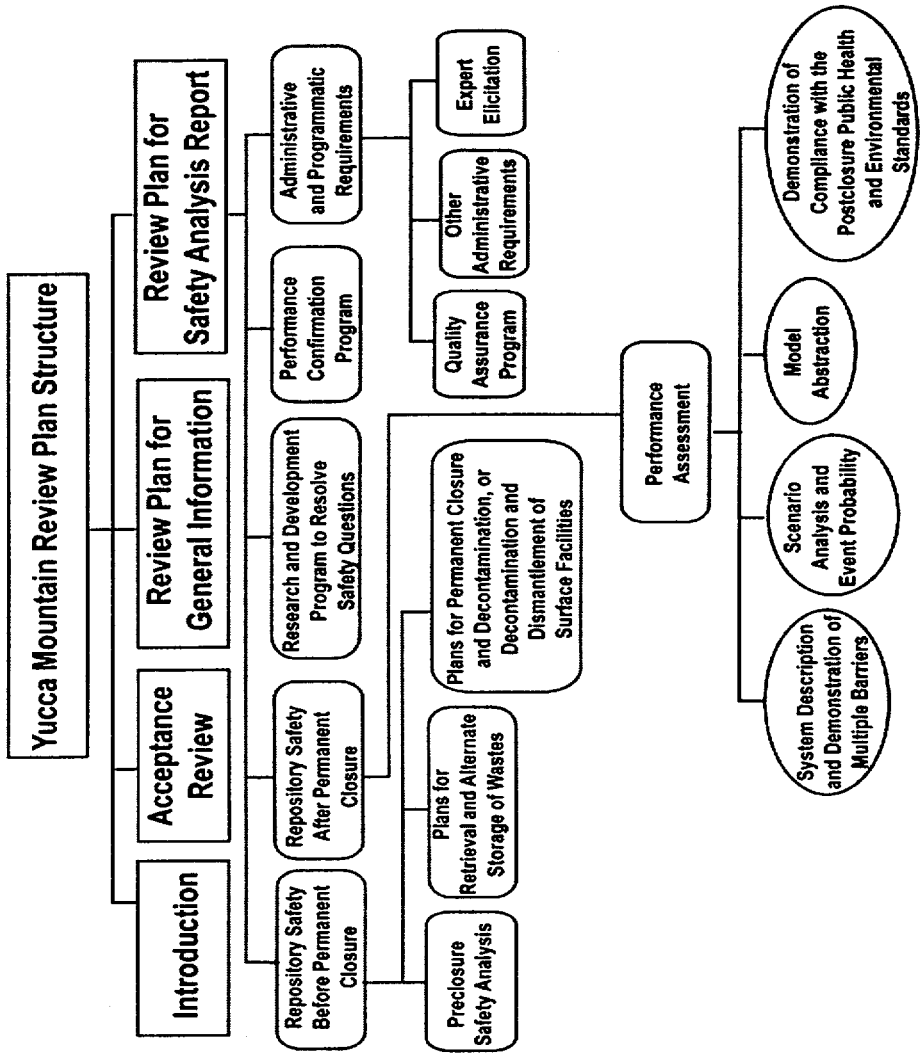

Figure 1-2. Structure of the Yucca Mountain Review Plan

understanding of what aspects of the Yucca Mountain site and its environs (Section 3.5) influence repository design and performance. Understanding the performance of the design in the context of the Yucca Mountain site and its environs allows the U.S. Department of Energy to make risk-informed, performance-based judgments regarding compliance with the regulations, which are subsequently evaluated by the staff elsewhere in the Safety Analysis Report (Chapter 4). Accordingly, the material to be reviewed by the staff is generally informational in nature, with the more detailed technical discussions and descriptions found elsewhere in the Safety Analysis Report section of the license application. Notable exceptions are the information found in Sections 3.2, 3.3, and 3.4 of the Yucca Mountain Review Plan. Overall, there are five sections in Chapter 3, and the extent to which each of these sections incorporates risk-informed, performance-based principles varies.

Section 3.1, "General Description," provides for review of a general description of the geologic repository operations area, including its major structures, systems, and components. The material in this section is generally informational in nature, comparable to that typically found in an executive summary, and no detailed technical analysis is required by the reviewer. The detailed review of information covered by these subjects will be conducted in other sections of the Yucca Mountain Review Plan. Because the geologic repository operations area design is generally presented in the context of how compliance with the performance objectives will be achieved, this section of the license application is implicitly risk-informed, performance-based, and the staff's subsequent review will be likewise.

Section 3.2, "Proposed Schedules for Construction, Receipt, and Emplacement of Waste," provides for review of general schedules for various phases of repository construction and operation. Again, the material to be reviewed is informational in nature, and no detailed technical analysis is required by the reviewer. Because the geologic repository operations area design is generally presented in the context of how compliance with the performance objectives will be achieved, this section of the license application is implicitly risk-informed, performance-based, and the staff's subsequent review will be likewise.

Section 3.3, "Physical Protection Plan," provides for a review to determine with reasonable assurance that the U.S. Department of Energy has committed to having an adequate physical protection system. The system must provide assurance that activities involving high-level radioactive waste do not constitute an unreasonable risk to the public health and safety. General and specific performance objectives for the U.S. Department of Energy to meet are listed in this section. The physical protection system should be designed to protect against a loss of control of the geologic repository operations area that could be sufficient to cause radiation exposure exceeding the dose defined in 10 CFR 72.106. Physical protection requirements for high-level radioactive waste at a geologic repository operations area are codified under 10 CFR 73.51. This section is risk-informed, performance-based.

Section 3.4 provides for a review of the Material Control and Accounting Program plan submitted by the U.S. Department of Energy. The plan describes how the system will be established, implemented, and maintained to ensure that it is adequate to protect against, detect, and respond to the loss of high-level radioactive waste. Material control and accounting requirements for high-level radioactive waste are required by 10 CFR 63.21(b)(4) and stipulated in 10 CFR 63.78. This section provides for a risk-informed, performance-based review of the

U.S. Department of Energy program and its capability to meet the requirement in 10 CFR 63.78. High priority will be given to the overall system detection and resolution capabilities at an implementation level.

Section 3.5, "Description of Site Characterization Work," provides for review of an overview description of the site characterization work conducted up to the time of license application, and the results of that work, necessary to support the license application. The material to be reviewed is generally informational in nature and is intended to place the geologic repository operations area in the context of the Yucca Mountain site and environs. Although there are no performance objectives addressed in this section of the license application, the information summaries provided in this section support the detailed safety reviews conducted in the preclosure and postclosure safety evaluation sections of the Yucca Mountain Review Plan. Therefore, the adequacy and sufficiency of site characterization activities and the resulting information will be judged, not in this section of the license application, but in the context of the compliance demonstrations and supporting technical bases provided in the Safety Analysis Report section of the license application. Therefore, the information contained in this section of the license application is implicitly risk-informed, performance-based, and the staff's subsequent review will be likewise.

1.3.2 Developing a Risk-Informed, Performance-Based Review Plan for Preclosure Safety Evaluation

Section 4.1.1, "Preclosure Safety Analysis," provides for review of compliance with the performance objectives, in 10 CFR Part 63, which are based on permissible levels of doses to workers and the public established on the basis of acceptable levels of risk. 10 CFR 63.21(c)(5) requires a preclosure safety analysis of the geologic repository operations area for the period before permanent closure, to ensure compliance with the performance objectives. Preclosure safety analysis is a systematic examination of the site; the design; the potential hazards and initiating events and their consequences; and the potential dose consequences to workers and the public. Preclosure safety analysis considers the probability of potential hazards, taking into account the range of uncertainty associated with the data that support the probability calculations. Event sequences are defined based on well-established (discipline-specific) methodologies that allow a combination of probabilistic and deterministic estimates. Sequences of human-induced and natural events are used as inputs to calculate consequences of potential failures of structures, systems, and components in terms of doses to workers and the public. These calculated doses are compared to allowable doses in establishing the importance of structures, systems, and components. The structures, systems, and components that must be functional to comply with the performance objective dose limits are identified as structures, systems, and components important to safety. Preclosure safety analysis also identifies and describes the controls that are relied on to prevent potential event sequences from occurring or to mitigate their consequences, and identifies measures taken to ensure the availability of the safety systems. The end products of the preclosure safety analysis are a list of structures, systems, and components important to safety (also known as the Q-List) and the associated design criteria and technical specifications necessary to keep them functional and to meet the performance objectives. The structures, systems, and components important to safety may also be further categorized, based on relative safety significance, using risk information from the preclosure safety analysis. This distinction may be used to focus the

requirement of design details and the application of quality assurance controls through a graded quality assurance program. The Yucca Mountain Review Plan provides criteria appropriate to evaluate the U.S. Department of Energy technical basis for categorizing structures, systems, and components and grading quality assurance requirements.

The staff review is focused on items that preclosure safety analysis determines to be important to safety. The rigor of review for the design items on the Q-List and the level of attention to detail depend on relative safety significance. No prescriptive design criteria are imposed in the Yucca Mountain Review Plan, because 10 CFR Part 63 allows the U.S. Department of Energy to develop the design criteria and demonstrate their appropriateness. Thus, the U.S. Department of Energy has flexibility to use any codes, standards, and methodologies it demonstrates to be applicable and appropriate. The risk-informed review process in the Yucca Mountain Review Plan focuses on determining compliance with performance objectives, as demonstrated by the U.S. Department of Energy preclosure safety analysis. In summary, the review philosophy is based on the following premises: (i) the U.S. Department of Energy must demonstrate, through its preclosure safety analysis, that the repository will be designed, constructed, and operated to meet the specified exposure limits (performance objectives) throughout the preclosure period; (ii) the staff must focus the review on the design of the structures, systems, and components important to safety, in the context of the design's ability to meet the performance objectives; and finally (iii) the staff resources will be focused proportionately on the inspection and review of high-risk significant structures, systems, and components important to safety.

Section 4.1.2, "Plans for Retrieval and Alternate Storage of Radioactive Wastes," contains the performance objectives specified at 10 CFR Part 63. Review methods and acceptance criteria were developed from the associated regulatory requirements in 10 CFR Part 63. Specific emphasis is placed on allowing the U.S. Department of Energy flexibility in demonstrating compliance, which is a performance-based approach. This section is risk-informed because the option is preserved to retrieve waste throughout the period that wastes are being emplaced, until the completion of a performance confirmation program.

Section 4.1.3, "Plans for Permanent Closure and Decontamination and Dismantlement of Surface Facilities," identifies two areas of review: (i) the description of design considerations intended to facilitate closure and decontamination, and (ii) the plans for permanent closure and decontamination. The acceptance criteria do not prescribe additional requirements other than a description of the features incorporated into the design that may facilitate closure. The section makes reference to the Nuclear Material Safety and Safeguards decommissioning plans, which are also consistent with risk-informed, performance-based regulation, only to the extent that the U.S. Department of Energy may have information related to closure and decontamination available at the time of license application submittal. The Yucca Mountain Review Plan explicitly acknowledges that information submitted by the U.S. Department of Energy in the license application, regarding closure and decontamination, will be preliminary.

1.3.3 Developing a Risk-Informed, Performance-Based Review Plan for Postclosure Safety Evaluation

Section 4.2, "Repository Safety after Permanent Closure," provides for a risk-informed, performance-based review of the U.S. Department of Energy performance assessment. The performance assessment quantifies repository performance to demonstrate compliance with the postclosure public health and environmental standards at 10 CFR Part 63, Subpart L. The U.S. Department of Energy performance assessment is a systematic analysis that answers the three risk questions: what can happen?; how likely is it to happen?; and what are the consequences? The Yucca Mountain performance assessment is a sophisticated analysis that involves various complex considerations and evaluations. Examples include evolution of the natural environment, degradation of engineered barriers over a 10,000-year period, and disruptive events such as seismicity and igneous activity. The staff will also consider the technical support for models and parameters of the performance assessment, based on detailed process models, laboratory and field experiments, and natural analogs. Because the performance assessment encompasses such a broad range of issues, the staff will use risk information throughout the review process. Using risk information will ensure that the review focuses on those items most important to performance.

Section 4.2.1 requires the staff to apply risk information throughout the review of the performance assessment. First, the staff reviews the barriers important to waste isolation in Section 4.2.1.1. The U.S. Department of Energy must identify the important barriers (engineered and natural) for the performance assessment, describe each barrier's capability, and provide the technical basis for that capability. This risk information includes the U.S. Department of Energy understanding of each barrier's importance. Staff review of the U.S. Department of Energy barrier analysis considers risk insights from previous performance assessments conducted for the Yucca Mountain site, detailed process-level modeling efforts, laboratory and field experiments, and natural analog studies. The result of this review is a staff understanding of each barrier's importance to waste isolation, which focuses the reviews conducted in Sections 4.2.1.2, "Scenario Analysis and Event Probability" and 4.2.1.3, "Model Abstraction."

Scenario analysis and model abstraction are key aspects of the performance assessment. The risk information drawn from the review of the multiple barriers section will direct the staff review to those topics, within scenario analysis and model abstraction, that are important to waste isolation. Section 4.2.1.2 provides the review methods and acceptance criteria for scenarios for both nominal and disruptive events. An acceptable scenario selection method includes identification and screening of features, events, and processes, and construction of scenarios from the retained features, events, and processes considered at the Yucca Mountain site. Then, abstracted models used in the performance assessment for the retained scenarios will be reviewed. The performance assessment review focuses on the 14 model abstractions in Section 4.2.1.3. These model abstractions are derived from those aspects of the engineered, geosphere, and biosphere subsystems shown to be most important to performance, based on prior performance assessments, knowledge of site characteristics, and repository design. Figure 1-3 presents these model abstractions and their relation to subsystem components. The staff developed each of the 14 sections in substantial detail, allowing for a detailed review. However, it is unlikely that each of the abstractions will have the same risk significance. The

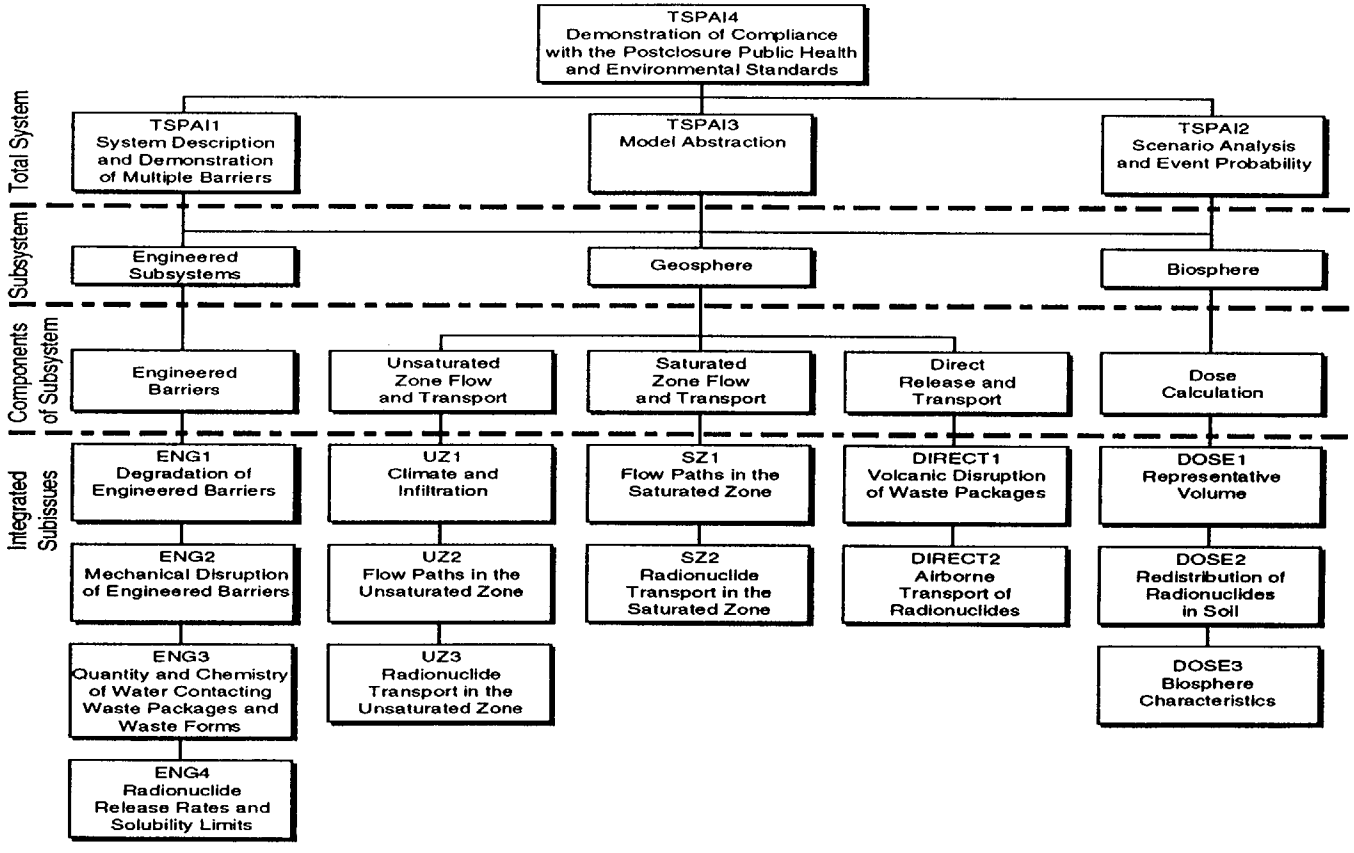

Figure 1-3. Components of Performance Assessment Review

staff will review the abstractions according to their risk significances determined in the multiple barrier review. Nevertheless, until the U.S. Department of Energy completes its safety case and the license application, the review plan sections dealing with model abstractions must remain flexible, and in substantial detail, so the U.S. Department of Energy will understand how U.S. Nuclear Regulatory Commission will review the abstractions. After the staff completes the review of scenarios and model abstractions, it will update, as necessary, its assessment of the U.S. Department of Energy barrier analysis.

The staff will use 14 model abstractions in Section 4.2.1.3 to determine compliance with 10 CFR 63.113 and 63.114. The abstractions consider the engineered, geosphere, and biosphere subsystems that may be important to performance. Important to performance means important to meeting the performance objectives specified in 10 CFR 63.113. The staff will focus its review to understand the importance to performance of the various assumptions, models, and data in the performance assessment. The staff will also focus its review to ensure that the degree of technical support for models and data abstractions is appropriate for their contribution to risk. This means the staff will review each model abstraction to a detail level suitable for the degree the U.S. Department of Energy relies on it to prove its safety case. The staff will be familiar with the U.S. Department of Energy safety case because of the multiple barrier review (conducted using Section 4.2.1.1). In the multiple barrier review, the staff will evaluate the capability of the barriers. For example, if the U.S. Department of Energy relies on the unsaturated zone to provide significant delay in the transport of radionuclides and/or radionuclide concentrations to the reasonably maximally exposed individual, then the staff will perform a detailed review of this abstraction. However, if the U.S. Department of Energy shows that this abstraction has a minor impact on the delay of radionuclide transport to the reasonably maximally exposed individual, then the staff will conduct a simplified review focusing on the bounding assumptions. The staff will use the review methods and acceptance criteria in these sections to decide whether the U.S. Department of Energy properly characterized and factored the features, events, and processes into the performance assessment. This is necessary to decide whether the U.S. Department of Energy performance assessment is acceptable and complies with 10 CFR 63.114. The review methods and acceptance criteria the staff will use to evaluate compliance with the postclosure public health and environmental standards are in Section 4.2.1.4 of the Yucca Mountain Review Plan.

Section 4.2.1.4, "Demonstration of Compliance with the Postclosure Public Health and Environmental Standards," focuses on the role of the performance assessment to demonstrate that the performance objectives have been met with reasonable expectation. This is where the probability estimates from Section 4.2.1.2, "Scenario Analysis and Event Probability," and consequence estimates from model abstraction are combined to form the risk estimate for the repository. It includes reasonable expectation of compliance with the postclosure individual protection standard, the human intrusion standard, and the ground-water protection standards. Consideration is given to parameter uncertainty and alternate conceptual models.

1.3.4 Developing a Risk-Informed, Performance-Based Review Plan for the Research and Development Program to Resolve Safety Questions

Section 4.3 provides for a review of the "Research and Development Program for Resolving Safety Questions." The program applies to structures, systems, and components important to

safety and engineered or natural barriers important to waste isolation. The program identifies, describes, and discusses those safety features or components for which further technical information is required to confirm the adequacy of design. This section is performance-based because it focuses on those items most important to safety and waste isolation.

1.3.5 Developing a Risk-Informed, Performance-Based Review Plan for the Performance Confirmation Program

Section 4.4 provides for a review of the "Performance Confirmation Program." The program is comprised of tests, experiments, and analyses conducted to evaluate the adequacy of the information used to demonstrate compliance with the performance objectives. The need for a performance confirmation program is unique to the high-level radioactive waste program. This uniqueness reflects the uncertainties in estimating geologic repository performance over thousands of years. The bases for the acceptance criteria are the requirements for performance confirmation, in 10 CFR Part 63, that are performance-based. Where suitable, the acceptance criteria are also risk-informed because performance confirmation focuses on those parameters and natural and engineered barriers already identified to be important to performance.

1.3.6 Development of the Administrative and Programmatic Requirements Section

This portion of the Yucca Mountain Review Plan is the most difficult for which to implement a risk-informed, performance-based approach. No performance objectives are provided in 10 CFR Part 63 for this section. Existing U.S. Nuclear Regulatory Commission regulatory guidance and standard review plans were examined for examples of appropriate review methods and acceptance criteria that could be incorporated in the Yucca Mountain Review Plan. However, some of these examples were greatly prescriptive, while others seemed inadequate, based on our knowledge of expected repository operations and administrative programs. This situation is complicated by the unique nature of the high-level radioactive waste regulatory program and the lack of an operational history, or historical performance measure, such as are available for most other types of nuclear facilities. To the extent possible, acceptance criteria and review methods for this section of the Yucca Mountain Review Plan are based on similar existing and successful U.S. Nuclear Regulatory Commission regulatory programs, considering expected operations and associated risks, while taking advantage of opportunities to omit prescriptive requirements, when appropriate.

The quality assurance section of the Yucca Mountain Review Plan is risk-informed, explicitly as a result of the application of a graded quality assurance program. The review methods and acceptance criteria are written to either accommodate such a graded program or to support review of a nongraded program. The quality assurance section provides for quality assurance controls to be applied in a graded manner, based on the safety-risk-significance of the structures, systems, and components and the barriers important to safety or waste isolation. These quality assurance control provisions are intended to be applied to high-safety-risk-significant structures, systems, and components, and barriers and their related activities. The U.S. Department of Energy may propose reduced quality assurance requirements for

low-safety-risk- significant structures, systems, and components, barriers, and their related activities. The quality assurance section also contains many review provisions for areas such as quality assurance for scientific investigations, software, and commercial-grade item dedication. The quality assurance section of the Yucca Mountain Review Plan is performance-based as a result of allowing the U.S. Department of Energy to concentrate its quality assurance activities on high-safety-risk-significant items and activities. 10 CFR Part 63 specifically requires that the quality assurance program be prescriptive by describing how the quality assurance requirement will be satisfied. The prescriptive requirements for the quality assurance program contained in this regulation are similar to regulatory requirements contained in 10 CFR Parts 50, 70, 71, and 72. Thus, the quality assurance section of the Yucca Mountain Review Plan contains prescriptive review provisions that are intended to be applied to high-safety-risk-significant items and activities.

The other administrative and programmatic sections in the Yucca Mountain Review Plan are nonprescriptive, providing flexible acceptance criteria and review methods and referring the reviewer to other U.S. Nuclear Regulatory Commission guidance documents, but not specifying the standards or practices the U.S. Department of Energy must use for compliance demonstration. Rather, these sections require the U.S. Department of Energy to: (i) identify any standards, programs, and procedures that will be used; (ii) demonstrate that those standards, programs, and procedures are appropriate; and (iii) commit to implement them properly. The acceptance criteria and review methods require the staff to evaluate the administrative and programmatic sections of the U.S. Department of Energy license application, based on the validity and adequacy of the basis that the U.S. Department of Energy has presented in the application.

In developing this section of the Yucca Mountain Review Plan, there has been a specific effort to implement a risk-informed, performance-based philosophy based on current U.S. Nuclear Regulatory Commission guidance. For example, "Emergency Planning," Section 4.5.7, assesses several items that represent the frequency and consequence components of risk. Each acceptance criterion in "Emergency Planning" has measurable and inspectable performance requirements. Information provided in the administrative and programmatic sections is based, to the extent possible, on prelicensing interactions. This is especially true for quality assurance. In most cases, however, the U.S. Department of Energy has not committed to specific administrative and programmatic procedures, and the level of detail in the Yucca Mountain Review Plan is minimal. U.S. Nuclear Regulatory Commission guidance is identified in the Yucca Mountain Review Plan, but selection of the compliance demonstration approach is left to the U.S. Department of Energy.

1.4 Components of Each Review Section

Each Yucca Mountain Review Plan section provides the complete procedures and acceptance criteria for all areas of review pertinent to that section. Because the U.S. Nuclear Regulatory Commission is implementing a risk-informed, performance-based regulatory approach using risk insights, the staff reviewer may select and emphasize particular aspects from each Yucca Mountain Review Plan section, as appropriate. Consequently, in the review of the license application, the staff may not carry out in detail all the review steps listed in each Yucca Mountain Review Plan section. In some cases, the staff may rely on a more detailed evaluation

made in the prelicensing consultative phase of the program. Thus, the staff should be able to use the technical understanding and basis for issue resolution developed during prelicensing to help focus its review on areas where a more detailed, prelicensing consultative review was not done.

Each section of a U.S. Nuclear Regulatory Commission review plan typically contains areas of review, review methods, acceptance criteria, evaluation findings, and references.

Areas of Review Subsection

This subsection identifies the topical areas and defines the scope for the reviews. Having this scope in mind enables the reviewer to prepare for the review, including examining any technical or regulatory background material necessary to support the review.

Review Methods Subsection

The review methods provide the specific step-by-step procedures that the reviewer will use to assess compliance with regulatory requirements. The review methods are often technically specific, but their level of detail and complexity is determined by the particular regulatory requirements.

Acceptance Criteria Subsection

This subsection delineates criteria that can be applied by the reviewer to determine the acceptability of the applicant's compliance demonstration. The technical bases for these criteria have been derived from 10 CFR Part 63; the U.S. Nuclear Regulatory Commission regulatory guides; general design criteria; codes and standards; branch technical positions; standard testing methods (e.g., American Society for Testing and Materials standards); technical papers; and other similar sources. These sources typically include solutions and approaches previously determined to be acceptable by the staff for making compliance determinations for the specific area of review, or are based on the staff work from its first-of-a-kind reviews related to a high-level radioactive waste repository, such as the postclosure performance assessment.

The acceptance criteria have been defined so that staff reviewers can use consistent and well-documented approaches from prelicensing consultation to support the review of the license application. Flexibility is provided to enable the U.S. Department of Energy to implement the type of operations appropriate for the geologic repository operations area. The U.S. Department of Energy may take approaches, to demonstrating compliance, that are different from those presented in the Yucca Mountain Review Plan, as long as the staff can make the requisite decisions concerning compliance with the applicable regulations. However, the U.S. Department of Energy should recognize that, as is the case for all regulatory guidance, substantial staff time and effort have gone into the development of the review methods and acceptance criteria in the Yucca Mountain Review Plan. Staff use of these criteria in its review is one of the important ways the U.S. Nuclear Regulatory Commission will meet the 3-year mandated deadline for completing the license review. Thus, if the U.S. Department of Energy proposes solutions and approaches to safety problems or safety-related design in areas other

than those described in the Yucca Mountain Review Plan, it could result in longer review times and an increase in the number of U.S. Nuclear Regulatory Commission requests for additional information. The staff will consider proposals for other solutions and approaches on a generic basis, apart from a specific application, to avoid the impact of the additional review time for individual cases.

Evaluation Findings Subsection

This subsection presents general conclusions and findings of the staff that result from review of each area of the application as well as an identification of the applicable regulatory requirements. A conclusion is included in the safety evaluation report for each Yucca Mountain Review Plan section. The safety evaluation report contains a description of the review; the basis for the staff findings, including aspects of the review selected or emphasized; where the facility design or the applicant programs deviate from the criteria stated in the Yucca Mountain Review Plan; and the evaluation findings. An example of how the reviewer can document the evaluation findings is provided in each review section.

References Subsection

The references subsection of the review plan lists any references used in the development of the Yucca Mountain Review Plan. Often, the U.S. Nuclear Regulatory Commission review plans reference more detailed information to support review methods, rather than reproducing detailed technical procedures or specifications within the review plan.

Yucca Mountain Review Plan Updates

The Yucca Mountain Review Plan will be revised and updated periodically, as the need arises, to clarify the content or correct errors and to incorporate modifications approved by the U.S. Nuclear Regulatory Commission management. As noted above, such modifications could also result from revisions in the U.S. Nuclear Regulatory commission regulations or requirements, following the normal public rulemaking process. A revision number and publication date will be printed at a lower corner of each page of the Yucca Mountain Review Plan. Since individual sections will be revised as needed, the revision numbers and dates may not be the same for all sections.

1.5 References

National Research Council. "Technical Bases for Yucca Mountain Standards." Washington, DC: National Academy Press. 1995.

U.S. Nuclear Regulatory Commission. NUREG–1614, "FY2000–2005 Strategic Plan." Washington, DC: U.S. Nuclear Regulatory Commission. September 2000.

———. SECY–99–100. "Commission White Paper on Risk-Informed and Performance-Based Regulation." Washington, DC: U.S. Government Printing Office. March 11, 1999.

2 ACCEPTANCE REVIEW

2.1 Description and Purpose of Acceptance Review

The staff will do an acceptance review of the license application to check whether the information is complete. The reviewer will evaluate whether the information is sufficient to support a detailed review, and will assess the schedule for any later U.S. Nuclear Regulatory Commission milestones. The license application will be acceptable to docket if the information is complete in scope and detail about the site and engineering design. The acceptance review does not determine the technical adequacy of the submitted information.

The acceptance review is the first screening of the U.S. Department of Energy license application. The application must provide enough information, by inclusion or reference, to show that it meets the requirements of the regulations. If the license application does not meet this minimum standard, the staff will tell the U.S. Department of Energy that the application is not complete enough to conduct a detailed technical review, and give specific guidance on the corrective action.

The staff will send the results of the acceptance review, with a projected schedule for the rest of the review, to the U.S. Department of Energy within 90 days of receiving the license application. The staff will document the acceptance review in a brief, one- to two-page letter recommending either acceptance to begin the detailed review, or rejection. If the license application is acceptable for docketing, the letter will also set a schedule for the detailed technical review, including any intermediate milestones and the anticipated completion dates. The letter will contain a disclaimer stating that a request for additional information may result from the detailed technical review. The disclaimer will also note that the projected review schedule will depend on the U.S. Department of Energy supplying high-quality, timely responses to any request for additional information. The letter will inform the U.S. Department of Energy that failure to respond to a request for additional information in the specified period may be grounds to deny the application under 10 CFR 2.108(a) requirements. The letter will also provide a request for additional information needed to make the application complete. Detailed technical questions are not required, but may be included.

2.2 Acceptance Review Checklist

The staff will conduct the acceptance review using a checklist, based on the structure of 10 CFR 63.21 ("Content of Application"). However, neither the U.S. Department of Energy license application nor the Yucca Mountain Review Plan will be organized strictly on this structure. Therefore, the U.S. Department of Energy will provide a table that relates the sections of the license application to the regulatory requirements in 10 CFR Part 63. The reviewer will also use this U.S. Department of Energy table during the acceptance review.

To conduct the acceptance review, staff will use its extensive knowledge developed during prelicensing and will specifically compare the contents of the license application with the requirements in 10 CFR 63.21 ("Content of Application"). The acceptance review will include an assessment of the legibility of drawings, the general adequacy of information, any proprietary information, and obvious technical inadequacies. Most license application sections incorporate multidisciplinary input. Therefore, the staff will conduct acceptance reviews with teams of

individuals from suitable disciplines. During the acceptance review, the staff will determine whether the U.S. Department of Energy has provided, in sufficient scope and detail, the following items that 10 CFR 63.21 describes. The staff provides a simple scale of acceptability to help the reviewers document their results.

- A general description of the proposed geologic repository at the Yucca Mountain site. This description will identify the geologic repository operations area location, the general character of the proposed activities, and the basis for the U.S. Nuclear Regulatory Commission to exercise licensing authority.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- Proposed schedules to build, receive waste, and emplace wastes at the geologic repository operations area.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- A description of the detailed security measures for the physical protection of high-level radioactive waste. This plan must include the design for physical protection, the licensee's safeguards contingency plan, and the training and qualification plan for the security organization. The plan must list tests, inspections, audits, and other means to show compliance.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- A description of the material control and accounting program.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- A description of work conducted to characterize the Yucca Mountain site.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- A description of the Yucca Mountain site, with appropriate attention to those features, events, and processes of the site that might affect the design of the geologic repository operations area and the performance of the geologic repository. The site description should include information about features, events, and processes outside the site to the extent the information is relevant and material to safety or performance of the geologic repository. The site description should include:

  - — Location of the geologic repository operations area with respect to the site boundary;
  - — Information about the geology, hydrology, and geochemistry of the site, including geomechanical properties and conditions of the host rock;
  - — Information about the surface-water hydrology, climatology, and meteorology of the site; and
  - — Information about the location of the reasonably maximally exposed individual and local human behaviors and characteristics, as needed, to select conceptual models and parameters used to define the reference biosphere and the reasonably maximally exposed individual.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- Information relative to materials of construction of the geologic repository operations area (including geologic media, general arrangement, and approximate dimensions), and codes and standards that the U.S. Department of Energy proposes to apply to the design and construction of the geologic repository operations area.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

Acceptance Review

- A description and discussion of the design of the various components of the geologic repository operations area and the engineered barrier system, including:

  — Dimensions, material properties, specifications, analytical and design methods used, and any applicable codes and standards;

  — Design criteria and their relation to the preclosure and postclosure performance objectives; and

  — Design bases and their relation to the design criteria.

  ☐ Accept for Review

  ☐ Accept, but Request for Additional Information Prepared

  ☐ Reject, Inadequate to Support Detailed Review

- A description of the kind, amount, and specifications of the radioactive material proposed for receipt and possession at the geologic repository operations area.

  ☐ Accept for Review

  ☐ Accept, but Request for Additional Information Prepared

  ☐ Reject, Inadequate to Support Detailed Review

- A preclosure safety analysis of the geologic repository operations area, for the period before permanent closure, that assumes that operations will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the license application.

  ☐ Accept for Review

  ☐ Accept, but Request for Additional Information Prepared

  ☐ Reject, Inadequate to Support Detailed Review

- A description of the program for control and monitoring of radioactive effluents and occupational radiological exposures to maintain such effluents and exposures in accordance with the preclosure performance objectives.

  ☐ Accept for Review

  ☐ Accept, but Request for Additional Information Prepared

  ☐ Reject, Inadequate to Support Detailed Review

- A description of plans for retrieval and alternate storage of the radioactive wastes.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- A description of design considerations that are intended to facilitate permanent closure and decontamination or decontamination and dismantlement of surface facilities.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An assessment of the degree to which features, events and processes expected to materially affect compliance with the postclosure performance objectives have been characterized and the extent to which they affect waste isolation. Investigations must extend from the surface to a depth sufficient to determine principal pathways for radionuclide migration. Specific features events and processes must be investigated outside the site if they affect performance.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An assessment of the anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the range of design thermal loadings, given the fracture patterns and other discontinuities and the heat transfer properties of the rock mass and water.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An assessment of the ability of the proposed repository to limit radiological exposures to the reasonably maximally exposed individual for the period after permanent closure.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared

Acceptance Review

- ☐ Reject, Inadequate to Support Detailed Review

- An assessment of the ability of the proposed geologic repository to limit releases of radionuclides into the accessible environment.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An assessment of the ability of the proposed geologic repository to limit radiological exposures to the reasonably maximally exposed individual for the period after permanent closure in the event of human intrusion into the engineered barrier system.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An evaluation of the natural features of the geologic setting and design features of the engineered barrier system that are considered barriers important to waste isolation.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An explanation of measures used to support models for performance assessments. These models should be supported using an appropriate combination of methods such as field tests *in situ* tests, laboratory tests representative of field conditions, monitoring data, and natural analog studies.

  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

- An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, that require research and development to confirm the adequacy of design. For structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, the license application should provide a detailed description of the programs designed to

resolve safety questions. This should include a schedule showing when the U.S. Department of Energy would resolve these questions.

- ☐ Accept for Review
- ☐ Accept, but Request for Additional Information Prepared
- ☐ Reject, Inadequate to Support Detailed Review

- A description of the performance confirmation program.
  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review
- An identification and justification for selecting those variables, conditions, or other items that are determined to be probable subjects of license specifications.
  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review
- An explanation of how the U.S. Department of Energy used expert elicitation.
  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review
- A description of the quality assurance program to be applied to the structures, systems, and components important to safety and to the engineered and natural barriers important to waste isolation, including a discussion of how the applicable requirements of 10 CFR 63.142 will be satisfied.
  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

Acceptance Review

- A description of the plan for responding to, and recovering from, radiological emergencies that may occur at any time before permanent closure and decontamination or decontamination and dismantlement of surface facilities.

  - ☐ Accept for Review

  - ☐ Accept, but Request for Additional Information Prepared

  - ☐ Reject, Inadequate to Support Detailed Review

- Information concerning activities at the geologic repository operations area, including:

  - — Organizational structure of the U.S. Department of Energy as it pertains to construction and operation of the geologic repository operations area, including a description of any delegations of authority and assignments of responsibilities, whether in the form of regulations, administrative directives, contract provisions, or otherwise;

  - — Identification of key positions that are assigned responsibility for safety at, and operation of, the geologic repository operations area;

  - — Personnel qualifications and training requirements;

  - — Plans for startup activities and startup testing;

  - — Plans for conduct of normal activities, including maintenance, surveillance, and periodic testing of structures, systems, and components of the geologic repository operations area;

  - — Plans for permanent closure and plans for the decontamination or decontamination and dismantlement of surface facilities; and

  - — Plans to use the geologic repository operations area for purposes other than disposal of radioactive wastes. The plans should include an analysis of the effects, if any, that such uses may have on the operation of structures, systems, and components important to safety and the engineered and natural barriers important to waste isolation.

  - ☐ Accept for Review

  - ☐ Accept, but Request for Additional Information Prepared

  - ☐ Reject, Inadequate to Support Detailed Review

- A description of the program to be used to maintain records.

  - ☐ Accept for Review

- ☐ Accept, but Request for Additional Information Prepared
- ☐ Reject, Inadequate to Support Detailed Review

- A description of the controls that the U.S. Department of Energy will apply to restrict access and to regulate land use at the Yucca Mountain site and adjacent areas. This should include a conceptual design of monuments that would be used to identify the site after permanent closure.
  - ☐ Accept for Review
  - ☐ Accept, but Request for Additional Information Prepared
  - ☐ Reject, Inadequate to Support Detailed Review

3 REVIEW PLAN FOR GENERAL INFORMATION

Chapter 3, "General Information," reviews the requirements specified in 10 CFR 63.21(b). The intent of providing general information in the license application is twofold. First, it allows the U.S. Department of Energy to provide an overview of its engineering design concept for the repository (Section 3.1). Second, it allows the U.S. Department of Energy to demonstrate its understanding of what aspects of the Yucca Mountain site and its environs (Section 3.5) influence repository design and performance. Understanding the performance of the design, in the context of the Yucca Mountain site and its environs, allows the U.S. Department of Energy to make risk-informed, performance-based judgments regarding compliance with the regulations, which are subsequently evaluated by the U.S. Nuclear Regulatory Commission staff elsewhere in the Safety Analysis Report (Chapter 4). Accordingly, the material to be reviewed by the staff is generally informational in nature, with the more detailed technical discussions and descriptions found elsewhere in the Safety Analysis Report section of the license application. Notable exceptions in this chapter are the information found in Sections 3.2, 3.3, and 3.4 of the Yucca Mountain Review Plan. Overall, there are five sections in Chapter 3, and the extent to which each of these sections incorporates risk-informed, performance-based principles varies.

3.1 General Description

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

3.1.1 Areas of Review

This section reviews the general information to be included in the license application for the proposed geologic repository at Yucca Mountain. Reviewers will evaluate the information required by 10 CFR 63.21(b)(1).

The "General Information" section of the license application is expected to contain a broad overview that describes the proposed geologic repository at Yucca Mountain, including its major structures, systems, and components, as well as a discussion of proposed geologic repository operations area operations and activities. The level of detail presented should be similar to that in an "executive summary." The material to be reviewed is informational in nature, with the more detailed technical discussions and descriptions found elsewhere in the Safety Analysis Report section of the license application. Therefore, no detailed technical analysis of the information addressed in this section of the Yucca Mountain Review Plan is required. The detailed review of the information covered by these other technical subjects will be conducted under other sections of this review plan.

This review will address the following:

- A description of the location and facilities of structures, systems, and components of the geologic repository operations area, both surface and subsurface;
- A discussion of the proposed geologic repository operations area operations and activities; and

- The delineation of the statutory and regulatory basis for proposed geologic repository operations.

The "General Information" to be reviewed will be evaluated using the review methods and acceptance criteria found in Sections 3.1.2 and 3.1.3, respectively, of the Yucca Mountain Review Plan. In general, these review methods and acceptance criteria are based on well-established and accepted U.S. Nuclear Regulatory Commission regulatory activities. Because some of the information contained in this portion of the license application is informational in nature and may not concern performance-related issues, some of the review methods used to evaluate this information may generally not be risk-informed, performance-based. In instances such as these, there will be no performance measures against which the review methods can be compared.

3.1.2 Review Methods

Review Method 1 Location and Arrangement of Structures, Systems, and Components of the Geologic Repository Operations Area

Confirm that the U.S. Department of Energy has provided an accurate general description of the geologic repository operations area. This general description, at a minimum, should include:

- A general discussion of the physical characteristics of the proposed repository site and environs critical to repository performance;

- Scaled drawings or maps, showing the location of the geologic repository operations area and its associated structures, systems, and components, including but not limited to, engineered barriers, roads and connecting transportation infrastructure, utility services, and natural and man-made boundaries;

- A summary of the major design features of the above- and below-ground structures, systems, and components, with a designation of whether they are temporary or permanent;

- Those geologic repository operations area structures, systems, and components to be dismantled for the purposes of decommissioning and permanent closure;

- The identification and description of each major structure, system, and component of the geologic repository operations area, including a definition of the purpose of each and a description of the interrelationships among these structures, systems, and components;

- A general discussion of the plans to restrict access to the geologic repository operations area and to regulate land uses around the geologic repository operations area (the detailed technical review of this information will take place in Section 4.5.8 of the Yucca Mountain Review Plan);

- The identification and description of radiological and environmental monitoring instrumentation and activities, including the U.S. Department of Energy plans for the mitigation of environmental impacts associated with the construction and operation of the proposed repository; and

- Information that is consistent with the U.S. Department of Energy Final Environmental Impact Statement for Yucca Mountain.

Review Method 2 General Nature of the Geologic Repository Operations Area Activities

The staff should confirm that the U.S. Department of Energy has provided a summary description of the proposed geologic repository operations area operations. An acceptable summary description would include:

- Information on the types, kinds, and amounts of spent nuclear fuel and other high-level radioactive waste to be disposed of at the proposed repository;

- Information on routine waste package receipt, handling, and emplacement operations (the detailed technical review of this information will take place in Section 4.5.6 of the Yucca Mountain Review Plan);

- Plans for the inspection and testing of waste forms and waste packages as they are received at the geologic repository operations area (the detailed technical review of this information will take place in Section 4.5.6 of the Yucca Mountain Review Plan);

- An explanation as to how the U.S. Department of Energy will address the situation, in the context of its nuclear material control and accounting procedures, where the U.S. Department of Energy will not be able to inspect the contents of the waste disposal containers, such as the Naval Reactor fuel;

- Plans for the retrieval, and the alternative storage of, waste packages from emplacement drifts (the detailed technical review of this information will take place in Section 4.1.2 of the Yucca Mountain Review Plan);

- A summary of the criteria used to decide when, and under what conditions, waste retrieval operations would be necessary;

- Plans for decommissioning and permanent closure of the geologic repository operations area (the detailed technical review of this information will take place in Section 4.1.3 of the Yucca Mountain Review Plan);

- A general discussion of possible uses of the geologic repository operations area for purposes other than the disposal of spent nuclear fuel and other types of high-level radioactive waste (the detailed technical review of this information will take place in Section 4.5.9 of the Yucca Mountain Review Plan); and

- Plans for responses to emergencies. (The detailed technical review of this information will take place in Section 4.5.7 of the Yucca Mountain Review Plan.)

In general, the reviewer should verify that the aforementioned summaries include adequate plans and procedures for the movement of personnel, materiel, and equipment during construction and normal operations.

Review Method 3 Basis for the Commission's Licensing Authority

The staff should verify that the license application contains a presentation of the appropriate provisions of the statutory authority and the citations from the U.S. Nuclear Regulatory Commission regulations that apply to the proposed activities at the geologic repository operations area. The reviewer should also verify inclusion of a confirmation that no applicable regulatory citations have been omitted.

3.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.21(b)(1), relating to the description of the general information.

Acceptance Criterion 1 The Location and Arrangement of the Geologic Repository Operations Area are Adequately Defined.

