COMPLIANCE DETERMINATION STRATEGY

5.2 ASSESSMENT OF COMPLIANCE WITH THE DESIGN CRITERIA FOR THE WASTE PACKAGE AND ITS COMPONENTS

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(14)
10 CFR 60.131(b)(7)
10 CFR 60.135

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analyses (Type 4)
Detailed Safety Review Supported by Independent Tests, Analyses, or Site Investigations (Type 5)

RATIONALE FOR TYPES OF REVIEW:

Acceptance Review (Type 1) Rationale:

This regulatory requirement topic is considered to be license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)," it must be addressed by the U.S. Department of Energy (DOE) in its license application. Therefore, the staff will conduct an Acceptance Review of the license application for this regulatory requirement topic.

Safety Review (Type 3) Rationale:

This regulatory requirement is considered to be related to radiological safety, retrieval, containment, and waste isolation. It is a requirement for which compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31 (i.e., regulatory requirements in Subparts E, G, H, and I). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with this regulatory requirement.

There are a number of review plan topics which are closely-related to the waste package. These topics concern both design and performance and must be considered when the waste package design is evaluated for adequacy. This regulatory requirement topic focuses on the review of compliance with design criteria for the waste package, which are set forth in 10 CFR 60.131(b)(7) and 60.135. Since the waste package must perform both preclosure and postclosure roles, both preclosure and

postclosure aspects must be considered during this review. In particular, the waste package design controls criticality [10 CFR 60.131(b)(7)] and retrievability [10 CFR 60.135(b)(3)], and it may contribute significantly to radiation protection during operations (including retrieval). The strategy for review of these aspects of waste package design is, by necessity, design-dependent, and it is expected that compliance determination methods would be developed to be specific to the waste package design, reflecting the functions which will be required of the waste package. Review of the design of the engineered barrier system (EBS) elements of the underground facility, exclusive of the waste package, with the pertinent 10 CFR Part 60 post-closure design criteria, is the subject of Review Plan 5.3 ("Assessment of Compliance with the Design Criteria for the Postclosure Features of the Underground Facility") of the license application. Assessment of compliance with the pre-closure design criteria for the underground facility will be considered in Section 4.4 ("Assessment of Compliance with Design Criteria for the Geologic Repository Operations Area (GROA) Underground Facility") of the license application. Finally, the integrated review of compliance of the EBS, including the waste package, will be the subject of the staff review in Section 5.4 (Assessment of Compliance with the Engineered Barrier System (EBS) Performance Objectives). It should be noted that the description provided in Section 5.1 ("Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting") of the license application, will support the reviews described above.

This regulatory requirement focuses on design criteria, specified in various portions of 10 CFR 60.131 and 10 CFR 60.135, with which DOE's waste package design must demonstrate compliance. These design criteria apply to high-level radioactive waste (HLW), including spent nuclear fuel and reprocessed liquid or solid wastes, although they also address other waste forms such as low-level, greater-than-class-C, or transuranic radioactive wastes (LLW, GTCC, and TRU, respectively) that might possibly be disposed of in the repository. These waste forms are described in Section 2.5 ("Radioactive Material Description") of the license application.

For example, 10 CFR 60.135 specifies both general and specific design criteria for HLW packages. Consistent with the general design criteria for the waste package (and its components), as set forth in 10 CFR 60.135(a), DOE must design the waste package so that the *in situ* chemical, physical, and nuclear properties of the waste package, and its interactions with the emplacement environment, do not compromise the intended function of the waste package and/or the performance of the underground facility or the geologic setting. Those general design factors that must be considered include, but are not limited to, solubility, oxidation/reduction, corrosion, hydriding, gas generation, thermal effects, mechanical strength and toughness, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads and synergistic interactions.

To comply with the specific design criteria for the waste package (and its components), as set forth in 10 CFR 60.135(b), DOE's waste package design must not contain explosive, pyrophoric, or chemically reactive materials in amounts which could compromise the ability of the underground facility to contribute to waste isolation or the ability of the geologic repository to satisfy the performance objectives. Other specific design criteria for the waste package include limitations on the amounts of free liquids, handling requirements, and provisions for unique identification. Detailed design criteria are also specified in 10 CFR 60.135(c) for the waste form relative to solidification, consolidation, and combustibles.

As specified in 10 CFR 60.135(d) design criteria for waste forms other than HLW (e.g., LLW, GTCC, and TRU) will be addressed on an individual basis if and when they are proposed for disposal in a geologic repository.

The general and specific design criteria for the waste package, as described above, are considered to be minimum requirements. There may well be conditions other than those specified in the rule (e.g., effects of microbially influenced corrosion) that DOE will need to consider as it develops its waste package design. It is important, therefore, that DOE have a process in place early to identify and evaluate those technical uncertainties that might influence waste package design.

From the staff's perspective, the more important design-related technical uncertainties include, but are not limited to, the following:

(1) the identification of those processes or factors that may lead to early failures of waste packages and their impact on waste package degradation,

(2) the identification of the range or variation of waste-package environments pertinent to the design and testing of the waste package and its components,

(3) variations in waste-package materials properties and corresponding effect on materials degradation,

(4) production of radiolysis products in the near-field environment and their impact on waste-package degradation.