- A general but accurate description of the geologic repository operations area is provided. This description includes:
  - A discussion of the physical characteristics of the site and the natural setting;
  - Scaled drawings or maps showing the location of the geologic repository operations area and its associated structures, systems, and components;
  - A summary of the design features of the above- and below-ground structures, systems, and components, with a designation of whether they are permanent or temporary;
  - A definition of the purpose of each geologic repository operations area structure, system, and component, and any interrelationships among them;
  - Plans to restrict access to, and to regulate land uses around, the geologic repository operations area; and
  - A description of environmental monitoring instrumentation and activities, including the U.S. Department of Energy plans for the mitigation of environmental impacts associated with the construction and operation of the proposed repository.

Acceptance Criterion 2 The General Nature of the Activities to be Conducted at the Geologic Repository is Adequately Described.

- A summary description of the types, kinds, and amounts of spent nuclear fuel and other high-level radioactive waste to be disposed of is provided;
- A summary description of the proposed operations is provided that includes receipt, handling, emplacement, retrieval, of waste and waste packages This description includes basic plans for the movement of personnel, material, and equipment during construction and normal operations;
- Plans for the inspection and testing of waste forms and waste packages;
- An explanation of material control and accounting procedures when the contents of waste disposal containers cannot be inspected;
- Plans for the retrieval and the alternative storage of radioactive wastes, should retrieval be necessary, are included;
- Plans for decommissioning and permanent closure of the geologic repository operations area are provided;
- A general discussion of possible uses of the geologic repository operations area for purposes other than the disposal of spent nuclear fuel and other types of high-level radioactive waste is incorporated; and
- Plans for responses to emergencies are provided.

Acceptance Criterion 3 An Adequate Basis for the Exercise of the U.S. Nuclear Regulatory Commission Licensing Authority is Provided.

- The license application contains a presentation of the appropriate provisions of the statutory authority and the citations from the U.S. Nuclear Regulatory Commission regulations that apply to the proposed activities at the geologic repository. This information includes a confirmation that no applicable regulatory citations have been omitted.

3.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 3.1.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the "General Information" and other docketed material and has found, with reasonable assurance, that they satisfy the requirements

of 10 CFR 63.21(b)(1). An adequate general description of the geologic repository has been provided that identifies the location of the geologic repository operations area, discusses the general character of the proposed activities at the geologic repository operations area, and provides the basis for the exercise of the Commission's licensing authority.

3.1.5 References

None.

3.2 Proposed Schedules For Construction, Receipt, and Emplacement of Waste

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

3.2.1 Areas of Review

This section reviews proposed schedules for construction, receipt, and emplacement of waste. Reviewers will evaluate the information required by 10 CFR 63.21(b)(2).

The staff will evaluate the following parts of proposed schedules for construction, receipt, and emplacement of waste, using the review methods and acceptance criteria in Sections 3.2.2 and 3.3.3.

The material to be reviewed is informational in nature, and no detailed technical analysis is required. Because some of the information contained in this portion of the license application is informational in nature and may not concern performance-related issues, some of the review methods used to evaluate this information may generally not be risk-informed, performance-based. In instances such as these, there will be no performance measures against which the review methods can be compared.

- Schedules for construction of structures, systems, and components of the geologic repository operations area (including development of requisite infrastructure both on- and off-site); and

- Proposed schedules for the receipt, handling, and emplacement of waste package canisters.

3.2.2 Review Methods

Review Method 1 Major Steps for the Completion of Each Significant Work Element

Determine that the schedules for each significant work element necessary for both on- and off-site construction (including infrastructure development) and the receipt and emplacement of waste provide an adequate description of planned project activities. Traditional project management techniques (i.e., critical-path method diagrams, Gantt charts, etc.) should be used

to convey the necessary information. In evaluating the adequacy of project planning, recognize that scheduling will be a function of evolving circumstances and expect distant scheduling to be less detailed than near-term scheduling. This review of project planning schedules should include:

- Verifying that the schedules, time-scaled charts, or work progress flow charts are complete, consistent, and reflect a logical sequence of work;
- Ensuring that the scheduled time allocated for each work step and the identified interdependence of work steps are sufficient to provide an overall understanding of the geologic repository operations area and infrastructure construction and waste-emplacement operations; and
- Verifying that construction of geologic repository operations area facilities will be substantially complete before the proposed scheduled receipt and emplacement of wastes.

3.2.3 Acceptance Criteria

The following acceptance criterion is based on meeting the requirements of 10 CFR 63.21(b)(2) relating to proposed schedules for construction, receipt, and emplacement of waste.

Acceptance Criterion 1 Major Steps for the Completion of Each Significant Work Element are Adequately Described.

- Major steps for the completion of each significant work element during construction of geologic repository operations area facilities and the associated infrastructure are identified in the proposed schedule of activities;
- Major steps and activities associated with the receipt of and emplacement of wastes are identified in the proposed schedule of activities; and
- For each of the activities described in the various phases of geologic repository operations area operations and activities, an adequate description of planned overall project progress is provided. Specifically:
  - Schedules, work-flow diagrams, and other project-management planning tools are complete, consistent, and reflect a logical sequence of planned work and routine operational activities; and
  - The scheduled time allocated for each major activity and the identified interdependence of major activities are sufficient to provide an overall understanding of the geologic repository operations area and infrastructure construction and routine waste-emplacement operations.

3.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 3.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the "General Information" and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.21(b)(2). The U.S. Department of Energy provides schedules for construction, receipt of waste, and waste emplacement at the geologic repository operations area that are sufficiently detailed to allow staff to evaluate the overall construction program for the geologic repository operations area and its infrastructure.

3.2.5 References

None.

3.3 Physical Protection Plan

This review determines with reasonable assurance whether the U.S. Department of Energy has committed to having a physical protection system that provides high assurance that activities involving high-level radioactive waste do not present an unreasonable risk to the public health and safety. The physical protection system should be designed to protect against a loss of control of the geologic repository operations area that could be sufficient to cause radiation exposure exceeding the dose defined in 10 CFR 72.106. Physical protection requirements for high-level radioactive waste at a geologic repository operations area are at 10 CFR 73.51. These regulations specify the physical protection measures a licensee must observe, and to which a licensee must commit, in a U.S. Nuclear Regulatory Commission-approved physical protection plan. In light of the terrorist attacks of September 11, 2001, the Commission has directed the staff to conduct a comprehensive reevaluation of U.S. Nuclear Regulatory Commission physical requirements. If this effort indicates that U.S. Nuclear Regulatory Commission regulations or requirements warrant revision, such changes would occur through a public rulemaking or other appropriate methods and, if necessary, the Yucca Mountain Review Plan would be revised accordingly.

Review Responsibilities—High-Level Waste Branch, Division of Fuel Cycle Safety and Safeguards, and Environmental and Performance Assessment Branch

3.3.1 Areas of Review

This section reviews the physical protection plan. Reviewers will evaluate the information required by 10 CFR 63.21(b)(3). Although the U.S. Department of Energy is not expected to submit a physical protection plan with the license application, the U.S. Department of Energy should commit to developing and implementing a physical protection system that meets or

exceeds the acceptance criteria, in Section 3.3.3, before receipt of waste at the geologic repository operations area.

The reviewer should evaluate the U.S. Department of Energy submittal for an acceptable physical protection system that protects against a loss of control of the geologic repository operations area that could be sufficient to cause radiation exposure exceeding the dose as defined in 10 CFR 72.106. The reviewer should ensure that the U.S. Department of Energy has described how the general performance requirements, the performance capabilities, and the specific measures included in 10 CFR 73.51 will be met through developing, implementing, and maintaining a physical protection system.

The staff will evaluate the following parts of the physical protection plan, using the review methods and acceptance criteria in Sections 3.3.2 and 3.3.3:

- Introduction and schedule for implementation;
- General performance objectives;
- Protection goal;
- Security organization;
- Physical barrier subsystems;
- Access control subsystems and procedures;
- Detection, surveillance, and alarm subsystems and procedures;
- Communication subsystems;
- Equipment operability and compensatory measures;
- Contingency and response plans and procedures; and
- Reporting of safeguards events.

3.3.2 Review Methods

Review Method 1 Geologic Repository Operations Area Description and Schedule for Implementation

Verify that the U.S. Department of Energy specifies the geologic repository operations area location. The U.S. Department of Energy should describe the geologic repository operations area facilities, the nature of the wastes to be disposed of, the geologic repository operations area layout, the surrounding area, and the surrounding terrain. Ensure that the U.S. Department of Energy has included a map of the entire facility, and other maps and illustrations, to assess the physical protection plan. The U.S. Department of Energy should

indicate on these maps the controlled area; the location of all buildings; the locations of physical protection systems, subsystems, and major components; the protected area; and all entry/exit points, entry/exit control points, alarm stations, and security posts.

Confirm that the U.S. Department of Energy has presented an adequate schedule for implementing the physical protection plan. High-level radioactive waste may not be stored or used at the geologic repository operations area until the physical protection system is implemented and operational.

Review Method 2 General Performance Objectives

Verify that the U.S. Department of Energy commitments for the physical protection plan are consistent with 10 CFR 73.51. Items to be verified include that:

- The U.S. Department of Energy has described, in general terms, how the physical protection system will provide high assurance that activities involving high-level radioactive waste do not present an unreasonable risk to the public health and safety;

- The U.S. Department of Energy has adequately described how, through establishing, maintaining, and arranging a physical protection system, the general performance objective and requirements in 10 CFR 73.51 will be met;

- The U.S. Department of Energy has identified and adequately described those portions of the physical protection system for which redundant and diverse components and redundant and diverse subsystems and components are necessary to ensure adequate performance, as required by 10 CFR 73.51(b)(2). In general terms, the U.S. Department of Energy should describe the subsystems and components to be used to provide this redundancy and diversity and the ways in which these subsystems and components are redundant and diverse; and

- The U.S. Department of Energy has adequately described how the physical protection system is designed, tested, and maintained to ensure its continual effectiveness, reliability, and availability. This verification should be conducted on-site by the reviewer before plan approval.

Review Method 3 Protection Goal

Verify that the U.S. Department of Energy has committed to protect against a loss of control of the geologic repository operations area that could cause radiation exposure exceeding the dose defined in 10 CFR 72.106. The U.S. Department of Energy should have established a physical protection strategy that would deny unauthorized access to areas of the geologic repository operations area which could result in a loss of control sufficient to cause radiation exposure exceeding the dose as described in 10 CFR 72.106. Ensure that the U.S. Department of Energy has committed to maintain and update the physical protection plan to reflect any changes that are necessary to ensure the continual ability to protect against situations leading to loss of control of the geologic repository operations area.

Review Method 4 Security Organization

Verify that the U.S. Department of Energy has described an adequate security organization to manage, control, and implement the physical protection system, consistent with the physical protection plan and consistent with maintaining its effectiveness. The security organization will be acceptable if the U.S. Department of Energy commitments are consistent with the requirements in 10 CFR 73.51(d); associated Appendixes B, C, and G of 10 CFR Part 73; and the following criteria:

- The U.S. Department of Energy has stated whether the security organization is employed directly by the U.S. Department of Energy or is a contractor to the U.S. Department of Energy. Ensure, if the security organization is managed by a contractor, that the U.S. Department of Energy has described adequate written agreements, between the U.S. Department of Energy and contract guard force management, that will govern how the security force will meet requirements at 10 CFR 73.51(d) and Appendix B, "General Criteria for Security Personnel," to 10 CFR Part 73;

- The U.S. Department of Energy has committed to providing adequate structure and management for the security organization. This should include both uniformed security personnel and other persons responsible for security-related functions, consistent with 10 CFR 73.51(d). The structure description should include each supervisory and management position with responsibilities and lines of authority to facility and corporate management. The security organization must provide for sufficient personnel each shift to monitor detection systems and to conduct surveillance, assessment, access control, and communications, to assure adequate response time against a security threat;

- The U.S. Department of Energy has committed to reviewing the physical protection program at least once every 24 months, by individuals who are independent of physical protection management and who have no direct responsibility for implementation of the physical protection program. The physical protection program review shall evaluate the effectiveness of the physical protection system, and of the liaison established with the designated response force or local law enforcement agency;

- The U.S. Department of Energy has committed to an approved Guard Force Training Plan, that meets 10 CFR Part 73, Appendix B, "General Criteria for Security Personnel," being in effect. The physical protection plan should commit to train, equip, and qualify all members of the security organization to perform their security duties in accordance with 10 CFR Part 73, Appendix B, "General Criteria for Security Personnel," consistent with 10 CFR 73.51(d)(5); and

- The U.S. Department of Energy has committed to records, required by 10 CFR 73.51(d)(13), being maintained/retained and adequately describing how they will be maintained/retained.

Review Plan for General Information

Review Method 5 Physical Barrier Subsystems

A performance objective of physical barriers is to define areas within which authorized activities and conditions are permitted. Other barrier performance objectives are to channel persons, vehicles, and material to or from entry/exit control points; to delay or deny unauthorized penetration attempts by persons, vehicles, or material; to delay attempts to cause loss of control of the geologic repository operations area; to assist detection and assessment; and to permit a timely response by the security force or local law enforcement to prevent the intended act.

Ensure that the U.S. Department of Energy has adequately described the physical barrier subsystems for the geologic repository operations area. This description will be acceptable if the U.S. Department of Energy commitments to the physical protection plan are consistent with the following criteria:

- The U.S. Department of Energy has committed to high-level radioactive waste being stored only within a protected area. Access to material in the protected area shall require passage or penetration through two physical barriers—one barrier at the perimeter of the protected area, and one barrier offering substantial penetration resistance. The physical barrier at the perimeter of the protected area must be as defined in 10 CFR 73.2. The barrier offering substantial resistance to penetration must be adequately defined and described. The U.S. Department of Energy should commit to installing the protected area barrier fence, so that it cannot be lifted to allow an individual to crawl under it. The U.S. Department of Energy should describe any access points through the protected area barrier, the manner in which they are to be used, and the means to control and protect them to ensure the integrity of the barrier. Barriers designed to protect against the malevolent use of a vehicle are not required at the geologic repository operations area;

- The U.S. Department of Energy has adequately described the location and size of any geologic repository operations area isolation zones. The U.S. Department of Energy should commit to isolation zones alongside physical barriers at the perimeter of the protected area, being at least 6.1-meters (20-feet) wide and being maintained clear of obstacles or structures on either side of the barriers, to permit assessment consistent with 10 CFR 73.51(d)(1); and

- The U.S. Department of Energy has described the lighting system sufficiently to demonstrate that it will be adequate to ensure illumination for monitoring, observation, and assessment activities for exterior areas within the protected area. The illumination must be sufficient to assess unauthorized penetrations of, or activities within, the protected area, consistent with 10 CFR 73.51(d)(2). The U.S. Department of Energy should demonstrate acceptable emergency backup power for protected area lighting and security assessment if normal power is lost. Illumination should be maintained during all periods of darkness (not just during periods of assessment). The level of illumination should be sufficient for the security assessment means proposed; however, 10 CFR 73.51 defines no specific required illumination level. The reviewer should consider that the physical layout of the geologic repository operations area may

complicate maintaining a consistent level of illumination throughout the protected area because of obstruction from such structures as storage casks.

Review Method 6 Access Control Subsystems and Procedures

The performance objectives of access authorization controls and procedures are to verify the identity of persons, vehicles, and materials, and to initiate timely response measures to deny unauthorized entries.

Ensure that the U.S. Department of Energy has committed to providing adequate access control subsystems for the geologic repository operations area. These subsystems will be acceptable if the U.S. Department of Energy commitments are consistent with the requirements in 10 CFR 73.51(d)(9), and the following criteria:

- The U.S. Department of Energy will establish and maintain a personnel identification system to limit access only to authorized individuals. The personnel identification system should provide unique identification of individuals granted access to the protected area. A picture identification system using a driver's license photograph, a name badge system using a badge medium that is difficult to counterfeit, or facial recognition could be used. Use of facial recognition should be justified (e.g., long-term employment and small site population);

- The U.S. Department of Energy has described adequate procedures for control of points of personnel access into the protected area, consistent with 10 CFR 73.51(d)(9). These procedures should include a discussion of methods used to identify individuals and to verify individual authorization. Procedures should also describe techniques for conducting visual searches of individuals, vehicles, and hand-carried packages for explosives before entry into the protected area. If an individual can be positively identified, is authorized access, and has been searched for explosives without positive findings, then no escort is required. If the individual cannot meet any one of these three criteria, access to the protected area should be denied;

- The U.S. Department of Energy has committed to a controlled lock system being established and maintained, to limit access to authorized individuals, consistent with 10 CFR 73.51(d)(7). Regulatory Guide 5.12, "General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials" (U.S. Nuclear Regulatory Commission, 1973) should be used as guidance for developing a controlled lock system; and

- The U.S. Department of Energy has committed to retaining the following documentation for 3 years after the record is made or until termination of the license: (i) a log of individuals granted access to the protected area; (ii) screening records of members of the security organization; (iii) a log of all patrols; (iv) a record of each alarm received, identifying the type of alarm, location, date, and time when received—and disposition of the alarm; and (v) the physical protection program review reports.

Review Method 7 Detection, Surveillance, and Alarm Subsystems and Procedures

The performance objectives of detection, surveillance, and alarm subsystems and procedures are to detect, assess, and communicate any unauthorized access or penetrations, or such attempts by persons, vehicles, or materials at the time of occurrence, so the response will prevent the unauthorized access or penetration.

Ensure that the U.S. Department of Energy has adequate detection, surveillance, and alarm subsystems for the geologic repository operations area. These subsystems will be acceptable if they are consistent with the requirements in 10 CFR 73.51(d), and the following criteria:

- An adequate intrusion detection system will be installed in the isolation zone between the two barriers at the protected area perimeter, consistent with 10 CFR 73.51(d)(3). The U.S. Department of Energy should commit to providing a volumetric intrusion-detection system capable of detecting an individual, weighing a minimum of 77 pounds, whether the individual is running, walking, crawling, jumping, or rolling through the isolation zone of the protected area. The capabilities, installation, and testing of the intrusion-detection equipment should be consistent with Regulatory Guide 5.44, "Perimeter Intrusion Alarm Systems," Revision 3 (U.S. Nuclear Regulatory Commission, 1997);

- The location, construction, and characteristics of the central and secondary alarm stations are consistent with 10 CFR 73.51(d)(3). The U.S. Department of Energy should commit to having all required alarms annunciate in a continuously manned central alarm station located within the protected area and in at least one other continuously manned independent on-site station. Continuous manning of alarm stations and methods used for annunciation of required alarms should be described, along with protection afforded the stations (both procedural and physical), so that a single act cannot remove the capability of calling for assistance or responding to an alarm. The reviewer should confirm that access to the alarm stations will be controlled on a need-to-know basis, and that the central alarm station will not contain any activities that would interfere with the alarm response. The annunciation systems at the alarm stations should indicate the status of all alarms and alarm zones in both alarm stations. The secondary location need only provide a summary indication that an alarm has been generated. The U.S. Department of Energy should follow the guidelines of Regulatory Guide 5.44, "Perimeter Intrusion Alarm Systems," Revision 3 (U.S. Nuclear Regulatory Commission, 1997) for alarm annunciation;

- Detection systems and supporting subsystems must be tamper-indicating with line supervision. These systems and the surveillance/assessment and illumination systems must be maintained in operable condition; and

- The U.S. Department of Energy has committed to monitoring the protected area with daily random patrols, consistent with 10 CFR 73.51(d)(4). To evaluate the proposed frequency of random patrols, the reviewer should consider the remoteness of the geologic repository operations area, the nature of activities adjacent to the site, and the size of the geologic repository operations area. A minimum of two patrols per security

duty work shift should be conducted, unless the facility is in a remote area where more patrols may be necessary.

Review Method 8 Communication Subsystems

The performance objective of communication subsystems is to notify of an attempted unauthorized intrusion, so response can prevent loss of control of the geologic repository operations area.

Ensure that the U.S. Department of Energy will have adequate communications subsystems for the geologic repository operations area. The communications subsystems will be acceptable if they are consistent with the requirements in 10 CFR 73.51(d), and the following criteria:

- The individual in each continuously manned alarm station should be able to call for assistance from other guards and watchmen and from local law enforcement;
- Redundant and diverse systems should be used to ensure communications with the local law enforcement authority, consistent with 10 CFR 73.51(d)(8); and
- The methods used to maintain communications systems in operable condition should be consistent with 10 CFR 73.51(d)(11).

Review Method 9 Equipment Operability and Compensatory Measures

The performance objective of test and maintenance procedures is to provide confidence that security equipment will be available and reliable to perform when needed.

Ensure that the U.S. Department of Energy will have adequate test and maintenance programs for the geologic repository operations area. The test and maintenance programs will be acceptable if they are consistent with the requirements in 10 CFR 73.51(d), and the U.S. Department of Energy commits to a testing program for the perimeter intrusion detection system consistent with Regulatory Guide 5.44, Revision 3 (U.S. Nuclear Regulatory Commission, 1997).

Review Method 10 Contingency and Response Plans and Procedures

The performance objective for contingency response plans and procedures is to provide predetermined response to safeguards contingency events, so the adversary will be engaged and impeded until off-site assistance arrives.

Ensure that the U.S. Department of Energy has adequate contingency and response plans for the geologic repository operations area. The contingency and response plans will be acceptable if the U.S. Department of Energy plans are consistent with the requirements in 10 CFR 73.51(d)(10), Appendix C to 10 CFR Part 73, and the following criteria:

- The U.S. Department of Energy has provided a commitment to develop a safeguards contingency plan for unauthorized penetrations of, or activities within, the protected

area, that includes the Category 5, "Procedures," of Appendix C to 10 CFR Part 73, consistent with 10 CFR 73.51(d)(10); and

- The U.S. Department of Energy will have adequate documented response arrangements with designated response force or local law enforcement agencies, consistent with the requirements of 10 CFR 73.51(d)(6). The designated response force could be a privately contracted security force that meets the requirements of Appendix B to 10 CFR Part 73. If the designated response force cannot respond quickly enough, additional protective measures may be required, including the use of armed guards.

Review Method 11 Reporting of Safeguards Events

Verify that the U.S. Department of Energy has committed to reporting safeguards events to the U.S. Nuclear Regulatory Commission, consistent with the criteria in 10 CFR Part 73, Appendix G, "Reportable Safeguards."

3.3.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.21(b)(3), relating to the physical protection plan.

Acceptance Criterion 1 The Physical Protection Plan Contains an Adequate Geologic Repository Operations Area Description and Provides an Acceptable Schedule for Implementation.

- The physical protection plan adequately specifies the location of the geologic repository operations area, the geologic repository operations area facilities, the nature of the wastes to be disposed of, the geologic repository operations area layout, the surrounding area, and the surrounding terrain. Adequate maps are provided to support the physical protection plan; and

- An acceptable schedule is provided for implementing the physical protection plan. High-level radioactive waste will not be stored or used at the geologic repository operations area facility, until the physical protection system is implemented and operational.

Acceptance Criterion 2 General Performance Objectives Will be Met.

- The physical protection system will provide high assurance that activities involving high-level radioactive waste do not present an unreasonable risk to the public health and safety;

- Through establishing, maintaining, and arranging a physical protection system, the general performance objective and requirements prescribed in 10 CFR 73.51 will be met;

- Those portions of the physical protection system for which redundant and diverse components, and redundant and diverse subsystems and components, are necessary to ensure adequate performance, will meet the requirements of 10 CFR 73.51(b)(2); and

- The physical protection system will be designed, tested, and maintained to ensure its continual effectiveness, reliability, and availability.

Acceptance Criterion 3 The Protection Goal Will be Met.

The physical protection system will be designed to protect against a loss of control of the geologic repository operations area that could cause radiation exposure exceeding the dose defined in 10 CFR 72.106. The U.S. Department of Energy will have a physical protection strategy that will deny unauthorized access to areas of the geologic repository operations area which could result in a loss of control sufficient to cause radiation exposure exceeding the dose as described in 10 CFR 72.106. The U.S. Department of Energy will maintain and update the physical protection plan to reflect any changes that are necessary to ensure the continual ability to protect against situations leading to loss of control of the geologic repository operations area.

Acceptance Criterion 4 The Security Organization Will be Adequate.

The U.S. Department of Energy has an adequate security organization to manage, control, and implement the physical protection system consistent with the physical protection plan and will continually maintain its effectiveness.

- The U.S. Department of Energy has stated whether the security organization is employed directly by the U.S. Department of Energy or is a contractor to the U.S. Department of Energy. The U.S. Department of Energy has, or has committed to, adequate written agreements between the U.S. Department of Energy and the contract guard force;

- The U.S. Department of Energy has an adequate structure and management for the security organization, including both uniformed security personnel and other persons responsible for security-related functions. The security organization provides for sufficient personnel each shift to monitor detection systems and to conduct surveillance, assessment, access control, and communications to assure adequate response time against security threats;

- The U.S. Department of Energy will review the physical protection program at least once every 24 months using individuals who are independent of physical protection management, and who have no direct responsibility for implementation of the physical protection program. The physical protection program review will evaluate the effectiveness of the physical protection system, and of the liaison established with the designated response force or local law enforcement agency;

- The U.S. Department of Energy will establish an adequate Guard Force Training Plan. The physical protection plan will commit to properly train, equip, and qualify members of the security organization to perform their security duties; and

- The U.S. Department of Energy will adequately maintain the records required by 10 CFR 73.51(d)(13).

Acceptance Criterion 5 Physical Barrier Subsystems Will be Adequate.

The physical barriers will control areas within which authorized activities and conditions are permitted. The barriers will channel persons, vehicles, and material to or from entry/exit control points; will delay or deny unauthorized penetration attempts by persons, vehicles, or material; will delay any attempts to cause loss of control of the geologic repository operations area; will assist detection and assessment; and will permit a timely response by the security force or local law enforcement to prevent the intended act.

The U.S. Department of Energy has adequate physical barrier subsystems at the geologic repository operations area.

- High-level radioactive waste will be stored only within a protected area. Access to material in the protected area will require passage or penetration through two physical barriers; one barrier at the perimeter of the protected area, and one barrier offering substantial penetration resistance. The physical barrier at the perimeter of the protected area will be as defined in 10 CFR 73.2. The barrier offering substantial resistance to penetration is adequately defined and described. The U.S. Department of Energy will install the protected area barrier fence, so that it cannot be lifted to allow an individual to crawl under it. Access points through the protected area barrier, the manner in which they are to be used, and the means to control and protect them to ensure the integrity of the barrier are adequately described;

- The location and size of any geologic repository operations area isolation zones are adequately defined. The isolation zones adjacent to the physical barriers at the perimeter of the protected area will be at least (20-feet) wide, and will be maintained clear of obstacles or structures on either side of the barriers, to permit assessment consistent with 10 CFR 73.51(d)(1); and

- The U.S. Department of Energy has described the lighting system sufficiently to demonstrate that it will be adequate to ensure illumination for monitoring, observation, and assessment activities for exterior areas within the protected area. The illumination will be sufficient to permit assessment of unauthorized penetrations of, or activities within, the protected area, consistent with 10 CFR 73.51(d)(2). The U.S. Department of Energy demonstrates that there will be acceptable emergency backup power for protected area lighting and security assessment capability if normal power is lost. Illumination will be maintained during all periods of darkness. The level of illumination will be sufficient for the security assessment means proposed.

Acceptance Criterion 6 Access Control Subsystems and Procedures Will be Adequate.

Controls and procedures are adequate to verify the identity of persons, vehicles, and materials, and to initiate timely response measures to deny unauthorized entries.

The U.S. Department of Energy will provide adequate access control subsystems for the geologic repository operations area.

- The U.S. Department of Energy will establish and maintain an adequate personnel identification system to limit access only to authorized individuals. The personnel identification system will provide unique identification of individuals granted access to the protected area;

- The U.S. Department of Energy will provide adequate procedures for control of points of personnel access into the protected area. These procedures will include appropriate methods to identify individuals and to verify individual authorization, and techniques for conducting visual searches of individuals, vehicles, and hand-carried packages for explosives before entry into the protected area;

- The U.S. Department of Energy will employ an adequate controlled lock system to limit access to authorized individuals, consistent with 10 CFR 73.51(d)(7); and

- The U.S. Department of Energy will maintain adequate records of access control.

Acceptance Criterion 7 Detection, Surveillance, and Alarm Subsystems and Procedures Will be Adequate.

Detection, surveillance, and alarm subsystems and procedures will be adequate to detect, assess, and communicate any unauthorized access or penetrations, or such attempts by persons, vehicles, or materials at the time of the act or the attempt, so the response can prevent the unauthorized access or penetration.

The U.S. Department of Energy has adequate detection, surveillance, and alarm subsystems for the geologic repository operations area.

- An adequate intrusion-detection system will be installed in the isolation zone between the two barriers at the protected area perimeter;

- The location, construction, and characteristics of the central and secondary alarm stations are consistent with 10 CFR 73.51(d)(3). The U.S. Department of Energy will have all required alarms annunciate in a continuously manned central alarm station located within the protected area, and in at least one other continuously manned independent on-site station. The U.S. Department of Energy will provide continuous manning of alarm stations, and methods used for annunciation of required alarms are adequate, so that a single act cannot remove the capability of calling for assistance or responding to an alarm. Access to the alarm stations will be controlled on a need-to-know basis, and the central alarm station will not contain any operational activities that would interfere with the execution of alarm response functions. The annunciation systems at the alarm stations will indicate the status of all alarms and alarm zones in both alarm stations;

- Detection systems and supporting subsystems will be tamper-indicating with line supervision. These systems and the surveillance/assessment and illumination systems will be maintained in operable condition; and

- The protected area will be monitored with adequate daily random patrols.

Acceptance Criterion 8 Communication Subsystems Will be Adequate.

The communication subsystems will provide adequate notification of an attempted unauthorized intrusion, so that response can prevent loss of control of the geologic repository operations area.

The U.S. Department of Energy will have adequate communications subsystems for the geologic repository operations area.

- The individual in each continuously manned alarm station will be capable of calling for assistance from other guards and watchmen and from local law enforcement authorities;

- Redundant and diverse systems will be used to ensure the capability of communications with the local law enforcement authority; and

- The methods used to maintain communications systems in operable condition are adequate.

Acceptance Criterion 9 Equipment Operability and Compensatory Measures are Adequate.

Test and maintenance procedures provide adequate confidence that security equipment will be available and reliable to perform when needed.

The U.S. Department of Energy will have adequate test and maintenance programs for the geologic repository operations area physical protection systems.

Acceptance Criterion 10 Contingency and Response Plans and Procedures Will be Adequate.

Contingency response plans and procedures will provide adequate predetermined response to safeguards contingency events, so that the adversary will be engaged and impeded until off-site assistance arrives.

The U.S. Department of Energy has adequate contingency and response plans for the geologic repository operations area.

- The U.S. Department of Energy will provide an adequate safeguards contingency plan for dealing with unauthorized penetrations of, or activities within, the protected area; and

- The U.S. Department of Energy will have adequate documented response arrangements with designated response force or local law enforcement agencies.

Acceptance Criterion 11 Reporting of Safeguards Events Will be Adequate.

The U.S. Department of Energy will provide adequate reporting of safeguards events to the U.S. Nuclear Regulatory Commission.

3.3.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 3.3.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.21(b)(3). The U.S. Department of Energy will implement an adequate physical protection program for high-level radioactive waste that includes physical protection, a safeguards contingency plan, and a security organization personnel training and qualification plan that complies with 10 CFR 73.51 of this chapter.

3.3.5 References

U.S. Nuclear Regulatory Commission. Regulatory Guide 5.44, "Perimeter Intrusion Alarm Systems." Revision 3. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. October 1997.

———. Regulatory Guide 5.12, "General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. November 1973.

3.4 Material Control and Accounting Program

This review is to ensure the U.S. Department of Energy material control and accounting plan describes, establishes, implements, and maintains a program adequate to protect against, detect, and respond to loss of high-level radioactive waste. Material control and accounting requirements for high-level radioactive waste are required by 10 CFR 63.21(b)(4) and stipulated in 10 CFR 63.78.

Review Responsibilities—High-Level Waste Branch, Division of Fuel Cycle Safety and Safeguards, and Environmental and Performance Assessment Branch

In conducting this review, the reviewer should consider that emplaced waste is stored until the repository is closed.

3.4.1 Areas of Review

This section reviews the material control and accounting program. Reviewers will evaluate the information required by 10 CFR 63.21(b)(4).

The staff will evaluate the following parts of the material control and accounting program, using the review methods and acceptance criteria in Sections 3.4.2 and 3.4.3. The program may not be in place when the U.S. Department of Energy submits a license application. Therefore, the U.S. Department of Energy commitments to implement the material control and accounting program requirements are sufficient for construction.

- Material balance, inventory, and records and procedures for stored high-level radioactive waste;
- Procedures for preparing accidental criticality or loss of special nuclear material reports;
- Procedures for preparing material status reports; and
- Procedures for preparing nuclear material transfer reports.

3.4.2 Review Methods

Review Method 1 Material Balance, Inventory, and Record-Keeping Procedures

Verify that the material control and accounting plan establishes the bases for identifying, controlling, and accounting for the nuclear materials that the U.S. Department of Energy will be authorized to possess at the geologic repository operations area.

Verify records will adequately document the receipt, inventory (including location), disposal, acquisition, and transfer of spent nuclear fuel and high-level radioactive waste, including provision to maintain inventory during any retrieval operations. Information on the waste form, proposed waste package, characteristics of any encapsulation material, radionuclide characteristics, heat generation rate, and history should be provided in these records. Ensure procedures require that records be maintained for as long as the material is stored, and for 5 years after the repository is closed. Verify that the following minimum information will be included in the retained records:

- Name of shipper;
- Estimated quantity of radioactive material per item, including high-level radioactive waste;
- Item identification and seal number;
- Storage or emplacement location;
- On-site movement of each fuel assembly or storage canister; and

- Ultimate disposal.

Determine that a physical inventory of spent nuclear fuel and high-level radioactive waste in storage will be made at intervals not to exceed 12 months (unless directed otherwise by the U.S. Nuclear Regulatory Commission). The license application should include a commitment to retain a copy of the current inventory until the U.S. Nuclear Regulatory Commission terminates the license.

Verify that policies, practices, and procedures are designed and implemented to ensure the quality of physical inventories, and the control and maintenance of records and documentation associated with the physical inventories. A copy of the current inventory should be maintained until the U.S. Nuclear Regulatory Commission terminates the license.

Confirm that written material control and accounting procedures, sufficient for the U.S. Department of Energy to account for the material in storage, will be established, maintained, and followed. The license application should include a commitment to retain a copy of the current material control and accounting procedures until the U.S. Nuclear Regulatory Commission terminates the license.

Verify that checks and balances in the material control and accounting system ensure that falsification of data and reports that could conceal a diversion of high-level radioactive waste by employees acting individually, or in collusion, will be readily detected.

Determine that records of spent nuclear fuel or high-level radioactive waste in storage will be in duplicate. Duplicate sets of records should be at separate locations, so a single event will not destroy both sets. The license application should include a commitment to preserve records of spent nuclear fuel or high-level radioactive waste transferred out of the geologic repository operations area for a minimum of 5 years after transfer.

Review Method 2 Reports of Accidental Criticality or Loss of Special Nuclear Material

Verify that any loss is considered and incorporated in a collusion protection program designed to thwart attempts from an insider to divert special nuclear material.

Verify that procedures ensure that anomalies (off-normal or abnormal situations), suggesting a likelihood that a significant quantity of special nuclear material may be missing (whether or not the cause is assumed deliberate), are promptly and accurately reported to the U.S. Nuclear Regulatory Commission.

Ensure that the anomaly reporting system is able to respond promptly to alarms indicating potential loss of special nuclear material and discrimination of actual loss or system error is readily determined. Verify appropriate remedial action is planned, verified, and reported after alarms are tripped.

Confirm adequate procedures for reporting accidental criticality or loss of special nuclear material to the U.S. Nuclear Regulatory Commission Operations Center, using the Emergency Notification System. If this system is inoperable, commercial telephone, other dedicated

telephonic service, or any means that assures the U.S. Nuclear Regulatory Commission receipt of the report may be used. Reports should be made within one hour of the discovery of accidental criticality or any loss of special nuclear material.

Review Method 3 Procedures for Preparation of Material Status Reports

Determine whether procedures that require a material status report will be completed, in computer-readable format, and submitted to the U.S. Nuclear Regulatory Commission in accordance with instructions in NUREG/BR–0007 (U.S. Nuclear Regulatory Commission, 2000a) and Nuclear Materials Management and Safeguards Report D–24, "Personal Computer Data Input for U.S. Nuclear Regulatory Commission Licensees" (U.S. Nuclear Regulatory Commission, 1994). Information on special nuclear material contained in the spent nuclear fuel possessed, received, transferred, disposed of, or lost by the licensee should be reported. Confirm procedures require material status reports as of March 31 and September 30 of each year, to be filed within 30 days after the end of the period covered by the report, unless otherwise specified by the U.S. Nuclear Regulatory Commission or by 10 CFR 75.35, pertaining to implementation of the United States/International Atomic Energy Agency Safeguards Agreement.

Review Method 4 Procedures for Preparation of Nuclear Material Transfer Reports

Determine that the U.S. Department of Energy establishes auditable records sufficient to demonstrate reporting requirements have been met. Verify procedures specify forms of records and adequate safeguards to ensure the integrity of records. Verify procedures require that whenever spent nuclear fuel is transferred or received, a Nuclear Material Transaction Report will be completed, in computer-readable format, in accordance with instructions in NUREG/BR–0006 (U.S. Nuclear Regulatory Commission, 2000b) and Nuclear Materials Management and Safeguards System Report D–24, "Personal Computer Data Input for U.S. Nuclear Regulatory Commission Licensees" (U.S. Nuclear Regulatory Commission, 1994), as required by 10 CFR 72.78.

3.4.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.78, relating to the material control and accounting program achieving the system capabilities stipulated by 10 CFR 72.72, 72.74, 72.76, and 72.78.

Acceptance Criterion 1 Material Balance, Inventory, and Record-Keeping Procedures for Spent Nuclear Fuel and High-Level Radioactive Waste Are Adequate.

- The material control and accounting plan establishes the basis for identifying, controlling, and accounting for the nuclear materials that the U.S. Department of Energy will be authorized to possess;

- Records adequately document the receipt, inventory (including location), disposal, acquisition, and transfer of spent nuclear fuel and high-level radioactive waste, including

provision to maintain inventory during any retrieval operations. Adequate information on the waste form, proposed waste package, characteristics of any encapsulation material, radionuclide characteristics, heat generation rate, and history is provided. The procedures require that records be maintained for as long as the material is stored and for 5 years after the repository is closed. The information in the retained records will include:

— Name of shipper;

— Estimated quantity of radioactive material per item, including high-level radioactive waste;

— Item identification and seal number;

— Storage or emplacement location;

— On-site movement of each fuel assembly or storage canister; and

— Ultimate disposal.

- A physical inventory of spent nuclear fuel and high-level radioactive waste in storage will be made at intervals not to exceed 12 months (unless directed otherwise by the U.S. Nuclear Regulatory Commission);

- Adequate policies, practices, and procedures are designed and implemented to ensure the quality of physical inventories, and the control and maintenance of records and documentation associated with the physical inventories. A copy of the current inventory will be retained until the U.S. Nuclear Regulatory Commission terminates the license;

- Written material control and accounting procedures sufficient for the U.S. Department of Energy to account for the material in storage are established, maintained, and followed. A copy of the current material control and accounting procedures will be retained until the U.S. Nuclear Regulatory Commission terminates the license;

- The material control and accounting system incorporates checks and balances sufficient to detect falsification of data and reports that could conceal a possible diversion of high-level radioactive waste by employees acting individually or in collusion; and

- Records of spent nuclear fuel or high-level radioactive waste in storage are in duplicate. Duplicate sets of records are kept at separate locations, so a single event will not destroy both sets. Records of spent nuclear fuel or high-level radioactive waste transferred out of the facility will be preserved for a minimum of 5 years after transfer.

Acceptance Criterion 2 Procedures Are Adequate to Ensure Timely Reports of Accidental Criticality or Loss of Special Nuclear Material.

- The U.S. Department of Energy will have an adequate collusion protection program to thwart attempts from an insider to divert special nuclear material;

- The U.S. Department of Energy will report to the U.S. Nuclear Regulatory Commission any anomalies (off-normal or abnormal conditions or situations) suggesting a likelihood that a significant quantity of special nuclear material may be missing (whether or not the cause is deliberate);

- The U.S. Department of Energy anomaly reporting system is able to respond promptly to alarms indicating a potential loss of special nuclear material, and allows determination of whether the unusual observable condition is caused by an actual loss or by a system error. The reporting procedure and resolution program will identify the type of system error or innocent cause, so remedial action can be taken. The response will be timely to ensure that indicators that might result from diversion, loss or other misuse, are investigated and resolved promptly; and

- Procedures for reporting accidental criticality or loss of special nuclear material to the U.S. Nuclear Regulatory Commission Operations Center, using the Emergency Notification System, are adequate. If this system is inoperable, commercial telephone, other dedicated telephonic service, or any means that assures the U.S. Nuclear Regulatory Commission receipt of the report may be used. Reports should be made within 1 hour of the discovery of accidental criticality or any loss of special nuclear material.

Acceptance Criterion 3 Procedures for Preparation of Material Status Reports Are Adequate.

- Procedures require that a material status report be completed, in computer-readable format, and submitted to the U.S. Nuclear Regulatory Commission, in accordance with instructions in NUREG/BR–0007 (U.S. Nuclear Regulatory Commission, 2000a) and Nuclear Materials Management and Safeguards System Report D–24, "Personal Computer Data Input for U.S. Nuclear Regulatory Commission Licensees" (U.S. Nuclear Regulatory Commission, 1994). Information on the amount of spent nuclear fuel possessed, received, transferred, disposed of, or lost by the licensee will be reported. Procedures require material status reports as of March 31 and September 30 of each year, to be filed within 30 days after the end of the period covered by the report, unless otherwise specified by the U.S. Nuclear Regulatory Commission or by 10 CFR 75.35, pertaining to implementation of the United States/International Atomic Energy Agency Safeguards Agreement.

Acceptance Criterion 4 Procedures for Preparation of Nuclear Material Transfer Reports Are Adequate.

- The U.S. Department of Energy will establish auditable records sufficient to demonstrate that reporting requirements have been met. In addition, each record pertaining to receipt and disposal of spent nuclear fuel will be retained until the Commission terminates the license;
- The procedures specify in what form those records will be kept;
- The procedures provide adequate safeguards against tampering with and loss of records; and
- Procedures require that whenever spent nuclear fuel is transferred or received, a Nuclear Material Transaction Report is completed, in computer-readable format, in accordance with instructions in NUREG/BR–0006 (U.S. Nuclear Regulatory Commission, 2000b) and Nuclear Materials Management and Safeguards System Report D–24, "Personal Computer Data Input for U.S. Nuclear Regulatory Commission Licensees" (U.S. Nuclear Regulatory Commission, 1994), as required by 10 CFR 72.78.

3.4.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 3.4.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.78. The U.S. Department of Energy has established a material control and accounting program that meets the requirements of 10 CFR 72.72, 72.74, 72.76, and 72.78.

3.4.5 References

U.S. Nuclear Regulatory Commission. NUREG/BR–0006, "Instructions for Completing Nuclear Material Transfer Reports." Revision 4. Washington, DC: U.S. Nuclear Regulatory Commission. February 2000a.

———. NUREG/BR–0007, "Instructions for the Preparation and Distribution of Material Status Reports." Revision 3. Washington, DC: U.S. Nuclear Regulatory Commission. February 2000b.

———. "Personal Computer Data Input for U.S. Nuclear Regulatory Commission Licensees." Nuclear Materials Management and Safeguards System Report D–24. Washington, DC: U.S. Nuclear Regulatory Commission. May 1994.

3.5 Description of Site Characterization Work

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

3.5.1 Areas of Review

This section reviews the description of site characterization work performed at Yucca Mountain, and its results, that support the technical discussions and descriptions found elsewhere in the Safety Analysis Report. The reviewers will evaluate the information required by 10 CFR 63.21(b)(5).

The level of detail presented in this section of the license application should be similar to that in an executive summary. The material to be reviewed is informational in nature, with the more detailed technical discussions and descriptions found elsewhere in the Safety Analysis Report section of the license application. Therefore, no detailed technical analysis of the information contained in this section of the Yucca Mountain Review Plan is required. The detailed review of the information covered by these other technical subjects will be conducted using other sections of the Yucca Mountain Review Plan.

The staff will review the following parts of the description of site characterization work, using the review methods and acceptance criteria in Sections 3.5.2 and 3.5.3.

- Geology;
- Hydrology;
- Geochemistry;
- Geotechnical properties and conditions of the host rock;
- Climatology, meteorology, and other environmental sciences;
- Reference biosphere definition; and
- Rationale/strategy for site characterization activities.

Because the information contained in this section of the Yucca Mountain Review Plan is generally informational in nature and may not concern performance-related issues, some of the review methods may generally not be risk-informed, performance-based. In instances such as these, there are no performance measures against which the review methods can be compared.

3.5.2 Review Methods

Review Method 1 Description of Site Characterization Activities

Confirm that site characterization has been described in the "General Information" section of the license application. This general description, at a minimum, should include site-specific information in the following areas:

- Geology;
- Hydrology;
- Geochemistry;
- Geotechnical properties and conditions of the host rock;
- Climatology, meteorology, and other environmental sciences; and
- Reference biosphere definition.

For each of the aforementioned areas, the U.S. Department of Energy should identify how the information was provided (i.e., whether it was obtained from the published technical literature, derived from site characterization investigations specific to the Yucca Mountain site, or formally/informally elicited from knowledgeable subject matter experts). Place particular emphasis on information elicited to condition the preclosure safety analysis and the total system performance assessment.

Verify that the U.S. Department of Energy has provided an adequate rationale/strategy that explains how its site characterization activities met specific information needs in the requisite technical evaluations found elsewhere in the Safety Analysis Report.

Review Method 2 Summary of Site Characterization Results

Confirm that the results of site characterization activities have been described in the "General Information" section of the license application. An acceptable summary description should include areas such as:

- An overview of geology, consistent with other site characterization summaries, that includes:
  - A description of the physical setting of the site, including the major physiographic and geographic features;
  - A description of the principal rock units, at the surface and in the subsurface, and their stratigraphic relationships;

- A description, and location of potentially important stratigraphic and structural features (such as faults, fractures, and joint sets and systems);
- A description of geotechnical properties of stratigraphic units involved in the operation and performance of the proposed repository;
- The delineation of the proposed geologic system to be used in estimating the performance of the proposed repository;
- A summary of regional geomorphic, tectonic, seismic, and volcanic models (i.e., conceptual, technical basis, interpretation of data), with particular emphasis on those features, events, and processes that may have an effect on repository operations and performance;
- The identification of potential geologic hazards requiring complex engineering measures;
- A summary evaluation of seismic probability;
- A summary evaluation of volcanic probability;
- The extent to which there are alternative, credible conceptual models or system state descriptions; and
- The extent to which uncertainty in geologic data, models, or system states affects the compliance with performance objectives.

• An overview of hydrology consistent with other site characterization summaries that includes:

  - A description of hydrogeologic (aquifers and confining units) features, including those occurring at the receptor location, with emphasis on known or inferred hydrologic significance: this description should include information on hydraulic conductivity, transmissivity, porosities, permeability, and other important hydrogeologic parameters of the major hydrostratigraphic units, as appropriate;
  - An interpretation of the regional ground-water flow system, including a discussion of the major features and controls that effect local and regional ground-water supply: this information should identify modes of flow with respect to dominance by matrix flow, fracture flow, or an appropriate combination of the two modes, within the respective aquifers;
  - The delineation of the proposed hydrogeologic system (saturated and unsaturated) to be used in estimating the performance of the proposed repository;

- A description and discussion of local climate, including precipitation, temperature, and surface runoff;
- A discussion of ground-water quality;
- A discussion of current water-use patterns, including ground-water withdrawals by aquifer source;
- An estimated water budget for the respective aquifer systems;
- The identification of surface hydrologic features, including impoundments and stream channels (either continuous or intermittent), or other geomorphic features, that could potentially affect geologic repository operations area operations and/or performance;
- A description of the Quaternary-age paleohydrologic conditions in the Yucca Mountain region;
- The identification and discussion of possible measures necessary to prevent future development of ground-water resources;
- The extent to which there are alternative, credible conceptual models or system state descriptions; and
- The extent to which uncertainty in geohydrologic data, models, or system states affects compliance with performance objectives.

• An overview of geochemistry consistent with other site characterization summaries that includes:

  - A delineation of the proposed geochemical environment (system) to be used in estimating the performance of the proposed repository;
  - Evaluation of ground water to determine characteristics such as water chemistry, radionuclide solubility, and radionuclide sorption capability, and other factors;
  - An evaluation of the host rock and other hydrogeologic units to determine such characteristics as radionuclide solubilities, radionuclide sorption capabilities, and other parameters significant to performance;
  - The results of other geochemical analyses (of rock matrix, fracture fillings, etc.) necessary to define the proposed geochemical environment;
  - A discussion of the results of thermal-mechanical-hydrologic-chemical modeling of the host rock and its immediate environs, to predict the evolution of the proposed geochemical environment;

- — A model of the anticipated geochemical environment under both ambient and proposed thermally perturbed conditions in the vicinity of emplaced waste packages, to predict the evolution of the proposed geochemical environment;

- — The extent to which there are alternative, credible conceptual models or system state descriptions; and

- — The extent to which uncertainty in geochemical data, models, or system states affects compliance with performance objectives.

- An overview of geotechnical properties and conditions consistent with other site characterization summaries that includes:

  - — A discussion of the results of site investigations necessary to characterize the engineering properties of the soils present at the site;

  - — A discussion of the results of site investigations necessary to characterize the engineering properties of the rock types present at the site, with particular emphasis on the host rock and its immediate environs necessary for the underground excavation of the geologic repository;

  - — A description of the types and kinds of geotechnical investigations conducted and the basis for the selection of the various design parameters, based on the investigations described;

  - — The statistical representativeness of the geotechnical data collected for parameters characterizing design conditions;

  - — A discussion and description of other site characterization work conducted, necessary to define the relevant geotechnical properties and anticipated response/performance of both surface and subsurface facilities;

  - — A discussion of the results of predictive thermal-mechanical-hydrologic-chemical modeling, of the host rock and its immediate environs, to describe the short-term and long-term thermal-mechanical-hydrologic-chemical response of the host rock and its immediate environs, from thermal loading by the emplacement of waste; and

  - — The extent to which uncertainty in geologic data, models, or system states affects decisions regarding the selection of key geotechnical design parameters, and investigations to characterize those parameters.

- An overview of climatological, meteorological, and other environmental information and data found in the U.S. Department of Energy Final Environmental Impact Statement (to be adopted by the U.S. Nuclear Regulatory Commission to the extent practicable). This overview should also include a description of paleoclimate features, events, and

processes as well as future changes likely to occur during the time frame of regulatory interest; and

- An overview of the reference biosphere. The biosphere pathways selected for dose assessments should be consistent with arid or semi-arid conditions found in a mid-latitude desert. In addition, inasmuch as the location and characteristics of the reasonably maximally exposed individual are already specified in the regulation, the U.S. Department of Energy need not repeat that information in this section of the license application. The detailed review of information on the characteristics of the reasonably maximally exposed individual is conducted using Section 4 ("Review Plan for Safety Analysis Report") of the Yucca Mountain Review Plan. The overview of the reference biosphere should be consistent with:

  — Present knowledge or theories of natural processes in and around the Yucca Mountain site, and

  — Present knowledge regarding the future geologic and climatic evolution in the Yucca Mountain region based on interpretation of the geologic/paleoclimatological record.

3.5.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.21(b)(5), relating to the description of site characterization work provided in the "General Information" section of the license application. (In general, the detailed technical review of this information will take place in Section 4 of the Yucca Mountain Review Plan.)

Acceptance Criterion 1 The "General Information" Contains an Adequate Description of the Yucca Mountain Site and its Environs. This Description Includes:

- An overview of the geology; hydrology; geochemistry; geotechnical properties and conditions of the host rock; climatology, meteorology, and other environmental sciences; and a reference biosphere definition;

- An understanding of current features and processes present in the Yucca Mountain region;

- An understanding of future features, events, and processes likely to be present in the Yucca Mountain region that could affect future repository performance; and

- A rationale/strategy that explains how site characterization activities support specific information needs in the technical evaluations found elsewhere in the Safety Analysis Report.

Acceptance Criterion 2 The "General Information" Contains an Adequate Summary of the Scientific Activities and Investigations Conducted at Yucca Mountain.

- The description permits the reviewer to trace the information and data presented to original/authoritative sources to confirm the accuracy, applicability, or appropriateness of the information and data. Sources such as the following were used:
  - Existing technical literature;
  - Previous and current site characterization investigations specific to Yucca Mountain, the Nevada Test Site, or its environs; and
  - Formally/informally elicited information from knowledgeable subject matter experts.

Acceptance Criterion 3 In Describing the Yucca Mountain Site and its Environs, the "General Information" Addresses Limitations That Would Qualify the Descriptions.

- Uncertainty in the data and/or models supporting the description;
- The potential for alternative, credible conceptual models or system states to be used and the rationale for selection of the preferred model or system description;
- Features and processes that may exist, but not be detected;
- Additional site characterization work necessary to increase basic scientific understanding of any significant feature, event and process;
- Areas for which performance confirmation work may be necessary to confirm technical assumptions related to siting, design, and performance; and
- The descriptions found in the "General Information" address the statistical representativeness of the data collected for parameters characterizing features, events, and processes.

Acceptance Criterion 4 The "General Information" Contains an Adequate Description of the Reference Biosphere and the Reasonably Maximally Exposed Individual.

- Consistent with present knowledge of natural processes in and around the Yucca Mountain site, including the reasonably maximally exposed individual location; and
- Consistent with present knowledge regarding the future geologic and climatic evolution in the Yucca Mountain region, including the reasonably maximally exposed individual location, based on interpretation of the geologic/paleoclimatological record.

3.5.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 3.5.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the general information and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.21(b)(5). There is an adequate summary description of the work done to characterize the Yucca Mountain site, and a summary of the results from that work, to allow staff to evaluate if the overall sufficiency of the program has been provided.

3.5.5 References

None.

4 REVIEW PLAN FOR SAFETY ANALYSIS REPORT

Dose Projections: Determination of compliance with the preclosure and postclosure dose limits involves the use of computer programs for estimating potential exposures. The regulations specify a total effective dose equivalent as the measure to be used in estimating the dose. The staff should use the sum of the committed effective dose equivalent from internal doses resulting from one year's exposure to radioactive materials, and the effective dose equivalent from external radiation exposure during the year to calculate potential exposures. Additionally, the staff should use organ weighting factors, from Federal Guidance Report 12 and International Commission on Radiological Protection in its Publication 26, for external dose calculations. (Note: The Statement of Considerations to 10 CFR Part 63 describe the method to be used for calculating the total effective dose equivalent.)

Occupational Dose Monitoring: Actual exposures to radiation workers at the site will be measured to assure compliance with 10 CFR Part 20 requirements.

4.1 Repository Safety Before Permanent Closure

4.1.1 Preclosure Safety Analysis

Risk-Informed Review Process for Preclosure Safety Analysis—This section provides for review of compliance with the performance objectives in 10 CFR Part 63, which are based on permissible levels of doses to workers and the public, established on the basis of acceptable levels of risk. 10 CFR 63.21(c)(5) requires a preclosure safety analysis of the geologic repository operations area for the period before permanent closure, to ensure compliance with the performance objectives. Preclosure safety analysis is a systematic examination of the site; the design; the potential hazards, and initiating events and their consequences; and the potential dose consequences to workers and the public. Preclosure safety analysis considers the probability of potential hazards, taking into account the range of uncertainty associated with the data that support the probability calculations. Event sequences are defined, and these sequences of human-induced and natural events are used as inputs to calculate consequences of potential failures of structures, systems, and components, in terms of doses to workers and the public. These calculated doses are compared to allowable doses in establishing compliance with performance objectives. The structures, systems, and components that must be functional to comply with the performance objective dose limits are identified as structures, systems, and components important to safety. Preclosure safety analysis also identifies and describes the controls that are relied on to prevent potential event sequences from occurring or to mitigate their consequences, and identifies measures taken to ensure the availability of the safety systems. The end products of the preclosure safety analysis are a list of structures, systems, and components important to safety (also known as the Q-List) and the associated design criteria and technical specifications necessary to keep them functional and to meet the performance objectives. The structures, systems, and components important to safety may also be further categorized, based on relative safety significance, using risk information from the preclosure safety analysis. This distinction may be used to focus on the level of design details to be provided in the license application and the application of quality assurance controls through a graded quality assurance program. The U.S. Department of Energy plans on categorizing structures, systems, and components based on safety/risk-significance and implementing a graded quality assurance program commensurate with safety significance.

Accordingly, the Yucca Mountain Review Plan has included appropriate criteria to evaluate the U.S. Department of Energy technical basis for categorizing structures, systems, and components and grading quality assurance requirements.

The staff review is focused on items that the preclosure safety analysis has determined to be important to safety. The rigor of review for the design items on the Q-List, and the level of attention to detail depend on relative safety significance. No prescriptive design criteria are imposed in the Yucca Mountain Review Plan, because 10 CFR Part 63 allows the U.S. Department of Energy to develop the design criteria and demonstrate their appropriateness. Thus, the U.S. Department of Energy has flexibility to use any codes, standards, and methodologies it demonstrates to be applicable and appropriate. The performance-based review process in the Yucca Mountain Review Plan focuses on determining compliance with performance objectives as demonstrated by the U.S. Department of Energy preclosure safety analysis. In summary, the review philosophy is based on the following premises: (i) the U.S. Department of Energy must demonstrate, through its preclosure safety analysis, that the repository will be designed, constructed, and operated to meet the specified exposure limits (performance objectives) throughout the preclosure period; (ii) the staff must focus the review on the design of the structures, systems, and components important to safety in the context of the design's ability to meet the performance objectives; and finally, (iii) the staff resources will be focused proportionately on the inspection and review of high-risk significant structures, systems, and components important to safety.

4.1.1.1 Site Description as it Pertains to Preclosure Safety Analysis

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.1.1 Areas of Review

This section provides guidance on the review of site description, as it pertains to preclosure safety analysis and geologic repository operations area design. The reviewers will also evaluate the information required by 10 CFR 63.21(c)(1)(i)–(iii).

The adequacy of the site description should be assessed in the context of the information required to conduct the preclosure safety analysis and geologic repository operations area design. The reviewers of this section should coordinate their reviews with the reviewers of Sections 4.1.1.3 ("Identification of Hazards and Initiating Events") and 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls) of the Yucca Mountain Review Plan.

The staff will evaluate the following parts of the site description, as they pertain to preclosure safety analysis and geologic repository operations area design, using the review methods and acceptance criteria in Sections 4.1.1.1.2 and 4.1.1.1.3.

- Site geography;
- Regional demography;

- Local meteorology and regional climatology;
- Regional and local surface and ground-water hydrology;
- Site geology and seismology, including geoengineering properties that are relevant to design of surface and subsurface facilities;
- Igneous activity;
- Site geomorphology; and
- Site geochemistry.

4.1.1.1.2 Review Methods

Review Method 1 Description of Site Geography

Verify that the site location is adequately defined and is specified relative to prominent natural and man-made features, such as mountains, streams, military bases, civilian and military airports, population centers, roads, railroads, transmission lines, wetlands, surface water bodies, and potentially hazardous commercial operations and manufacturing centers, that may be significant for the review of the preclosure safety analysis and geologic repository operations area design.

Confirm that the characteristics of natural and man-made features, within the restricted area of the site, that may be significant for evaluation of the preclosure safety analysis and geologic repository operations area design, have been acceptably defined.

Ascertain that maps of the site and nearby facilities are included, and are of sufficient detail and of appropriate scale to provide information needed to review the preclosure safety analysis and geologic repository operations area design. A site map should clearly indicate the site boundary and the restricted area, restricted area access points, and distances from the boundary to significant features of the installation. Maps should describe the site topography and surface drainage patterns, as well as roads, railroads, transmission lines, wetlands, and surface-water bodies.

Review Method 2 Description of Regional Demography

Verify that regional demographic information is based on current census data, and presents the population distribution as a function of distance from the geologic repository operations area. The demographic information should be in sufficient detail to determine the location of real members of the public. The demographic information should be projected for the operational period.

Review Method 3 Description of Local Meteorology and Regional Climatology

Evaluate the adequacy of the license application data on local meteorology and regional climatology that may be significant for the review of the preclosure safety analysis and geologic repository operations area design, including items such as:

- Temperature extremes;
- Atmospheric stability;
- Average wind speeds and prevailing wind direction;
- Extreme winds; and
- Tornadoes.

Confirm that data collection techniques are based on accepted methods [e.g., those described in NUREG–0800 (U.S. Nuclear Regulatory Commission, 1987)], and that technical bases for data summaries are provided.

Assess the information provided on the annual amount and forms of precipitation, and the probable maximum precipitation at the site. Confirm that acceptable methods were used to develop this information.

Confirm that the license application adequately defines the type, frequency, magnitude, and duration of severe weather, such as tornados, lightning, and storms; and assess the validity of the design bases/criteria provided for the severe weather assessment.

Determine whether the U.S. Department of Energy conducted appropriate trending analyses supported by sufficient historical data.

Review Method 4 Description of Regional and Local Surface and Ground-Water Hydrology

Evaluate the description of the Yucca Mountain surface and ground-water hydrology, to ensure that hydrologic features relevant to the preclosure safety analysis and geologic repository operations area design are adequately identified, such as:

- Stream locations;
- Natural drainage features;
- Flooding potential;
- Perched water;
- River or stream control structures; and

- Depth of aquifers beneath the site, and their recharge and discharge features.

Verify that the analyses of the effects of any proposed changes to natural drainage features on geologic repository operations area design are acceptable. To make this determination, coordinate with the reviewer of Section 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls") of the Yucca Mountain Review Plan.

Ensure the calculation of probable maximum flood is supported by sufficient data, including actual storm data for the drainage basin. Section 2.4.3 of NUREG–0800 (U.S. Nuclear Regulatory Commission, 1987) may be used to conduct this review.

Review Method 5 Descriptions of Site Geology and Seismology

Verify that the U.S. Department of Energy has provided sufficient data on the geology of the site to support the preclosure safety analysis and geologic repository operations area design, including the stratigraphy and lithology for the entire surface and subsurface construction area. To make this determination, coordinate with the reviewers of Section 4.2.1.3 ("Model Abstraction") of the Yucca Mountain Review Plan.

Confirm that site characterization data include geomechanical properties and conditions of host rock, based on *in situ* and laboratory test results for the rock formations, where major construction activities will take place. Collection and processing of these data should be based on accepted industry techniques and standards. These rock property data should include parameters such as:

- Elastic properties and uniaxial compressive and tensile strength of intact rock;
- Triaxial compressive strength and triaxial test data of intact rock;
- Thermal conductivity, thermal expansion coefficient, and specific heat;
- Strata porosity, and permeability;
- Lithophysae characteristics and distribution;
- Jointing characteristics, including joint mechanical properties;
- Rock-mass classification;
- Rock-mass properties relevant to the design of geologic repository operations area facilities;
- *In situ* stresses; and
- Backfill characteristics.

Verify that rock mechanics testing data support the license application analyses of the stability of subsurface materials. Note that evaluation of the sufficiency of data and appropriateness of design parameters will be conducted using the appropriate subsection of Section 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls") of the Yucca Mountain Review Plan.

Confirm that the engineering properties provided for soils in the areas where surface facilities will be constructed are based on laboratory and *in situ* test results. Verify that the U.S. Department of Energy collected and processed these data, using accepted industry techniques. The soil properties should include parameters such as:

- Soil classification;
- Particle size distribution, Atterberg limits, and water content;
- Drained and undrained shear strength;
- Allowable bearing capacities;
- Blow counts for standard penetration tests; and
- Shear wave velocity.

Confirm that detailed soil testing data support the license application analyses of the stability of surface materials, considering surface subsidence, previous loading histories, and liquefaction potential.

Consult with the reviewers of Section 4.2.1.3.2.3 ("Acceptance Criteria—Mechanical Disruption of Engineered Barriers") of the Yucca Mountain Review Plan, to ensure the vibratory ground motion and surface and subsurface fault displacements of the site have been adequately characterized. This assessment should include a list of capable faults, areal seismic source zones, earthquake parameters such as maximum magnitude and recurrence for each source, historical earthquake data, paleoseismic data, and ground motion attenuation models. Topical Report YMP/TR–002–NP: Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain, Revision 1, August 1997 (U.S. Department of Energy, 1997) presents an acceptable method.

Determine that conversion of the characterized vibratory ground motion and surface and subsurface fault displacements of the site to engineering design parameters uses acceptable methods.

Evaluate the analyses of the static and dynamic stability of facility foundations, subsurface emplacement drifts, and natural and man-made slopes (both cut and fill), the failure of which could lead to radiological release. Ensure that appropriate methods are used for the analyses, data used are appropriate for the methods, and results are properly interpreted.

Review Method 6 Site Igneous Activity Information

Consult with the reviewer of Section 4.2.1.2 ("Scenario Analysis and Event Probability") of the Yucca Mountain Review Plan to ensure the license application adequately considers igneous activity at the site, including volcanic eruption, subsurface magmatic activity/flow, and volcanic ash flow/ash fall.

Review Method 7 Site Geomorphology Information

Evaluate the analysis of site geomorphology [using guidance such as NUREG/CR–3276 (Schumm and Chorley, 1983) and "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites" (U.S. Nuclear Regulatory Commission, 1989), as appropriate]. Assess the extent of erosion of the land surface and the likelihood that extreme erosion, such as landslides, rock avalanches, other mass wasting, and rapid fluvial degradation in channels or interfluves, might affect site structures or operations.

Review Method 8 Site Geochemical Information

Evaluate the description of the geochemical information at Yucca Mountain that is relevant to the preclosure safety analysis and geologic repository operations area design, to ensure that it is adequate, including items such as:

- Geochemical composition of any subsurface water held within the rock matrix or perched water zones, or episodically flowing through fractures to determine corrosivity;
- Geochemical composition of rock strata within and above the repository horizon to identify minerals that might leach and increase the corrosivity of water flowing through the strata; and
- Any geochemical alterations to the rock fractures and rock matrix through heating or other processes that might significantly alter geomechanical rock mass properties.

4.1.1.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.112(c) relating to the site description as it pertains to the preclosure safety analysis.

Acceptance Criterion 1 The License Application Contains a Description of the Site Geography Adequate to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The site location is adequately defined. The site location is specified relative to prominent natural and man-made features, such as mountains, streams, military bases, civilian and military airports, population centers, and potentially hazardous commercial operations and manufacturing centers, that may be significant for the review of the preclosure safety analysis and geologic repository operations area design;

- The characteristics of natural and man-made features, within the restricted area of the site, that may be significant for evaluation of the preclosure safety analysis and geologic repository operations area design, are adequately defined; and

- Maps of the site and nearby facilities are included, and are of sufficient detail and of appropriate scale to provide information needed to review the preclosure safety analysis and geologic repository operations area design. A site map clearly indicates the site boundary and the restricted area, restricted area access points, and distances from the boundary to significant features of the installation. Maps describe the site topography and surface drainage patterns, as well as roads, railroads, transmission lines, wetlands, and surface water bodies.

Acceptance Criterion 2 The License Application Contains a Description of the Regional Demography Adequate to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- Regional demographic information is based on current census data and presents the population distribution as a function of distance from the geologic repository operations area.

Acceptance Criterion 3 The License Application Contains a Description of the Local Meteorology and Regional Climatology Adequate to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application data on local meteorology and regional climatology, that may be significant for the review of the preclosure safety analysis and geologic repository operations area design, are adequate;

- The data collection techniques are based on accepted methods, and the technical bases for data summaries are provided;

- Adequate information is provided on the annual amount and forms of precipitation, and the probable maximum precipitation at the site. Acceptable methods are used to develop this information;

- The license application adequately defines the type, frequency, magnitude, and duration of severe weather. Valid design bases/criteria are provided for the severe weather assessment; and

- Trending analyses are appropriately conducted and supported by sufficient historical data presented in the license application.

Acceptance Criterion 4 The License Application Contains Sufficient Local and Regional Hydrological Information to Support Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The description of the Yucca Mountain surface and ground-water hydrology, adequately identifies hydrologic features relevant to the preclosure safety analysis and geologic repository operations area design;
- The analyses of the effects of any proposed changes to natural drainage features on geologic repository operations area design are acceptable; and
- The calculation of probable maximum flood is supported by sufficient data, including actual storm data for the drainage basin.

Acceptance Criterion 5 The License Application Contains Descriptions of the Site Geology and Seismology Adequate to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application provides sufficient data on the geology of the site to support the preclosure safety analysis and geologic repository operations area design, including the stratigraphy and lithology for the entire surface and subsurface construction area;
- Site characterization data adequately include rock mechanics properties based on *in situ* and laboratory test results for the rock formations where major construction activities will take place. Collection and processing of these data are based on accepted industry techniques;
- Rock mechanics testing data adequately support the license application analyses of the stability of subsurface materials;
- The engineering properties provided for soils in the areas where surface facilities will be constructed are based on laboratory and *in situ* test results. These data are collected and processed using accepted industry techniques;
- Detailed soil testing data support the license application analyses of the stability of surface materials, considering surface subsidence, previous loading histories, and liquefaction potential;
- The vibratory ground motion and surface and subsurface fault displacements of the site are adequately characterized, taking into account the assessment in Section 4.2.1.3.2.3 ("Mechanical Disruption of Engineered Barriers") of the Yucca Mountain Review Plan and considering a list of capable faults, areal seismic source zones, earthquake parameters such as maximum magnitude and recurrence for each source, historical earthquake data, paleoseismic data, and ground motion attenuation models. Topical

report YMP/TR–002–NP (U.S. Department of Energy, 1997) presents an acceptable methodology for vibratory ground motion and fault displacement hazards;

- Acceptable methods are used to develop seismic design data using the characterized vibratory ground motion and surface and subsurface fault displacement; and

- The license application provides adequate analyses of the stability of the facility foundations, subsurface emplacement drifts, and natural and man-made slopes (both cut and fill), the failure of which could result in radiological release. Appropriate methods are used for the analyses, data used are appropriate for the methods, and results are properly interpreted.

Acceptance Criterion 6 The License Application Contains Descriptions of the Historical Regional Igneous Activity Adequate to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application adequately considers igneous activity at the site, including volcanic eruption, subsurface magmatic activity/flow, and volcanic ash flow/ash fall.

Acceptance Criterion 7 The License Application Provides Analysis of Site Geomorphology Adequate to Permit Evaluation of the Preclosure Safety Analysis and Geologic Repository Operations Area Design.

- The license application adequately considers the extent of erosion of the land surface and the likelihood that extreme erosion, such as landslides, rock avalanches, other mass wasting, and rapid fluvial degradation in channels or interfluves, might affect site structures or operations.

Acceptance Criterion 8 The License Application Contains Site-Sufficient Geochemical Information to Support Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- Information on the geochemical composition of subsurface water held within the rock matrix or perched water zone, or from episodic flows through fractures, is sufficient to determine corrosivity;

- The geochemical composition of the rock strata, within and above the repository horizon, is adequately defined to identify minerals that might leach and add to the corrosivity of water flowing through the strata; and

- Potential geochemical alterations to the rock fractures and the rock matrix, through heating or other processes that might significantly alter geomechanical rock mass properties, are adequately characterized.

4.1.1.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.1.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.112(c). Requirements for conducting an adequate preclosure safety analysis and evaluation of geologic repository operations area design have been met in that adequate data from the Yucca Mountain site and the surrounding region have been provided to identify naturally occurring and human-induced hazards and geomechanical properties and conditions of the host rock.

4.1.1.1.5 References

U.S. Department of Energy. "Topical Report YMP/TR–002–NP: Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain, Revision 1." Washington, DC: U.S. Department of Energy. 1997.

U.S. Nuclear Regulatory Commission. "Standard Format and Content for Documentation of Remedial Action Selection at Title I Uranium Mill Tailings Sites." Washington, DC: U.S. Nuclear Regulatory Commission. 1989.

———. NUREG–0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants." LWR Edition. Washington, DC: U.S. Nuclear Regulatory Commission. 1987.

Schumm, S.A., and R.J. Chorley. NUREG/CR–3276, "Geomorphic Controls on the Management of Nuclear Waste." Washington, DC: U.S. Nuclear Regulatory Commission. 1983.

4.1.1.2 Description of Structures, Systems, Components, Equipment, and Operational Process Activities

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.2.1 Areas of Review

This section provides guidance on the review of the description of structures, systems, and components, equipment, and operational process activities. The reviewers will also evaluate the information required by 10 CFR 63.21(c)(2), (c)(3)(i), and (c)(4).

The description of structures, systems, and components, equipment, and operational process activities should be sufficient for the reviewer to understand the design of geologic repository operations area facilities, and to identify hazards and event sequences. The reviewers of this section should coordinate their reviews with the reviews under Sections 4.1.1.3 ("Identification of Hazards and Initiating Events") and 4.1.1.4 ("Identification of Event Sequences") of the Yucca Mountain Review Plan.

The staff will evaluate the following parts of the description of structures, systems, and components, equipment, and operational process activities, using the review methods and acceptance criteria in Sections 4.1.1.2.2 and 4.1.1.2.3.

- Descriptions of location of surface facilities and their functions, including structures, systems and components, and equipment;
- Descriptions of, and design details for, structures, systems, and components, equipment, and utility systems of surface facilities;
- Descriptions of, and design details for, structures, systems, and components, equipment, and utility systems of the subsurface facility;
- Description of high-level radioactive waste characteristics;
- Descriptions of engineered barrier system components (e.g., waste package, drip shield, and backfill); and
- Description of geologic repository operations area processes activities and procedures, including interfaces and interactions between structures, systems, and components.

4.1.1.2.2 Review Methods

Review Method 1 Description of Location of Surface Facilities and their Functions

Determine that the license application describes all surface facilities, including their locations and arrangements at the site, and their distances from the site boundary. This description should include drawings of sufficient detail and appropriate scale.

Verify that the description of the design of the surface facilities is adequate to permit an evaluation of the preclosure safety analysis.

Verify that descriptions of the functional requirements for all the facilities are sufficient to provide an understanding of geologic repository operations area operational activities, sequences, and locations, sufficient for evaluation of the preclosure safety analysis and geologic repository operations area design.

Verify that the license application has descriptions of the capabilities of the equipment, training of the operators, and testing/maintenance plans, sufficient for evaluation of the preclosure safety analysis. Make this verification in collaboration with the reviewers for Sections 4.5.3

("Training and Certification of Personnel") and 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan.

Review Method 2 Descriptions of, and Design Details for, Structures, Systems, and Components, and Equipment of Surface Facilities

Confirm the license application has provided adequate descriptions and design information for the structures, systems, and components, equipment, and the utility systems that support the structures, systems, and components of the surface facilities, such as:

- Design codes and standards employed;
- Building and facility structure floor plans and drawings;
- Materials of construction;
- Equipment layout;
- Process flow diagrams;
- Piping and instrumentation diagrams;
- Electrical systems;
- Pressure relief systems;
- Crane systems;
- Welding systems;
- Heating, ventilation, air conditioning, and filtration systems;
- Transportation systems;
- Confinement system;
- Decontamination system;
- Safety systems (e.g., interlocks, radiation detection, and fire suppression systems);
- Waste package and cask receipt, transfer, and handling systems;
- Loading and unloading systems (including remote operations);
- Emergency and radiological safety systems;

- Criticality and radiological monitoring systems;
- Criticality safety program;
- Communication and control systems;
- Power distribution systems, including any backup power supplies;
- Shielding and criticality control systems; and
- Water supply systems.

Focus on systems used for radiological waste handling, packaging, transfer, containment, or storage, and on any other structures, systems, and components important to safety. Identification of structures, systems, and components important to safety is reviewed using Section 4.1.1.6 ("Identification of Structures, Systems, and Components Important to Safety; Safety Controls; and Measures to Ensure Availability of the Safety Systems") of the Yucca Mountain Review Plan.

Confirm the license application has provided adequate descriptions of potential interactions among support systems and structures, systems, and components.
Verify the license application has provided adequate descriptions of the location and functional arrangement of the structures, systems, and components within each facility.

Confirm the license application has provided adequate discussion of design information about the capability of the surface facilities to withstand natural phenomena (e.g., seismic ground motions). The appropriateness and adequacy of the design will be reviewed using Section 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls") of the Yucca Mountain Review Plan.

Review Method 3 Descriptions of, and Design Details for, Structures, Systems, and Components, and Equipment of the Subsurface Facility

Confirm the license application has provided adequate descriptions and design information for the structures, systems, components, equipment, and utility systems that support the structures, systems, and components of the subsurface facility, such as:

- The layout of the subsurface facility in relation to any constraints imposed by natural conditions (geologic and hydrologic) and generic design goals (e.g., maximum rock temperature allowable);
- Ground control/support systems;
- Power distribution systems;
- Subsurface ventilation systems;

- Communication and inspection/monitoring systems;
- Transportation systems;
- Safety, detection, and suppression systems for fire and radiological emergencies;
- Waste package emplacement system;
- Emergency and radiological safety systems;
- Air seal systems to separate the waste emplacement area from the emplacement drift construction area;
- Waste package support/invert systems;
- Drip shield and drip shield placement systems;
- Backfill emplacement systems;
- Instrumentation and control systems; and
- Limits and interlocks.

Review Method 4 Description of Spent Nuclear Fuel and High-Level Radioactive Waste Characteristics

Verify that the license application has adequately characterized the ranges of parameters that describe the spent nuclear fuel, such as:

- Reactor type (e.g., boiling water, pressurized water);
- Cask type;
- Fuel assembly manufacturer, model designation, and number;
- Fuel assembly physical characteristics and dimensions;
- Fuel cladding material (including crud deposits, oxide layer, hydride content, and extent of failure and damage);
- Thermal characteristics;
- Heat generation rate and dose rate;
- Radionuclide inventory;
- Radiochemical characteristics; and

- History (enrichment, burnup, and postirradiation storage).

Confirm that the license application has adequately characterized properties of the high-level radioactive waste besides spent nuclear fuel, such as:

- Waste form composition and amount;
- Waste form characteristics (phase stability and product consistency);
- Canister and characteristics of any waste encapsulation;
- Radionuclide inventory;
- Radiochemistry;
- Heat generation rate and dose rate;
- Proposed storage unit of material; and
- History.

Review Method 5 Description of Engineered Barrier System and Its Components

Confirm that the principal characteristics of the waste package, including dimensions, weights, materials, fabrications, weldings, and results of nondestructive examination and inspection, have been provided.

Ensure that adequate discussion on analyses and characterization of functional features of the waste package and canister, such as containment, criticality control, shielding, drop fracture resistance, and confinement, has been provided.

Verify that the discussion of analyses and characterization of engineered barrier system components, such as drip shields, backfill (if used in the license application design), support/inverts, and sorption barrier, is sufficient for evaluation in the preclosure safety analysis and geologic repository operations area design review.

Review Method 6 Description of Geologic Repository Operations Area Operational Processes and Procedures

Evaluate the descriptions of operational processes and procedures to ensure that they provide an adequate understanding of the component and facility functions and sequences of activities.

Verify that information provided on operational process design, equipment design and specifications, and instrumentation and control systems is sufficient to assess the preclosure safety analysis.

The descriptions and information should include:

- Modes of operations, for example, normal process operations; maintenance;
- The purpose of each operational process and its relationship to overall geologic repository operations area operations;
- Basic operational process function and theory, including a discussion of the basic theory of operational processes and an adequate discussion of ranges and limits for measured variables used to ensure safe operation of processes;
- Diagrams or flow charts that demonstrate the interfaces and interactions of parts of the operational processes, such as schematics or descriptions showing the inventory, location, and geometry of nuclear materials, moderators, and other materials associated with processes;
- Procedures for the startup, shutdown, normal, and emergency operations;
- Hazardous material locations and quantities;
- Locations and types of interlocks and controls;
- Process block diagrams, including decontamination and monitoring;
- Safety equipment; control systems; and instrumentation locations, characteristics, and functions;
- Maximum intended inventories of radioactive materials; and
- Criticality safety program.

4.1.1.2.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 63.112(a), relating to the description of structures, systems, and components, equipment, and operational process activities.

Acceptance Criterion 1 The License Application Contains a Description of the Location of the Surface Facilities and Their Designated Functions Sufficient to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application has a description of surface facilities that includes their location and arrangement at the site and their distance from the site boundary. This description includes drawings of sufficient detail and appropriate scale;

- The description of the design of the surface facilities is sufficient to permit an evaluation of the preclosure safety analysis;

- The descriptions of the functional requirements for the facilities are adequate to provide an understanding of geologic repository operations area operational activities, sequences, and locations, sufficient for evaluation of the preclosure safety analysis and geologic repository operations area design; and

- The descriptions of the capabilities of the equipment, training of the operators, and testing/maintenance plan are sufficient for evaluation of the preclosure safety analysis.

Acceptance Criterion 2 The License Application Contains Descriptions and Design Details for Structures, Systems, and Components, and Equipment, of the Surface Facilities, Sufficient to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application provides adequate descriptions and design information for the structures, systems, and components, and equipment, of the surface facilities;

- The license application provides adequate discussion on potential interactions among support systems and structures, systems, and components.

- The license application provides adequate descriptions of the location and functional arrangement of the structures, systems, and components within each facility; and

- The license application provides adequate discussion of design information, regarding the capability of the surface facilities to withstand the effects of natural phenomena.

Acceptance Criterion 3 The License Application Contains Descriptions and Design Details for Structures, Systems, and Components, and Equipment of the Subsurface Facility, Sufficient to Permit Evaluation of the Preclosure Safety Analysis and the Geologic Repository Operations Area Design.

- The license application provides adequate descriptions and design information for the structures, systems, and components, and equipment, of the subsurface facility.

Acceptance Criterion 4 The License Application Describes the Characteristics of the Spent Nuclear Fuel and High-Level Radioactive Waste, Sufficiently to Permit Evaluation of the Preclosure Safety Analysis and the Waste Package Design.

- The license application adequately characterizes the ranges of parameters that describe the spent nuclear fuel; and

- The license application adequately characterizes the properties of the high-level radioactive waste besides spent nuclear fuel.

Acceptance Criterion 5 The License Application Provides a General Description of the Engineered Barrier System and Its Components, Sufficient to Support Evaluation of the Preclosure Safety Analysis and the Engineered Barrier System Design.

- The principal characteristics of the waste package, including dimensions, weights, materials, fabrications, and weldings, are defined;

- Adequate characterization of functional features of the waste package and canister, such as criticality control, shielding, drop fracture resistance, and confinement, is provided; and

- The discussion of analyses and characterization of engineered barrier system components, such as drip shields, backfill, support/inverts, and sorption barrier, is sufficient to support evaluations in the preclosure safety analysis and geologic repository operations area design reviews.

Acceptance Criterion 6 The Description of the Operational Processes to be Used at the Geologic Repository Operations Area is Sufficient for Review of the Preclosure Safety Analysis.

- Descriptions of geologic repository operations area operational processes provide an adequate understanding of the component and facility functions and sequences of activities; and

- Information provided on interfaces and interactions part of the operational process design, equipment design and specifications, and instrumentation and control systems, is sufficient to assess the preclosure safety analysis.

4.1.1.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.112(a) in that an adequate general description of the structures, systems, and components, equipment, and process activities of the geologic repository operations area, has been provided.

4.1.1.2.5 References

None.

4.1.1.3 Identification of Hazards and Initiating Events

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.3.1 Areas of Review

This section provides guidance on the review of the identification of hazards and initiating events. The reviewers of this section should coordinate their reviews with the reviewers of Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis") and 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(5).

The staff will evaluate the following parts of the identification of hazards and initiating events, using the review methods and acceptance criteria in Sections 4.1.1.3.2 and 4.1.1.3.3.

- Technical basis and assumptions for methods used for identification of hazards and initiating events;
- Use of relevant data for identification of hazards and initiating events;
- Determination of frequency or probability of occurrence of hazards and initiating events;
- Technical basis for inclusion or exclusion of specific hazards and initiating events; and
- List of hazards and initiating events to be considered in the preclosure safety analysis.

4.1.1.3.2 Review Methods

Review Method 1 Technical Basis and Assumptions for Methods Used for Identification of Hazards and Initiating Events

Confirm that methods used to identify hazards and initiating events are consistent with Agency guidance or standard industry practices [e.g., NUREG/CR–2300 (U.S. Nuclear Regulatory Commission, 1983a); NUREG–1513 (U.S. Nuclear Regulatory Commission, 2001); NUREG–1520 (U.S. Nuclear Regulatory Commission, 2000a); and the American Institute of Chemical Engineers (1992), Appendixes A and B]. If expert elicitation was used, review the expert elicitation process, using Section 4.5.4 ("Expert Elicitation") of the Yucca Mountain Review Plan.

If Agency guidance or standard industry practices are not used by the U.S. Department of Energy, evaluate whether the U.S. Department of Energy basis and justification for choosing a particular hazard and initiating event identification method are defensible.

Ensure that methods selected for hazard and initiating event identification are appropriate for the available data on the site and geologic repository operations area. Review descriptions of the site and its structures, systems, and components using Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety") and 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan.

Confirm that assumptions used to identify naturally occurring and human-induced hazards and initiating events are well-defined and have adequate technical basis, and are supported by information in Section 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis") and Section 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan.

Review Method 2 Use of Relevant Data for Identification of Site-Specific Hazards and Initiating Events

Verify that appropriate site-specific data (including frequency of occurrence, where relevant) have been used to identify naturally occurring and human-induced hazards and initiating event, such as:

- Seismicity and faulting;
- Winds and tornadoes;
- Volcanic activity;
- Slope instability;
- Other extreme meteorological or geological conditions; and
- Human-induced events.

Coordinate with the reviewer for Section 4.2 ("Repository Safety after Permanent Closure") of the Yucca Mountain Review Plan, to ensure that naturally occurring hazards (e.g., seismicity, faulting, and igneous activity) identified in this section are consistent with the list of features, events, and processes.

Verify that the appropriate properties and factors are considered in determining the adequacy of the hazard and initiating event identification, such as:

- Heat generation from the high-level radioactive waste;
- Flammable, corrosive, pressurized, and toxic materials;

- Conditions under which available fissionable material could pose a criticality hazard; and
- Potential interactions among hazardous materials and conditions.

Confirm that the identification of human-induced hazards encompasses relevant aspects of the geologic repository operations area radiological systems. In particular, consider the list of such systems evaluated, using Section 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan. Confirm that the identification of hazards encompasses all modes of operation. Modes of operation include normal process operations; maintenance (e.g., shutting down critical equipment); and backfilling operations (if included in the license application design) within waste emplacement drifts.

Consult with reviewers of Section 4.1.1.2.3 ("Acceptance Criteria—Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan, to ensure that system descriptions used to support hazard and initiating event identification are adequate.

Review Method 3 Determination of Frequency or Probability of Occurrence of Hazards and Initiating Events

Ensure that methods selected for determining probability or frequency of occurrence for hazards and initiating events are appropriate. Also, ensure that uncertainties associated with the frequency or probability estimates are quantified.

If Agency guidance or standard industry practices are not used by the U.S. Department of Energy, evaluate whether the U.S. Department of Energy basis and justification for choosing the method(s) used to determine the frequency or probability of occurrence of hazards and initiating events are defensible.

If relevant frequency or probability data are insufficient or not available, verify that appropriate bounding values are used, and defensible technical bases are provided. Also, evaluate the adequacy of the associated bounding calculations. If expert elicitation was used, review the expert elicitation process using Section 4.5.4 ("Expert Elicitation") of the Yucca Mountain Review Plan.

Consult with the reviewers of Section 4.2.1.2.1 ("Identification of Features, Events, and Processes Affecting Compliance with the Overall Performance Objectives") of the Yucca Mountain Review Plan, to ensure the validity of the frequencies and/or probabilities established for naturally occurring events. Also, assess the validity of the frequencies and/or probabilities established for human-induced hazards and initiating events.

Ensure that human errors that may lead to radiological consequences are adequately identified, and that adequate human reliability analyses are performed. Ensure that the U.S. Department of Energy provides an adequate technical basis for any human reliability method used, its range of applicability, and its assumptions and uncertainties. Guidance from documents such as NUREG–1278 (U.S. Nuclear Regulatory Commission, 1983b); NUREG–1624 (U.S. Nuclear

Regulatory Commission, 2000b); and NUREG–2300 (U.S. Nuclear Regulatory Commission, 1983a), can assist the review.

Review Method 4 Technical Basis for Inclusion or Exclusion of Specific Hazards and Initiating Events

Verify that adequate technical bases for the inclusion and exclusion of hazards and initiating events are provided.

Determine if technical bases are defensible and consistent with site and system information reviewed in Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis") and 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan.

Ensure that technical bases include consideration of uncertainties.

Review Method 5 List of Hazards and Initiating Events To Be Considered in the Preclosure Safety Analysis

Verify that the U.S. Department of Energy list of hazards and initiating events contains the credible natural and human-induced events.

Perform limited independent assessment to confirm that the list of hazards and initiating events that may result in radiological releases is acceptable.

4.1.1.3.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.112(b) and (d), relating to the identification of hazards and initiating events.

Acceptance Criterion 1 Technical Basis and Assumptions for Methods Used for Identification of Hazards and Initiating Events are Adequate.

- Methods used for hazard and initiating event identification are consistent with standard industry practices;
- If Agency guidance or standard industry practices are not used, the U.S. Department of Energy basis and justification for choosing particular hazard and initiating event identification method(s) are defensible;
- Methods selected for hazard and initiating event identification are appropriate for the available data on the site and geologic repository operations area; and
- Assumptions used to identify naturally occurring and human-induced hazards and initiating events are well-defined, have adequate technical basis, and are supported by information on the site and its structures, systems, components, equipment and operational processes.

Acceptance Criterion 2 Site Data and System Information are Appropriately Used in Identification of Hazards and Initiating Events.

- Appropriate site-specific data are used to identify naturally occurring hazards and initiating events;
- In determining the adequacy of the hazard and initiating event identification, the appropriate properties and factors are considered; and
- The identification of human-induced hazards encompasses relevant aspects of the geologic repository operations area radiological systems. The identification of hazards encompasses all geologic repository operations area modes of operation.

Acceptance Criterion 3 Determination of Frequency or Probability of Occurrence of Hazards and Initiating Events is Acceptable.

- Methods selected for determining probability or frequency of occurrence for hazards and initiating events are appropriate, and uncertainties are adequately quantified;
- An appropriate basis and justification are provided for any use of nonstandard practices for determining frequency or probability estimates;
- The frequencies and/or probabilities established for naturally occurring events and human-induced hazards and initiating events are valid; and
- Human errors that may lead to radiological consequences are adequately identified, and adequate human reliability analyses are performed.

Acceptance Criterion 4 Adequate Technical Bases for the Inclusion and Exclusion of Hazards and Initiating Events are Provided.

- The technical bases are defensible and consistent with site and system information; and
- The technical bases include adequate consideration of uncertainties, associated with frequency or probability of the hazards and initiating events.

Acceptance Criterion 5 The List of Hazards and Initiating Events That May Result in Radiological Releases is Acceptable.

- The U.S. Department of Energy list of hazards and initiating events contains the credible natural and human-induced events; and
- Independent assessment confirms that the list of hazards and initiating events that may result in radiological releases is acceptable.

4.1.1.3.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.3.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.112(b), related to identification of hazards and initiating events. The naturally occurring and human-induced hazards and potential initiating events have been adequately identified. The identification of the initiating events and the associated probabilities of occurrence are acceptable.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.112(d). An adequate technical basis for either inclusion or exclusion of specific naturally occurring or human-induced hazards and initiating events has been provided.

4.1.1.3.5 References

American Institute of Chemical Engineers. "Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples." New York, New York: American Institute of Chemical Engineers, Center for Chemical Process Safety. 1992.

U.S. Nuclear Regulatory Commission. NUREG–1513, "Integrated Safety Analysis Guidance Document." Washington, DC: U.S. Nuclear Regulatory Commission. 2001.

———. NUREG–1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility, Draft Report." Washington, DC: U.S. Nuclear Regulatory Commission. 2000a.

———. NUREG–1624, "Technical Basis and Implementation Guidelines for A Technique for Human Event Analysis (ATHEANA)." Revision 1. Washington, DC: U.S. Nuclear Regulatory Commission. 2000b.

———. NUREG/CR–2300, "PRA Procedures Guide–A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants." Washington, DC: U.S. Nuclear Regulatory Commission. 1983a.

———. NUREG–1278, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Application." Washington, DC: U.S. Nuclear Regulatory Commission. 1983b.

4.1.1.4 Identification of Event Sequences

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.4.1 Areas of Review

This section provides guidance on the review of the identification of event sequences considered in the preclosure safety analysis. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(5).

The staff will evaluate the following parts of the identification of event sequences, using the review methods and acceptance criteria in Sections 4.1.1.4.2 and 4.1.1.4.3.

- Technical bases for methods used and assumptions made for identification of event sequences, and
- Category 1 and 2 event sequences.

4.1.1.4.2 Review Methods

Review Method 1 Technical Basis and Assumptions for Methods Used for Identification of Event Sequences

Ensure that methods selected for event sequence identification are appropriate, and are consistent with standard practices [e.g., NUREG/CR–2300 (U.S. Nuclear Regulatory Commission, 1983); and American Institute of Chemical Engineers (1992), Appendixes A and B].

Confirm that methods selected are consistent with, and supported by, site-specific data.

Verify that assumptions made in identifying the event sequences are justified and valid.

Review Method 2 Categories 1 and 2 Event Sequences

Verify that the U.S. Department of Energy has properly considered the hazards and initiating events reviewed in Section 4.1.1.3 ("Identification of Hazards and Initiating Events") of the Yucca Mountain Review Plan. Confirm that the U.S. Department of Energy has appropriately applied the methods for identification of event sequences.

Ensure that the potentially relevant human factors reviewed using Section 4.1.1.3 ("Identification of Hazards and Initiating Events") of the Yucca Mountain Review Plan have been appropriately considered in event sequence identification. To the extent practical, NUREG–1624 ["Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA)"] (U.S. Nuclear Regulatory Commission, 2000a) can be used to assist the review.

Verify that the U.S. Department of Energy has considered reasonable combinations of initiating events and the associated event sequences that could lead to exposure of individuals to radiation.

Verify that Category 1 event sequences include those sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area.

Verify that Category 2 event sequences include those event sequences that have at least one chance in 10,000 of occurring before permanent closure. Confirm that the methods and technical bases for determining those event sequence probabilities are consistent with the applicable governing regulation, policy, and guidance, including appropriate portions of the following:

- NUREG–0800 Chapter 19, "Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision-Making: General Guidance (U.S. Nuclear Regulatory Commission, 1998);"
- NUREG–1513, "Integrated Safety Analysis Guidance Document." (Draft Report) (U.S. Nuclear Regulatory Commission, 2000b);
- NUREG–1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility." (Draft Report) (U.S. Nuclear Regulatory Commission, 2000c);
- NUREG/CR–2300, "PRA Procedures Guide–A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants." (U.S. Nuclear Regulatory Commission,1983); and
- Electric Power Research Institute (1995). EPRI TR–105396, "PSA Applications Guide."

Perform limited independent assessments as appropriate to confirm that possible event sequences that may lead to radiological releases have been adequately identified, and to verify that the U.S. Department of Energy analyses and calculations were performed properly.

4.1.1.4.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.112(b), relating to the identification of event sequences.

Acceptance Criterion 1 Adequate Technical Basis and Justification are Provided for the Methodology Used and Assumptions Made to Identify Preclosure Safety Analysis Event Sequences.

- Methods selected for event sequence identification are appropriate, and are consistent with Agency guidance or standard industry practices;
- The methods selected are consistent with, and supported by, site-specific data; and

- Assumptions made in identifying event sequences are valid and reasonable.

Acceptance Criterion 2 Categories 1 and 2 Event Sequences are Adequately Identified.

- The U.S. Department of Energy has adequately considered the relevant hazards and initiating events. Methods selected for identification of event sequences have been applied properly;

- The potentially relevant human factors are appropriately considered in the event sequence identification;

- The U.S. Department of Energy considers reasonable combinations of initiating events and the associated event sequences that could lead to exposure of individuals to radiation;

- Category 1 event sequences are identified on the basis that they will occur one or more times before permanent closure of the geologic repository operations area, and the technical methods used to determine the event sequences are acceptable;

- Category 2 event sequences include all those event sequences that have at least 1 chance in 10,000 of occurring during the preclosure period, and the technical methods used to determine the probabilities of occurrence are acceptable; and

- Limited independent assessments confirm that possible event sequences that may cause radiological releases are adequately identified, and related U.S. Department of Energy analyses and calculations are performed properly.

4.1.1.4.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.4.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy, in part, the requirements of 10 CFR 63.112(b). A reasonably comprehensive identification and analysis of potential event sequences has been provided.

4.1.1.4.5 References

American Institute of Chemical Engineers. "Guidelines for Hazard Evaluation Procedures, Second Edition with Worked Examples." New York, New York: American Institute of Chemical Engineers, Center for Chemical Process Safety. 1992.

Electric Power Research Institute. "PSA Applications Guide." EPRI TR–105396. Walnut Creek, California: Electric Power Research Institute. 1995.

U.S. Nuclear Regulatory Commission. NUREG–1624, "Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA)." Revision 1. Washington, DC: U.S. Nuclear Regulatory Commission. 2000a.

———. NUREG–1513, "Integrated Safety Analysis Guidance Document." Draft Report. Washington, DC: U.S. Nuclear Regulatory Commission. 2000b.

———. NUREG–1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility." Draft Report. Washington, DC: U.S. Nuclear Regulatory Commission. 2000c.

———. NUREG–0800, "Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision-Making: General Guidance." Chapter 19. Washington, DC: U.S. Nuclear Regulatory Commission. 1998

———. NUREG/CR–2300, "PRA Procedures Guide–A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants." Washington, DC: U.S. Nuclear Regulatory Commission. 1983.

4.1.1.5 Consequence Analyses

4.1.1.5.1 Consequence Analysis Methodology and Demonstration that the Design Meets 10 CFR Parts 20 and 63 Numerical Radiation Protection Requirements for Normal Operations and Category 1 Event Sequences

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.5.1.1 Areas of Review

This section provides guidance on the review of the consequence analysis methodology and demonstration that the design meets 10 CFR Parts 20 and 63 numerical radiation protection requirements for normal operations and Category 1 event sequences. The reviewers will also evaluate the information required by 10 CFR 63.21(c)(5).

The staff will evaluate the following parts of consequence analysis methodology and demonstration that the design meets 10 CFR Parts 20 and 63 numerical radiation protection requirements for normal operations and Category 1 event sequences, using the review methods and acceptance criteria in Sections 4.1.1.5.1.2 and 4.1.1.5.1.3.

- Consequence evaluations for normal operations and Category 1 event sequences;
- On-site and off-site doses during normal operations and Category 1 event sequences; and

- Compliance with performance objectives.

4.1.1.5.1.2 Review Methods

Review Method 1 Consequence Analyses of Normal Operations, Category 1 Event Sequences, and Factors that Allow an Event Sequence to Propagate within the Geologic Repository Operations Area

Ensure that the U.S. Department of Energy has conducted consequence analyses for normal operations and Category 1 event sequences, that were reviewed using Section 4.1.1.4 ("Identification of Event Sequences") of the Yucca Mountain Review Plan. Verify that consequence analyses consider the following:

- Hazard event sequences that could lead to radiological consequences (including the controls used to prevent or mitigate the event sequences);

- Interactions of identified hazards and proposed controls;

- Modes of geologic repository operations area operation, including normal process operations; maintenance (e.g, shutting down critical equipment); removal of damaged nuclear waste disposal containers from subsurface to surface facilities; and backfilling operations (if included in the license application design) within waste emplacement drifts. Analyses should assume that operations will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the license application; and

- Descriptions of event sequences for which consequences (radiation dose) will be determined, including information on the hazard, structures, systems, and components that take part in the event sequences, and controls relied on to prevent or mitigate the event sequences.

Review Method 2 Assessment of Calculations of Consequences to Workers and Members of the Public from Normal Operations and Category 1 Event Sequences

Evaluate methods used to perform the consequence (radiation dose) calculations. Verify that adequate technical bases for selecting these methods have been provided. Ensure that adequate technical bases have been provided for assumptions used for the calculations and methods. Confirm methods are consistent with site-specific data and system design and process information that were evaluated using Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis") and 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan.

Evaluate the identification of the member of the public likely to receive the highest dose from geologic repository operations area normal operations or Category 1 event sequences, and the rationale for this identification. Confirm that the dose to this individual bounds the annual dose to any real member of the public located beyond the site boundary.

Ensure that input data and information used for the consequence analyses are identified, and are consistent with site-specific data and system design and process information. Verify that adequate technical bases are provided for selection of this input data and information and that uncertainty in the input data is appropriately considered in the consequences analyses.

Evaluate the calculation of the source term, and confirm the following:

- Characteristics of the high-level radioactive waste used in the source term calculation (e.g., enrichment, burnup, and decay time) reasonably represent or bound the range of characteristics of waste that will be handled at the geologic repository operations area, as reviewed using Section 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan; and

- The type, quantity, and concentration of airborne radionuclides released during normal operations and Category 1 event sequences are supported by appropriate data, or are in accordance with appropriate U.S. Nuclear Regulatory Commission guidance documents, such as NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000).

Evaluate the calculations of on-site and off-site direct exposures, during normal operations and Category 1 event sequences, and ensure the following:

- The analyses are consistent with commonly acceptable shielding calculations, such as the guidance in NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000), and are provided in sufficient detail to allow independent confirmatory calculations;

- Credit taken for shielding materials that reduce direct exposure dose rates is appropriate, and accounts for any degradation that may occur as a result of the event sequences;

- Methodologies used in shielding analyses are appropriate for the radiation types and geometries and materials modeled, and have been validated using dose rate measurements from similar facilities; and

- Flux-to-dose conversion factors, atmospheric dispersion data, and cross-section data used in the analyses are consistent with accepted practice, such as is documented in American National Standards Institute/American Nuclear Society 6.1.1 and American National Standards Institute/American Nuclear Society 6.1.2 (American Nuclear Society Standards Committee Working Group, 1977, 1989).

Evaluate the calculations of dose to workers and members of the public from airborne radionuclides, during normal operations and after Category 1 event sequences, and ensure the following:

- Credit taken for the use of ventilation and filtration systems in mitigating the release of airborne radioactive materials is appropriate;

- For the calculation of dose to the public from airborne radionuclides:
  - Airborne transport modeling uses acceptable methods, such as those outlined in Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission, 1977) for routine releases; and
  - Appropriate exposure pathways are considered, such as direct exposure to airborne radionuclides, inhalation of airborne radionuclides, and pathways associated with radionuclides deposited on the ground in the receptor location, for potential long-term exposure of the receptor.
- For the calculation of dose to workers from airborne radionuclides:
  - The calculation of airborne radioactivity concentrations within the geologic repository operations area uses times and levels of elevated airborne radioactivity concentrations that are reasonable or conservative, based on technically defensible data, and
  - The times that workers are assumed to be exposed to elevated radiation fields and airborne concentrations of radioactivity are reasonable or conservative, based on technically defensible data.
- The inhalation dose conversion factors used in the analyses are standard for dose assessments, such as those in Federal Guidance Report # 11 (Eckerman, et al., 1992).

Review Method 3 Limitation of Dose to Workers and Members of the Public from Normal Operations and Category 1 Event Sequences to Within Limits Specified in 10 CFR 63.111(a)

Confirm that normal operations and Category 1 event sequences that could adversely affect radiological exposures have been considered.

Verify that an appropriate method has been used to aggregate the doses from normal operations and annualized doses from Category 1 event sequences.

Verify that the dose to workers and members of the public from normal operations and Category 1 event sequences will not exceed the limits specified in 10 CFR 63.111(a).

Confirm that the doses to workers and members of the public will be as low as is reasonably achievable, as evaluated using Section 4.1.1.8 ("Meeting the 10 CFR Part 20 As Low As Is Reasonably Achievable Requirements for Normal Operations and Category 1 Event Sequences") of the Yucca Mountain Review Plan.

4.1.1.5.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.111(a)(1), (a)(2), (b)(1), (c)(1), and (c)(2), relating to consequence analysis

methodology and demonstration that the design meets 10 CFR Parts 20 and 63 numerical radiation protection requirements for normal operations and Category 1 event sequences.

Acceptance Criterion 1 Consequence Analyses Adequately Assess Normal Operations and Category 1 Event Sequences, as Well as Factors That Allow an Event Sequence to Propagate Within the Geologic Repository Operations Area.

- The U.S. Department of Energy conducts consequence analyses for normal operations and Category 1 event sequences that adequately consider hazard event sequences that could lead to radiological consequences, interactions of identified hazards and proposed controls, and all modes of geologic repository operations area operation. Analyses assume that operations are carried out at the maximum capacity and rate of receipt of radioactive waste stated in the license application. The consequence analyses provide details on the related hazard and the structures, systems, and components, and controls that are relied on to prevent or mitigate event sequences.

Acceptance Criterion 2 Consequence Calculations Adequately Assess the Consequences to Workers and Members of the Public From Normal Operations and Category 1 Event Sequences.

- Adequate methods are used to perform the consequence calculations, and adequate technical bases are provided for selecting these methods. Adequate technical bases are also provided for assumptions used for the calculations and methods. The selected methods are consistent with site-specific data and system design and process information;

- The identification of the member of the public likely to receive the highest dose from geologic repository operations area normal operations or Category 1 event sequences is adequate, and the rationale for this identification is adequate. The dose to this individual bounds the annual dose to any real member of the public located beyond the site boundary;

- Input data and information used for the consequence analysis are identified, and are consistent with site-specific data and system design and process information. Adequate technical bases are provided for selection of this data and information and uncertainty in this input data is appropriately considered in the consequence analyses;

- The calculation of the source term is acceptable, and is based on the following:

  — Characteristics of the high-level radioactive waste used in the source term calculation reasonably represent or bound the range of characteristics of waste that will be handled at the geologic repository operations area; and

  — The type, quantity, and concentration of airborne radionuclides released during normal operations and Category 1 event sequences are supported by

appropriate data, or are in accordance with U.S. Nuclear Regulatory Commission guidance documents.

- The calculations of on-site and off-site direct exposures, during normal operations and Category 1 event sequences, are based on the following:

  — The analyses are consistent with commonly acceptable shielding calculations, and are provided in sufficient detail to allow independent confirmatory calculations;

  — Credit taken for shielding materials that reduce direct exposure dose rates is appropriate and accounts for any degradation that may occur as a result of the event sequences;

  — Methodologies used in any shielding analyses are appropriate for the radiation types and geometries and materials modeled, and are validated using dose rate measurements from similar facilities; and

  — Flux-to-dose conversion factors, atmospheric dispersion data, and cross-section data used in the analyses are consistent with accepted practice.

- The calculations of dose to workers and members of the public from airborne radionuclides, during normal operations and after Category 1 event sequences, are adequate and are based on the following:

  — Credit taken for the use of ventilation and filtration systems in mitigating the release of airborne radioactive materials is appropriate;

  — For the calculation of dose to the public from airborne radionuclides, airborne transport modeling is conducted using acceptable methods, and the U.S. Department of Energy considers appropriate exposure pathways;

  — For the calculation of dose to workers from airborne radionuclides, the calculation of airborne radioactivity concentrations within the geologic repository operations area uses times and levels of elevated airborne radioactivity concentrations that are reasonable or conservative, based on technically defensible data. The times that workers are assumed to be exposed to elevated radiation fields and airborne concentrations of radioactivity are reasonable or conservative, based on technically defensible data; and

  — The inhalation dose conversion factors used in the analyses are appropriate for dose assessments.

Acceptance Criterion 3 The Dose to Workers and Members of the Public From Normal Operations and Category 1 Event Sequences is Within the Limits Specified in 10 CFR 63.111(a).

- Normal operations and Category 1 event sequences that could adversely affect radiological exposures are adequately considered;
- An appropriate method is used to aggregate annual doses from normal operations and annualized doses from Category 1 event sequences;
- Doses to workers and members of the public from normal operations and Category 1 event sequences will not exceed the limits in 10 CFR 63.111(a); and
- Doses to workers and members of the public will be as low as is reasonably achievable.

4.1.1.5.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.5.1.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(a)(1). Performance objectives for the geologic repository operations area, up to the time of permanent closure, have been met in that the radiation exposure limits in 10 CFR Part 20 will not be exceeded.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(a)(2). Performance objectives for the geologic repository operations area up to the time of permanent closure have been met in that, during normal operations and for Category 1 event sequences, the annual dose to any real member of the public, located beyond the boundary of the site, will not exceed 0.15 mSv (15 mrem).

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(b)(1). The geologic repository operations area has been designed such that, taking into consideration normal operation and Category 1 event sequences, radiation exposures, radiation levels, and releases of radioactive materials will be maintained, within the limits of 10 CFR 63.111(a).

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(c)(1). The preclosure safety analysis meets the requirements specified at

10 CFR 63.112, and demonstrates that the radiation protection limits of 10 CFR Part 20 will be met. During normal operations and Category 1 event sequences, the annual dose to any real member of the public, located beyond the boundary of the site, will not exceed 0.15 mSv [15 mrem].

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(c)(2). The preclosure safety analysis meets the requirements specified at 10 CFR 63.112, and demonstrates that the preclosure numerical radiation protection requirements will be met for geologic repository operations area normal operations and Category 1 event sequences.

4.1.1.5.1.5 References

American Nuclear Society Standards Committee Working Group. "Neutron and Gamma-Ray Cross Sections for Nuclear Radiation Protection Calculations for Nuclear Power Plants." American Nuclear Society 6.1.2–1989. Washington, DC: American National Standards Institute. 1989.

———. "Neutron and Gamma Ray Flux-to-Dose-Rate Factors." American National Standards Institute/American Nuclear Society 6.1.1-1977. Washington, DC: American National Standards Institute. 1977.

Eckerman, K.F., A.B. Wolbarst, and A. Richardson. Federal Guidance Report #11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." Springfield, Virginia: U.S. Department of Commerce. 1992.

U.S. Nuclear Regulatory Commission. NUREG–1567, "Standard Review Plan for Spent Fuel Storage Facilities, Final Report." Washington, DC: U.S. Nuclear Regulatory Commission. 2000.

———. Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50." Appendix I. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1977.

4.1.1.5.2 Demonstration That the Design Meets 10 CFR Part 63 Numerical Radiation Protection Requirements for Category 2 Event Sequences

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.5.2.1 Areas of Review

This section provides guidance on the review of the design meeting 10 CFR Part 63 numerical radiation protection requirements for Category 2 event sequences. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(5).

The staff will evaluate the following parts of the design meeting 10 CFR Part 63 numerical radiation protection requirements for Category 2 event sequences, using the review methods and acceptance criteria in Sections 4.1.1.5.2.2 and 4.1.1.5.2.3.

- Consequence evaluations for Category 2 event sequences;
- Off-site doses for Category 2 event sequences; and
- Compliance with performance objectives.

4.1.1.5.2.2 Review Methods

Review Method 1 Consequence Analyses of Category 2 Event Sequences and Factors That Allow An Event Sequence to Propagate within the Geologic Repository Operations Area

Ensure that the U.S. Department of Energy has conducted consequence analyses for Category 2 event sequences that were reviewed using Section 4.1.1.4 ("Identification of Event Sequences") of the Yucca Mountain Review Plan. Verify that consequence analyses consider the following:

- Hazard event sequences that could result in radiological consequences (including the controls used to prevent or mitigate the event sequences);
- Interactions of identified hazards and proposed controls;
- Whether the U.S. Department of Energy analyses assume that operations will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the license application; and
- Descriptions of event sequences for which consequences (radiation dose) will be determined, including information on the hazard, structures, systems, and components that take part in the event sequences and controls relied on to prevent or mitigate the event sequences.

Review Method 2 Assessment of Calculations of Consequences to Members of the Public from Category 2 Event Sequences

Evaluate the methods used to perform consequence calculations, and verify that adequate technical bases for selecting these methods have been provided. Ensure that adequate technical bases have also been provided for assumptions used for the calculations and

methods. Confirm that methods are consistent with site-specific data and system design and process information that was evaluated using Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis") and 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan.

Evaluate the identification of the hypothetical member of the public, located on or beyond the site boundary, likely to receive the highest dose from the geologic repository operations area during a Category 2 event sequence, and the rationale for this identification.

Ensure that input data and information used for the consequence analyses are identified, and are consistent with site-specific data and system design and process information. Verify that adequate technical bases are provided for selection of this input data and information and that uncertainty in the input data is appropriately considered in the consequence analyses.

Evaluate the calculation of the source term, and confirm the following:

- Characteristics of the high-level radioactive waste used in the source term calculation (e.g., enrichment, burnup, and decay time) reasonably represent or bound the range of characteristics of waste that will be handled at the geologic repository operations area, as reviewed using Section 4.1.1.2 ("Description of Structures, Systems, Components, Equipment, and Operational Process Activities") of the Yucca Mountain Review Plan; and

- The type, quantity, and concentration of airborne radionuclides that could be released during Category 2 event sequences are supported by appropriate data and analyses, or are estimated in accordance with the U.S. Nuclear Regulatory Commission guidance documents, such as NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000).

Evaluate the calculations of off-site dose from direct exposure after Category 2 event sequences, and ensure the following:

- The analyses are consistent with commonly acceptable shielding calculations, such as the guidance in NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000). The analyses are provided in sufficient detail to allow independent confirmatory calculations;

- Credit taken for shielding materials that reduce direct exposure dose rates is appropriate, and accounts for any degradation that may occur as a result of the event sequences;

- Methodologies used in shielding analyses are appropriate for the radiation types and geometries and materials modeled, and have been validated using dose rate measurements from similar facilities;

- The time a member of the public is assumed to be exposed to elevated levels of radiation from Category 2 event sequences is reasonable. This time is based on the amount of time required for the facility to recover from the event sequence; and

- Flux-to-dose conversion factors and cross-section data used in the analyses are consistent with accepted practice, such as is documented in "American National Standards Institute/American Nuclear Society 6.1.1" and "American National Standards Institute/American Nuclear Society 6.1.2," (American Nuclear Society Standards Committee Working Group, 1977, 1989).

Evaluate the calculation of dose to members of the public from airborne radionuclides after Category 2 event sequences, and ensure that:

- Credit taken for the use of ventilation and filtration systems in mitigating the release of airborne radioactive materials is appropriate. The analyses consider credible damage to the ventilation system that may result from event sequences, such as ventilation duct collapse, fan failure, or filter blowout;

- Airborne transport modeling uses an acceptable method, such as that outlined in Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants" (U.S. Nuclear Regulatory Commission, 1983);

- The U.S. Department of Energy has considered appropriate exposure pathways, such as:

  — Direct exposure to airborne radionuclides;

  — Inhalation of airborne radionuclides;

  — Pathways associated with radionuclides deposited on the ground in the receptor location for potential long-term exposure of the receptor. This pathway may be omitted if the site emergency plan [reviewed using Section 4.5.7 (Emergency Plan) of the Yucca Mountain Review Plan] has provisions to mitigate doses to members of the public after any accident that releases significant quantities of radioactive material;

- The time that a member of the public is assumed to be exposed to airborne radioactive materials from Category 2 event sequences is reasonable, and is based on the time that radioactive effluents are released from the geologic repository operations area, and

- The inhalation dose conversion factors used in the analyses are standard for dose assessments, such as those in Federal Guidance Report # 11 (Eckerman, et al., 1992).

Review Method 3 Limitation of Dose to Hypothetical Members of the Public from Category 2 Event Sequences to Limits Specified in 10 CFR 63.111(b)(2)

Confirm that Category 2 event sequences that could adversely affect radiological exposures have been considered. Also, verify that no identified Category 2 event sequence will lead to a dose to a member of the public that exceeds the dose limit in 10 CFR 63.111(b)(2).

4.1.1.5.2.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.111(b)(2) and (c), relating to the design meeting 10 CFR Part 63 numerical radiation protection requirements for Category 2 event sequences.

Acceptance Criterion 1 Consequence Analyses Include Category 2 Event Sequences as Well as Factors That Allow an Event Sequence to Propagate Within the Geologic Repository Operations Area.

- The U.S. Department of Energy conducts consequence analyses for Category 2 event sequences that adequately consider hazard event sequences that could lead to radiological consequences, interactions of identified hazards and proposed controls, and the maximum capacity and rate of receipt of radioactive waste. The consequence analyses provide details on the structures, systems, and components and controls that are relied on to prevent or mitigate event sequences.

Acceptance Criterion 2 Consequence Calculations Adequately Assess the Consequences to Members of the Public from Category 2 Event Sequences.

- Adequate methods are used to perform the consequence calculations, and adequate technical bases are provided for selecting these methods. Adequate technical bases are also provided for assumptions used for the calculations and methods. The selected methods are consistent with site-specific data and system design and process information;

- The identification of the hypothetical member of the public, located on or beyond the site boundary, likely to receive the highest dose from the geologic repository operations area during a Category 2 event sequence, is adequate, and the rationale for this identification is adequate;

- Input data and information used for the consequence analysis are identified, and are consistent with site-specific data and system design and process information. Adequate technical bases are provided for their selection and uncertainty in the input data is appropriately considered in the consequence analyses;

- The calculation of the source term is based on the following:

  — Characteristics of the high-level radioactive waste used in the source term calculation reasonably represent or bound the range of characteristics of waste that will be handled at the geologic repository operations area; and

  — The type, quantity, and concentration of airborne radionuclides that could be released during Category 2 event sequences are supported by appropriate data and analyses, or are estimated in accordance with U.S. Nuclear Regulatory Commission guidance documents.

- The calculations of off-site dose from direct exposure after Category 2 event sequences are adequate, and are based on the following:

  — The analyses are consistent with commonly acceptable shielding calculations, and are provided in sufficient detail to allow independent confirmatory calculations;

  — Credit taken for shielding materials that reduce direct exposure dose rates is appropriate, and accounts for any degradation that may occur as a result of the event sequence;

  — Methodologies used in any shielding analyses are appropriate for the radiation types and geometries and materials modeled, and are validated using dose rate measurements from similar facilities;

  — The time that a member of the public is assumed to be exposed to elevated levels of radiation from Category 2 event sequences is reasonable. The time is based on the amount of time required for the facility to recover from the event sequence; and

  — Flux-to-dose conversion factors and cross-section data used in the analyses are consistent with accepted practice.

- The calculation of dose to members of the public from airborne radionuclides after Category 2 event sequences is adequate, and is based on the following:

  — Credit taken for the use of ventilation and filtration systems in mitigating the release of airborne radioactive materials is appropriate. The analyses consider credible damage to the ventilation system that may result from event sequences;

  — Airborne transport modeling uses an acceptable method;

  — The U.S. Department of Energy considers appropriate exposure pathways;

  — The time that a member of the public is assumed to be exposed to airborne radioactive materials from Category 2 event sequences is reasonable, and is based on the time that radioactive effluents are released from the facility; and

  — The inhalation dose conversion factors used in the analyses are standard for dose assessments.

Acceptance Criterion 3 The Dose to Hypothetical Members of the Public from Category 2 Event Sequences is Within the Limits Specified in 10 CFR 63.111(b)(2).

- Category 2 event sequences that could adversely affect radiological exposures are adequately considered; and

- No identified Category 2 event sequence will lead to a dose to a member of the public that exceeds the dose limit in 10 CFR 63.111(b)(2).

4.1.1.5.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.5.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(b)(2). The design of the geologic repository operations area is such that, taking into consideration Category 2 event sequences, no individual located on, or beyond, any point on the boundary of the site will receive, as a result of the single Category 2 event sequence, the more limiting of a total effective dose equivalent of 0.05 Sv (5 rem), or the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 0.5 Sv (50 rem). The lens dose equivalent will not exceed 0.15 Sv (15 rem), and the shallow dose equivalent to skin will not exceed 0.5 Sv (50 rem).

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(c). The preclosure safety analysis meets the requirements specified at 10 CFR 63.112, including a demonstration that the numerical guides for design objectives for Category 2 events in 10 CFR 63.111(b)(2), are met.

4.1.1.5.2.5 References

American Nuclear Society Standards Committee Working Group. "Neutron and Gamma-Ray Cross Sections for Nuclear Radiation Protection Calculations for Nuclear Power Plants." American Nuclear Society–6.1.2–1989. Washington, DC: American National Standards Institute. 1989.

———. "Neutron and Gamma Ray Flux-to-Dose-Rate Factors." American National Standards Institute/American Nuclear Society 6.1.1-1977. Washington, DC: American National Standards Institute. 1977.

Eckerman, K.F., A.B. Wolbarst, and A. Richardson. Federal Guidance Report # 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." Springfield, Virginia: U.S. Department of Commerce. 1992.

U.S. Nuclear Regulatory Commission. NUREG–1567, "Standard Review Plan for Spent Fuel Storage Facilities, Final Report." Washington, DC: U.S. Nuclear Regulatory Commission. 2000.

———. NUREG–1536, "Standard Review Plan for Dry Cask Storage Systems." Washington, DC: U.S. Nuclear Regulatory Commission. 1997.

———. Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1983.

4.1.1.6 Identification of Structures, Systems, and Components Important to Safety, Safety Controls, and Measures to Ensure Availability of the Safety Systems

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.6.1 Areas of Review

This section provides guidance on the review of the identification of structures, systems, and components important to safety, safety controls, and measures to ensure availability of the safety systems. Items on this list (Q-List) are important to safety and are subject to quality assurance requirements in Subpart G of 10 CFR Part 63. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(5). The quality assurance program must control activities affecting the quality of Q-List items to an extent consistent with their importance to safety. The Q-List items are categorized consistent with their importance to safety.

The staff will evaluate the following parts of the identification and categorization of structures, systems, and components important to safety, safety controls, and measures, to ensure availability of the safety systems, using the review methods and acceptance criteria in Sections 4.1.1.6.2 and 4.1.1.6.3.

- Structures, systems, and components important to safety and measures to ensure availability of safety systems;
- Administrative or engineered safety controls for structures, systems, and components important to safety; and
- Risk-significance categorization of structures, systems, and components important to safety.

4.1.1.6.2 Review Methods

Review Method 1 List of Structures, Systems, and Components Important to Safety; Technical Bases for Identification of Structures, Systems, and Components and Safety Controls; and List and Analysis of Measures to Ensure Availability of Safety Systems

Verify that analysis and classification of structures, systems, and components for the geologic repository operations area used the results of the iterative preclosure safety analysis reviewed in Section 4.1.1.3 (Identification of Hazards and Initiating Events), Section 4.1.1.4 (Identification of Event Sequences), and Section 4.1.1.5 (Consequence Analyses) of the Yucca Mountain review Plan. The identification of hazards, initiating events, event sequences, and consequence analysis should form the basis to identify structures, systems, and components that are important to safety that should be functional to meet the performance objectives. All structures, systems, and components and controls assumed to be functional in the consequence analyses should be considered in the list. Confirm that structures, systems, and components are classified as important to safety according to the definition specified in 10 CFR 63.2.

Confirm that analyses used to identify structures, systems, and components important to safety, safety controls, and measures to ensure the availability of the safety systems include adequate consideration of:

- Means to limit concentration of radioactive material in air, such as:
  - Ventilation systems designed in accordance with Regulatory Guide 3.32, "General Design Guide for Ventilation Systems for Fuel Reprocessing Plants," (U.S. Nuclear Regulatory Commission, 1975);
  - Use of seals and/or air locks as part of geologic repository operations area design; and
  - Installation of radiation-monitoring systems that provide information on the dose rate and concentration of airborne radioactive material in selected areas.
- Means to limit time required to perform work in the vicinity of radioactive materials, such as:
  - Features that minimize the time that maintenance, health physics, or inspection personnel must remain in restricted areas; and
  - Use of remotely operated or robotic equipment, such as welders, wrenches, cutting tools, and radiation monitors, and means to remotely place temporary shielding.

- Suitable shielding, such as:
  - Shielding provided by the radioactive material being stored;
  - Neutron capture provided by borated water in casks and waste transfer pools, and by borated materials incorporated into casks;
  - Gamma and neutron shielding provided by the structural and nonstructural materials in the walls and ends of storage/transfer casks;
  - Temporarily positioned shielding used during operations for preparing the storage cask for storage or retrieval, and/or during transfer into the storage position at the storage location, and shielding provided by any pool facility interior and exterior walls; and
  - Verify that the shielding design includes selection of appropriate shielding materials, and that the design analysis of the shielding performance for normal and Category 1 and 2 event sequence is acceptable. Coordinate with the reviewer of the repository design for Section 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls") of the Yucca Mountain Review Plan.
- Means to monitor and control dispersal of radioactive contamination;
- Means to control access to high radiation areas, very high radiation areas, or airborne radioactivity areas, to ensure compliance with the requirements of Subparts G and H of 10 CFR Part 20, such as:
  - Analyses that identify airborne radioactivity areas. These analyses should provide a technical basis for any inability to practically apply process or other engineering controls, to restrict the concentrations of radioactive material in air to values below those that define an airborne radioactivity area;
  - A plan for monitoring and limiting intakes of radiation (e.g., controlling access, limiting individual exposure times, using individual respiratory protection equipment); and
  - Application of design guidance in Regulatory Guide 8.38, "Control of Access to High and Very High Radiation Areas of Nuclear Power Plants," (U.S. Nuclear Regulatory Commission, 1993).
- Means to prevent or control criticality, such as complying with American National Standards Institute/American Nuclear Society–8 nuclear criticality safety standard documents listed in Regulatory Guide 3.71 (U.S. Nuclear Regulatory Commission, 1998a);

- A radiation alarm system designed to warn of significant increases in radiation levels, concentrations of radionuclides in air, and increased radioactivity in effluents. This system should be designed to provide prompt notification to personnel both in the work area where an increase in radiation is detected and in control centers. Features of control centers should include:

  — Appropriate installation of radiation alarms in areas where waste is being stored, transferred, or processed/repackaged;

  — Availability of backup power systems for radiation alarm systems; and

  — Design and operation of interior evacuation signals and signs consistent with Regulatory Guide 8.5, "Criticality and Other Interior Evacuation Signals," (U.S. Nuclear Regulatory Commission, 1981).

- The ability of structures, systems, and components to perform their intended safety functions, assuming the occurrence of event sequences, considering results from the review of consequence analyses using Section 4.1.1.5 ("Consequence Analyses") of the Yucca Mountain Review Plan;

- Explosion and fire detection systems and appropriate suppression systems, features of which may include:

  — Installation of detection and suppression systems near probable sources of fire or explosion, and

  — Designs to accommodate the interactions of ventilation systems with potential fires or explosions.

- Means to control radioactive waste and radioactive effluents, and to permit prompt termination of operations and evacuation of personnel during an emergency, such as:

  — Design and operation of the geologic repository operations area to reduce the quantity of radioactive waste generated;

  — Off-gas treatment, filtration, and ventilation systems for control of airborne radioactive effluents;

  — Liquid waste management systems to handle the expected volume of potentially radioactive liquid waste generated during normal operations and Categories 1 and 2 event sequences. Design features and procedures for these systems should minimize generation of liquid waste and the possibility of spills, and should provide for control of spills, overflows, or leakage during packaging and transfer of site-generated radioactive liquid waste; and

— Solid waste management systems to handle the expected volume of potentially radioactive solid waste (e.g., contaminated equipment and personnel clothing) generated during normal operations and Categories 1 and 2 event sequences.

- Means to provide reliable and timely emergency power to instruments, utility service systems, and operating systems important to safety, such as:

  — Instrumentation and/or monitoring systems with battery power, for which the duration of backup battery life should be consistent with reasonable time periods of primary power loss;

  — Uninterruptible power supplies on process control computers; and

  — Standby diesel generators that should start on demand if primary power is lost, and should continue to operate for the required period of time.

- Means to provide redundant systems necessary to maintain, with adequate capacity, the capability of utility services important to safety, such as electrical systems, ventilation systems, air supply systems, water supply systems for fire suppression, and communication systems. Examples of design features for consideration in these systems may include electrical systems, ventilation systems, water supply systems, and communication systems; and

- Means to inspect, test, and maintain structures, systems, and components important to safety, as necessary, to ensure their continued function and readiness. This assessment should take into account the review of plans for conduct of normal activities, including maintenance, surveillance, and periodic testing conducted using Section 4.5.6 ("Plans for Conduct of Normal Activities, Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan.

Review Method 2 Administrative or Procedural Safety Controls to Prevent Event Sequences or Mitigate Their Effects

Confirm that management systems and procedures are sufficient to ensure that administrative or procedural safety controls will function properly. Coordinate with the reviewer for Sections 4.5.5 ("Plans for Startup Activities and Testing") and 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan. Examples of such management systems are:

- Procedures;

- Training;

- Maintenance, calibration, and surveillance plans and schedules;

- Configuration controls for structures, systems, and components;

- Human factor evaluations;
- Audits and self-assessments;
- Emergency planning; and
- Accident/incident investigation requirements.

Confirm that administrative or procedural safety controls required for the structures, systems, and components to be functional and to meet the dose requirements are included in the list of structures, systems, and components important to safety.

Review Method 3 Risk Significance Categorization of Structures, Systems, and Components Important to Safety

Evaluate the methodology used for risk significance categorization of structures, systems, and components important to safety in the geologic repository operations area to ensure that the methodology is technically sound and defensible. Verify categorization methodology for structures, systems, and components important to safety is supported by appropriate qualitative descriptions and quantitative or semi-quantitative methods. Ensure that the risk significance categorization of structures, systems, and components important to safety is consistent with the governing regulation and applicable policy and guidance, including applicable portions of the following:

- Federal Register (60 FR 42622), "Use of Probabilistic Risk Assessment Methods in Nuclear Activities: Final Policy Statement" (U.S. Nuclear Regulatory Commission, 1995);
- Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis" (U.S. Nuclear Regulatory Commission, 1998b);
- Regulatory Guide 1.176, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Graded Quality Assurance" (U.S. Nuclear Regulatory Commission, 1998c);
- SECY–98–144, "White Paper on Risk-Informed and Performance-Based Regulation" (U.S. Nuclear Regulatory Commission, 1998d);
- SECY–99–100, "Framework for Risk-Informed Regulation in the Office of Nuclear Materials Safety and Safeguards" (U.S. Nuclear Regulatory Commission, 1999);
- NUREG–0800 Chapter 19, "Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision-Making: General Guidance" (U.S. Nuclear Regulatory Commission, 1998e)

- NUREG–1513, "Integrated Safety Analysis Guidance Document" (Draft Report) (U.S. Nuclear Regulatory Commission, 2000a);
- NUREG–1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility" (Draft Report) (U.S. Nuclear Regulatory Commission, 2000b);
- NUREG/CR–2300, "PRA Procedures Guide–A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants" (U.S. Nuclear Regulatory Commission, 1983); and
- Electric Power Research Institute, EPRI TR–105396, "PSA Applications Guide" (Electric Power Research Institute, 1995).

Confirm that the identification of structures, systems, and components important to safety (Q-List generation) is done using a Preclosure Safety Analysis methodology consistent with the requirements in 10 CFR 63.112. Verify the categorization methodology incorporates both event sequence frequencies and consequences in its consideration of risk.

Ensure the categorization methodology provides due consideration of uncertainties and sensitivity analyses for event sequence frequencies in a manner that is consistent with the applicable portions of existing U.S. Nuclear Regulatory Commission policy and guidance.

Ensure that the categorization of structures, systems, and components important to safety is consistent with their relative importance to safety, as required in 10 CFR 63.142(c)(1). Verify that the distinctions between quality levels have a well defined and well documented technical basis. Verify that the frequencies and consequences of failures of structures, systems, and components important to safety identified for the various quality levels are well defined and consistent with applicable portions of existing U.S. Nuclear Regulatory Commission policy and guidance. Confirm that all structures, systems, and components important to safety identified in Review Methods 1 and 2 of this section are properly categorized and technical bases are adequately documented.

Verify that the categorization methodology is flexible enough to accommodate multiple revisions of the preclosure safety analysis and the subsequent re-evaluation of risk significance. Ensure that the categorization methodology permits revision to the categorization of structures, systems, and components important to safety as a result of the introduction of new data or design changes.

Ensure the documentation, analysis, and criteria used for risk significance categorization of structures, systems, and components important to safety is transparent and traceable with a well defined technical basis. Verify that the categorization methodology is presented in such a manner that the reviewer can gain a clear understanding of every step of what has been done, what the results are, and the technical bases for the results. Verify that the categorization methodology includes an unambiguous and comprehensive record of the decisions, criteria, and assumptions made, and the process used in arriving at a given conclusion or result.

4.1.1.6.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.112(e), relating to the identification of structures, systems, and components important to safety, safety controls, and measures to ensure availability of the safety systems.

Acceptance Criterion 1 An Adequate List of Structures, Systems, and Components Identified as Being Important to Preclosure Radiological Safety; the Technical Bases for the Approaches Used to Identify Structures, Systems, and Components Important to Safety, and Safety Controls Based on Analysis of Their Performance; and a List and Analysis of the Measures to be Taken to Ensure That the Safety Systems are Available

- The analysis and classification of structures, systems, and components for the geologic repository operations area uses results of the hazard assessment, identification of event sequences, and consequence analyses as a basis to identify those structures, systems, and components that are important to safety; and

- The analyses used to identify structures, systems, and components important to safety, safety controls, and measures to ensure the availability of the safety systems, include adequate consideration of:

  — Means to limit concentration of radioactive material in air;

  — Means to limit time required to perform work in the vicinity of radioactive materials;

  — Suitable shielding;

  — Means to monitor and control dispersal of radioactive contamination;

  — Means to control access to high radiation areas, very high radiation areas, or airborne radioactivity areas;

  — Means to prevent or control criticality;

  — A radiation alarm system designed to warn of significant increases in radiation levels, concentrations of radionuclides in air, and increased radioactivity in effluents;

  — Ability of structures, systems, and components to perform their intended safety functions, assuming the occurrence of event sequences;

  — Explosion and fire detection systems and appropriate suppression systems;

— Means to control radioactive waste and radioactive effluents, and to permit prompt termination of operations and evacuation of personnel during an emergency;

— Means to provide reliable and timely emergency power to instruments, utility service systems, and operating systems important to safety;

— Means to provide redundant systems necessary to maintain, with adequate capacity, the capability of utility services important to safety; and

— Means to inspect, test, and maintain structures, systems, and components important to safety, as necessary, to ensure their continued function and readiness.

Acceptance Criterion 2 Administrative or Procedural Safety Controls Needed to Prevent Event Sequences, or Mitigate Their Effects, Are Adequate, and Are Included in the List of Structures, Systems, and Components Important to Safety.

- Management systems and procedures are sufficient to ensure that administrative or procedural safety controls will function properly; and

- Administrative or procedural safety controls required for structures, systems, and components to be functional, and to meet dose requirements, are included in the list of structures, systems, and components important to safety.

Acceptance Criterion 3 The Approach and Criteria for Risk Significance Categorization of Structures, Systems, and Components Important to Safety Are Defensible and the Structures, Systems, and Components Important to Safety Are Adequately Categorized

- Methodology for categorization of structures, systems, and components important to safety in the geologic repository operations area is technically sound and defensible;

  — The risk significance categorization of structures systems and components important to safety are technically sound with a well supported technical basis and is consistent with regulatory framework;

  — The categorization methodology for structures, systems, and components important to safety is supported by appropriate qualitative descriptions and quantitative or semi-quantitative methods;

  — The identification of structures, systems, and components important to safety are consistent with the governing regulation and applicable policy and guidance;

- — The identification of structures, systems, and components important to safety (Q-List generation) is done using a Preclosure Safety Analysis methodology that is consistent with and fulfills the requirements in 10 CFR 63.112;

- — The categorization methodology considers the frequency of event sequences (Categories 1 & 2) defined in 10 CFR 63.2;

- — The categorization methodology considers the dose limits in 10 CFR 63.111 (including 10 CFR Part 20); and

- — The categorization methodology provides due consideration of uncertainties and sensitivity analyses for event sequence frequencies in a manner that is consistent with the applicable portions of existing U.S. Nuclear Regulatory Commission policy and guidance.

- The risk significance categorization of structures, systems, and components important to safety is consistent with their relative importance to safety:

  - — The categorization methodology ensures that structures, systems, and components important to safety are categorized consistent with their risk significance and relative importance to safety [10 CFR 63.142(c)(1)];

  - — The distinctions between quality levels has a well defined and well documented technical basis;

  - — The frequencies and consequences of failures of structures, systems, and components important to safety identified for the various quality levels are well defined and consistent with applicable portions of existing U.S. Nuclear Regulatory Commission policy and guidance; and

  - — All structures, systems, and components important to safety are properly categorized and technical bases are adequately documented.

- The risk significance categorization of structures, systems, and components important to safety demonstrates flexibility:

  - — The categorization methodology is flexible enough to accommodate multiple revisions of the integrated safety analysis and the subsequent reevaluation of risk significance; and

  - — The categorization methodology permits the revision of the categorization level of individual and groups of structures, systems, and components important to safety as a result of the introduction of new data or design changes.

- The documentation and analysis for the risk significance categorization of structures, systems, and components important to safety is transparent and traceable:

— The categorization methodology is developed and presented in such a manner that the reviewer can gain a clear understanding of every step of what has been done, what the results are, and the technical bases for the results; and

— The categorization methodology includes an unambiguous and complete record of the decisions and assumptions made, and the process used in arriving at a given conclusion or result.

4.1.1.6.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.6.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.112(e). An adequate analysis of the performance of the structures, systems, and components important to safety has been provided. In particular, this analysis demonstrates that:

- Structures, systems, and components important to safety are identified;
- Criteria for categorization of structures, systems, and components important to safety are adequately developed and categorization of items is acceptable;
- Controls that will be relied on to limit or prevent potential event sequences, or mitigate their consequences, are acceptable; and
- Measures are adequate to ensure the availability of structures, systems, and components important to safety.

4.1.1.6.5 References

Electric Power Research Institute. "PSA Applications Guide." EPRI TR–105396. Walnut Creek, California: Electric Power Research Institute. 1995.

U.S. Nuclear Regulatory Commission. NUREG–1513, "Integrated Safety Analysis Guidance Document." Draft Report. Washington, DC: U.S. Nuclear Regulatory Commission. 2000a.

———. NUREG–1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility." Draft Report. Washington, DC: U.S. Nuclear Regulatory Commission. 2000b.

———. SECY–99–100. "Framework for Risk-Informed Regulation in the Office of Nuclear Materials Safety and Safeguards." Washington, DC: U.S. Government Printing Office. 1999.

———. Regulatory Guide 3.71, "Nuclear Criticality Safety Standards for Fuels and Material Facilities." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1998a.

———. Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1998b.

———. Regulatory Guide 1.176, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Graded Quality Assurance." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1998c.

———. SECY–98–144. "White Paper on Risk-Informed and Performance-Based Regulation." Washington, DC: U.S. Government Printing Office. 1998d.

———. NUREG–0800, "Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision-Making: General Guidance." Chapter 19. Washington, DC: U.S. Nuclear Regulatory Commission. 1998e.

———. "Use of Probabilistic Risk Assessment Methods in Nuclear Activities: Final Policy Statement." *Federal Register*. Vol. 60, 60 FR 42622. p. 42622. August 16, 1995.

———. Regulatory Guide 8.38, "Control of Access to High and Very High Radiation Areas in Nuclear Power Plants." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1993.

———. NUREG/CR–2300, "PRA Procedures Guide–A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants." Washington, DC: U.S. Nuclear Regulatory Commission. 1983.

———. Regulatory Guide 8.5, "Criticality and Other Interior Evacuation Signals." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1981.

———. Regulatory Guide 3.32, "General Design Guide for Ventilation Systems for Fuel Reprocessing Plants." Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1975.

4.1.1.7 Design of Structures, Systems, and Components Important to Safety and Safety Controls

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.7.1 Areas of Review

This section provides guidance on the review of the design of structures, systems, and components important to safety and safety controls. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(2) and (c)(3), and coordinate review of information, such as the geologic media, general arrangement, and dimensions, as specified in 10 CFR 63.21(c)(2), with the review of Sections 4.1.1.1 and 4.1.1.2 of the Yucca Mountain Review Plan.

The staff will evaluate the following parts of the design of structures, systems, and components important to safety and safety controls using the review methods and acceptance criteria in Sections 4.1.1.7.2 and 4.1.1.7.3.

- Design criteria and design bases;
- Design methodologies; and
- Geologic repository operations area design and design analyses.

The determination of the geologic repository operations area structures, systems, and components important to safety will depend largely on the final design and preclosure safety analysis results. The review methods and acceptance criteria provided in the following sections are examples. These structures, systems, and components may, or may not, be important to safety. If some structures, systems, and components listed below are determined not to be important to safety, based on the review conducted using Section 4.1.1.6 of the Yucca Mountain Review Plan, the reviewer may not have to review these structures, systems, and components. Similarly, for structures, systems, and components that are identified to be important to safety, but are not included in the Yucca Mountain Review Plan, the general aspects of the review methods and acceptance criteria provided below may still be applicable. However, for the remaining aspects not addressed in the following sections, the reviewer should exercise professional judgment to conduct the review.

4.1.1.7.2 Review Methods

4.1.1.7.2.1 Design Criteria and Design Bases

Review Method 1 Definitions of Relationship between Design Criteria and 10 CFR 63.111(a) and (b) Requirements; Relationship between Design Bases and Design Criteria; and Design Criteria and Design Bases for Structures, Systems, and Components Important to Safety

Verify that design criteria and bases for structures, systems, and components important to safety and for those structures, systems, and components that affect the proper functioning of the structures, systems, and components important to safety have been identified. Confirm these design criteria and bases are derived from the site characteristics and consequence analyses reviewed using Sections 4.1.1.1 ("Site Description as it Pertains to Preclosure Safety Analysis"), and 4.1.1.5 ("Consequence Analyses") of the Yucca Mountain Review Plan. Ensure

that these design criteria and bases are consistent with analyses used to identify structures, systems, and components as reviewed using Section 4.1.1.6 ("Identification of Structures, Systems, and Components Important to Safety; Safety Controls; and Measures to Ensure Availability of the Safety Systems") of the Yucca Mountain Review Plan.

Determine whether the design criteria for normal operating conditions are adequately developed, so that designs do not result in any degradation of the capabilities of the geologic repository operations area to protect radiological health and safety. Verify that design criteria do not permit degradation of the geologic repository operations area structures, systems, and components, important to safety, which will reduce:

- Radioactive material-handling and waste-processing capability;
- Capability to withstand further occurrence of Categories 1 and 2 event sequences without remedial action; or
- Capability to perform design functions for the full system lifetime without remedial action.

Ensure that design criteria adequately consider preclosure safety analysis results. Verify that structures, systems, and components important to safety will continue to prevent consequences, such as unacceptable releases of radioactive material, unacceptable radiation doses for workers or the public, and loss of removal capability.

Confirm that structural design criteria and bases for structures, systems, and components important to safety meet relevant guidance, such as that provided in:

- Regulatory Guides 1.76 (U.S. Atomic Energy Commission, 1974) and 1.117 (U.S. Nuclear Regulatory Commission, 1978a) for tornado protection;
- Regulatory Guides 1.29 (U.S. Nuclear Regulatory Commission, 1978b); 1.60 (U.S. Atomic Energy Commission, 1973a); 1.61 (U.S. Atomic Energy Commission, 1973b); 1.92 (U.S. Nuclear Regulatory Commission, 1976a); and 1.122 (U.S. Nuclear Regulatory Commission, 1978c), for protection against seismic events;
- Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978d) for explosion protection;
- Regulatory Guides 1.59 (U.S. Nuclear Regulatory Commission, 1977a) and 1.102 (U.S. Nuclear Regulatory Commission, 1976b), as well as American National Standards Institute/American Nuclear Society–2.8 (American National Standards Institute/American Nuclear Society, 1992a), for flood protection; and
- NUREG–0800 (U.S. Nuclear Regulatory Commission, 1987) and other accepted U.S. Nuclear Regulatory Commission guidelines, such as "Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects" (Kennedy, 1975) for tornado missile protection.

Verify that the design criteria and bases for thermal considerations are consistent with guidance, such as that provided in Regulatory Guide 1.120 (U.S. Nuclear Regulatory Commission, 1976c) and American National Standards Institute/American Nuclear Society–15.17 (American National Standards Institute/American Nuclear Society, 1981), for fire protection.

Verify that the design criteria and bases for shielding and confinement systems use, where appropriate, guidance provided in:

- American National Standards Institute/American Nuclear Society–6.4 (American National Standards Institute/American Nuclear Society, 1997a);
- Regulatory Guide 1.143 (U.S. Nuclear Regulatory Commission, 1979a);
- Regulatory Guide 8.5 (U.S. Nuclear Regulatory Commission,1981);
- Regulatory Guide 8.25 (U.S. Nuclear Regulatory Commission, 1992a); and
- Regulatory Guide 8.34 (U.S. Nuclear Regulatory Commission, 1992b).

Confirm that designs for fixed-area radiation monitors and continuous airborne monitoring instrumentation for radiological protection are consistent with references, such as:

- American National Standards Institute N13.1–1993, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities," (American Nuclear Society Standards Committee Working Group, 1993);
- American National Standards Institute–HPSSC–6.8.1–1981, "Location and Design Criteria for Area Radiation Monitoring Systems for Light Water Reactors," (American National Standards Institute, 1981);
- NUREG–0800, Section 11.5, "Process and Effluent Radiological Monitoring Instrumentation and Sampling Systems," (U.S. Nuclear Regulatory Commission, 1996);
- Regulatory Guide 8.25, "Air Sampling in the Workplace," (U.S. Nuclear Regulatory Commission, 1992a); and
- Regulatory Guide 4.1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants," (U.S. Nuclear Regulatory Commission, 1975a).

Verify that criticality design criteria are developed based on the consequence analysis results from the preclosure safety analysis. Confirm that criticality design criteria are factored into models and assumptions used for criticality analysis. These criteria should be consistent with those given in NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000) and those American

National Standards Institute/American Nuclear Society–8 nuclear criticality standards adopted by the U.S. Nuclear Regulatory Commission as listed in Regulatory Guide 3.71 (U.S. Nuclear Regulatory Commission, 1998). For example:

- American National Standards Institute/American Nuclear Society–8.10, "Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement," (American National Standards Institute/American Nuclear Society, 1983);

- American National Standards Institute/American Nuclear Society–8.1, "Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors," (American National Standards Institute/American Nuclear Society, 1988);

- American National Standards Institute/American Nuclear Society–8.3, "Criticality Accident Alarm System," (American National Standards Institute/American Nuclear Society, 1997b);

- American National Standards Institute/American Nuclear Society–8.7, "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials," (American National Standards Institute/American Nuclear Society, 1998);

- American National Standards Institute/American Nuclear Society–8.20, "Nuclear Criticality Safety Training," (American National Standards Institute/American Nuclear Society, 1991b);

- American National Standards Institute/American Nuclear Society–8.22, "Nuclear Criticality Safety Based on Limiting and Controlling Moderators," (American National Standards Institute/American Nuclear Society, 1997c); and

- American National Standards Institute/American Nuclear Society–8.23, "Nuclear Criticality Accident Emergency Planning and Response," (American National Standards Institute/American Nuclear Society, 1997d).

Verify that design bases and design criteria are based on the above listed, or other guidance documents and standards, considering the normal geologic repository operations area operating conditions and Categories 1 and 2 event sequences. For example, these design bases should include:

- Thermal design bases and criteria that include temperatures for those temperature-sensitive structures, systems, and components important to safety that consequence analyses (reviewed using Section 4.1.1.5 of the Yucca Mountain Review Plan) pose a potential radiological hazard if the design temperatures are not met. In reviewing adequacy of the structural design bases and criteria, the staff should:

  — Verify that thermal design criteria for the surface and subsurface facilities have been adequately developed, based on the maximum design waste inventory;

— Verify that design criteria for fire protection (e.g., fire ratings, fire barriers) are adequate, based on the maximum credible geologic repository operations area fire (duration and temperature), if determined to be of design importance from the consequence analyses (reviewed using Section 4.1.1.5 of the Yucca Mountain Review Plan); and

— Verify that design criteria for the surface and subsurface ventilation systems have been adequately developed, based on thermal and fire protection design criteria, in addition to airborne radiological dose limits.

- Structural design bases and criteria, including maximum loads, stress/pressure loadings (static and/or dynamic), and displacements for structures, systems, and components important to safety, that consequence analyses (reviewed using Section 4.1.1.5 of the Yucca Mountain Review Plan) show pose a potential radiological hazard if the design loads and displacements are violated. In reviewing adequacy of the structural design bases and criteria:

  — Verify that event sequences are properly converted into structural loads, pressures, and/or displacements, based on accepted methods; and

  — Verify that the use of factored loads and load combinations is based on accepted methods or codes and standards.

- Shielding design bases and criteria, including maximum dose rates and annual dose rates to workers and the public from the exterior of shielding surfaces, for structures, systems, and components important to safety;

- Criticality design bases and criteria, including fuel geometry configurations, moderators, and waste forms effective neutron multiplication factor limits, to ensure that nuclear fuel remains subcritical during handling, transfer, repackaging, storage, and retrieval; and

- Operating design bases and criteria, including the maximum limits of travel, vertical lift, and/or velocity, for structures, systems, and components important to safety for handling and transfer of high-level radioactive waste or containers that consequence analyses (reviewed using Section 4.1.1.5 of the Yucca Mountain Review Plan) show present a potential radiological hazard if operating limits are violated.

4.1.1.7.2.2 Design Methodologies

Review Method 1 Geologic Repository Operations Area Design Methodologies

Confirm that proposed design methodologies are supported by adequate technical bases, and are consistent with established industry practice. Verify that uncertainties associated with the proposed methodologies have been adequately addressed.

If the design methodologies depend on site-specific test data, confirm that such data are available. Also, ensure that any analytical or numerical models used to support the design

methodologies have been verified, calibrated, and validated. Verify that any assumptions or limitations relating to the proposed methodologies are identified, and that their implications for the design have been adequately analyzed and documented.

If the design methodologies depend on data from expert elicitations, coordinate with the reviewer of Section 4.5.4 ("Expert Elicitation") of the Yucca Mountain Review Plan, to ensure that these elicitations are conducted and documented in accordance with NUREG–1563 (Kotra, et al., 1996).

Confirm that seismic design methodologies use ground motion information that is consistent with proposed U.S. Department of Energy methodologies for hazard assessment, and that, taken together, they provide adequate input for seismic design and for performance assessments.

4.1.1.7.2.3 Geologic Repository Operations Area Design and Design Analyses

I. Designs and Design Analyses for Structures, Systems, and Components, Equipment, and Safety Controls That are Safety Related for Surface Facilities

Review Method 1 Design Codes and Standards

Ensure that applicable design codes and standards are specified for the structural, thermal, shielding and confinement, criticality, and decommissioning designs. This review should include:

- Confirmation that structural design, fabrication, and testing of waste packages for storage of spent nuclear fuel is in accordance with the Boiler and Pressure Vessel Code, Section III, Subsections NB or NC. Welds on these waste packages should be in accordance with Section IX (American Society of Mechanical Engineers, 1993);

- Verification that prestressed and reinforced concrete structures, within the geologic repository operations area, that are used for containment of radioactive material are designed in accordance with American Concrete Institute 359 (American Concrete Institute and American Society of Mechanical Engineers, 1992);

- Confirmation that design, construction, material selection, and specifications for reinforced concrete structures that are not within the scope of ACI 359 (American Concrete Institute and American Society of Mechanical Engineers, 1992), but are considered important to safety, are in accordance with ACI 349 (American Concrete Institute, 1997) and American National Standards Institute/American Nuclear Society–57.9 (American National Standards Institute/American Nuclear Society, 1984);

- Determination that steel structures and components are designed and constructed in accordance with applicable steel design codes and standards [e.g., "Specification for Structural Steel Buildings—Allowable Stress Design and Plastic Design," American Institute of Steel Construction (1989); "Load and Resistance Factor Design Specification for Structural Steel Buildings," American Institute of Steel Construction (1993); and

"Code of Standard Practice for Steel Buildings and Bridges," American Institute of Steel Construction (1992)];

- Determination that foundations supporting structures, systems, and components important to safety are constructed in accordance with the applicable American Construction Institute code standards, and that site-related geotechnical parameters are obtained based on guidelines such as those provided in American National Standards Institute/American Nuclear Society–2.11 (American National Standards Institute/American Nuclear Society, 1978a);

- Verification that applicable standards and codes have been used for design and construction of processing equipment and facility power systems, instrumentation, control, and other operations systems including, for example:

  — Crane systems [Nuclear Standard NOG–1–1995 (American Society of Mechanical Engineers, 1995); NUREG–0554 (U.S. Nuclear Regulatory Commission, 1979b); and appropriate Crane Manufacturers' Association of America standards];

  — Electrical/power systems [appropriate National Electrical Manufacturers' Association codes and Institute of Electrical and Electronics Engineers, Inc. nuclear standards; Regulatory Guide 1.118 (U.S. Nuclear Regulatory Commission, 1995); Regulatory Guide 1.32 (U.S. Nuclear Regulatory Commission, 1977b); Regulatory Guide 1.75 (U.S. Nuclear Regulatory Commission, 1978e); and Regulatory Guide 1.120, for designing electrical systems for protection from fires (U.S. Nuclear Regulatory Commission, 1976c)];

  — Air control systems powering nuclear safety-related components and other equipment important to safety [American National Standards Institute/American Nuclear Society–59.3 (American National Standards Institute/American Nuclear Society, 1992a)];

  — Instrumentation and control systems (appropriate International Society for Measurement and Control and Institute of Electrical and Electronics Engineers codes);

  — Fire detection and suppression systems [NFPA22 (National Fire Protection Association, 1987); NFPA801 (National Fire Protection Association, 1998); and other appropriate National Fire Protection Association codes]; and

  — Ventilation systems [Regulatory Guide 3.32 (U.S. Nuclear Regulatory Commission, 1975); Regulatory Guide 1.120 related to fire protection and removal of fire combustion products (U.S. Nuclear Regulatory Commission, 1976c)]; American National Standards Institute/American Nuclear Society–56.7 (American National Standards Institute/American Nuclear Society, 1978b); and applicable standards or guides published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers [e.g., ASHRAE Handbook,

Chapter 23—"Nuclear Facilities;" (American Society of Heating, Refrigeration, and Air Conditioning Engineers, 1995)].

If other methods, standards, or guides are used for design, verify that the license application has provided adequate technical bases for their usage.

Review Method 2 Consistency of Materials with Design Methodologies

Verify that materials used for structures, systems, and components important to safety in surface facility design are consistent either with the accepted design criteria, codes, standards, and specifications, or with those specifically developed by the U.S. Department of Energy. For example, if American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Subsection NB or NC (American Society of Mechanical Engineers, 1993), is used for waste package design criteria, the materials should be consistent with those prescribed by the particular Section III paragraphs of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, or their equivalent. Other examples include:

- For concrete and steel design, applicable American Society for Testing and Materials standard specifications as listed in Section 5.4.3.3 of NUREG–1567 (U.S. Nuclear Regulatory Commission, 2000); and

- For shielding materials, American National Standards Institute/American Nuclear Society 6.4.2, "Specification for Radiation Shielding Materials," (American National Standards Institute/American Nuclear Society, 1985) may be used, and the geometric arrangement and the potential for shielding material to experience changes in material properties and geometry at high temperatures should be assessed. Confirm, based on review of the license application shielding analyses/design, that any temperature-sensitive shielding materials will not be subject to temperatures at or above their design limitations during normal operations and Categories 1 and 2 event sequences.

Evaluate the material properties and allowable stresses and strains for the design to verify the adequacy of the materials.

Confirm that the materials and their properties are appropriate for the expected design loading conditions. Also, confirm that anticipated stress limits for each material are based on maximum temperatures established in the thermal analysis evaluation in the license application.

Verify that the U.S. Department of Energy has considered the potential for creep or brittle fracture and drop fracture resistance of materials, to ensure that structures, systems, and components important to safety are adequate to perform their safety functions.

Review Method 3 Load Combinations Used for Normal and Categories 1 and 2 Event Sequence Conditions

Verify that loads used in the design analyses are consistent with those normal and Categories 1 and 2 event sequence loadings for structures, systems, and components important to safety.

Evaluate load combinations used in the design analyses for consistency with those accepted by the U.S. Nuclear Regulatory Commission for the design of similar types of nuclear facilities, and for steel and reinforced concrete structures designed in accordance with American National Standards Institute/American Nuclear Society 57.9 (American National Standards Institute/American Nuclear Society, 1984) and ACI 359 (American Concrete Institute/American Society of Mechanical Engineers, 1992).

Verify that design analyses use appropriate techniques that were correctly applied to provide design temperatures, mechanical loads, and pressures for the structures, systems, and components important to safety.

Review Method 4 Performance and Documentation of Design Analyses

Verify that design analyses include the relevant structural, thermal, shielding, criticality, confinement, and decommissioning factors, such as:

- For all analyses:
  - Computational models, data, assumptions, and results are adequately documented;
  - Computational models are validated;
  - Data are derived from relevant site and system information;
  - Assumptions are conservative, and adequate technical justifications or bases are provided;
  - Normal operations and Categories 1 and 2 event sequences are considered in developing system loadings and environments;
  - Analyses are based on the maximum capacity and rate of receipt of radioactive waste; and
  - Limited confirmatory calculations are performed.
- For shielding design and design analyses:
  - Dose rate estimates are presented for representative areas; and
  - Bases for flux-to-dose conversions are adequately documented [conversion factors acceptable to the U.S. Nuclear Regulatory Commission are contained in American National Standards Institute/American Nuclear Society 6.1.1 (American National Standards Institute/American Nuclear Society, 1991a)].

- For criticality design and design analyses:
  - Calculations determine the highest waste forms effective neutron multiplication factor that is likely to occur under the examined loading conditions;
  - Calculations are appropriate for the material properties; and
  - Analyses are consistent with those for similar facilities.
- For thermal design and design analyses:
  - Analyses are consistent with limiting fuel burnup and cooling times; and
  - Analyses specify the maximum and minimum temperatures for all components.
- For structural design and design analyses, loadings are correctly translated into either static or time-varying nodal forces, or element face pressures.

Confirm that values of material properties used for the design analyses have adequate technical bases, and are consistent with site-specific data.

Ensure that loads and load combinations used in the design analyses are consistent with defined normal operations and Categories 1 and 2 event sequences.

Verify that analytical methods, models, and codes used for the design analyses are appropriate for the conditions analyzed, and are properly benchmarked.

Confirm that technical bases for the assumptions used in the design analyses are conservatively defined and based on accepted engineering practice.

Ensure that designs and design analyses for structures, systems, and components important to safety are performed correctly. Also, verify that these structures, systems, and components have sufficient capability to withstand normal and Categories 1 and 2 event sequence loadings.

Conduct limited confirmatory checks or analyses using appropriate analytical methods, models, or codes.

II. Designs and Design Analyses for Structures, Systems, and Components, Equipment, and Safety Controls That are Safety Related for Subsurface Facility

Review Method 1 Design Assumptions, Codes, and Standards

Ensure the applicable design codes, standards, or other detailed criteria used for the design of the subsurface facility are specified. Codes and standards should be equivalent to, and consistent with, those accepted by the U.S. Nuclear Regulatory Commission for design of nuclear facilities with similar hazards and functions. If nonstandard approaches are used,

confirm that the license application has provided adequate technical bases to justify why they are used.

Verify that the assumptions made for the design of the subsurface facility are technically defensible.

Confirm that geologic repository operations area subsurface facility designs for steel and concrete structures and components, air control systems, electrical power systems, and ventilation systems for the subsurface facility use applicable standards, such as those listed in Section 4.1.1.7.2.3 ("Geologic Repository Operations Area Design and Design Analyses") of the Yucca Mountain Review Plan.

Review Method 2 Design of Subsurface Operating Systems

Verify that the methods, assumptions, and input data used in the ventilation design are consistent with proposed thermal loading performance goals in the emplacement drifts. Conduct limited confirmatory analyses to verify the results presented in the license application. Also, confirm that the analyses adequately address the thermal load in the ventilation tunnel and shafts and raises.

Evaluate design analyses of control system functions, equipment, instrumentation, control links, and communication systems to ensure that the subsurface monitoring and control systems are appropriate for the structures, systems, and components important to safety during waste transportation, emplacement, and monitoring.

Assess the design of the waste transport and emplacement system for compatibility with proposed waste transport and emplacement procedures. Also, verify that interfaces with other systems are identified and assessed, and that continuity of operations and safety can be achieved.

Evaluate the layout of the subsurface facilities. Ensure that emplacement drifts are located away from major faults, consistent with the seismic design, and that the subsurface layout is appropriate for the quantity of waste to be emplaced and the design thermal load.

Ensure that the geologic repository operations area design permits implementation of the performance confirmation plan provided in Section 4.4, as specified in 10 CFR 63.111(d).

Verify that standards and codes used for design of subsurface operating systems were properly applied.

Review Method 3 Materials and Material Properties Used for Subsurface Facility Design

Confirm that the selection of materials and the properties of these materials are appropriate for the anticipated subsurface environment.

Verify that materials and material properties are consistent with applicable design criteria, codes, standards, and specifications. If no standards are used, evaluate the technical bases

provided to ensure that they are acceptable. Confirm that applicable American Society for Testing and Materials standard specifications, such as American Society for Testing and Materials B575–99a (American Society for Testing and Materials, 2000a) and American Society for Testing and Materials A666–00 (American Society for Testing and Materials, 2000b), are used.

Evaluate whether the selection of ground support materials accounts for degradation of such materials under elevated temperature and thermal loading. Also, ensure that plausible mechanisms for material degradation are identified and properly incorporated in assessments of subsystem structure, system, and component performance.

Verify that subsurface ventilation systems are constructed of fire-resistant materials (e.g., fire-resistant filters) to protect against fires occurring inside or outside the systems. Verify that ventilation equipment/components and materials, particularly those within or near waste emplacement drifts, are designed to withstand prolonged high temperature conditions, effects of sudden blast cooling, and wet and corrosive environments, to minimize maintenance/ replacement of potentially contaminated ventilation components.

Review Method 4 Load Combinations Used for Normal and Categories 1 and 2 Event Sequences

Confirm that the arrangement of waste packages within the subsurface facility satisfies the thermal load design criteria.

Ensure that the magnitude and time history of the applied thermal loading are consistent with the anticipated characteristics of the proposed nuclear waste, repository design configurations, and design areal mass loading.

Verify that thermal analyses have an appropriate technical basis; use site-specific thermal property data; consider temperature dependency and uncertainties of thermal property data; and use thermal models and analyses that are properly documented. If credit is taken for use of ventilation, confirm that assessments of the effects of ventilation are adequate.

Ensure that design analyses consider appropriate *in situ* stresses, potential running ground conditions, and hydrologic changes to the rock mass, during the heating period, that might affect mechanical properties.

Confirm that dynamic loads used in design analyses are consistent with the seismic design ground motion parameters (including any repeated seismic effects); consider faulting effects; and are consistent with accepted methodologies for assessing faulting hazards.

Review Method 5 Models and Site-Specific Properties of Host Rock Used in Design Analyses and Consideration of Spatial and Temporal Variation and Uncertainties in Such Properties

Ensure that appropriate combinations of continuum and discontinuum modeling, as well as two- and three-dimensional modeling, have been used for assessing the behavior of a fractured rock

mass under prolonged heated conditions and Categories 1 and 2 event sequences. Confirm that the bases for the choice of specific models and model combinations are adequate, and that appropriate bases for the assumptions and limitations of the modeling approach are provided.

Confirm that principles for the design analyses, the underlying assumptions, and the anticipated limitations are documented; are consistent with modeling objectives; and are technically sound.

Verify that values for the rock-mass thermal expansion coefficient are consistent with properly interpreted site-specific data, and that such interpretation accounts for likely scale effects and temperature dependency. Ensure that uncertainty in the thermal expansion coefficient has been adequately assessed and considered in the thermal stress calculation.

For continuum rock-mass modeling, confirm that values for rock-mass elastic parameters (Young's modulus and Poisson's ratio) and strength parameters (friction angle and cohesion) are consistent with properly interpreted site-specific data. If the parameter values are obtained through empirical correlations with a rock quality index, verify that the empirical equations used are appropriate for the site, and are applied correctly. Confirm that the values of the index are consistent with site-specific data. If intact-rock-scale values are used, ensure that the bases for application of the values to the rock-mass scale are adequate.

For discontinuum rock-mass modeling, verify that the selection of fracture patterns for numerical modeling is appropriate for the objectives of the design and analyses. Confirm that the interpretation of modeling results adequately considers effects of simplification of the characteristics of the modeled fracture network, compared with those of the *in situ* fracture network.

Confirm that the selection of stiffness and strength parameters for rock blocks between any fractures that are explicitly represented in the model are appropriate and account for fractures that are not explicitly represented.

Verify that the values for fracture stiffness and strength parameters are consistent with properly interpreted site-specific data.

For both continuum and discontinuum modeling, confirm that time-dependent mechanical degradation of the rock mass, fractures, and ground support that may occur after the emplacement of nuclear waste is adequately accounted for in thermal-mechanical analyses. This may be based on extrapolations from the U.S. Department of Energy long-term exploratory studies facility's heated-drift and single-heater test studies, the cross-drift thermal test study, or other methods. Verify that the bases for the magnitude and rate of mechanical degradation applied in the analyses are appropriately established, and are technically defensible.

Ensure that uncertainties in rock mass and fracture mechanical properties are adequately estimated, and considered in both continuum and discontinuum modeling.

Verify that the models adequately address the stability of openings around drift intersections, considering the rock mass and its degraded properties and thermal loading. This information should be used in the design of ground support.

Conduct limited confirmatory continuum and discontinuum analyses to verify the rock mass behavior results presented in the license application, under design (normal) operating conditions and Categories 1 and 2 event sequences.

Review Method 6 Design Methodologies and Interpretations of Modeling Results for Ground Support Systems

Confirm that design methodologies or combinations of design methodologies are properly applied to the design of ground support systems. Ensure that, when used, the empirical design approach is consistent with accepted technology in the underground tunneling and mining industry. Also, verify that the evaluation and selection of ground support systems are supported by analyses that satisfy Acceptance Criteria 4 and 5 under Subsection II in Section 4.1.1.7.3.3 ("Geologic Repository Operations Area Design and Design Analyses") of the Yucca Mountain Review Plan. These analyses should provide mechanical evaluation of ground support systems under thermal and dynamic loads.

Confirm that the ground support system responses are adequately evaluated, based on the results of model analyses. If the ground support system is explicitly modeled, verify that the ground support responses include an adequate assessment of deformation and potential failure of the ground support systems. Ensure that the interaction between the ground support system and the host rock units (e.g., interactions of rock bolts with lithophysae) is considered in the analysis. Review Method 5, under this subsection, and Acceptance Criterion 5, under Subsection II in Section 4.1.1.7.2.3 ("Geologic Repository Operations Area Design and Design Analyses"), of the Yucca Mountain Review Plan, should be used in assessing ground support system responses, where applicable. If the ground support system is not explicitly modeled, confirm that the anticipated ground support system responses from the modeling results are reasonably estimated, and that technical bases for these estimations are adequate.

Verify that geometrical, thermal, and mechanical characteristics of the ground support system used in the thermal-mechanical analyses are consistent with the design and construction specifications. Also, confirm that the time-dependent mechanical degradation of the ground support system under heated conditions is adequately accounted for in the analyses.

Verify that stability of emplacement drifts, ventilation tunnels, and shafts is adequately assessed, both with and without ground support. The assessment should identify rock blocks with potential to fall in the drifts; the potential for cave-in, collapse, or closure of the excavations; and the extent and severity of rock-mass disturbance near excavations. Ensure that selection of a ground support system is consistent with the anticipated rock-mass responses and potential failure mechanisms of the rock mass near the excavations.

Review Method 7 Design of Ventilation Systems

Confirm that the design of subsurface ventilation systems is consistent with the design criteria, codes, standards, and specifications normally used by the underground mining industry, or with those specifically developed by the U.S. Department of Energy.

Confirm that subsurface ventilation systems (including their power sources) important to safety (reviewed using Section 4.1.1.6 of the Yucca Mountain Review Plan) are designed to function under normal subsurface operating conditions (e.g., high temperature, potentially wet environments) and under Categories 1 and 2 event sequences. Coordinate with the reviewer of Sections 4.1.1.3, 4.1.1.4, and 4.1.1.5 to ensure subsurface ventilation design has adequately considered event sequences that have radiological safety consequences.

Confirm that, to the extent applicable, ventilation design guidance, such as that provided in Regulatory Guide 3.32, "General Design Guide for Ventilation Systems for Fuel Reprocessing Plants" (U.S. Nuclear Regulatory Commission, 1975b) for surface nuclear facilities, is met for the subsurface ventilation design. Specifically consider: (i) general radiological safety; (ii) occupied area ventilation systems; (iii) process area ventilation systems; (iv) exhaust ventilation and filtration systems; (v) fans; (vi) ventilation system construction and layout; (vii) ventilation system testing and monitoring; and (viii) quality assurance. Regulatory Guide 1.120 (U.S. Nuclear Regulatory Commission, 1976c) contains guidance for protection from fires.

Confirm that subsurface ventilation equipment important to safety has backup or standby equivalents. This equipment should also have fail-safe mechanisms (e.g., backflow prevention) for the primary ventilation equipment (i.e., in a high radiation area). Alternatively, the U.S. Department of Energy ventilation design and analysis can demonstrate that such equipment could be repaired/replaced, without causing a subsurface radiation safety hazard.

Confirm that subsurface ventilation equipment important to safety has recording devices to give continuous readouts of important parameters to control centers (e.g., operating temperature, pressures, vibration levels).

Verify that subsurface ventilation systems important to safety are designed to continue operating in the event of a main subsurface power outage (e.g., ventilation fans operated from an independent power circuit or other emergency backup power source is readily available), if determined to be necessary.

Confirm that the U.S. Department of Energy has an adequate periodic inspection, testing, and maintenance program to assure that ventilation requirements can be maintained, and that concentrations of radioactive materials within the subsurface worker operations areas, escape routes, and exhaust air are as low as is reasonably achievable. Verify that this program includes among others:

- Periodic replacement of high-efficiency particulate air filters in the geologic repository operations area exhaust shafts, ramps, or other high radiation areas;
- Periodic testing/calibration of radiological monitoring devices that activate or deactivate high-efficiency particulate air filter systems;
- Routine testing of any standby/backup ventilation equipment and emergency power to assure readiness to maintain ventilation functions and radiation safety; and

- Routine testing and calibration of airborne radiological monitoring devices, smoke detectors, and temperature sensors.

Verify that the U.S. Department of Energy subsurface ventilation design is adequate to seal off or isolate potential airborne radiological release areas (e.g., waste haulage routes, emplacement drifts) to limit the extent of radiological contamination and worker exposure.

Ensure that the U.S. Department of Energy ventilation design analysis is based on accepted industry codes or methods, incorporates site-specific data (i.e., resistance factors, humidity levels, time-varying waste package heat fluxes), and is based on an accurate representation of the subsurface drift structure (i.e., varying drift shapes and dimensions, varying flow rates between emplacement drifts and main drifts). Verify that subsurface ventilation flows from the least likely contaminated areas to the most contaminated areas, and meets design criteria (e.g., worker radiation exposure limits or other contaminant limits, air temperature limits, pressure differentials between high radiation/nonradiation areas).

Verify that the waste package design has considered the potential effects of unavailability of subsurface ventilation because of failure of the system on both preclosure and postclosure performance, if any.

Conduct limited confirmatory analyses as an independent verification of the U.S. Department of Energy ventilation design analyses results.

Review Method 8 Design of Subsurface Power and Power Distribution Systems

Verify that the design of subsurface electric power supplies (e.g., electric transformers, electric substations) and power distribution systems, for structures, systems, and components important to safety, is consistent with accepted design criteria, codes, standards, and specifications for underground usage. Confirm these systems are suitable for the normal geologic repository operations area operating environment and those Categories 1 and 2 event sequences of radiological consequence reviewed using Section 4.1.1.5 of the Yucca Mountain Review Plan.

Confirm that the design incorporates proper grounding of electrical power sources/equipment to protect workers.

Ensure that the design has sufficient emergency backup power capability to support equipment that is important to safety.

Verify that the U.S. Department of Energy design of electric power systems important to safety permits appropriate periodic inspection and testing.

Review Method 9 Maintenance Plan for Subsurface Facility Structures, Systems, and Components, Equipment, and Controls Important to Safety

Evaluate the adequacy of the maintenance plan developed to maintain drift stability before permanent closure of the repository. Ensure that the maintenance plan considers the likely

effects of uncertainties caused by high temperature and high radiation levels, and is based on an appropriate interpretation of modeling results that assess the possibility of degradation of both the rock mass and the ground support system under sustained thermal load.

Verify that adequate maintenance plans for other subsurface facility structures, systems, and components, equipment, and controls important to safety are in place, and that they account for drift stability and accessibility during the period before permanent closure. Also, ensure that the consideration of drift stability effects in the maintenance plan is based on an appropriate interpretation of modeling results. Plans for conduct of normal activities including maintenance, surveillance, and periodic testing are reviewed using Section 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan.

III. Designs for Structures, Systems, and Components and Safety Controls That are Safety-Related for Waste Package/Engineered Barrier System

Review Method 1 Design of Waste Package and Engineered Barrier System Structures, Systems, and Components and Their Controls

Confirm that the waste package/engineered barrier system design adequately incorporates containment (considering corrosion resistance), criticality control, shielding, structural strength and drop fracture resistance of waste packages, thermal control, waste form degradation, drip shield, waste package support/invert, backfill, and sorption barrier, as appropriate.

Verify that the description and assessment of components for the waste packages include containers and internal structures, such as structural guides, baskets, fuel baskets, fuel basket plates with neutron absorbers, neutron absorber rods, canisters, fillers, and fill gas. The description and assessment should also consider specific components of the engineered barrier system, such as drip shield, backfill, and sorption barrier. Confirm that the design analyses for these components are adequate.

Verify that the materials, methods, and processes used in the fabrication of containers, internal waste package components, and engineered barrier system components are consistent with accepted design criteria, codes, standards, and specifications, such as American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III (American Society of Mechanical Engineers, 1993). Confirm that processes specified for fabrication, assembly, closure, and inspection are based on accepted industry technology. Confirm that the license application documents significant discrepancies or uncertainties related to the corrosion and mechanical resistance of container materials and relevant engineered barrier system components ,such as the drip shield. If the U.S. Department of Energy uses design criteria, codes, standards, specifications, and industry technology, other than those mentioned above, evaluate the adequacy of the technical bases provided.

Confirm that specifications for the container and internal waste package materials are in agreement with those established in the final design. Verify that the specifications for closure welding, preparation for welding, materials to be used in welds, and inspection of welding comply with appropriate American Society of Mechanical Engineers codes, such as American

Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section IX (American Society of Mechanical Engineers, 1993). Assess the acceptability of any documented deficiencies or variations with respect to the specifications of the code.

Verify that appropriate methods for nondestructive examination of fabricated containers and other structural components of waste packages have been identified to detect and evaluate fabrication defects and any other defects that may lead to premature failure.

Confirm that criticality design criteria are consistent with those used in model calculations that support the design, and that isotopic enrichment of waste is properly characterized for these models. Verify the model configurations are appropriate for the postulated repository environments, and that appropriate computer models are used in design calculations.

Verify that the assessment of shielding provided by the containers is adequate. This assessment should include estimates of dose rates, a description of the source of data for the evaluation, and the methods for estimating dose rate, including the use of computational codes.

Ensure that the components of the waste package and internals have been designed to sustain loads from normal operation and Categories 1 and 2 event sequences.

Confirm that thermal control is such that the fuel cladding temperature is sufficiently low to prevent cladding failure. Verify that appropriate models have been used for calculating decay heat, considering fuel age and fuel blending inside waste packages.

Verify that the materials used in construction of the internal components of the waste package are compatible with the waste form, and that interactions among these materials will not be detrimental to the stability of the waste form. This verification should confirm that no pyrophoric, explosive, or chemically reactive materials are introduced in the waste package.

Confirm that the design of any drip shield, including materials of construction, configuration, and method of emplacement, is adequate to prevent water from contacting the waste packages. Confirm that the safety aspects of the engineered barrier system design and waste package handling are not impaired by the drip shield.

Verify that the design of backfill (if used in the license application design), including materials and physical characteristics, configuration, and methods of emplacement and compaction is adequate to reduce the relative humidity near the waste packages. The design should also divert the flow of water away from the drip shield and waste packages, and prevent direct impact of rockfall on the drip shield. These design features should retain the safety aspects of the engineered barrier system design and waste package handling.

Confirm that the design of any sorption barrier is adequate to control the migration of radionuclides, and that materials and sorption properties, depth of placement, mixing with other materials, and degree of compaction provide adequate sorption barrier performance.

4.1.1.7.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.112(f), relating to the design of structures, systems, and components important to safety and safety controls.

4.1.1.7.3.1 Design Criteria and Design Bases

Acceptance Criterion 1 The Relationship Between the Design Criteria and the Requirements Specified in 10 CFR 63.111(a) and (b), the Relationship Between the Design Bases and the Design Criteria, and the Design Criteria and Design Bases for Structures, Systems, and Components Important to Safety are Adequately Defined.

- Design criteria and bases for structures, systems, and components important to safety and for those structures, systems, and components that affect the proper functioning of structures, systems, and components important to safety, are identified, and these criteria and bases are derived from the specific site characteristics and consequence analyses. The design criteria and bases are consistent with the analyses used in the identification of the structures, systems, and components;

- Design criteria for normal operating conditions are adequately developed, so that designs do not result in any degradation of the capabilities of the geologic repository operations area to protect radiological health and safety. Design criteria do not permit degradation of the performance of geologic repository operations area structures, systems, and components important to safety;

- Design criteria adequately consider preclosure safety analysis results, to ensure that structures, systems, and components important to safety will continue to prevent unacceptable consequences;

- Structural design criteria and bases for structures, systems, and components important to safety meet relevant guidance;

- Thermal design criteria and bases are consistent with relevant regulatory guidance;

- Design criteria and bases for shielding and confinement systems use appropriate guidance;

- Designs for fixed-area radiation monitors and continuous airborne monitoring instrumentation are consistent with relevant regulatory guidance;

- Criticality design criteria are developed, based on consequence analysis results from the preclosure safety analysis ,and are consistent with relevant regulatory guidance. Design criteria are adequately factored into the models and assumptions used for criticality analysis; and

- Design bases and criteria are clearly identified for thermal, structural, shielding, criticality, and other operating limits for the geologic repository operations area facilities.

4.1.1.7.3.2 Design Methodologies

Acceptance Criterion 1 Geologic Repository Operations Area Design Methodologies Are Adequate.

- Proposed design methodologies are supported by adequate technical bases, are consistent with established industry practice, and address uncertainties.

- If the design methodologies depend on site-specific test data, such data are available. Analytical or numerical models used to support the design methodologies are verified, calibrated, and validated; and assumptions or limitations relating to the proposed methodologies are identified, and their implications for the design are adequately analyzed and documented;

- Expert elicitations are properly conducted; and

- Seismic design methodologies use ground motion information that is consistent with proposed U.S. Department of Energy methodologies for hazard assessment, and, taken together, they provide adequate input for seismic design and for performance assessments.

4.1.1.7.3.3 Geologic Repository Operations Area Design and Design Analyses

I. Designs and Design Analyses for Structures, Systems, and Components, Equipment, and Safety Controls That are Safety Related for Surface Facilities

Acceptance Criterion 1 Design Codes and Standards Used for the Design of Surface Facility Structures, Systems, and Components Important to Safety Are Identified, and Are Appropriate for the Design Methodologies Selected.

- Applicable design codes and standards are specified for structural, thermal, shielding and confinement, criticality, and decommissioning designs; and

- If other methods are used for design, the license application provides adequate technical bases for those methods.

Acceptance Criterion 2 The Materials to Be Used for Structures, Systems, and Components Important to Safety Related to Surface Facility Design Are Consistent with the Design Methodologies.

- Materials used for structures, systems, and components important to safety related to surface facility design are consistent either with the accepted design criteria, codes,

standards, and specifications, or with those specifically developed by the U.S. Department of Energy;

- Materials are adequate, considering the material properties and allowable stresses and strains associated with the design;

- Materials and their properties are appropriate for the expected design loading conditions. In addition, anticipated stress limits for each material are based on maximum temperatures as established in the thermal analysis evaluation presented in the license application; and

- The potential for creep or brittle fracture and drop fracture resistance of materials is adequately assessed, to ensure that structures, systems, and components important to safety will perform their safety functions.

Acceptance Criterion 3 Design Analyses Use Appropriate Load Combinations for Normal and Categories 1 and 2 Event Sequence Conditions.

- The loads used in the U.S. Department of Energy design analyses are consistent with those normal and Categories 1 and 2 event sequence loadings of radiological importance;

- The load combinations used in the design analyses are consistent with those used and accepted by the U.S. Nuclear Regulatory Commission for the design of similar types of nuclear facilities and for steel and reinforced concrete structures; and

- The design analyses use appropriate techniques that are correctly applied to provide established design temperatures, mechanical loads, and pressures for the structures, systems, and components important to safety.

Acceptance Criterion 4 Design Analyses Are Properly Performed and Documented.

- The design analyses include relevant structural, thermal, shielding, criticality, confinement, and decommissioning factors;

- Values of material properties used for the design analyses have adequate technical bases and are consistent with site-specific data;

- Loads and load combinations used in the design analyses are consistent with defined normal operations and Categories 1 and 2 event sequences;

- Analytical methods, models, and codes used for the design analyses are appropriate for the conditions analyzed, and are properly benchmarked;

- Technical bases for the assumptions used in the design analyses are conservatively defined, and are based on accepted engineering practice;

- The designs and design analyses for structures, systems, and components important to safety are performed correctly. These structures, systems, and components have sufficient capability to withstand normal and Categories 1 and 2 event sequence loadings; and

- Confirmatory checks indicated that the design analyses are adequate.

II. Designs and Design Analyses for Structures, Systems, and Components, Equipment, and Safety Controls That are Safety Related for Subsurface Facility

Acceptance Criterion 1 Design Assumptions, Codes, and Standards Used for the Design of Subsurface Facility Structures, Systems, and Components Important to Safety Are Acceptable.

- Applicable design codes, standards, or other detailed criteria used for the design of the subsurface facility are specified. Codes and standards are equivalent to, and consistent with, those accepted by the U.S. Nuclear Regulatory Commission for design of nuclear facilities with similar hazards and functions. If nonstandard approaches are used, the license application provides adequate technical bases to justify why they are used;

- Assumptions made for the design of the subsurface facility are technically defensible; and

- Designs for steel and concrete structures and components, air controlled systems, electrical power systems, and ventilation systems use applicable standards.

Acceptance Criterion 2 The Design of Subsurface Operating Systems Is Adequate.

- Methods, assumptions, and input data, used in the ventilation design, are consistent with proposed thermal loading performance goals. Confirmatory analyses verify the results in the license application. Analyses adequately address the thermal loads;

- Subsurface monitoring and control systems are appropriately designed for the safety functions of the structures, systems, and components during waste transportation, emplacement, and monitoring;

- The design of the waste transport and emplacement system is compatible with proposed waste transport and emplacement procedures. Interfaces with other systems are identified and assessed, and continuity of operations and safety can be achieved;

- Emplacement drifts are located away from major faults, consistent with the seismic design, and the subsurface layout is appropriate for the quantity of waste to be emplaced and the design thermal load;

- The design of the geologic repository operations area accommodates implementation of the performance confirmation program, as specified in 10 CFR 63.111(d); and

- Standards and codes used for design of subsurface operating systems are properly applied.

Acceptance Criterion 3 Materials and Material Properties Used for the Subsurface Facility Design Are Appropriate.

- The selection of materials, and the properties of these materials, are appropriate for the anticipated subsurface environment;

- Materials and material properties are consistent with applicable design criteria, codes, standards, and specifications. If no standards are used, the technical bases provided are acceptable;

- The selection of ground support materials accounts for degradation of such materials under elevated temperature and thermal loading. Plausible mechanisms for material degradation are identified, and properly incorporated in assessments of subsystem structures, systems and components performance; and

- Fire-resistant materials are incorporated into the design of the subsurface ventilation systems. Ventilation equipment/components are designed to withstand prolonged high temperature conditions, effects of sudden blast cooling, and wet and corrosive environments.

Acceptance Criterion 4 Design Analyses Use Appropriate Load Combinations for Normal and Categories 1 and 2 Event Sequence Conditions.

- The arrangement of waste packages within the subsurface facility satisfies the thermal load design criteria;

- The magnitude and time history of the applied thermal loading are consistent with the anticipated characteristics of the proposed nuclear waste, repository design configurations, and design areal mass loading;

- Thermal analyses have an appropriate technical basis, use site-specific thermal property data, consider temperature dependency and uncertainties of thermal property data, and use thermal models and analyses that are properly documented. If credit is taken for use of ventilation, assessments of the effects of ventilation are adequate;

- Design analyses consider appropriate *in situ* stresses, potential running ground conditions, and hydrologic changes to the rock mass during the heating period; and

- The dynamic loads used in design analyses are consistent with seismic-design ground-motion parameters, including any repeated seismic effects, consider faulting effects, and are consistent with accepted methodologies for assessing faulting hazards.

Acceptance Criterion 5 Design Analyses Use Appropriate Models and Site-Specific Properties of the Host Rock, and Consider Spatial and Temporal Variation and Uncertainties in Such Properties.

- Appropriate combinations of continuum and discontinuum modeling, as well as two- and three-dimensional modeling, are conducted, to assess the behavior of a fractured rock mass under prolonged heated conditions and identified Categories 1 and 2 event sequences. The bases for the choice of specific models and model combinations are adequate. Appropriate bases for the assumptions and limitations of the modeling approach are provided;

- Principles for the design analyses, the underlying assumptions, and the anticipated limitations are documented, are consistent with modeling objectives, and are technically sound;

- Values for the rock-mass thermal-expansion coefficient are consistent with properly interpreted site-specific data, and such interpretation accounts for likely scale effects and temperature dependency. The uncertainty in the thermal-expansion coefficient is adequately assessed, and considered in the thermal-stress calculation;

- For continuum rock-mass modeling, the values for rock-mass elastic parameters (Young's modulus and Poisson's ratio) and strength parameters (friction angle and cohesion) are consistent with properly interpreted site-specific data. If the parameter values are obtained through empirical correlations with a rock-quality index, the empirical equations used are appropriate for the site and are applied correctly, and the values of the index are consistent with site-specific data. If intact-rock-scale values are used, the bases for application of the values to the rock-mass scale are adequate;

- For discontinuum rock-mass modeling, the selection of fracture patterns for numerical modeling is appropriate for the objectives of the design and analyses. The interpretation of modeling results adequately considers effects of simplification of the characteristics of the modeled fracture network, compared with those of the *in situ* fracture network;

- For discontinuum modeling, the selection of stiffness and strength parameters for rock blocks between any fractures that are explicitly represented in the model are appropriate, and account for fractures that are not explicitly represented;

- For discontinuum modeling, the values for fracture stiffness and strength parameters are consistent with properly interpreted site-specific data;

- For both continuum and discontinuum modeling, time-dependent mechanical degradation of the rock mass, fractures, and ground support that may occur after the emplacement of nuclear waste is adequately accounted for in thermal-mechanical analyses. The bases for the magnitude and rate of mechanical degradation applied in the analyses are appropriately established, and are technically defensible;

- Uncertainties in rock-mass and fracture-mechanical properties are adequately estimated, and considered in both continuum and discontinuum modeling;

- Models adequately address the stability of openings around drift intersections, considering the rock mass and its degraded properties and thermal loading; and

- Confirmatory checks indicate that the design analyses are adequate.

Acceptance Criterion 6 The Design of Ground Support Systems Is Based on Appropriate Design Methodologies and Interpretations of Modeling Results.

- Design methodologies, or combinations of design methodologies, are properly applied to the design of ground support systems. When used, the empirical design approach is consistent with accepted technology in the underground tunneling and mining industry. The evaluation and selection of ground support systems are supported by analyses that satisfy the previous two acceptance criteria, and that provide mechanical evaluation of ground support systems under thermal and dynamic loads;

- The ground support system responses are adequately evaluated, based on the results of model analyses. If the ground support system is explicitly modeled, the ground support responses include an adequate assessment of deformation and potential failure of the ground support systems. The interaction between the ground support system and the host rock units is adequately considered in the analysis. If the ground support system is not explicitly modeled, the anticipated ground support system responses from the modeling results are reasonably estimated, and the technical bases for these estimates are adequate;

- The geometrical, thermal, and mechanical characteristics of the support system used in the thermal-mechanical analyses are consistent with design and construction specifications. The time-dependent mechanical degradation of the support system, under heated conditions, is adequately accounted for in the analyses; and

- Stability of drifts, shafts, and ventilation tunnels is adequately assessed both with and without ground support. Such assessment includes identification of rock blocks that have potential to fall in the drifts; the potential for cave-in, collapse, or closure of the emplacement drifts; and the extent and severity of rock-mass disturbance near the excavations. The selection of a ground support system is consistent with the anticipated rock-mass responses and potential failure mechanisms of the rock mass near the excavations.

Acceptance Criterion 7 The Subsurface Ventilation Systems Are Adequately Designed.

- The design of subsurface ventilation systems is consistent with the design criteria, codes, standards, and specifications, or with those specifically developed by the U.S. Department of Energy;

- The subsurface ventilation systems (including their power sources) important to safety are designed to continue functioning under normal subsurface operating conditions and under Categories 1 and 2 event sequences;

- Applicable ventilation design guidance is met for the subsurface ventilation design;

- Subsurface ventilation equipment important to safety has backup or standby equivalents and fail safe mechanisms, where required, or the U.S. Department of Energy ventilation design and analysis adequately show that such backup is not required;

- Subsurface ventilation equipment important to safety has adequate recording devices for important parameters;

- Subsurface ventilation systems important to safety are designed to continue operating in case of a main subsurface power outage, if necessary;

- There is an adequate periodic inspection, testing, and maintenance program, to assure that concentrations of radioactive materials meet the limits specified in 10 CFR Parts 20 and 63, as practicable;

- The subsurface ventilation design is adequate to seal off, or isolate, airborne radiation, within areas that could have a potential release;

- The ventilation design analysis is based on accepted industry codes or methods, incorporates site-specific data, and is based on an accurate representation of the subsurface drift structure. The ventilation design analysis shows that subsurface ventilation flows from the least likely contaminated areas to the most likely contaminated areas, and meets all other specified design criteria; and

- Effect of lack of subsurface ventilation, resulting from unavailability of the system, on the waste package design has been evaluated.

- Confirmatory checks indicate that the design analyses are adequate.

Acceptance Criterion 8 The Design of Subsurface Power and Power Distribution Systems for Structures, Systems, and Components and Operations Important to Safety Is Adequate.

- The design of subsurface electric power supplies and power distribution systems for structures, systems, and components important to safety is consistent with accepted design criteria, codes, standards, and specifications for underground usage, and is suitable for the normal operating environment and Categories 1 and 2 event sequences;

- The design incorporates proper grounding of electrical power sources/equipment;

- The design has sufficient emergency backup power capability for structures, systems, and components important to safety; and

- The design of electric power systems important to safety permits appropriate periodic inspection and testing.

Acceptance Criterion 9 An Adequate Maintenance Plan Exists for Subsurface Facility Structures, Systems, and Components, Equipment, and Controls Important to Safety.

- The maintenance plan developed to maintain drift stability, before permanent closure of the repository, is adequate. This maintenance plan considers the likely effects of uncertainties caused by high temperature and high radiation levels, and is based on an appropriate interpretation of modeling results that assesses the possibility of degradation of both the rock mass and the ground support system under sustained thermal load; and

- Adequate maintenance plans for other subsurface facility structures, systems, and components, equipment, and controls important to safety are in place, and they account for drift stability and accessibility during the period before permanent closure. The consideration of drift stability effects in the maintenance plan is based on an appropriate interpretation of modeling results.

III. Designs for Structures, Systems, and Components and Safety Controls that Are Safety-Related for Waste Package/Engineered Barrier System

Acceptance Criterion 1 Waste Package and Engineered Barrier System Structures, Systems, and Components and Their Controls Are Adequately Designed.

- The waste package/engineered barrier system design adequately incorporates containment, criticality control, shielding, structural strength of waste packages, thermal control, waste form degradation, drip shield, waste package support/invert, backfill, and sorption barrier, as appropriate;

- The description and assessment of the components for the various types of waste packages include containers and internal structures, such as structural guides, baskets, fuel baskets, fuel basket plates with neutron absorbers, neutron absorber rods, canisters, fillers, and fill gas, in addition to specific components of the engineered barrier system, such as drip shield, backfill, and sorption barrier. The design analyses for these components are adequate;

- The materials, methods, and processes used in the fabrication of containers, internal waste package components, and engineered barrier system components are consistent with accepted design criteria, codes, standards, and specifications. Processes specified for fabrication, assembly, closure, and inspection are based on accepted industry technology. The license application documents any significant discrepancies or uncertainties related to the corrosion and mechanical resistance of container materials and relevant engineered barrier system components, such as the drip shield. If the U.S. Department of Energy chooses to use design criteria, codes, standards,

specifications, and industry technology different from those normally used, the technical bases provided are adequate;

- The specifications for container and internal waste package materials are in agreement with those established in the final design. The specifications for closure welding, preparation for welding, materials to be used in welds, and inspection of welding comply with applicable American Society of Mechanical Engineers codes. Any documented deficiencies or variations with respect to the specifications of the code are adequately supported;

- Appropriate methods for nondestructive examination of fabricated containers and other structural components of waste packages are identified to detect and evaluate fabrication defects and any other defects that may lead to premature failure;

- Criticality design criteria are consistent with those used in model calculations that support the design. Isotopic enrichment of waste is properly characterized for these models. Model configurations are appropriate for the various postulated repository environments, and appropriate computer models are used in design calculations;

- The assessment of shielding provided by the containers is sufficient. The assessment includes estimates of dose rates, a description of the source of data for the evaluation, and the methods for estimating dose rate, including the use of computational codes;

- The components of the waste package and internals are designed to sustain loads from normal operation, drop events, and Categories 1 and 2 event sequences;

- Thermal control is such that the fuel cladding temperature will be sufficiently low to prevent cladding failure. Appropriate models are used for the calculation of decay heat, taking into consideration fuel age and fuel blending inside waste packages;

- The materials used in construction of the internal components of the waste package are compatible with the waste form, and interactions among these materials will not be detrimental to the stability of the waste form. No pyrophoric, explosive, or chemically reactive materials will be introduced in the waste package;

- The design of any drip shield, including materials of construction, configuration, and method of emplacement, is sufficient to prevent water from contacting the waste packages. The safety aspects of the engineered barrier system design and waste package handling are not impaired by the drip shield;

- The design of any backfill, including materials and physical characteristics, configuration, and methods of emplacement and compaction, is adequate to reduce the relative humidity near the waste packages. The design will divert the flow of water away from the drip shield and waste packages, and prevent direct impact of rockfall on the drip shield, without impairing the safety aspects of the engineered barrier system design and waste package handling; and

- The design of any sorption barrier is adequate to control the migration of radionuclides and materials. Sorption properties, depth of placement, mixing with other materials, and degree of compaction provide adequate sorption barrier performance.

4.1.1.7.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.7.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(d) and 63.112(f). An adequate description of the geologic repository operations area design that satisfactorily defines the relationship between design criteria and the performance objectives, and that identifies the relationship between the design bases and the design criteria has been provided.

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4.1.1.8 Meeting the 10 CFR Part 20 As Low As Is Reasonably Achievable Requirements for Normal Operations and Category 1 Event Sequences

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.1.8.1 Areas of Review

This section provides guidance on the review of meeting the 10 CFR Part 20 as low as is reasonably achievable requirements for normal operations and Category 1 event sequences. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(5) and (c)(6).

The staff will evaluate the following parts of meeting the 10 CFR Part 20 as low as is reasonably achievable requirements for normal operations and Category 1 event sequences, using the review methods and acceptance criteria in Sections 4.1.1.8.2 and 4.1.1.8.3:

- Policy Considerations;
- Design Considerations; and
- Operational Considerations.

4.1.1.8.2 Review Methods

Review Method 1 Management Commitment to Maintain Exposures As Low As Is Reasonably Achievable

Confirm that the management commitment includes provisions for ensuring that:

- No practice involving radiation exposure will be undertaken, unless its use produces a net benefit;
- Supervisors will integrate appropriate radiation protection controls into work activities;
- Personnel are aware of the management commitment to as low as is reasonably achievable principles;
- Workers will receive sufficient and appropriate initial and periodic training related to as low as is reasonably achievable principles, considering the review of training and certification of personnel conducted, using Section 4.5.3 ("Training Certification of Personnel") of the Yucca Mountain Review Plan; and
- An operations program to control radiation exposure will be implemented. This program will ensure that individual and collective doses are as low as is reasonably achievable, considering the review of plans for conduct of normal operations conducted, using Section 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan.

Review Method 2 Consideration of As Low As Is Reasonably Achievable Principles in the Geologic Repository Operations Area Design

Verify that the design of the geologic repository operations area has considered the as low as is reasonably achievable philosophy, as stated in Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposure at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable" (U.S. Nuclear Regulatory Commission, 1978). Note that Regulatory Guide 8.8 is for nuclear power plants, where radiation hazards are more severe than the radiation hazards at the geologic repository operations area; consider this aspect when using this guidance.

Confirm that as low as is reasonably achievable principles are adopted in the design considerations, to the extent possible, to ensure the following:

- Engineered design features minimize the time workers must stay in radiation areas;
- Remotely operated or robotic equipment, such as welders, wrenches, or radiation monitors, are used to minimize worker dose;
- Suitable methods are used to monitor for possible blockage of air cooling passages, or to perform inspection of materials;
- Design permits placement of equipment and temporary shielding by remote control to reduce doses, where possible;
- Materials and design features minimize the potential for accumulation of radioactive materials or surface contamination, to facilitate decontamination, or decontamination and dismantlement, of surface facilities;
- Offices, security areas, and laboratory facilities are located away from radiation sources;
- Radioactive material handling and storage facilities are located sufficiently far from the site boundary and from other on-site work stations. The controlled area of the facility is sufficient to maintain doses at locations accessible to members of the public at acceptable levels;
- Transfer routes for high-level radioactive waste will maintain the desired distance from the site perimeter; and
- Multiple restricted areas within the controlled area provide control of access to areas with radiation levels that would pose unacceptable risk to workers within those areas, if appropriate.

Confirm that modifications to the design of the geologic repository operations area to maintain doses as low as is reasonably achievable have been incorporated in the preclosure safety analysis, to ensure they do not adversely influence other components of the design.

Review Method 3 Incorporation of As Low As Is Reasonably Achievable Principles into Proposed Operations at the Geologic Repository Operations Area

Verify that operational procedures follow the as low as is reasonably achievable philosophy in Regulatory Guides 8.8 and 8.10 (U.S. Nuclear Regulatory Commission, 1978, 1977). Plans for conduct of normal activities, including maintenance, surveillance, and testing, should be reviewed, using Section 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan.

Confirm that geologic repository operations area operational procedures will ensure that the doses to workers and members of the public will be as low as is reasonably achievable, including the consideration of items such as:

- An operations program designed to control radiation exposure will be implemented, to ensure that both individual and collective doses are as low as is reasonably achievable plans for conduct of normal operations, and are reviewed, using Section 4.5.6 ("Plans for Conduct of Normal Activities, Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan);

- Tradeoffs between requirements for increased monitoring or maintenance activities (and the increased exposures that would result), and the potential hazards associated with reduced frequency of these activities;

- Placement sequence of high-level radioactive waste in a manner that maximizes shielding by casks or structures;

- Dry runs to develop proficiency in procedures involving radiation exposures, to determine exposures likely to be associated with specific procedures, and to consider alternative procedures, to minimize exposures;

- Development of tested contingency procedures for potential off-normal occurrences; and

- As low as is reasonably achievable operational alternatives based on experience with independent spent nuclear fuel storage installations, pool facilities, and waste management facilities.

Confirm that modifications to proposed operations of the geologic repository operations area to maintain doses as low as is reasonably achievable have been incorporated in the preclosure safety analysis, to ensure that they do not adversely influence other aspects of geologic repository operations area operations.

4.1.1.8.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.111(a)(1) and (c)(1), relating to meeting the 10 CFR Part 20 as low as is reasonably achievable requirements for normal operations and Category 1 event sequences.

Acceptance Criterion 1 An Adequate Statement of Management Commitment to Maintain Exposures to Workers and the Public as Low as Is Reasonably Achievable Is Provided.

- The management commitment includes provisions for ensuring that:
  - No practice involving radiation exposure will be undertaken, unless its use produces a net benefit;
  - Supervisors will integrate appropriate radiation protection controls into work activities;
  - Personnel are aware of the management commitment to as low as is reasonably achievable principles;
  - Workers will receive sufficient and appropriate initial and periodic training related to as low as is reasonably achievable principles; and
  - An operations program to control radiation exposure will be implemented. This program will ensure that individual and collective doses are as low as is reasonably achievable.

Acceptance Criterion 2 As Low as Is Reasonably Achievable Principles Are Adequately Considered in Geologic Repository Operations Area Design.

- The design of the geologic repository operations area adequately considers the as low as is reasonably achievable philosophy; and
- As low as is reasonably achievable principles are adopted in the design considerations, to the extent possible, to ensure the following:
  - Engineered design features minimize the time workers must stay in radiation areas;
  - Remotely operated or robotic equipment such as welders, wrenches, or radiation monitors are used to minimize worker dose;
  - Suitable methods are used to monitor for possible blockage of air-cooling passages, or to perform inspection of materials;
  - Design permits placement of equipment and temporary shielding by remote control, to reduce doses, where possible;
  - Materials and design features minimize the potential for accumulation of radioactive materials or surface contamination, to facilitate decontamination, or decontamination and dismantlement, of surface facilities;
  - Offices, security areas, and laboratory facilities are located away from radiation sources;

- Radioactive material handling and storage facilities are located sufficiently far from the site boundary and from other on-site work stations. The controlled area of the facility is sufficient to maintain doses at locations accessible to members of the public at acceptable levels;

- Transfer routes for high-level radioactive waste will maintain the desired distance from the site perimeter; and

- Multiple restricted areas, within the controlled area, provide control of access to areas with radiation levels that would pose unacceptable risk to workers within those areas;

• Modifications to the design of the geologic repository operations area to maintain doses as low as is reasonably achievable have been incorporated in the preclosure safety analysis, to ensure they do not adversely influence other components of the design.

Acceptance Criterion 3 Proposed Operations at the Geologic Repository Operations Area Adequately Incorporate as Low as Is Reasonably Achievable Principles.

• Operational procedures follow the as low as is reasonably achievable philosophy;

• Geologic repository operations area operational procedures will ensure that the doses to workers and members of the public will be as low as is reasonably achievable, including the consideration of items such as:

- An operations program designed to control radiation exposure will be implemented, to ensure both individual and collective doses are as low as is reasonably achievable;

- Tradeoffs between requirements for increased monitoring or maintenance activities (and the increased exposures that would result) and the potential hazards associated with reduced frequency of these activities;

- Placement sequence of high-level radioactive waste in a manner that maximizes shielding by casks or structures;

- Dry runs to develop proficiency in procedures involving radiation exposures, to determine exposures likely to be associated with specific procedures, and to consider alternative procedures to minimize exposures;

- Development of tested contingency procedures for potential off-normal occurrences; and

- As low as is reasonably achievable operational alternatives, based on experience with independent spent nuclear fuel storage installations, pool facilities, and waste management facilities.

- Modifications to proposed operations of the geologic repository operations area to maintain doses as low as is reasonably achievable have been incorporated in the preclosure safety analysis, to ensure that they do not adversely influence other aspects of geologic repository operations area operations;

- Verify that operational procedures follow the as low as is reasonably achievable philosophy in Regulatory Guides 8.8 and 8.10 (U.S. Nuclear Regulatory Commission, 1978, 1977). Plans for conduct of normal activities, including maintenance, surveillance, and testing, should be reviewed, using Section 4.5.6 ("Plans for Conduct of Normal Activities Including Maintenance, Surveillance, and Periodic Testing") of the Yucca Mountain Review Plan;

- Confirm that geologic repository operations area operational procedures will ensure that the doses to workers and members of the public will be as low as is reasonably achievable, including the consideration of items such as:

  — An operations program designed to control radiation exposure will be implemented, to ensure both individual and collective doses are as low as is reasonably achievable ("Plans for Conduct of Normal Activities, Including Maintenance, Surveillance, and Periodic Testing") and reviewed, using Section 4.5.6 of the Yucca Mountain Review Plan);

  — Tradeoffs between requirements for increased monitoring or maintenance activities (and the increased exposures that would result) and the potential hazards associated with reduced frequency of these activities;

  — Placement sequence of spent nuclear fuel in a manner that maximizes shielding by casks or structures;

  — Dry runs to develop proficiency in procedures involving radiation exposures, to determine exposures likely to be associated with specific procedures, and to consider alternative procedures to minimize exposures;

  — Development of tested contingency procedures for potential off-normal occurrences; and

  — As low as is reasonably achievable operational alternatives, based on experience with independent spent nuclear fuel storage installations, pool facilities, and waste management facilities.

- Confirm that modifications to proposed operations of the geologic repository operations area, to maintain doses as low as is reasonably achievable, have been incorporated in the preclosure safety analysis, to ensure that they do not adversely influence other aspects of geologic repository operations area operations.

4.1.1.8.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.1.8.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(a)(1). The operations at the geologic repository operations area, through permanent closure, will comply with the as low as is reasonably achievable requirements in 10 CFR Part 20.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they meet the performance objective at 10 CFR 63.111(c)(1). The requirements of 10 CFR 63.111(a) for as low as is reasonably achievable will be met.

4.1.1.8.5 References

U.S. Nuclear Regulatory Commission. Regulatory Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable." Revision 3. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1978.

———. Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable." Revision 1. Washington, DC: U.S. Nuclear Regulatory Commission, Office of Standards Development. 1977.

4.1.2 Plans for Retrieval and Alternate Storage of Radioactive Wastes

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.2.1 Areas of Review

This section provides guidance on the review of plans for retrieval and alternate storage of radioactive wastes. Reviewers will also evaluate the information specified in 10 CFR 63.21(c)(7).

The staff will evaluate the following parts of plans for retrieval and alternate storage of radioactive wastes, using the review methods and acceptance criteria in Sections 4.1.2.2 and 4.1.2.3.

- Plans meeting performance objectives in 10 CFR 63.111(a) and (b);
- Adequate alternate storage for retrieved wastes; and
- Reasonable retrieval schedule.

4.1.2.2 Review Methods

Review Method 1 Waste Retrieval Plans

Confirm that waste retrieval plans include a discussion of: (i) retrieval operations processes; (ii) equipment to be used; and (iii) compliance with 10 CFR 63.111(a) and (b) preclosure performance objectives, during retrieval of waste.

Verify that the U.S. Department of Energy has developed scenarios under which retrieval operations will take place. Confirm that development of the scenarios has considered the 50-year requirement for the retrievability option, and the projected duration of retrieval operations. Assess the reasonableness of the scenarios developed.

Confirm that adequate methodologies have been established for identifying and analyzing potential problems for the various retrieval operations scenarios. Evaluate whether the solutions proposed for the problems identified are feasible, and are based on sound engineering principles. Ensure that the extent of degradation of the emplacement drifts, during the period of retrieval operations, has been appropriately considered in the retrieval plans. Verify that retrieval plans contain acceptable maintenance plans to support the completion of retrieval, within the projected duration.

If the backfilling option is used in emplacement drifts before the end of the period of design for retrievability, determine whether the retrieval plans adequately address the requirements of 10 CFR 63.111(e).

Verify that the U.S. Department of Energy has provided a discussion of the potential effect of the duration of the planned performance confirmation program on the time frame required to maintain the option of waste retrieval. Assess whether there is a need for a different time frame for the period of design for retrievability so it will be consistent with the duration proposed by the U.S. Department of Energy for conducting the performance confirmation program.

Review Method 2 Compliance with Preclosure Performance Objectives

Verify the U.S. Department of Energy has demonstrated that preclosure performance objectives in 10 CFR 63.111(a) and (b) can be met during waste retrieval. Assess if the as low as is reasonably achievable requirements are met during retrieval operation using the review methods and acceptance criteria in Section 4.1.1.8 ("Meeting the 10 CFR Part 20 As Low As Is Reasonably Achievable Requirements for Normal Operations and Category 1 Event Sequences") of the Yucca Mountain Review Plan.

Review Method 3 Proposed Alternate Storage

Determine whether the physical location and boundary of the proposed alternate storage area are adequately defined.

Determine if the proposed alternate storage area is sufficient to hold the waste to be retrieved.

Assess whether the plans are adequate for protection of workers and the public, while transporting the retrieved wastes to the alternate storage area.

Review Method 4 Retrieval Operations Schedule

Verify that plans for retrieval meet the 10 CFR 63.111(e)(3) requirement that retrieval can be completed within a time frame consistent with that required to construct the geologic repository operations area and emplace waste.

4.1.2.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.111(e), relating to plans for retrieval and alternate storage of radioactive wastes.

Acceptance Criterion 1 Plans for Retrieval of Waste Packages, Based on a Reasonable Schedule, Starting at Any Time up to 50 years after Waste Emplacement Operations Are Initiated, Are Provided and Can Be Implemented, If Necessary.

- Waste retrieval plans include an adequate discussion of: (i) retrieval operations processes; (ii) equipment to be used; and (iii) compliance with 10 CFR 63.111(a) and (b) preclosure performance objectives, during retrieval of waste;

- The U.S. Department of Energy has prepared reasonable scenarios under which retrieval operations will take place. The scenarios consider the 50-year requirement for retrievability option, and the projected duration required to complete retrieval operations;

- Adequate methodologies are established for identifying and analyzing potential problems for the various retrieval operations scenarios. The solutions proposed for the problems identified are feasible, and are based on sound engineering principles. The extent of degradation of emplacement drifts, during the period of retrieval operations, is appropriately considered in the retrieval plans. The retrieval plans contain acceptable maintenance plans to support the completion of retrieval, within the projected duration;

- Should the backfilling option be used in emplacement drifts, before the end of the period of design for retrievability, the retrieval plans adequately address the requirements of 10 CFR 63.111(e); and

- The U.S. Department of Energy provides a discussion of the potential effect of the duration of the planned performance confirmation program on the time frame required, to maintain the option of waste retrieval. If there is a need for a different time frame for

the period of design for retrievability, the time frame is consistent with the duration proposed by the U.S. Department of Energy for conducting the performance confirmation program.

Acceptance Criterion 2 The Proposed Retrieval Operations Comply with the Requirements of the Preclosure Performance Objectives.

- The retrieval plan is adequate to meet preclosure performance objectives of 10 CFR 63.111(a) and (b) and adequately consider the as low as is reasonably achievable requirements.

Acceptance Criterion 3 The Proposed Alternate Storage of Retrieved Radioactive Wastes Is Reasonable.

- The physical location and boundary of the proposed alternate storage area are adequately defined;
- The proposed alternate storage area is sufficient to hold the waste to be retrieved; and
- Plans are adequate for protection of workers and the public, while transporting the retrieved wastes to the alternate storage area.

Acceptance Criterion 4 A Reasonable Schedule for Potential Retrieval Operations Is Provided.

- Plans for retrieval meet the 10 CFR 63.111(e)(3) requirement that retrieval can be completed within a time frame consistent with that required to construct the geologic repository operations area and emplace waste.

4.1.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.111(e). The geologic repository operations area has been designed to allow for retrievability of wastes. The option of waste retrieval has been preserved until completion of a performance confirmation program, and the U.S. Nuclear Regulatory Commission review of that program. The design allows for retrieval on a reasonable schedule.

4.1.2.5 References

None.

4.1.3 Plans for Permanent Closure and Decontamination, or Decontamination and Dismantlement of Surface Facilities

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.1.3.1 Areas of Review

This section provides guidance on the review of plans for permanent closure and decontamination, or decontamination and dismantlement of surface facilities. Reviewers will evaluate the information required by 10 CFR 63.21(c)(8) and (c)(16)(vi).

In determining the acceptability of these plans, the reviewer should consider that plans submitted at the time of initial licensing will be prospective in nature, and will not reflect knowledge gained over the course of facility operation (e.g., detailed knowledge of the types, extent, and precise locations of contamination). Therefore, it is not reasonable to expect plans submitted with the initial license application to have the same level of detail as final plans, especially with respect to elements, such as planned decontamination activities and the final radiation survey. The U.S. Department of Energy will be required to submit final plans; these will be reviewed and approved before license termination.

In preparing for the review of the proposed plans for permanent closure, decontamination, and dismantlement, the reviewer should consult the general review procedures contained in any Office of Nuclear Material Safety and Safeguards decommissioning standard review plan. However, the reviewer should keep in mind that these documents are for use with final plans that are prepared at the time of license termination.

The staff will review the following parts of plans for permanent closure and decontamination, or decontamination and dismantlement of surface facilities, using the review methods and acceptance criteria in Sections 4.1.3.2 and 4.1.3.3.

- The description of design considerations that are intended to facilitate permanent closure and decontamination, or decontamination and dismantlement of surface facilities; and
- Plans for permanent closure and decontamination, or decontamination and dismantlement.

4.1.3.2 Review Methods

Review Method 1 Design Considerations That Will Facilitate Permanent Closure and Decontamination, or Decontamination and Dismantlement

Ensure that the license application describes the functions of design features as they relate to permanent closure and decontamination, or decontamination and dismantlement.

Determine whether the repository design is compatible with the objectives of permanent closure and decontamination, or decontamination and dismantlement. Note that the design could be considered to meet this requirement if design provisions included, where feasible and economical, design choices that support closure and decontamination, or decontamination and dismantlement over competing alternatives. If such features were not chosen, an acceptable rationale for not adopting the more favorable alternatives should be provided. Examples of favorable design features include:

- Selection of materials and processes to minimize waste production;
- Minimization of the mass of shielding materials, subject to neutron activation;
- Use of modular design and inclusion of lifting points, to facilitate removal and dismantlement;
- Selection of materials for compatibility with projected closure and decontamination, or decontamination and dismantlement, or waste processing procedures;
- Use of minimum surface roughness finishes on structures, systems, and components that have potential for contamination;
- Use of coatings that preclude penetration into porous materials by radioactive gas, condensate, deposited aerosols, or spills, to permit decontamination by surface treatment;
- Incorporation of features to contain leaks and spills;
- Incorporation of waste minimization techniques; and
- Incorporation of features that would maintain occupational and public radiation exposures as low as is reasonably achievable during decommissioning.

Coordinate with reviewers of the design of waste management systems for Section 4.1.1.7 ("Design of Structures, Systems, and Components Important to Safety and Safety Controls") of the Yucca Mountain Review Plan, to ensure that these designs will facilitate closure and decontamination, or decontamination and dismantlement.

Review Method 2 Plans for Permanent Closure and Decontamination, or Decontamination and Dismantlement

Confirm that the license application presents adequate preliminary plans for permanent closure and decontamination, or decontamination and dismantlement of the surface facilities, as appropriate. Use any Nuclear Material Safety and Safeguards decommissioning standard review plan as guidance for evaluating the adequacy of the preliminary plans. In conducting the review, consider that permanent closure and decommissioning and dismantlement would not begin for many years after the submittal of the license application. Therefore, do not expect the U.S. Department of Energy to submit detailed plans for permanent closure and decommissioning and dismantlement with the license application. However, the preliminary

plans that the U.S. Department of Energy does submit with the license application should have detail sufficient to indicate that the U.S. Department of Energy has considered what the requirements, process, and impact of permanent closure and decommissioning and dismantlement may be in the future.

Evaluate whether the U.S. Department of Energy, in its preliminary plans for permanent closure and decommissioning and dismantlement, has addressed the content areas in any decommissioning standard review plan. For each section of such standard review plan, evaluate whether the preliminary plans provided by the U.S. Department of Energy indicate that the U.S. Department of Energy has evaluated the requirements, process, and impacts of permanent closure, and decommissioning and dismantlement. Specifically, evaluate the following:

Facility history: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to the facility's operating history. This will include information such as records documenting the radionuclides received and processed at the facility and the locations of the processing activities. The U.S. Department of Energy should also indicate how it would document the routine and nonroutine contamination of areas, within the facility, to facilitate future decommissioning activities. The reviewer should refer to any decommissioning standard review plan for a description of the types of information related to the facility's operating history that the U.S. Department of Energy will be required to provide at permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure that the necessary information will be available and defensible at the time of permanent closure and decommissioning.

Facility description: The U.S. Department of Energy should describe the type of information related to the facility and its environs that will be required to evaluate estimation of doses to on-site and off-site populations during, and at the completion of, permanent closure and decommissioning. Refer to any decommissioning standard review plan for a description of the types of information related to the facility and its environs that the U.S. Department of Energy will be required to provide at the time of permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

Radiological status of the facility: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning with respect to the facility's radiological status at permanent closure and decommissioning. This will include information such as the types and extent of radionuclide contamination in media at the facility, including buildings, systems and equipment, surface and subsurface soil, and surface and ground water. The U.S. Department of Energy should provide a preliminary description of the anticipated magnitude of decommissioning activities, with respect to these and any other media. Refer to any decommissioning standard review plan for a description of the types of information related to the facility's radiological status that the U.S. Department of Energy will be required to provide at permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure that the necessary information will be available and defensible at permanent closure and decommissioning.

Dose modeling evaluations: The U.S. Department of Energy should describe the general type of information that will be required to facilitate decommissioning, with respect to the dose modeling at the time of permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

Alternatives for decommissioning: The U.S. Department of Energy should describe the general type of information that will be required to facilitate decommissioning, with respect to evaluating alternative decommissioning strategies. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

As low as is reasonably achievable analysis: The U.S. Department of Energy should describe the general type of information that will be required to facilitate decommissioning, with respect to as low as is reasonably achievable analyses. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

Planned decommissioning activities: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to the planned closure and decommissioning activities. The U.S. Department of Energy should provide preliminary information to allow the reviewer to understand the general approach to decommissioning activities. The U.S. Department of Energy should also provide a preliminary schedule for completing the activities. Refer to any decommissioning standard review plan for a description of the types of information related to planned decommissioning activities that the U.S. Department of Energy will be required to provide at permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

Project management and organization: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to project management and organization. The U.S. Department of Energy should provide preliminary information to allow the reviewer to understand the general approach to managing closure and decommissioning activities. Refer to any decommissioning standard review plan for a description of the types of information related to the management of closure and decommissioning activities that the U.S. Department of Energy will be required to provide at permanent closure and decommissioning.

Health and safety program during decommissioning: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to health and safety program. The U.S. Department of Energy should indicate how the program would be developed and integrated with the preclosure health and safety program.

Environmental monitoring and control program: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to environmental monitoring and control. The U.S. Department of Energy should indicate how

the program would be developed and integrated with the preclosure environmental and control program.

Radioactive waste management program: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to the management of radioactive waste generated through planned closure and decommissioning activities. The U.S. Department of Energy should provide preliminary estimates of the types and quantities of radioactive waste that may be generated through closure and decommissioning activities. The U.S. Department of Energy should provide preliminary plans for minimizing the quantities of radioactive waste, and discuss preliminary plans for disposing of the radioactive waste. Refer to any decommissioning standard review plan for a description of the types of information related to radioactive waste management that the U.S. Department of Energy will be required to provide at permanent closure and decommissioning. The U.S. Department of Energy should indicate how it will ensure the necessary information will be available and defensible at permanent closure and decommissioning.

Quality assurance program: The U.S. Department of Energy should describe the type of information that will be required to facilitate decommissioning, with respect to quality assurance. The U.S. Department of Energy should indicate how the program would be developed and integrated with the preclosure quality assurance program. The U.S. Department of Energy quality assurance program is reviewed using Section 4.5.1 of the Yucca Mountain Review Plan.

Facility radiation surveys: The U.S. Department of Energy should describe the general type of information that will be required to facilitate decommissioning, with respect to radiation surveys to support closure and decommissioning activities.

Financial assurance: The U.S. Department of Energy is not required to provide a financial assurance plan in support of closure or decommissioning.

4.1.3.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.21(c)(8) and (c)(16)(vi), relating to plans for permanent closure and decontamination, or decontamination and dismantlement of surface facilities.

Acceptance Criterion 1 The License Application Describes and Provides Bases for Features of the Geologic Repository Operations Area Design That Will Facilitate Permanent Closure and Decontamination, or Decontamination and Dismantlement of Surface Facilities.

- The license application describes the functions of design features as they relate to permanent closure and decontamination, or decontamination and dismantlement;
- The repository design is compatible with the objectives of permanent closure and decontamination, or decontamination and dismantlement. Design provisions are included, where feasible and economical, and those design choices that support closure and decontamination, or decontamination and dismantlement are selected over

competing alternatives. An acceptable rationale for not adopting the more favorable alternatives is provided; and

- Designs will facilitate closure and decontamination, or decontamination and dismantlement.

Acceptance Criterion 2 The License Application Includes Adequate Preliminary Plans for Permanent Closure and Decontamination, or Decontamination and Dismantlement of Surface Facilities.

- The license application demonstrates that the U.S. Department of Energy is cognizant of the information, analyses, and programs that will be required at permanent closure, decommissioning, and dismantlement;

- The license application demonstrates that the U.S. Department of Energy will ensure that the necessary information to support closure and decommissioning—related to operating history, facility description and radiological status, dose evaluations, alternatives for decommissioning, and as low as is reasonably achievable requirements—will be available at the time of permanent closure and decommissioning;

- The license application demonstrates that the U.S. Department of Energy has an estimate of the scope of closure and decommissioning activities, has preliminary plans for conducting and managing the activities, and has preliminary estimates and plans for managing radioactive waste generated through closure and decommissioning activities; and

- The license application demonstrates that the U.S. Department of Energy has considered the requirements of the health and safety, environmental monitoring, and quality assurance programs required during closure and decommissioning, and has considered how these programs will be developed and integrated with the comparable preclosure programs.

4.1.3.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.1.3.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

The staff has reviewed the Safety Analysis Report and other docketed materials, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.21(c)(8). Requirements for the content of the license application have been met in that the U.S. Department of Energy has provided an adequate description of design considerations that are intended to facilitate permanent closure and decontamination, or decontamination and dismantlement of surface facilities.

The staff has reviewed the Safety Analysis Report and other docketed materials, and has found, with reasonable assurance, that they satisfy the requirements of 10 CFR 63.21(c)(16)(vi). The U.S. Department of Energy has provided adequate plans for permanent closure and decontamination, or decontamination and dismantlement of surface facilities.

4.1.3.5 References

U.S. Nuclear Regulatory Commission. NUREG/SR–1727, "NMSS Decommissioning Standard Review Plan." Washington, DC: U.S. Nuclear Regulatory Commission. 2000.

4.2 Repository Safety After Permanent Closure

4.2.1 Performance Assessment

Risk-Informed Review Process for Performance Assessment—The performance assessment quantifies repository performance, as a means of demonstrating compliance with the postclosure performance objectives at 10 CFR 63.113. The U.S. Department of Energy performance assessment is a systematic analysis that answers the triplet risk questions: what can happen; how likely is it to happen; and what are the consequences. The Yucca Mountain performance assessment is a sophisticated analysis that involves various complex considerations and evaluations. Examples include evolution of the natural environment, degradation of engineered barriers over a 10,000-year period, and disruptive events, such as seismicity and igneous activity. The staff needs to consider the technical support for models and parameters of the performance assessment, based on detailed process models, laboratory and field experiments, and natural analogs. In their evaluation of the technical support for models and parameter distributions, the staff will consider the implications for the repository system and the effects on the calculated dose. Because the performance assessment encompasses such a broad range of issues, the staff needs to use risk information throughout the review process. Using risk information will ensure the review focuses on those items most important to performance.

Section 4.2.1 requires the staff to apply risk information throughout the review of the performance assessment. First, the staff reviews the barriers important to waste isolation in Section 4.2.1.1. The U.S. Department of Energy must identify the important barriers (engineered and natural) of the performance assessment, describe each barrier's capability, and provide the technical basis for that capability. This risk information describes the U.S. Department of Energy understanding of each barrier's capability to prevent or substantially delay the movement of water or radioactive materials. Staff review of the U.S. Department of Energy performance assessment—first the barrier analysis and later the rest of the performance assessment—considers risk insights from previous performance assessments conducted for the Yucca Mountain site, detailed process modeling efforts, laboratory and field experiments, and natural analog studies. The result of the initial multiple barrier review is a staff understanding of each barrier's importance to waste isolation, which will influence the emphasis placed on the reviews conducted in Sections 4.2.1.2, "Scenario Analysis and Event Probability" and 4.2.1.3, "Model Abstraction." The emphasis placed on particular parts of the staff review will change based on changes to the risk insights or in response to preliminary review results.

Scenario analysis and model abstraction are the key attributes of the performance assessment. The risk information, drawn from the review of the multiple barriers section, will direct the staff review to those topics within scenario analysis and model abstraction that are important to waste isolation. Section 4.2.1.2 provides the review methods and acceptance criteria for scenarios for both nominal and disruptive events. An acceptable scenario selection method includes identification and classification, screening, and construction of scenarios from the features, events, and processes considered at the Yucca Mountain site. Then, it is necessary to review abstracted models used in the performance assessment for the retained scenarios. The performance assessment review focuses on the 14 model abstractions in

Section 4.2.1.3 and the implementation of the model abstractions in the total system performance assessment model. These model abstractions stemmed from those aspects of the engineered, geosphere, and biosphere subsystems shown to be most important to performance, based on prior performance assessments and knowledge of site characteristics and repository design. The staff developed each of the fourteen model abstraction sections in substantial detail, to allow for a detailed review. However, it is unlikely that each of the abstractions will have the same risk significance. The staff will review the abstractions according to the risk significance determined in the multiple barrier review, using Section 4.2.1.1. Nevertheless, until the U.S. Department of Energy completes its safety case and the license application, the review plan sections dealing with model abstractions must remain flexible and in enough detail, so that the U.S. Department of Energy will understand how the U.S. Nuclear Regulatory Commission will conduct the reviews .

The review of the model abstraction process begins with the review of the repository design and the data characterizing the geology and the performance of the design and proceeds through the development of models used in the performance assessment. The model abstraction review process ends with a review of how the abstracted models are implemented in the total system performance assessment model (e.g., parameter ranges and distributions, integration with model abstractions for other parts of the repository system, representation of spatial and temporal scales, and whether the performance assessment model appropriately implements the abstracted model). Reviews conducted on the early stages of the model abstraction process will be influenced by the final application of the information. For example, the review of parameter distributions will consider the relevant data, the corresponding uncertainty, and effects on the performance of the repository (i.e., the dose to the reasonably maximally exposed individual). The potential for risk dilution—the lowering of the risk, or dose, from an unsupported parameter range and distribution—will also be part of this review of model abstraction.

An unwanted risk dilution can easily result, if care is not exercised in selecting parameter ranges. For example, the parameter range for the retardation factor of a particular radionuclide could be expanded beyond that found in the supporting data in an effort to represent uncertainty. This expanded range could increase the spread in calculated arrival time for the radionuclide and, consequently, result in a smaller expected annual dose. The staff will review parameter ranges and distributions to evaluate whether they are technically defensible, whether they appropriately represent uncertainty, and the potential for risk dilution.

In many regulatory applications, a conservative approach can be used to decrease the need to collect additional information or to justify a simplified modeling approach. Conservative estimates for the dose to the reasonably maximally exposed individual may be used to demonstrate that the proposed repository meets U.S. Nuclear Regulatory Commission regulations and provides adequate protection of public health and safety. Approaches designed to overestimate a specific aspect of repository performance (e.g., higher temperatures within the drifts) may be conservative with respect to temperature but could lead to non-conservative results with respect to dose. The total system performance assessment is a complex analysis with many parameters, and the U.S. Department of Energy may use conservative assumptions to simplify its approaches and data collection needs. However, a technical basis that supports the selection of models and parameter ranges or distributions must be provided. The staff evaluation of the adequacy of technical bases supporting models

and parameter ranges or distributions will consider whether the approach results in calculated doses that would overestimate, rather than underestimate, the dose to the reasonably maximally exposed individual. In particular, the claim of conservatism as a basis for simplifying models and parameters should be carefully evaluated to ensure that any simplifications are justified and do not unintentionally result in nonconservative results.

The intentional use of conservatism to manage uncertainty also has implications for the staff's efforts to risk-inform its review. The staff will evaluate assertions that a given model or parameter distribution is conservative from the perspective of overall system performance (i.e., the dose to the reasonably maximally exposed individual). The staff will use any available information to risk-inform its review. For example, if the U.S. Department of Energy were to use an approach that overestimates a specific aspect of repository performance, then the staff would consider the effects of this approach on other parts of the total system performance assessment model, overall repository performance, and the representation or sensitivity of important phenomena.

4.2.1.1 System Description and Demonstration of Multiple Barriers

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.1.1 Areas of Review

This section addresses review of the system description and demonstration of multiple barriers. Reviewers will evaluate the information required by 10 CFR 63.21(c)(1), (9), (10), (14), and (15).

The staff will evaluate the following parts of the system description and demonstration of multiple barriers, using the review methods and acceptance criteria in Sections 4.2.1.1.2 and 4.2.1.1.3.

- Identification of barriers relied on for postclosure performance; (including at least one barrier from the engineered system and one from the natural system);
- Description of the capability of identified barriers to prevent or substantially delay the movement of water or radioactive materials, including the uncertainty associated with this capability and the consistency with approaches used in the total system performance assessment; and
- Discussion of the technical bases for assertions of barrier capability commensurate with the importance of a particular barrier in the performance assessment and with the associated uncertainties.

4.2.1.1.2 Review Methods

Review Method 1 Identification of Barriers

Verify that the U.S. Department of Energy has described the repository system in terms of the engineered components and attributes of the geologic setting, which are barriers contributing to the postclosure performance of the repository. Confirm that the U.S. Department of Energy has clearly linked identified barriers to a capability to prevent or substantially delay the movement of water or radioactive materials. Verify that, among the materials, structures, and features and processes identified as barriers, at least one is engineered and one is part of the geologic setting.

Review Method 2 Description of Barrier Capability

Verify that the U.S. Department of Energy description of barrier capability is explained in terms of a capability to prevent or substantially delay the movement of water or radioactive materials, and includes a characterization of the related uncertainty.

Confirm that information is provided on the time period over which each barrier performs its intended function, including any changes during the compliance period.
Confirm that the U.S. Department of Energy adequately describes the capability of each barrier, including uncertainties, consistent with the quantitative analyses in the U.S. Department of Energy total system performance assessment (e.g., sensitivity and uncertainty analyses, and intermediate results for individual barriers).

To the extent possible, use information gained from alternative total system performance assessment code audit calculations and/or other appropriate quantitative analyses to confirm each barrier's capabilities.

Review Method 3 Technical Basis for Barrier Capability

Use information gained from the review conducted, using Review Method 2, to focus review of the adequacy of the technical bases. Verify Department of Energy has provided technical bases to support the descriptions of barrier capability commensurate with the significance of each barrier's capability and the associated uncertainties. Confirm the technical bases are based on and consistent with the technical bases for the performance assessment. Based on the reviews conducted using Sections 4.2.1.2 ("Scenario Analysis and Event Probability") and 4.2.1.3 ("Model Abstraction"), confirm the quality and completeness of the technical bases for the barrier capabilities.

4.2.1.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements at 10 CFR 63.113(a) and 63.115(a)–(c).

Acceptance Criterion 1 Identification of Barriers Is Adequate.

Barriers relied on to achieve compliance with 10 CFR 63.113(b), as demonstrated in the total system performance assessment, are adequately identified, and are clearly linked to their capability. The barriers identified include at least one from the engineered system and one from the natural system.

Acceptance Criterion 2 Description of Barrier Capability to Isolate Waste Is Acceptable

The capability of the identified barriers to prevent or substantially delay the movement of water or radioactive materials is adequately identified and described:

- The information on the time period over which each barrier performs its intended function, including any changes during the compliance period, is provided;
- The uncertainty associated with barrier capabilities is adequately described; and
- The described capabilities are consistent with the results from the total system performance assessment.

Acceptance Criterion 3 Technical Basis for Barrier Capability Is Adequately Presented.

The technical bases are consistent with the technical basis for the performance assessment. The technical basis for assertions of barrier capability is commensurate with the importance of each barrier's capability and the associated uncertainties.

4.2.1.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.1.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed materials, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.113(a). An engineered barrier system has been designed that, working in combination with natural barriers, satisfies the requirement for a system of multiple barriers, in compliance with the postclosure performance objectives.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed materials, and has found, with reasonable expectation, that they satisfy the requirements at 10 CFR 63.115(a)–(c). Those design features of the engineered barrier system and natural features of the geologic setting that are considered barriers important to waste isolation have been identified. A description has been provided of the capability of barriers identified as important to waste isolation to isolate waste, taking into account uncertainties in characterizing and modeling the barriers, and the technical basis for this

description has been provided that is based on and consistent with the technical basis for the performance assessment.

4.2.1.1.5 References

None.

4.2.1.2 Scenario Analysis and Event Probability

4.2.1.2.1 Scenario Analysis

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.2.1.1 Areas of Review

This section reviews identification of features, events, and processes affecting compliance with the overall performance objective. Reviewers will also evaluate the information required by 10 CFR 63.21(c)(1) and (9).

Review the U.S. Department of Energy methodology for inclusion or exclusion of features, events, and processes in the total system performance assessment. The U.S. Department of Energy is not required to use steps provided here that involve categorization and screening of the initial comprehensive features, events, and processes list for an acceptable license application. However, many steps can be used in accordance with the requirements in 10 CFR Part 63 to reduce the burden of the analysis and to focus the representation of the system on those features, events, and processes that most affect compliance with the overall performance objective. All included features, events, and processes must be appropriately incorporated into the total system performance assessment, and will be reviewed as part of the model abstraction review conducted, using Section 4.2.1.3 of the Yucca Mountain Review Plan.

To evaluate repository postclosure safety, ensure that the U.S. Department of Energy has conducted analyses that consider potential future conditions a repository may be subjected to, during the period of regulatory concern. These analyses should address those features, events, and processes necessary to describe the future evolution of the repository system.

The staff will review the following parts of the identification of features, events, and processes affecting compliance with the overall performance objective, using the review methods and acceptance criteria in Sections 4.2.1.2.1.2 and 4.2.1.2.1.3:

- Identification of an initial list of features, events, and processes;
- Screening of the initial list of features, events, and processes;
- Formation of scenario classes using the reduced set of features, events and processes; and
- Screening of scenario classes.

4.2.1.2.1.2 Review Methods

Review Method 1 Identification of an Initial List of Features, Events, and Processes

Verify that the U.S. Department of Energy list of features, events, and processes includes all features, events, and processes having a potential to influence repository performance. Use knowledge gained reviewing the Yucca Mountain site and regional characterization data and the description of the modes of degradation, deterioration, and alteration of the engineered barriers to assess the completeness of the features, events, and processes list. The staff should use, as appropriate, available generic lists of features, events, and processes (e.g., Nuclear Energy Agency, 1997), as a reference to determine the completeness of the U.S. Department of Energy list of features, events, and processes.

Review Method 2 Screening of the Initial List of Features, Events, and Processes

Examine the excluded features and processes. Evaluate the adequacy of the rationale for excluding each feature and process, based on the description of the site, the design specifications, and the waste characteristics. Consider information from site and regional characterization, natural analog studies, and the repository design, during this evaluation.

Examine the U.S. Department of Energy event-screening rationale, to determine whether an event is appropriately defined. Use the results of the review, conducted using Section 4.2.1.2.2 of the Yucca Mountain Review Plan, for this purpose. Assess the U.S. Department of Energy justification (i.e., whether the probability of occurrence can be technically supported) for those events that fall below the regulatory probability criterion, to evaluate whether the U.S. Department of Energy defined these events too narrowly, and they were inappropriately excluded.

Review the criteria used to screen features, events, and processes related to the geologic setting, and the degradation, deterioration, or alteration of engineered barriers from the performance assessment, based on their limited effect on the magnitude and time of the average annual dose. Evaluate the U.S. Department of Energy analyses or calculations supporting this screening and the use of bounding or representative estimates for the consequences. Independently assess, using tools such as an alternative total system performance assessment code, the potential consequences to confirm the U.S. Department of Energy screening of features, events, and processes.

Review Method 3 Formation of Scenario Classes Using the Reduced Set of Events

Evaluate the U.S. Department of Energy description of the approach and technical bases, to determine whether the resulting scenario classes are mutually exclusive and include all events that have not been screened from the performance assessment.

Review Method 4 Screening of Scenario Classes

Review the criteria used by the U.S. Department of Energy to screen scenario classes from the performance assessment on the basis that their omission would not significantly change the magnitude nor time of the average annual dose. Examine the U.S. Department of Energy

analyses or calculations supporting this screening and the use of bounding or representative estimates for the consequences. Independently assess, using tools such as an alternative total system performance assessment code, as needed, the potential consequences to confirm the U.S. Department of Energy screening of scenario classes.

Evaluate whether the U.S. Department of Energy has adequately considered coupling of processes in estimates of consequences used to screen scenario classes. For each screened scenario class, assess related scenario classes to evaluate whether a narrow definition resulted in the premature exclusion of the scenario class.

Examine those scenario classes excluded for the Yucca Mountain repository and the supporting technical bases. Consider the site description, design specifications, and waste characteristics in this examination. Also, consider information from site and regional characterization, natural analog studies, and repository design, in this evaluation.

Use the results of the review, conducted using Section 4.2.1.2.2 of the Yucca Mountain Review Plan, to examine the U.S. Department of Energy technical justification for screening scenario classes from the performance assessment, based on their probability of being below the regulatory criterion.

4.2.1.2.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements at 10 CFR 63.114(e) and (f).

Acceptance Criterion 1 The Identification of an Initial List of Features, Events, and Processes Is Adequate

- The Safety Analysis Report contains a complete list of features, events, and processes, related to the geologic setting or the degradation, deterioration, or alteration of engineered barriers (including those processes that would affect the performance of natural barriers), that have the potential to influence repository performance. The list is consistent with the site characterization data. Moreover, the comprehensive features, events, and processes list includes, but is not limited to, potentially disruptive events related to igneous activity (extrusive and intrusive); seismic shaking (high-frequency-low magnitude, and rare large-magnitude events); tectonic evolution (slip on existing faults and formation of new faults); climatic change (change to pluvial conditions); and criticality.

Acceptance Criterion 2 Screening of the Initial List of Features, Events, and Processes Is Appropriate

- The U.S. Department of Energy has identified all features, events, and processes related to either the geologic setting or to the degradation, deterioration, or alteration of engineered barriers (including those processes that would affect the performance of natural barriers) that have been excluded;

- The U.S. Department of Energy has justified excluding each feature, event, and process. An acceptable justification for excluding features, events, and processes is that either the feature, event, and process is specifically excluded by regulation; probability of the feature, event, and process (generally an event) falls below the regulatory criterion; or omission of the feature, event, and process does not significantly change the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment; and

- The U.S. Department of Energy has provided an adequate technical basis for each feature, event, and process, excluded from the performance assessment, to support the conclusion that either the feature, event, or process is specifically excluded by regulation; the probability of the feature, event, and process falls below the regulatory criterion; or omission of the feature, event, and process does not significantly change the magnitude and time of the resulting radiological exposures to the reasonably maximally exposed individual, or radionuclide releases to the accessible environment.

Acceptance Criterion 3 Formation of Scenario Classes Using the Reduced Set of Events Is Adequate

- Scenario classes are mutually exclusive and complete, clearly documented, and technically acceptable.

Acceptance Criterion 4 Screening of Scenario Classes Is Appropriate

- Screening of scenario classes is comprehensive, clearly documented, and technically acceptable;

- The U.S. Department of Energy has adequately considered coupling of processes in estimates of consequences used to screen scenario classes. Scenario classes were not prematurely excluded by a narrow definition;

- Scenario classes that are screened from the performance assessment, on the basis that they are specifically ruled out by regulation or are contrary to stated regulatory assumptions are identified, and sufficient justifications are provided;

- Scenario classes that are screened from the performance assessment, on the basis that their probabilities fall below the regulatory criterion, are identified, and sufficient justifications are provided; and

- Scenario classes that are screened from the performance assessment, on the basis that their omission would not significantly change the magnitude and time of the average annual dose, are identified, and sufficient justifications are provided.

4.2.1.2.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.2.1.3 are appropriately satisfied, the staff concludes that this evaluation is

complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.114(e) and (f) in that:

- The Safety Analysis Report provides an adequate initial list of features, events, and processes related to the geologic setting or the degradation, deterioration, or alteration of engineered barriers (including those processes that would affect the performance of natural barriers) that have the potential to influence repository performance;
- The list of initial features, events, and processes has been appropriately screened;
- Scenario classes formed from the screened list of features, events, and processes are adequate; and
- Scenario classes have been appropriately screened.

4.2.1.2.1.5 Reference

Nuclear Energy Agency. "An International Database of Features, Events, and Processes [Draft]." Nuclear Energy Agency Working Group on the "Development of a Database of Features, Events, and Processes Relevant to the Assessment of Post-Closure Safety of Radioactive Waste Repositories, Safety Assessment of Radioactive Waste Repositories Series." United Kingdom: Safety Assessment Management Limited. June 24, 1997.

4.2.1.2.2 Identification of Events with Probabilities Greater Than 10^{-8} Per Year

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.2.2.1 Areas of Review

This section reviews identification of events with probabilities greater than 10^{-8} per year. Reviewers will also evaluate information required by 10 CFR 63.21(c)(1) and (9).

The staff will evaluate the following parts of the identification of events with probabilities greater than 10^{-8} per year, using the review methods and acceptance criteria in Sections 4.2.1.2.2.2 and 4.2.1.2.2.3:

- Definitions of events, such as faulting, seismicity, igneous activity, and criticality;
- The probability assigned to each event, and the technical bases used to support this assignment;

- Conceptual models evaluated or considered in determining the probabilities of events;
- Parameters used to calculate the probabilities of events; and
- Uncertainty in models and parameters used to calculate the probabilities of events.

4.2.1.2.2.2 Review Methods

Review Method 1 Event Definition

Evaluate whether the definitions for events (potentially beneficial or disruptive), applicable to the Yucca Mountain repository, are unambiguous; probabilities are estimated for the specific event; and event definitions are used consistently and appropriately in probability models.

Confirm that probabilities of intrusive and extrusive igneous events are calculated separately. Verify that definitions of faulting and earthquakes are derived from the historical record, paleoseismic studies, or geological analyses. Confirm that criticality events, for the purpose of initial screening of the features, events, and processes list, are calculated separately, only by location of the criticality event (e.g., in-package, near-field, and far-field).

Review Method 2 Probability Estimates

Evaluate whether the probability estimates for events applicable to Yucca Mountain are based on past patterns of natural events in the Yucca Mountain region, or are consistent with the design of the proposed repository system. Evaluate whether the U.S. Department of Energy interpretations of the likelihood of future occurrence of the events are compatible with current understandings of present and likely future conditions of the natural and engineered repository systems.

Verify that probability estimates for future igneous events are based on past patterns of igneous events in the Yucca Mountain region. Evaluate the adequacy and sufficiency of the U.S. Department of Energy characterization and documentation of past igneous activity. This should include uncertainties about the distribution, timing, and characteristics of past igneous activity. Confirm that, at a minimum, documentation of past igneous activity, since about 12 million years ago, encompasses the area within about 50 kilometers (30 miles) of the proposed repository site. Give particular attention to the documentation of the locations, ages, volumes, geochemistry, and geologic settings of less than 6-million-year-old basaltic igneous features, such as cinder cones, lava flows, igneous dikes, and sills. Verify that the U.S. Department of Energy used geological and geophysical information relevant to past igneous activity contained in the literature.

Verify that probability estimates for future faulting and seismic events are based on past patterns of these events in the Yucca Mountain region. Examine the adequacy and sufficiency of characterization and documentation of past faulting and seismicity in the Yucca Mountain region, since 2 million years ago. This should include characterization of uncertainties in the age, timing, magnitude (i.e., displacements), distribution, size, location, and style of faulting and seismicity. Evaluate whether interpretations of faulting and seismicity from surficial and underground mapping, interpretations of geophysical data, or analog investigations are

internally consistent and geologically feasible, so reasonable projections can be made about the probability of future faulting and earthquake-induced ground vibrations at the site.

Evaluate whether probability estimates for future criticality events are based on design characteristics and natural features of the proposed Yucca Mountain repository system. Ensure that the U.S. Department of Energy has included all fuel types to be disposed of at the proposed Yucca Mountain repository in calculating probability of future criticality events. Confirm that the estimate of probability of criticality is determined using methodology outlined in the "U.S. Department of Energy Topical Report on Disposal Criticality" (U.S. Department of Energy, 1998), as amended by responses to the U.S. Nuclear Regulatory Commission request for additional information,[2] and subject to conditions and limitations in the U.S. Nuclear Regulatory Commission safety evaluation report (U.S. Nuclear Regulatory Commission, 2000).

Review Method 3 Probability Model Support

Confirm that a technical justification is provided for models used to estimate the probability for events applicable to the Yucca Mountain repository. Determine whether justifications include comparison with results from detailed process models, or comparison with empirical observations, such as reasonably analogous natural systems or appropriate laboratory tests. Ensure that alternative modeling approaches, consistent with available data and current scientific understanding, are investigated, and results and limitations are appropriately factored into the probability models.

Examine whether the U.S. Department of Energy probability models are consistent with known less than 12-million-year-old basaltic igneous events in the Yucca Mountain magmatic system. Determine whether the U.S. Department of Energy probability models are consistent with patterns of igneous activity in other, comparable volcanic fields outside the Yucca Mountain region. Use independent models to estimate the probabilities of igneous activity, based on geologic information from the Yucca Mountain region. Verify that the U.S. Department of Energy considered alternative interpretations of probability for igneous events. Assess whether igneous-activity probability models are consistent with the range of tectonic models used to assess other geological processes, such as seismic source characterization, site geological models, and patterns of ground-water flow.

Determine whether results of the U.S. Department of Energy probabilistic and total system performance assessment models compare reasonably to results from seismotectonic process models, and/or empirical observations from appropriate analogs. Verify that the U.S. Department of Energy appropriately adopted acceptable and documented procedures, to construct and test empirical and physical models used to estimate the seismic and fault-displacement hazards. For faulting, ascertain whether the U.S. Department of Energy models, used to describe primary and secondary (or distributed) faulting, are justified technically, and are adequate to predict the effects of faulting on repository performance. For seismicity, determine whether the U.S. Department of Energy considered credible alternative modeling

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[2]U.S. Department of Energy. "U.S. Department of Energy (DOE) Response to U.S. Nuclear Regulatory Commission Request for Additional Information on the DOE Topical Report on Disposal Criticality Analysis Methodology." Letter (November 19) to C.W. Reamer, U.S. Nuclear Regulatory Commission. Washington, DC: U.S. Department of Energy. 1999.

approaches for determining tectonic ground motions that relate to repository performance. Assess whether faulting models are consistent with fault-slip rates, fault displacements, or earthquake data used in the seismic hazard analysis; and evaluate whether the timing and magnitude of future seismic events are consistent with the results of the fault-hazard analysis.

Confirm that models, used to estimate the probability of future criticality events, are validated, using methodology outlined in the "U.S. Department of Energy Topical Report on Disposal Criticality" (U.S. Department of Energy, 1998), as amended by responses to the U.S. Nuclear Regulatory Commission request for additional information,[3] and subject to conditions and limitations contained in the U.S. Nuclear Regulatory Commission safety evaluation report (U.S. Nuclear Regulatory Commission, 2000).

Probability model support for infrequent events should include data from analog systems that contain significantly more events than the Yucca Mountain system. This support should also include justification that the models reproduce the timing and characteristics of past events in the Yucca Mountain system. Confirm that probability models for natural events use geologic bases that are consistent with other relevant features, events, and processes.

Review Method 4 Probability Model Parameters

Determine whether the parameters used to calculate the probability of events, applicable to the Yucca Mountain repository, are reasonable, based on data from the Yucca Mountain region or analogous natural systems, and/or design and engineering characteristics of the proposed Yucca Mountain repository system.

Assess whether the parameters used in probabilistic volcanic hazard assessments are reasonable, based on data from the Yucca Mountain region, and confirm that comparable volcanic systems outside the Yucca Mountain region were considered in developing such parameters.

Verify whether parameter values used in probabilistic seismic and fault-displacement hazard assessments are adequately supported by Yucca Mountain region faulting and earthquake data or appropriate analogs, so the effects of faulting and seismicity are appropriately factored into repository performance. Ensure that parameters are consistent with the range of faulting characteristics and seismicity observed in the Yucca Mountain region, or with parameters derived from representative analogs, and ascertain that the parameters account for variability in data precision and accuracy. For example, determine whether the U.S. Department of Energy adequately evaluated uncertainties in faulting or earthquake activity (i.e., recurrence). Confirm that the U.S. Department of Energy has established reasonable and consistent correlations between parameters, where appropriate.

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[3]U.S. Department of Energy. "U.S. Department of Energy (DOE) Response to U.S. Nuclear Regulatory Commission Request for Additional Information on the DOE Topical Report on Disposal Criticality Analysis Methodology." Letter (November 19) to C.W. Reamer, U.S. Nuclear Regulatory Commission. Washington, DC: U.S. Department of Energy. 1999.

Where sufficient data do not exist, confirm that parameter values and conceptual models are based on appropriate use of other sources, such as expert elicitation, using NUREG–1563 (Kotra, et al., 1996).

Review Method 5 Uncertainty in Event Probability

For events applicable to the Yucca Mountain repository, determine whether the U.S. Department of Energy has adequately identified and propagated uncertainties in estimating probabilities. Ensure that an adequate technical basis, that includes treatment of uncertainty, is provided for the probability value. For probability distributions or ranges, confirm that a technical basis for the analysis is provided, and that the distribution or range accounts for the uncertainty in the probability estimates.

Assess the probability values used for igneous events by considering the range of values available in the literature for the Yucca Mountain region and comparable volcanic fields outside the Yucca Mountain region. To confirm that probability models are sufficiently robust to reasonably approximate the distribution of Yucca Mountain region igneous features, evaluate probability models by testing their sensitivity to uncertainties about the past distribution of volcanic vents, recurrence rates of volcanism, and relationships between igneous activity and tectonism.

Verify that probabilities used in the evaluation of faulting and seismicity effects on repository performance include both infrequent seismic and faulting events with relatively large-magnitude ground motions and fault displacements, and the cumulative effects of repeated ground motions or fault displacements from more frequent and lower-magnitude seismic or faulting events.

4.2.1.2.2.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements at 10 CFR 63.114(d).

Acceptance Criterion 1 Events Are Adequately Defined.

- Events or event classes are defined without ambiguity and used consistently in probability models, such that probabilities for each event or event class are estimated separately; and

- Probabilities of intrusive and extrusive igneous events are calculated separately. Definitions of faulting and earthquakes are derived from the historical record, paleoseismic studies, or geological analyses. Criticality events are calculated separately by location.

Acceptance Criterion 2 Probability Estimates for Future Events Are Supported by Appropriate Technical Bases.

- Probabilities for future natural events are based on past patterns of the natural events in the Yucca Mountain region, considering the likely future conditions and interactions of

the natural and engineered repository system. These probability estimates have specifically included igneous events, faulting and seismic events, and criticality events.

Acceptance Criterion 3 Probability Model Support Is Adequate.

- Probability models are justified through comparison with output from detailed process-level models and/or empirical observations (e.g., laboratory testing, field measurements, or natural analogs, including Yucca Mountain site data). Specifically:

  — For infrequent events, the U.S. Department of Energy justifies, to the extent possible, proposed probability models with data from reasonably analogous systems. Analog systems should contain significantly more events than the Yucca Mountain system, to provide reasonable evaluations of probability model performance;

  — The U.S. Department of Energy justifies, to the extent possible, the ability of probability models to reproduce the timing and characteristics (e.g., location and magnitude) of successive past events in the Yucca Mountain system; and

  — The U.S. Department of Energy probability models for natural events use underlying geologic bases (e.g., tectonic models) that are consistent with other relevant features, events, and processes evaluated, using Section 4.2.1.2.1.

Acceptance Criterion 4 Probability Model Parameters Have Been Adequately Established.

- Parameters used in probability models are technically justified and documented by the U.S. Department of Energy. Specifically:

  — Parameters for probability models are constrained by data from the Yucca Mountain region and engineered repository system to the extent practical;

  — The U.S. Department of Energy appropriately establishes reasonable and consistent correlations between parameters; and

  — Where sufficient data do not exist, the definition of parameter values and conceptual models is based on appropriate use of other sources, such as expert elicitation conducted in accordance with appropriate guidance.

Acceptance Criterion 5 Uncertainty in Event Probability Is Adequately Evaluated.

- Probability values appropriately reflect uncertainties. Specifically:

  — The U.S. Department of Energy provides a technical basis for probability values used, and the values account for the uncertainty in the probability estimates; and

  — The uncertainty for reported probability values adequately reflects the influence of parameter uncertainty on the range of model results (i.e., precision) and the

model uncertainty, as it affects the timing and magnitude of past events (i.e., accuracy).

4.2.1.2.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.2.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed materials, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.114(d). The license application considers those events that have at least one chance in 10,000 of occurring over 10,000 years.

4.2.1.2.2.5 References

Kotra, et al. NUREG–1563, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program." Washington, DC: U.S. Nuclear Regulatory Commission. 1996.

U.S. Department of Energy. "Disposal Criticality Analysis Methodology Topical Report." YMP/TR–004Q. Revision 0. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. November 1998.

U.S. Nuclear Regulatory Commission. "Draft Safety Evaluation Report on Disposal Criticality Analysis Methodology Topical Report." Revision 0. Washington, DC: U.S. Nuclear Regulatory Commission. 2000.

4.2.1.3 Model Abstraction

There are 14 model abstraction sections the staff will use to determine compliance with 10 CFR 63.114. The abstractions consider the engineered, geosphere, and biosphere subsystems that may be important to performance. Important to performance means important to meeting the performance objectives specified in 10 CFR 63.113 The staff will decide which abstractions are important to performance, by using risk insights gained from performance assessments, knowledge of site characteristics and repository design, and review of the U.S. Department of Energy safety case. Each section provides enough review methods and acceptance criteria to allow for a detailed review. However, it is unlikely that each of the 14 abstraction topics will have the same risk significance and need the same review level. Nevertheless, until the U.S. Department of Energy completes its safety case and the license application, the sections about model abstractions need to be flexible and in enough detail that the staff clearly understands how to conduct the review of abstraction information provided by the licensee. The staff will focus its review to understand the importance to performance of the various assumptions, models, and data in the performance assessment. The staff will also focus its review to ensure that the degree of technical support for models and data abstractions

is equal to their contribution to risk. This means the staff will review each model abstraction to a detail level suitable to the degree the U.S. Department of Energy relies on it to prove its safety case. The staff will be familiar with the U.S. Department of Energy safety case, because of the multiple barrier review (refer to Section 4.2.1.1). In the multiple barrier review, the staff will evaluate the capability of the barriers. For example, if the U.S. Department of Energy relies on the unsaturated zone to provide significant delay in the transport of radionuclides to the reasonably maximally exposed individual, then the staff will perform a detailed review of the abstraction of radionuclide transport in the unsaturated zone. However, if the U.S. Department of Energy shows that this abstraction has a minor impact on the delay in the transport of radionuclides to the reasonably maximally exposed individual, then the staff will conduct a simplified review focusing on the bounding assumptions. The staff will use the review methods and acceptance criteria in these sections to decide whether the U.S. Department of Energy properly characterized the features, events, and processes and properly factored them into the performance assessment. This is necessary to decide whether the U.S. Department of Energy performance assessment is acceptable and complies with 10 CFR 63.114 and 63.115. The review methods and acceptance criteria the staff will use to evaluate compliance with the performance objectives (numerical standard) are in Section 4.2.1.4 of the Yucca Mountain Review Plan.

4.2.1.3.1 Degradation of Engineered Barriers

To review this model abstraction, evaluate the adequacy of the U.S. Department of Energy license application, relative to the degree to which degradation of engineered barriers affects the U.S. Department of Energy safety case. Review this model abstraction, considering the risk information evaluated in the "Multiple Barriers" Section (4.2.1.1). For example, if the U.S. Department of Energy relies on the engineered barriers to provide significant delay in the transport of radionuclides to the reasonably maximally exposed individual, then perform a detailed review of this abstraction. If, on the other hand, the U.S. Department of Energy demonstrates this abstraction to have a minor impact on the dose to the reasonably maximally exposed individual, then conduct a simplified review focusing on the bounding assumptions. The review methods and acceptance criteria provided here are for a detailed review. Some of the review methods and acceptance criteria may not be necessary in a simplified review for those abstractions that have a minor impact on performance. The demonstration of compliance with the performances objective is evaluated using Section 4.2.1.4 of the Yucca Mountain Review Plan.

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.3.1.1 Areas of Review

This section reviews degradation of engineered barriers within the emplacement drift. Reviewers will also evaluate information, required by 10 CFR 63.21(c)(3), (9), (10), (15) and (19), that is relevant to the abstraction of degradation of engineered barriers. It is important to note that the scope of this review includes various parts of the engineered barrier system, as specified in 10 CFR 63.2.

The staff will evaluate the following parts of the abstraction of degradation of engineered barriers, using review methods and acceptance criteria in Sections 4.2.1.3.1.2 and 4.2.1.3.1.3:

- Description of the engineered barrier system, hydrology, geochemistry, and thermal effects related to the degradation of the engineered barrier system and the technical basis the U.S. Department of Energy provides to support model integration, across the total system performance assessment abstractions;
- Sufficiency of the data and parameters used to justify the total system performance assessment model abstraction;
- Methods the U.S. Department of Energy uses to characterize data uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Methods the U.S. Department of Energy uses to characterize model uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Approaches the U.S. Department of Energy uses to compare the total system performance assessment output to process-level model outputs and empirical studies; and
- Use of expert elicitation.

4.2.1.3.1.2 Review Methods

To review the abstraction of degradation of engineered barriers, recognize that models used in the total system performance assessments may range from highly complex process-level models to simplified models, such as response surfaces or look-up tables. Evaluate model adequacy, regardless of the level of complexity.

Review Method 1 Model Integration

Examine the U.S. Department of Energy license application description of design features, physical phenomena, and couplings, as well as the description of the waste package, and features of the engineered barrier system that contribute to high-level radioactive waste isolation. Assess the adequacy of the technical bases for these descriptions and for incorporating them in the total system performance assessment abstraction for the degradation of engineered barriers.

Examine assumptions, technical bases, data, and models used by the U.S. Department of Energy in the total system performance assessment abstraction degradation process models in the total system performance assessment abstraction of the degradation of engineered barriers, for consistency with other related U.S. Department of Energy abstractions. Evaluate whether the descriptions and technical bases provide transparent and traceable support for the abstraction of the degradation of the engineered barriers.

Evaluate whether the U.S. Department of Energy description of aspects of environmental conditions, within the waste package emplacement drifts, design features, physical phenomena, and couplings that may affect the degradation of the engineered barriers, is adequate. Verify that conditions and assumptions, used in the total system performance assessment abstraction of the degradation of the engineered barriers, are consistent with the body of data presented in the abstraction.

Confirm that the U.S. Department of Energy has propagated boundary and initial conditions, used in the total system performance assessment abstraction of the degradation of engineered barriers, throughout its abstraction approaches.

Examine how the features, events, and processes, related to the degradation of the engineered barriers have been included in the total system performance assessment abstraction.

Evaluate the technical bases that the U.S. Department of Energy used for selecting the design criteria, that mitigate any potential impact of in-package criticality on repository performance, including all features, events, and processes that may increase the reactivity of the system inside the waste package; all the configuration classes and configurations that have potential for nuclear criticality; and changes in radionuclide inventory and thermal conditions, in the abstraction of the degradation of engineered barriers.

Verify that the U.S. Department of Energy reviews follow guidance such as NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or other acceptable approaches.

Review Method 2 Data and Model Justification

Evaluate the sufficiency of the experimental and site characterization data used to support parameters used in conceptual models, process-level models, and alternative conceptual models, considered in the total system performance assessment abstraction of degradation of engineered barriers.

Verify whether sufficient data have been collected to adequately model degradation processes, as well as characteristics of the geochemistry, hydrology, design features, and thermal effects, to establish initial and boundary conditions for the total system performance assessment abstraction of degradation of engineered barriers. For example, mechanical property data should cover the range of anticipated temperatures and microstructural conditions. The corrosion data should consider the appropriate range of environmental conditions, such as chloride concentration.

Evaluate and confirm that data used to support the U.S. Department of Energy total system performance assessment abstraction of the degradation of engineered barriers are based on appropriate techniques, and are adequate for the accompanying sensitivity/uncertainty analyses. Evaluate the need for additional data, based on the sensitivity analyses.

Verify that the U.S. Department of Energy demonstrates the adequacy of the degradation of engineered barriers models used to assess the range of possible degradation processes.

Review Method 3 Data Uncertainty

Evaluate the technical bases for parameter values, assumed ranges, probability distributions, and bounding assumptions used in conceptual models, process models, and alternative conceptual models, considered in the total system performance assessment abstraction of degradation of engineered barriers. Evaluate the assessment of uncertainty and variability in these parameters, and verify that the technical bases reasonably account for the uncertainties and variabilities in the data.

Examine the abstraction for those degradation processes that the U.S. Department of Energy assumes are not important to performance and confirm that the parameters, used in these abstractions, are assigned values consistent with the abstractions of other degradation processes, determined to be significant to performance of the engineered barriers, as well as the initial and boundary conditions used in other abstractions for the total system performance assessment.

Determine whether the U.S. Department of Energy has used parameters, in the abstraction of the degradation of engineered barriers, that are based on laboratory experiments, field measurements, natural analog or industrial analog research, and process-level modeling studies, conducted under conditions relevant to the range of environmental conditions in the emplacement drifts located in the unsaturated zone at Yucca Mountain. Examine the results of the U.S. Department of Energy engineered barrier degradation tests, and confirm that the U.S. Department of Energy has provided adequate models.

Evaluate the methods used by the U.S. Department of Energy for nondestructive examination of fabricated engineered barriers, including the type, size, and location of fabrication defects, that may lead to premature failure, as a result of rapidly initiated engineered barrier degradation. Examine the justification for the allowable distribution of fabrication defects in the engineered barriers, and evaluate how the U.S. Department of Energy assesses the effect on engineered barrier performance of defects that cannot be detected.

Evaluate the methods used by the U.S. Department of Energy in conducting expert elicitation to define parameter values.

Review Method 4 Model Uncertainty

Evaluate the U.S. Department of Energy alternative conceptual models used in developing the total system performance assessment abstraction for degradation of engineered barriers. Examine the model parameters in the context of available site characterization data, laboratory corrosion tests, field measurements, and process-level modeling studies.

Where appropriate, use an alternative total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction of the degradation of engineered barriers, including waste package corrosion. Examine the effects of the alternative conceptual models on repository performance, and evaluate how model uncertainties are defined, documented and assessed.

Examine the mathematical models used in the analyses of degradation of engineered barriers.

Examine and evaluate the bases for excluding alternative conceptual models and the limitations and uncertainties of the chosen model.

Review Method 5 Model Support

Evaluate the output from the abstraction of the degradation of engineered barriers, and compare the results with a combination of data from laboratory corrosion testing and field measurements, as well as results obtained through process-level modeling. Evaluate the sensitivity analyses used to support the abstraction of the degradation of engineered barriers in the total system performance assessment.

Use detailed models of degradation processes to evaluate the total system performance assessment abstractions of the degradation of engineered barriers. If practical, use an alternative to the total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction of the degradation of the engineered barriers, and assess the effects on repository performance. Compare results of the U.S. Department of Energy abstraction to approximations shown to be appropriate for closely analogous systems, industrial experience, and experimental results.

Evaluate evidence to show that models used to evaluate performance are not likely to underestimate the actual degradation and failure of engineered barriers, as a result of corrosion or other degradation processes.

In developing supporting evidence for the models, verify that mathematical models for the degradation of engineered barriers are based on the same environmental parameters, material factors, assumptions, and approximations shown to be appropriate for closely analogous engineering or industrial applications and experimental investigations.

Examine the procedures used by the U.S. Department of Energy to construct and test its mathematical and numerical models.

As appropriate, use an alternative total system performance assessment model to evaluate the U.S. Department of Energy sensitivity or bounding analyses, and confirm that the U.S. Department of Energy has used ranges consistent with available site characterization data, field and laboratory tests, and industrial and natural analog research.

4.2.1.3.1.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.114(a)–(c) and (e)–(g), relating to the degradation of engineered barriers model abstraction. U.S. Nuclear Regulatory Commission staff should apply the following acceptance criteria, according to the level of importance established in the U.S. Department of Energy risk-informed safety case.

Acceptance Criterion 1 System Description and Model Integration Are Adequate.

- The total system performance assessment adequately incorporates important design features, physical phenomena, and couplings, and uses consistent and appropriate assumptions throughout the degradation of engineered barriers abstraction process;

- Assessment abstraction of the degradation of engineered barriers uses assumptions, technical bases, data, and models that are appropriate and consistent with other related U.S. Department of Energy abstractions. For example, the assumptions used for degradation of engineered barriers should be consistent with the abstractions of the quantity and chemistry of water contacting waste packages and waste forms (Section 4.2.1.3.3); climate and infiltration (Section 4.2.1.3.5); and mechanical disruption of waste packages (Section 4.2.1.3.2). The descriptions and technical bases provide transparent and traceable support for the abstraction of the degradation of engineered barriers;

- The descriptions of engineered barriers, design features, degradation processes, physical phenomena, and couplings that may affect the degradation of the engineered barriers are adequate. For example, materials and methods used to construct the engineered barriers are included, and degradation processes, such as uniform corrosion, pitting corrosion, crevice corrosion, stress corrosion cracking, intergranular corrosion, microbially influenced corrosion, dry-air oxidation, hydrogen embrittlement, and the effects of wet and dry cycles, material aging and phase stability, welding, and initial defects on the degradation modes for the engineered barriers are considered;

- Boundary and initial conditions used in the total system performance assessment abstractions are propagated consistently throughout the abstraction approaches. For example, the conditions and assumptions used in the degradation of engineered barriers abstraction are consistent with those used to model the quantity and chemistry of water contacting waste packages and waste forms (Section 4.2.1.3.3); climate and infiltration (Section 4.2.1.3.5); and mechanical disruption of waste packages (Section 4.2.1.3.2);

- Sufficient technical bases for the inclusion of features, events, and processes related to degradation of engineered barriers in the total system performance assessment abstractions are provided;

- Adequate technical bases are provided, for selecting the design criteria, that mitigate any potential impact of in-package criticality on repository performance, including considering all features, events, and processes that may increase the reactivity of the system inside the waste package. For example, the technical bases for the abstraction of the degradation of engineered barriers include configuration classes and configurations that have potential for nuclear criticality, changes in radionuclide inventory, and changes in thermal conditions; and

- Guidance in NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or other acceptable approaches, is followed.

Acceptance Criterion 2 Data Are Sufficient for Model Justification.

- Parameters used to evaluate the degradation of engineered barriers in the safety case are adequately justified (e.g., laboratory corrosion tests, site-specific data such as data from drift-scale tests, in-service experience in pertinent industrial applications, and test results not specifically performed for the Yucca Mountain site, etc.). The U.S. Department of Energy describes how the data were used, interpreted, and appropriately synthesized into the parameters;

- Sufficient data have been collected on the characteristics of the engineered components, design features, and the natural system to establish initial and boundary conditions for abstraction of degradation of engineered barriers;

- Data on the degradation of the engineered barriers (e.g., general and localized corrosion, microbially influenced corrosion, galvanic interactions, hydrogen embrittlement, and phase stability), used in the abstraction, are based on laboratory measurements, site-specific field measurements, industrial analog and/or natural analog research, and tests designed to replicate the range of conditions that may occur at the Yucca Mountain site. As appropriate, sensitivity or uncertainty analyses, used to support the U.S. Department of Energy total system performance assessment abstraction, are adequate to determine the possible need for additional data; and

- Degradation models for the processes that may be significant to the performance of the engineered barriers are adequate. For example, the U.S. Department of Energy models consider the possible degradation of the engineered barriers, as a result of uniform and localized corrosion processes, stress-corrosion cracking, microbially influenced corrosion, hydrogen embrittlement, and incorporate the effects of fabrication processes, thermal aging, and phase stability.

Acceptance Criterion 3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction

- Models use parameter values, assumed ranges, probability distributions, and/or bounding assumptions that are technically defensible and reasonably account for uncertainties and variabilities;

- For those degradation processes that are significant to the performance of the engineered barriers, the U.S. Department of Energy provides appropriate parameters, based on techniques that may include laboratory experiments, field measurements, industrial analogs, and process-level modeling studies conducted under conditions relevant to the range of environmental conditions within the waste package emplacement drifts. The U.S. Department of Energy also demonstrates the capability to predict the degradation of the engineered barriers in laboratory and field tests;

- For the selection of parameters used in conceptual and process-level models of engineered barrier degradation that can be expected under repository conditions, assumed range of values and probability distributions are not likely to underestimate the actual degradation and failure of engineered barriers as a result of corrosion;

- The U.S. Department of Energy uses appropriate methods for nondestructive examination of fabricated engineered barriers to assess the type, size, and location of fabrication defects that may lead to premature failure as a result of rapidly initiated engineered barrier degradation. The U.S. Department of Energy specifies and justifies the allowable distribution of fabrication defects in the engineered barriers, and assesses the effects of defects that cannot be detected on the performance of the engineered barriers; and

- Where sufficient data do not exist, the definition of parameter values and conceptual models, used by the U.S. Department of Energy, is based on appropriate use of other sources, such as expert elicitation conducted in accordance with NUREG–1563 (Kotra, et al., 1996). If other approaches are used, the U.S. Department of Energy adequately justifies their use.

Acceptance Criterion 4 Model Uncertainty Is Characterized and Propagated Through the Model Abstraction.

- Alternative modeling approaches of features, events, and processes are considered and are consistent with available data and current scientific understanding, and the results and limitations are appropriately considered in the abstraction;

- Conceptual model uncertainties are defined and documented, and conclusions regarding performance of the engineered barriers are properly assessed; and

- The U.S. Department of Energy uses alternative modeling approaches, consistent with available data and current scientific understanding, and evaluates the model results and limitations, using tests and analyses that are sensitive to the processes modeled. For example, for processes such as uniform corrosion, localized corrosion, and stress-corrosion cracking of the engineered barriers, the U.S. Department of Energy considers alternative modeling approaches, to develop its understanding of environmental conditions and material factors significant to these degradation processes.

Acceptance Criterion 5 Model Abstraction Output Is Supported by Objective Comparisons.

- Models implemented in this total system performance assessment abstraction provide results consistent with output from detailed process-level models and/or empirical observations (laboratory and field testings and/or natural analogs);

- Numerical corrosion models used to calculate the lifetimes of the engineered barriers are adequate representations, considering the associated uncertainties in the expected long-term behaviors, the range of conditions (including residual stresses), and the variability in engineered barrier fabrication processes (including welding);

- Evidence is sufficient to show that models used to evaluate performance are not likely to underestimate the actual degradation and failure of engineered barriers, as a result of corrosion or other degradation processes;

- Mathematical models for the degradation of engineered barriers are based on the same environmental parameters, material factors, assumptions, and approximations shown to be appropriate for closely analogous engineering or industrial applications and experimental investigations;

- Accepted and well-documented procedures are used to construct and test the numerical models that simulate the engineered barrier chemical environment and degradation of engineered barriers; and

- Sensitivity analyses or bounding analyses are provided to support the abstraction of degradation of engineered barriers that cover ranges consistent with the site data, field or laboratory experiments and tests, and industrial analogs.

4.2.1.3.1.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.3.1.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.114, regarding the abstraction of degradation of engineered barriers in the performance assessment. In particular, the U.S. Nuclear Regulatory Commission staff found that:

- Appropriate data from the site and surrounding region, uncertainties and variabilities in parameter values, and alternative conceptual models have been used in the analyses, in compliance with 10 CFR 63.114(a)–(c);

- Specific features, events, and processes have been included in the analyses, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(e);

- Specific degradation, deterioration, and alteration processes have been included in the analyses, taking into consideration their effects on annual dose, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(f); and

- Adequate technical bases have been provided for models used in the performance assessment, as required by 10 CFR 63.114(g).

4.2.1.3.1.5 References

Altman, W.D., J.P. Donnelly, and J.E. Kennedy. NUREG–1297, "Generic Technical Position on Peer-Review for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988a.

———. NUREG–1298, "Generic Technical Position on Qualification of Existing Data for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988b.

Kotra, J.P., et al. NUREG–1563, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program." Washington, DC: U.S. Nuclear Regulatory Commission. 1996.

4.2.1.3.2 Mechanical Disruption of Engineered Barriers

Mechanical disruption of a waste package is defined as partial or total mechanical failure of the waste package resulting from external events (man-made and/or natural), which immediately or eventually reduces its design life and intended performance, and, consequently, causes release of radionuclides. For example, a rock fall may cause a container to rupture or may cause a dent in its structure, which could lead to an accelerated rate of corrosion and failure sooner than under normal conditions.

To review this model abstraction, evaluate the adequacy of the U.S. Department of Energy license application, relative to the degree to which mechanical disruption of engineered barriers affects the U.S. Department of Energy safety case. Review this model abstraction, considering the risk information evaluated in the "Multiple Barriers" Section (4.2.1.1). For example, if the U.S. Department of Energy relies on the engineered barriers to provide significant delay in the transport of radionuclides to the reasonably maximally exposed individual, then perform a more detailed review of this abstraction. If, on the other hand, the U.S. Department of Energy demonstrates this abstraction to have a minor impact on the delay in the transport of radionuclides to the reasonably maximally exposed individual, then conduct a simplified review focusing on the bounding assumptions. The review methods and acceptance criteria provided here are for a detailed review. Some of the review methods and acceptance criteria may not be necessary in a simplified review for those abstractions that have a minor impact on performance. The demonstration of compliance with the performance objectives is evaluated using Section 4.2.1.4 of the Yucca Mountain Review Plan.

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.3.2.1 Areas of Review

This section reviews mechanical disruption of engineered barriers. Reviewers will also evaluate information, required by 10 CFR 63.21(c)(1)–(3), (9), (10), (15), and (19), that is relevant to the abstraction of mechanical disruption of engineered barriers.

The staff will evaluate the following parts of the abstraction of mechanical disruption of engineered barriers, using the review methods and acceptance criteria in Sections 4.2.1.3.2.2 and 4.2.1.3.2.3:

- Description of the geological and engineering aspects of mechanical disruption of engineered barriers and the technical bases the U.S. Department of Energy provides to support model integration across the total system performance assessment abstractions;
- Sufficiency of the data and parameters used to justify the model abstraction;
- Methods the U.S. Department of Energy uses to characterize data uncertainty, and propagate the effects of this uncertainty through the total system performance assessment;
- Methods the U.S. Department of Energy uses to characterize model uncertainty, and propagate the effects of this uncertainty through the total system performance assessment;
- Approaches the U.S. Department of Energy uses to compare total system performance assessment output to process-level model outputs and empirical studies; and
- Use of expert elicitation.

4.2.1.3.2.2 Review Methods

To review the abstraction of mechanical disruption of engineered barriers, recognize that models used in the total system performance assessment may range from highly complex process-level models to simplified models, such as response surfaces or look-up tables. Evaluate model adequacy, regardless of the level of complexity.

Review Method 1 Model Integration

Examine the description of design features, physical phenomena, and couplings included in the mechanical disruption of engineered barriers abstraction. Assess the adequacy of the technical bases for these descriptions and for incorporating them in the total system performance assessment abstraction of mechanical disruption of engineered barriers.

Evaluate whether the description of design features, physical phenomena, and couplings that may affect mechanical disruption of engineered barriers is adequate. Verify that conditions and assumptions, used in the total system performance assessment abstraction of mechanical disruption of engineered barriers, are consistent with the body of data presented in the description.

Examine assumptions, technical bases, data, and models, used by the U.S. Department of Energy in the total system performance assessment abstraction of mechanical disruption of engineered barriers, for consistency with other related U.S. Department of Energy abstractions.

Evaluate whether the descriptions and technical bases provide transparent and traceable support for the abstraction of mechanical disruption of engineered barriers.

Confirm that the U.S. Department of Energy has propagated boundary and initial conditions, used in the total system performance assessment abstraction of mechanical disruption of engineered barriers, throughout its abstraction approaches.

Examine how the features, events, and processes, related to mechanical disruption of engineered barriers, have been included in the total system performance assessment abstraction.

Evaluate the U.S. Department of Energy conclusion with respect to the impact of transient criticality on the integrity of the engineered barriers.

Verify that the U.S. Department of Energy reviews follow guidance, such as NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or make an acceptable case for using alternative approaches.

Review Method 2 Data and Model Justification

Evaluate the sufficiency of the geological and engineering data used to support parameters for conceptual models, process-level models, and alternative conceptual models considered in the abstraction of mechanical disruption of engineered barriers. Evaluate the basis for the data on physical phenomena, couplings, geology, and engineering used in the abstraction of mechanical disruption of engineered barriers. This basis may include a combination of techniques, such as laboratory experiments, site-specific field measurements, natural analog research, process-level modeling studies, and expert elicitation.

Verify that sufficient data have been collected to adequately characterize the geology of the natural system, engineering materials, and initial manufacturing defects to establish initial and boundary conditions for the abstraction of mechanical disruption of engineered barriers.

Evaluate and confirm that data used to support the U.S. Department of Energy abstraction of mechanical disruption of engineered barriers are based on appropriate techniques, and are adequate for the accompanying sensitivity/uncertainty analyses. Evaluate the need for additional data based on sensitivity analyses.

Verify that the U.S. Department of Energy demonstrates the adequacy of engineered barrier mechanical failure models for disruption events.

Review Method 3 Data Uncertainty

Evaluate the technical bases for parameter values, assumed ranges, probability distributions, and bounding assumptions, used in conceptual models, process-level models, and alternative conceptual models, considered in the abstraction of mechanical disruption of engineered barriers. Evaluate the assessment of uncertainty and variability in these parameters, and verify that the technical bases reasonably account for uncertainties and variabilities in the data.

Evaluate the U.S. Department of Energy justification of process-level models used to represent mechanically disruptive events within the emplacement drifts at the proposed Yucca Mountain repository. Verify that the U.S. Department of Energy parameter values are adequately constrained by Yucca Mountain site data, such that the effects of mechanically disruptive events on engineered barrier integrity are not underestimated. Confirm that the U.S. Department of Energy identifies parameters within conceptual models for mechanically disruptive events that are consistent with the range of characteristics observed at Yucca Mountain.

Assess how uncertainty is represented in parameter development for conceptual models, process-level models, and alternative conceptual models, considered in developing the abstraction of mechanical disruption of engineered barriers.

Evaluate the methods used by the U.S. Department of Energy in conducting expert elicitation to define parameter values.

Review Method 4 Model Uncertainty

Evaluate the U.S. Department of Energy alternative conceptual models used in developing the abstraction for mechanical disruption of engineered barriers. Examine the model parameters, considering available site characterization data, laboratory experiments, field measurements, natural analog research, and process-level modeling studies and evaluate their consistency.

Where appropriate, use an alternative total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction of mechanical disruption of engineered barriers. Examine the effects of the alternative conceptual model(s) on repository performance, and evaluate how model uncertainties are defined, documented, and assessed.

Examine the mathematical models included in the analyses of mechanical disruption of engineered barriers. Also, examine and evaluate the bases for excluding alternative conceptual models, and the limitations and uncertainties of the chosen model.

Review Method 5 Model Support

Evaluate the output from the abstraction of mechanical disruption of engineered barriers, and compare the results with an appropriate combination of site characterization data, process-level modeling, laboratory testing, field measurements, and natural analog research.

Use detailed models of geological and engineering processes to evaluate the total system performance assessment abstractions of mechanical disruption of engineered barriers. If practical, use an alternative total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction of mechanical disruption of engineered barriers, and evaluate the effects on repository performance. Compare results of the U.S. Department of Energy abstraction to approximations shown to be appropriate for closely analogous natural systems or experimental systems.

Examine the procedures used by the U.S. Department of Energy to develop and test its mathematical and numerical models.

As appropriate, use an alternative total system performance assessment model to evaluate the U.S. Department of Energy sensitivity or bounding analyses, and confirm that the U.S. Department of Energy has used ranges consistent with available site characterization data, field and laboratory tests, and natural analog research.

4.2.1.3.2.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.114(a)–(c) and (e)–(g), relating to the mechanical disruption of engineered barriers model abstraction. U.S. Nuclear Regulatory Commission staff should apply the following acceptance criteria, according to the level of importance established in the U.S. Department of Energy risk-informed safety case.

Acceptance Criterion 1 System Description and Model Integration Are Adequate.

- Total system performance assessment adequately incorporates important design features, physical phenomena, and couplings, and uses consistent and appropriate assumptions throughout the mechanical disruption of engineered barrier abstraction process;

- The description of geological and engineering aspects of design features, physical phenomena, and couplings, that may affect mechanical disruption of engineered barriers, is adequate. For example, the description may include materials used in the construction of engineered barrier components, environmental effects (e.g., temperature, water chemistry, humidity, radiation, etc.) on these materials, and mechanical-failure processes and concomitant failure criteria used to assess the performance capabilities of these materials. Conditions and assumptions in the abstraction of mechanical disruption of engineered barriers are readily identified and consistent with the body of data presented in the description;

- The abstraction of mechanical disruption of engineered barriers uses assumptions, technical bases, data, and models that are appropriate and consistent with other related U.S. Department of Energy abstractions. For example, assumptions used for mechanical disruption of engineered barriers are consistent with the abstraction of degradation of engineered barriers (Section 4.2.1.3.1 of the Yucca Mountain Review Plan). The descriptions and technical bases provide transparent and traceable support for the abstraction of mechanical disruption of engineered barriers;

- Boundary and initial conditions used in the total system performance assessment abstraction of mechanical disruption of engineered barriers are propagated throughout its abstraction approaches;

- Sufficient data and technical bases to assess the degree to which features, events, and processes have been included in this abstraction are provided;

- The conclusion, with respect to the impact of transient criticality on the integrity of the engineered barriers, is defensible; and

- Guidance in NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or other acceptable approaches, is followed.

Acceptance Criterion 2 Data Are Sufficient for Model Justification.

- Geological and engineering values, used in the safety case to evaluate mechanical disruption of engineered barriers, are adequately justified. Adequate descriptions of how the data were used, interpreted, and appropriately synthesized into the parameters are provided;

- Sufficient data have been collected on the geology of the natural system, engineering materials, and initial manufacturing defects, to establish initial and boundary conditions for the total system performance assessment abstraction of mechanical disruption of engineered barriers;

- Data on geology of the natural system, engineering materials, and initial manufacturing defects, used in the total system performance assessment abstraction, are based on appropriate techniques. These techniques may include laboratory experiments, site-specific field measurements, natural analog research, and process-level modeling studies. As appropriate, sensitivity or uncertainty analyses used to support the U.S. Department of Energy total system performance assessment abstraction are adequate to determine the possible need for additional data; and

- Engineered barrier mechanical failure models for disruption events are adequate. For example, these models may consider effects of prolonged exposure to the expected emplacement drift environment, material test results not specifically designed or performed for the Yucca Mountain site, and engineered barrier component fabrication flaws.

Acceptance Criterion 3 Data Uncertainty Is Characterized and Propagated Through the Model Abstraction.

- Models use parameter values, assumed ranges, probability distributions, and/or bounding assumptions that are technically defensible and reasonably account for uncertainties and variabilities;

- Process-level models used to represent mechanically disruptive events, within the emplacement drifts at the proposed Yucca Mountain repository, are adequate. Parameter values are adequately constrained by Yucca Mountain site data, such that the effects of mechanically disruptive events on engineered barrier integrity are not underestimated. Parameters within conceptual models for mechanically disruptive events are consistent with the range of characteristics observed at Yucca Mountain;

- Uncertainty is adequately represented in parameter development for conceptual models, process-level models, and alternative conceptual models considered in developing the assessment abstraction of mechanical disruption of engineered barriers. This may be done either through sensitivity analyses or use of conservative limits; and

- Where sufficient data do not exist, the definition of parameter values and conceptual models is based on appropriate use of expert elicitation, conducted in accordance with NUREG–1563 (Kotra, et al., 1996). If other approaches are used, the U.S. Department of Energy adequately justifies their use.

Acceptance Criterion 4 Model Uncertainty Is Characterized and Propagated Through the Model Abstraction.

- Alternative modeling approaches of features, events, and processes are considered and are consistent with available data and current scientific understanding, and the results and limitations are appropriately considered in the abstraction;

- Conceptual model uncertainties are adequately defined and documented, and effects on conclusions regarding performance are properly assessed; and

- Appropriate alternative modeling approaches are investigated that are consistent with available data and current scientific knowledge, and appropriately consider their results and limitations using tests and analyses that are sensitive to the processes modeled.

Acceptance Criterion 5 Model Abstraction Output Is Supported by Objective Comparisons.

- Models implemented in this total system performance assessment abstraction provide results consistent with output from detailed process-level models and/or empirical observations (laboratory and field testings and/or natural analogs);

- Outputs of mechanical disruption of engineered barrier abstractions reasonably produce or bound the results of corresponding process-level models, empirical observations, or both;

- Well-documented procedures, that have been accepted by the scientific community to construct and test the mathematical and numerical models, are used to simulate mechanical disruption of engineered barriers; and

- Sensitivity analyses or bounding analyses are provided to support the total system performance assessment abstraction of mechanical disruption of engineered barriers that cover ranges consistent with site data, field or laboratory experiments and tests, and natural analog research.

4.2.1.3.2.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.3.2.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.114, regarding the abstraction of mechanical disruption of engineered barriers in the performance assessment. In particular, the U.S. Nuclear Regulatory Commission staff found that:

- Appropriate data from the site and surrounding region, uncertainties and variabilities in parameter values, and alternative conceptual models have been used in the analyses, in compliance with 10 CFR 63.114(a)–(c);

- Specific features, events, and processes have been included in the analyses, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(e);

- Specific degradation, deterioration, and alteration processes have been included in the analyses, taking into consideration their effects on annual dose, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(f); and

- Adequate technical bases have been provided for models used in the performance assessment, as required by 10 CFR 63.114(g).

4.2.1.3.2.5 References

Altman, W.D., J.P. Donnelly, and J.E. Kennedy. NUREG–1297, "Generic Technical Position on Peer-Review for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988a.

———. NUREG–1298, "Generic Technical Position on Qualification of Existing Data for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988b.

Kotra, J.P., et al. NUREG–1563, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program." Washington, DC: U.S. Nuclear Regulatory Commission. 1996.

4.2.1.3.3 Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms

To review this model abstraction, evaluate the adequacy of the U.S. Department of Energy license application, relative to the degree to which the quantity and chemistry of water contacting waste packages and waste forms affect the U.S. Department of Energy safety case. Review this model abstraction, considering the risk information evaluated in the "Multiple Barriers" Section (4.2.1.1). For example, if the U.S. Department of Energy relies on the processes affecting the quantity and chemistry of water contacting waste packages and waste forms to significantly reduce dose to the reasonably maximally exposed individual, then a detailed review of this abstraction will be performed. If, on the other hand, the U.S. Department of Energy demonstrates that this abstraction has a minor impact on the dose to the reasonably maximally exposed individual, then a simplified review will be conducted focusing on the

bounding assumptions. The review methods and acceptance criteria provided here are for a detailed review. Some of the review methods and acceptance criteria may not be necessary, in a simplified review, for those abstractions that have a minor impact on performance. The demonstration of the performance objectives is evaluated in Section 4.2.1.4 of the Yucca Mountain Review Plan.

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.3.3.1 Areas of Review

This section reviews quantity and chemistry of water contacting waste packages and waste forms. Reviewers will also evaluate information, required by 10 CFR 63.21(c)(1)–(4), (9), (10), (15), and (19), that is relevant to the abstraction of quantity and chemistry of water contacting waste packages and waste forms.

The staff will evaluate the following parts of the abstraction of quantity and chemistry of water contacting waste packages and waste forms, using the review methods and acceptance criteria in Sections 4.2.1.3.3.2 and 4.2.1.3.3.3:

- Description of the geological, hydrological, and geochemical aspects of quantity and chemistry of water contacting waste packages and waste forms, and the technical bases the U.S. Department of Energy provides to support model integration across the total system performance assessment abstractions;
- Sufficiency of the data and parameters used to justify the model abstraction;
- Methods the U.S. Department of Energy uses to characterize data uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Methods the U.S. Department of Energy uses to characterize model uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Approaches the U.S. Department of Energy uses to compare total system performance assessment output to process-level model outputs and empirical studies; and
- Use of expert elicitation.

4.2.1.3.3.2 Review Methods

To review the abstraction of quantity and chemistry of water contacting waste packages and waste forms, recognize that models used in the total system performance assessments may range from highly complex process-level models to simplified models, such as response surfaces or look-up tables. Evaluate model adequacy regardless of the level of complexity.

Review Method 1 Model Integration

Examine the descriptions of design features (including drip shield, backfill, waste packages, drift design and support, thermal loading, and other engineered barrier components); relevant physical features; physical phenomena; and couplings, as well as the description of the geological, hydrological, geochemical, and geomechanical aspects of the unsaturated zone, included in the abstraction of quantity and chemistry of water contacting waste packages and waste forms. Assess the adequacy of the technical bases for these descriptions, and for incorporating them in the total system performance assessment to represent quantity and chemistry of water contacting waste packages and waste forms.

Evaluate whether the description of hydrology, geology, geochemistry, design features, physical phenomena, and couplings, that may affect the quantity and chemistry of water contacting waste packages and waste forms, is adequate. Verify that conditions, assumptions, and the technical bases, used in the abstraction of quantity and chemistry of water contacting waste packages and waste forms, are consistent with other related U.S. Department of Energy abstractions.

Verify that important design features, such as waste package design and material selection, backfill, drip shield, ground support, thermal loading strategy, and degradation processes, are included in determining the initial and boundary conditions for calculations of the quantity and chemistry of water contacting waste packages and waste forms.

Examine the spatial and temporal abstractions to determine whether they appropriately address the physical couplings (thermal-hydrologic-mechanical-chemical).

Assess the technical bases for the geological, hydrological, geochemical, and geomechanical descriptions, and for incorporating them in the total system performance assessment abstraction for coupled thermal-hydrologic-mechanical-chemical effects. Determine whether the technical bases used for modeling assumptions and approximations have been documented, and are adequate. Evaluate whether the descriptions provide transparent and traceable support to the abstraction, and are consistent with other model abstractions.

Evaluate the model abstraction for quantity and chemistry of water contacting waste packages and waste forms, to ensure that it reasonably bounds the expected ranges of environmental conditions within the waste package emplacement drifts, inside of breached waste packages, and contacting the waste forms.

Evaluate the consistency of the model abstraction for quantity and chemistry of water contacting waste packages and waste forms with detailed information on waste package design and other engineered features.

Examine how the features, events, and processes, related to the quantity and chemistry of water contacting waste packages and waste forms have been included in the total system performance assessment abstraction.

Determine whether processes that have been observed in thermal-hydrologic tests and experiments and that are significant to performance are included in the total system performance assessment model abstraction.

Ensure that the U.S. Department of Energy includes likely modes for container corrosion (Section 4.2.1.3.1 of the Yucca Mountain Review Plan) in determining the quantity and chemistry of water entering the waste packages and contacting waste forms. Evaluate the treatment of parameters such as pH and carbonate concentration, and the effect of waste package corrosion on the quantity and chemistry of water contacting waste packages and waste forms.

Evaluate the abstraction of in-package criticality or external-to-package criticality within the emplacement drift, and the associated technical basis for screening these events. Ensure that if either event is included in the total system performance assessment, the U.S. Department of Energy uses acceptable technical bases for selecting the design criteria that mitigate the potential impact of in-package criticality on repository performance; identifies the features, events, and processes that may increase the reactivity of the system inside the waste package; identifies the configuration classes and configurations that have potential for nuclear criticality; and includes changes in thermal conditions and degradation of engineered barriers in the abstraction of the quantity and chemistry of water contacting waste packages and waste forms.

Verify that the U.S. Department of Energy reviews follow the guidance in NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or make an acceptable case for using alternative approaches.

Review Method 2 Data and Model Justification

Evaluate the sufficiency of the geological, hydrological, and geochemical data used to support parameters used in conceptual models, process-level models, and alternative conceptual models (if any) considered in the abstraction of quantity and chemistry of water contacting waste packages and waste forms. Evaluate whether the basis for the data includes a combination of techniques, such as laboratory experiments, site-specific field measurements, natural analog research, process-level modeling studies, and expert elicitation. Assess how the data were used, interpreted, and synthesized into the parameters. Examine and confirm the sufficiency, transparency, and traceability of the data that support the technical bases for features, events, and processes, related to the quantity and chemistry of water contacting waste packages and waste forms, that have been included in the total system performance assessment abstraction.

Verify that sufficient data were collected on the characteristics of the natural system and engineered materials to establish initial and boundary conditions for conceptual models of thermal-hydrologic-mechanical-chemical coupled processes that affect seepage and flow and the waste package chemical environment, and the chemical environment for radionuclide release.

Ensure that the U.S. Department of Energy has used results from thermal-hydrologic tests to identify important processes and establish temperature ranges for repository conditions in

developing its mathematical models. Verify that the data are sufficient to support thermal-hydrologic conceptual models.

Evaluate the sufficiency of data used to support the conceptual approaches for water contact with the drip shield, waste package, and waste forms.

Examine the sufficiency of data used to support the analysis of the potential for microbial activity affecting the waste package chemical environment and the chemical environment for radionuclide release. Ensure that the data are sufficient to constrain the probability for microbially influenced corrosion and microbially enhanced dissolution of the high-level radioactive waste glass form.

Review Method 3 Data Uncertainty

Evaluate the sufficiency of the technical bases for parameter values and ranges used in conceptual models, process-level models, and alternative conceptual models considered in the total system performance assessment abstraction. Determine whether the U.S. Department of Energy has reasonably accounted for uncertainties and variabilities in developing parameter values and ranges.

Determine whether the parameter values are based on site-specific data obtained from techniques such as laboratory and field experiments. As necessary, evaluate whether the parameter values and ranges derived from natural analog research or process-level models are correctly incorporated in the model abstraction of quantity and chemistry of water contacting waste packages and waste forms.

Evaluate the initial and boundary conditions used to evaluate coupled thermal-hydrologic-mechanical-chemical effects on the quantity and chemistry of water contacting waste packages and waste forms for consistency with available data. As necessary, confirm that correlations between input values have been appropriately established in the U.S. Department of Energy total system performance assessment.

Evaluate the U.S. Department of Energy assessment of uncertainty and variability in parameters. Determine whether the U.S. Department of Energy incorporates data uncertainty and temporal and spatial variability in conditions affecting coupled thermal-hydrologic-mechanical-chemical effects into parameter ranges.

If in-package criticality or external-to-package criticality is included in the total system performance assessment, examine the methods and parameters used by the U.S. Department of Energy to calculate the effective neutron multiplication factor.

If expert elicitations were used as a basis for data uncertainty for this abstraction, confirm they were conducted in accordance with appropriate guidance (Kotra, et al., 1996).

Review Method 4 Model Uncertainty

Determine whether the U.S. Department of Energy has considered appropriate alternative conceptual models. Examine the bases for alternative conceptual models, considered in the

model abstraction of quantity and chemistry of water contacting waste packages and waste forms, and the limitations and uncertainties of the chosen model. Evaluate the discussion of alternative modeling approaches not considered in the final analysis, and the limitations and uncertainties of the chosen model. Evaluate the selected model for consistency with available data.

Evaluate the U.S. Department of Energy assessment of the effects of model uncertainty on conclusions regarding performance.

Review the methods used by the U.S. Department of Energy in considering the effects of thermal-hydrologic-mechanical-chemical coupled processes in different alternative conceptual models.

Determine whether the U.S. Department of Energy has provided an adequate demonstration of the effects on radiological exposures to the reasonably maximally exposed individual and releases of radionuclides into the accessible environment in its assessment of alternative conceptual models of coupled thermal-hydrologic-mechanical-chemical processes.

Review Method 5 Model Support

Evaluate the output from the abstraction of the quantity and chemistry of water contacting waste packages and waste forms, and compare the results with an appropriate combination of site characterization and design data, process-level modeling, laboratory testing, field measurements, and natural analog data.

Examine the analytical and numerical models used in the thermal-mechanical analyses for consistency with site-specific or natural analog data. Evaluate predicted changes in hydrologic properties and the magnitudes and distributions of changes resulting from effects of thermal-mechanical processes, for consistency with results of thermal-mechanical analyses of the underground facility.

Examine the output from the mathematical models for abstractions of coupled-process effects on the quantity and chemistry of water contacting waste packages and waste forms for consistency with conceptual models, based on inferences about the near-field environment, field data, and natural alteration observed at the site, and expected engineered materials properties. Examine the use of abstracted model results, and compare mathematical models to judge the robustness of results. Evaluate the acceptability of the sensitivity analyses used to support the abstraction of the quantity and chemistry of water contacting waste packages and waste forms in the total system performance assessment. To the extent practical, use an alternative total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction, and to evaluate the effects of the quantity and chemistry of water contacting waste packages and waste forms on repository performance.

4.2.1.3.3.3 Acceptance Criteria

The following acceptance criteria are based on meeting the requirements of 10 CFR 63.114(a))–(c) and (e)–(g), relating to the quantity and chemistry of water contacting waste packages and waste forms model abstraction. U.S. Nuclear Regulatory Commission

staff should apply the following acceptance criteria, according to the level of importance established in the U.S. Department of Energy risk-informed safety case.

Acceptance Criterion 1 System Description and Model Integration are Adequate.

- Total system performance assessment adequately incorporates important design features, physical phenomena, and couplings, and uses consistent and appropriate assumptions throughout the quantity and chemistry of water contacting waste packages and waste forms abstraction process;

- The abstraction of the quantity and chemistry of water contacting waste packages and waste forms uses assumptions, technical bases, data, and models, that are appropriate and consistent with other related U.S. Department of Energy abstractions. For example, the assumptions used for the quantity and chemistry of water contacting waste packages and waste forms are consistent with the abstractions of "Degradation of Engineered Barriers" (Section 4.2.1.3.1); "Mechanical Disruption of Waste Packages" (Section 4.2.1.3.2); "Radionuclide Release Rates and Solubility Limits" (Section 4.2.1.3.4); "Climate and Infiltration" (Section 4.2.1.3.5); and "Flow Paths in the Unsaturated Zone" (Section 4.2.1.3.6). The descriptions and technical bases provide transparent and traceable support for the abstraction of quantity and chemistry of water contacting waste packages and waste forms;

- Important design features, such as waste package design and material selection, backfill, drip shield, ground support, thermal loading strategy, and degradation processes, are adequate to determine the initial and boundary conditions for calculations of the quantity and chemistry of water contacting waste packages and waste forms;

- Spatial and temporal abstractions appropriately address physical couplings (thermal-hydrologic-mechanical-chemical). For example, the U.S. Department of Energy evaluates the potential for focusing of water flow into drifts, caused by coupled thermal-hydrologic-mechanical-chemical processes;

- Sufficient technical bases and justification are provided for total system performance assessment assumptions and approximations for modeling coupled thermal-hydrologic-mechanical-chemical effects on seepage and flow, the waste package chemical environment, and the chemical environment for radionuclide release. The effects of distribution of flow on the amount of water contacting the waste packages and waste forms are consistently addressed, in all relevant abstractions;

- The expected ranges of environmental conditions within the waste package emplacement drifts, inside of breached waste packages, and contacting the waste forms and their evolution with time are identified. These ranges may be developed to include: (i) the effects of the drip shield and backfill on the quantity and chemistry of water (e.g., the potential for condensate formation and dripping from the underside of the shield); (ii) conditions that promote corrosion of engineered barriers and degradation of waste forms; (iii) irregular wet and dry cycles; (iv) gamma-radiolysis; and (v) size and distribution of penetrations of waste packages;

- The model abstraction for quantity and chemistry of water contacting waste packages and waste forms is consistent with the detailed information on waste package design and other engineered features. For example, consistency is demonstrated for: (i) dimensionality of the abstractions; (ii) various design features and site characteristics; and (iii) alternative conceptual approaches. Analyses are adequate to demonstrate that no deleterious effects are caused by design or site features that the U.S. Department of Energy does not take into account in this abstraction;

- Adequate technical bases are provided, including activities such as independent modeling, laboratory or field data, or sensitivity studies, for inclusion of any thermal-hydrologic-mechanical-chemical couplings and features, events, and processes;

- Performance-affecting processes that have been observed in thermal-hydrologic tests and experiments are included into the performance assessment. For example, the U.S. Department of Energy either demonstrates that liquid water will not reflux into the underground facility or incorporates refluxing water into the performance assessment calculation, and bounds the potential adverse effects of alteration of the hydraulic pathway that result from refluxing water;

- Likely modes for container corrosion (Section 4.2.1.3.1 of the Yucca Mountain Review Plan) are identified and considered in determining the quantity and chemistry of water entering the waste packages and contacting waste forms. For example, the model abstractions consistently address the role of parameters, such as pH, carbonate concentration, and the effect of waste package corrosion on the quantity and chemistry of water contacting waste packages and waste forms;

- The abstraction of in-package criticality or external-to-package criticality, within the emplacement drift, provides an adequate technical basis for screening these events. If either event is included in the assessment, then the U.S. Department of Energy uses acceptable technical bases for selecting the design criteria that mitigate the potential impact of in-package criticality on repository performance; identifies the features, events, and processes that may increase the reactivity of the system inside the waste package; identifies the configuration classes and configurations that have potential for nuclear criticality; and includes changes in thermal conditions and degradation of engineered barriers in the abstraction of the quantity and chemistry of water contacting waste packages and waste forms; and

- Guidance in NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or other acceptable approaches, is followed.

Acceptance Criterion 2 Data are Sufficient for Model Justification.

- Geological, hydrological, and geochemical values used in the safety case are adequately justified. Adequate description of how the data were used, interpreted, and appropriately synthesized into the parameters is provided;

- Sufficient data were collected on the characteristics of the natural system and engineered materials to establish initial and boundary conditions for conceptual models

of thermal-hydrologic-mechanical-chemical coupled processes, that affect seepage and flow and the waste package chemical environment;

- Thermo-hydrologic tests were designed and conducted with the explicit objectives of observing thermal-hydrologic processes for the temperature ranges expected for repository conditions and making measurements for mathematical models. Data are sufficient to verify that thermal-hydrologic conceptual models address important thermal-hydrologic phenomena;

- Sufficient information to formulate the conceptual approach(es) for analyzing water contact with the drip shield, waste package, and waste forms is provided; and

- Sufficient data are provided to complete a nutrient- and energy-inventory calculation, if it has been used to justify the inclusion of the potential for microbial activity affecting the waste package chemical environment and the chemical environment for radionuclide release. As necessary, data are adequate to constrain the probability for microbially influenced corrosion and microbial effects, such as production of organic byproducts and microbially enhanced dissolution of the high-level radioactive waste glass form.

Acceptance Criterion 3 Data Uncertainty is Characterized and Propagated Through the Model Abstraction.

- Models use parameter values, assumed ranges, probability distributions, and/or bounding assumptions that are technically defensible, and reasonably account for uncertainties and variabilities;

- Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the total system performance assessment calculations of quantity and chemistry of water contacting waste packages and waste forms are technically defensible and reasonable, based on data from the Yucca Mountain region (e.g., results from large block and drift-scale heater and niche tests), and a combination of techniques that may include laboratory experiments, field measurements, natural analog research, and process-level modeling studies;

- Input values used in the total system performance assessment calculations of quantity and chemistry of water contacting engineered barriers (e.g., drip shield and waste package) are consistent with the initial and boundary conditions and the assumptions of the conceptual models and design concepts for the Yucca Mountain site. Correlations between input values are appropriately established in the U.S. Department of Energy total system performance assessment. Parameters used to define initial conditions, boundary conditions, and computational domain in sensitivity analyses involving coupled thermal-hydrologic-mechanical-chemical effects on seepage and flow, the waste package chemical environment, and the chemical environment for radionuclide release, are consistent with available data. Reasonable or conservative ranges of parameters or functional relations are established;

- Adequate representation of uncertainties in the characteristics of the natural system and engineered materials is provided in parameter development for conceptual models,

process-level models, and alternative conceptual models. The U.S. Department of Energy may constrain these uncertainties using sensitivity analyses or conservative limits. For example, the U.S. Department of Energy demonstrates how parameters used to describe flow through the engineered barrier system bound the effects of backfill and excavation-induced changes;

- If criticality is included in the total system performance assessment, then the U.S. Department of Energy uses an appropriate range of input parameters for calculating the effective neutron multiplication factor; and

- Where sufficient data do not exist, the definition of parameter values and conceptual models is based on other appropriate sources, such as expert elicitation conducted in accordance with NUREG–1563 (Kotra, et al., 1996).

Acceptance Criterion 4 Model Uncertainty is Characterized and Propagated Through the Model Abstraction.

- Alternative modeling approaches of features, events, and processes are considered and are consistent with available data and current scientific understanding, and the results and limitations are appropriately considered in the abstraction;

- Alternative modeling approaches are considered and the selected modeling approach is consistent with available data and current scientific understanding. A description that includes a discussion of alternative modeling approaches not considered in the final analysis and the limitations and uncertainties of the chosen model is provided;

- Adequate consideration is given to effects of thermal-hydrologic-mechanical-chemical coupled processes in the assessment of alternative conceptual models. These effects may include: (i) thermal-hydrologic effects on gas, water, and mineral chemistry; (ii) effects of microbial processes on the waste package chemical environment and the chemical environment for radionuclide release; (iii) changes in water chemistry that may result from the release of corrosion products from the waste package and interactions between engineered materials and ground water; and (iv) changes in boundary conditions (e.g., drift shape and size) and hydrologic properties, relating to the response of the geomechanical system to thermal loading; and

- If the U.S. Department of Energy uses an equivalent continuum model for the total system performance assessment abstraction, the models produce conservative estimates of the effects of coupled thermal-hydrologic-mechanical-chemical processes on calculated compliance with the postclosure public health and environmental standards.

Acceptance Criterion 5 Model Abstraction Output is Supported by Objective Comparisons.

- The models implemented in this total system performance assessment abstraction provide results consistent with output from detailed process-level models and/or empirical observations (laboratory and field testings and/or natural analogs);

- Abstracted models for coupled thermal-hydrologic-mechanical-chemical effects on seepage and flow and the waste package chemical environment, as well as on the chemical environment for radionuclide release, are based on the same assumptions and approximations demonstrated to be appropriate for process-level models or closely analogous natural or experimental systems. For example, abstractions of processes, such as thermally induced changes in hydrological properties, or estimated diversion of percolation away from the drifts, are adequately justified by comparison to results of process-level modeling, that are consistent with direct observations and field studies; and

- Accepted and well-documented procedures are used to construct and test the numerical models that simulate coupled thermal-hydrologic-mechanical-chemical effects on seepage and flow, waste package chemical environment, and the chemical environment for radionuclide release. Analytical and numerical models are appropriately supported. Abstracted model results are compared with different mathematical models, to judge robustness of results.

4.2.1.3.3.4 Evaluation Findings

If the license application provides sufficient information and the regulatory acceptance criteria in Section 4.2.1.3.3.3 are appropriately satisfied, the staff concludes that this evaluation is complete. The reviewer writes material suitable for inclusion in the safety evaluation report prepared for the entire application. The report includes a summary statement of what was reviewed and why the reviewer finds the submittal acceptable. The staff can document the review as follows.

U.S. Nuclear Regulatory Commission staff has reviewed the Safety Analysis Report and other docketed material, relevant to the quantity and chemistry of water contacting waste packages and waste forms, and has found, with reasonable expectation, that they satisfy the requirements of 10 CFR 63.114 for this abstraction. Technical requirements for conducting a performance assessment in the area of quantity and chemistry of water contacting waste packages and waste forms have been met. In particular, the U.S. Nuclear Regulatory Commission staff that:

- Appropriate data from the site and surrounding region, uncertainties and variabilities in parameter values, and alternative conceptual models have been used in the analyses, in compliance with 10 CFR 63.114(a)–(c);

- Specific features, events, and processes have been included in the analyses, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(e);

- Specific degradation, deterioration, and alteration processes have been included in the analyses, taking into consideration their effects on annual dose, and appropriate technical bases have been provided for inclusion or exclusion, in compliance with 10 CFR 63.114(f); and

- Adequate technical bases have been provided for models used in the performance assessment, as required by 10 CFR 63.114(g).

4.2.1.3.3.5 References

Altman, W.D., J.P. Donnelly, and J.E. Kennedy. NUREG–1297, "Generic Technical Position on Peer Review for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988a.

———. NUREG–1298, "Generic Technical Position on Qualification of Existing Data for High-Level Nuclear Waste Repositories." Washington, DC: U.S. Nuclear Regulatory Commission. 1988b.

Kotra, J.P., et al. NUREG–1563, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program." Washington, DC: U.S. Nuclear Regulatory Commission. 1996.

4.2.1.3.4 Radionuclide Release Rates and Solubility Limits

To review this model abstraction, evaluate the adequacy of the U.S. Department of Energy license application, relative to the degree to which the U.S. Department of Energy relies on radionuclide release rates and solubility limits, to demonstrate its safety case. Review this model abstraction considering the risk information evaluated in the "Multiple Barriers" Section (4.2.1.1). For example, if the U.S. Department of Energy safety case relies on the release rates and solubility limits to significantly reduce dose to the reasonably maximally exposed individual, then perform a detailed review of this abstraction. If, on the other hand, the U.S. Department of Energy demonstrates that this abstraction has a minor impact on the dose to the reasonably maximally exposed individual, then conduct a simplified review focusing on the bounding assumptions. The review methods and acceptance criteria provided here are for a detailed review. Some of the review methods and acceptance criteria may not be necessary, in a simplified review, for those abstractions that have minor impacts on performance. The demonstration of the performance objectives is evaluated in Section 4.2.1.4 of the Yucca Mountain Review Plan.

Review Responsibilities—High-Level Waste Branch and Environmental and Performance Assessment Branch

4.2.1.3.4.1 Areas of Review

This section reviews radionuclide release rates and solubility limits. Reviewers will also evaluate information, required by 10 CFR 63.21(c)(1)–(4), (9), (10), (15), and (19), that is relevant to the abstraction of radionuclide release rates and solubility limits.

The staff will evaluate the following parts of the abstraction of radionuclide release rates and solubility limits using the review methods and acceptance criteria in Sections 4.2.1.3.4.2 and 4.2.1.3.4.3:

- Description of the geological, hydrological, and geochemical aspects of radionuclide release rates and solubility limits, and the technical bases the U.S. Department of Energy provides to support model integration across the total system performance assessment abstractions;
- Sufficiency of the data and parameters used to justify the total system performance assessment model abstraction;
- Methods the U.S. Department of Energy uses to characterize data uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Methods the U.S. Department of Energy uses to characterize model uncertainty, and propagate the effects of this uncertainty through the total system performance assessment model abstraction;
- Approaches the U.S. Department of Energy uses to compare total system performance assessment output model abstraction to process-level model outputs and empirical studies; and
- Use of expert elicitation.

4.2.1.3.4.2 Review Methods

To review the abstraction of radionuclide release rates and solubility limits, recognize that models used in the total system performance assessments may range from highly complex process-level models to simplified models, such as response surfaces or look-up tables. Evaluate model adequacy, regardless of the level of complexity.

Review Method 1 Model Integration

Examine the descriptions of design features (including drip shield, backfill, waste packages, waste forms, thermal loading, and other engineered barrier components); relevant physical features; physical phenomena; and couplings, as well as the description of the geological, hydrological, and geochemical aspects of the unsaturated zone included in the abstraction of radionuclide release rates and solubility limits. Verify that the description is adequate, and that the conditions and assumptions in the total system performance assessment abstraction are consistent with the information presented in the description of barriers important to waste isolation, as reviewed using Section 4.2.1.1 of the Yucca Mountain Review Plan.

Assess the technical bases for these descriptions and for incorporating them in the total system performance assessment abstractions. Where simplifications for modeling coupled thermal-hydrologic-chemical effects on the chemical environment for radionuclide release rates and solubility limits were used in the total system performance assessment abstractions, determine

whether the technical bases used for modeling assumptions and approximations have been documented and are adequate. Evaluate whether the descriptions provide transparent and traceable support to the abstractions, and are consistent with other model abstractions.

Evaluate the design information on waste packages and engineered barrier systems, provided in the abstraction of radionuclide release rates and solubility limits. Verify that the information is sufficient and consistent with design information in other model abstractions.

Examine the U.S. Department of Energy description of environmental conditions expected inside breached waste packages and in the engineered barrier environment surrounding the waste package. Ensure that the ranges in conditions are described in sufficient detail.

Verify that the U.S. Department of Energy description of process-level conceptual and mathematical models is sufficiently complete, with respect to thermal-hydrologic processes affecting radionuclide release from the emplacement drifts.

Examine how the features, events, and processes related to radionuclide release rates and solubility limits have been included in the total system performance assessment abstraction of radionuclide release rates and solubility limits.

Evaluate the total system performance assessment abstraction of in-package criticality or external-to-package criticality, within the emplacement drift, and the associated technical basis for screening these events. Ensure that if either event is included in the total system performance assessment, the U.S. Department of Energy uses acceptable technical bases for selecting the design criteria that mitigate the potential impact of in-package criticality on the repository performance; identifies the features, events, and processes that may increase the reactivity of the system inside the waste package; identifies the configuration classes and configurations that have potential for nuclear criticality; and includes changes in thermal conditions and degradation of engineered barriers in the abstraction of radionuclide release rates and solubility limits.

Verify that the U.S. Department of Energy reviews follow the guidance in NUREG–1297 and NUREG–1298 (Altman, et al., 1988a,b), or make an acceptable case for using alternative approaches.

Review Method 2 Data and Model Justification

Evaluate the sufficiency of the geological, hydrological, and geochemical data used to support conceptual models, process-level models, and alternative conceptual models considered in the abstraction of radionuclide release rates and solubility limits. Evaluate the basis for the data on design features (including drip shield, backfill, waste packages, waste forms, and other engineered barrier components) used in the abstraction of radionuclide release rates and solubility limits.

Examine and confirm that the U.S. Department of Energy has provided sufficient data on the characteristics of the natural system, and engineered materials to establish initial and boundary conditions for conceptual models and simulations of thermal-hydrologic-chemical coupled processes.

Examine and evaluate the models used to support abstraction of solubility limits, and ensure that they are consistent with guidance in "Determination of Radionuclide Solubility in Ground Water for Assessment of High-Level Waste Isolation, Technical Position" (U.S. Nuclear Regulatory Commission, 1984).

Evaluate the U.S. Department of Energy corrosion and radionuclide release testing program for high-level radioactive waste forms intended for disposal. Verify that it provides consistent, sufficient, and suitable data for the in-package and in-drift chemistry, used in the abstraction of radionuclide release rates and solubility limits. Evaluate the justification for the use of test results not specifically collected from the Yucca Mountain site.

Review Method 3 Data Uncertainty

Evaluate whether the U.S. Department of Energy has developed parameter ranges, probability distributions, and bounding values that adequately account for data uncertainty and variability.

Evaluate the technical bases for parameter ranges, probability distributions, or bounding values. The reviewer should determine whether the parameter values are derived from site-specific data, or an analysis is included to show that the assumed parameter values lead to a conservative assessment of performance. Examine the technical bases for parameter values and ranges in conceptual models, process-level models, and alternative conceptual models considered in the abstraction.

Examine the initial conditions, boundary conditions, and computational domain used in sensitivity analyses, involving coupled thermal-hydrologic-chemical effects on radionuclide release, for consistency with available data.

Evaluate the U.S. Department of Energy assessment of uncertainty and variability in parameters used in model abstractions. Determine whether uncertainty in data from both temporal and spatial variations in conditions affecting radionuclide release, was incorporated into the parameter ranges.

Evaluate the parameters used to describe flow through and out of the engineered barrier, and ensure that they are sufficient to bound the effects of backfill, excavation-induced changes, and thermally induced mechanical changes that affect flow.

If in-package criticality or external-to-package criticality is included in the total system performance assessment, examine the methods and parameters used by the U.S. Department of Energy to calculate the effective neutron multiplication factor.

Verify that the U.S. Department of Energy uses an appropriate range of time-history of temperature, humidity, and dripping to constrain the probability for microbial effects.

Ensure that the U.S. Department of Energy adequately considers the uncertainties in the characteristics of the natural system and engineered materials, such as the type, quantity, and reactivity of material, in establishing initial and boundary conditions for conceptual models and simulations of thermal-hydrologic-chemical coupled processes that affect radionuclide release.

Determine whether expert elicitations were used as a basis for data uncertainty for this abstraction, and whether they were conducted in accordance with appropriate guidance.

Review Method 4 Model Uncertainty

Evaluate the U.S. Department of Energy alternative conceptual models used in developing the total system performance assessment abstraction for radionuclide release rates and solubility limits. Examine the model parameters in the context of available site characterization data; design data (engineered barrier system, waste packages, and waste forms); laboratory experiments; field measurements; natural analog research; and process-level modeling studies. When practical, use an alternative total system performance assessment model to evaluate the effect of alternative conceptual models on the assessment of repository performance.

Ensure that the U.S. Department of Energy uses appropriate models, tests, and analyses that are sensitive to the processes modeled for both natural and engineering systems. Verify that conceptual model uncertainties are adequately defined and documented, and effects on conclusions regarding performance are properly assessed.

Examine the mathematical models included in the analyses of coupled thermal-hydrologic-chemical effects on the chemical environment for radionuclide release. Evaluate the bases for excluding alternative conceptual models, and the limitations and uncertainties of the chosen model.

Review Method 5 Model Support

Evaluate the output from the abstraction of radionuclide release rates and solubility limits, and ensure that the U.S. Department of Energy has compared the results with an appropriate combination of site characterization and design data, process-level modeling, laboratory testing, field measurements, and natural analog data.

Examine the analytical and numerical models used in the thermal-mechanical analyses for consistency with site-specific or natural analog data. Evaluate predicted changes in hydrologic properties and the magnitudes and distributions of changes resulting from effects of thermal-mechanical processes for consistency with results of thermal-mechanical analyses of the underground facility. To the extent practical, use an alternative total system performance assessment model to evaluate selected parts of the U.S. Department of Energy abstraction, and to evaluate the effects of the quantity and chemistry of water contacting the waste packages and waste forms on repository performance.

Examine the output from the mathematical models for abstractions of coupled-process effects on radionuclide release for consistency with conceptual models. Compare the output from the abstractions with inferences about the near-field environment, field data, and natural alteration observed at the site, and expected engineered materials properties.

Evaluate where the U.S. Department of Energy will rely on performance confirmation for this model abstraction, and whether specific plans for monitoring radionuclide release are adequate for further testing, to acquire additional necessary information, as part of the performance confirmation program, using Section 4.4 of the Yucca Mountain Review Plan.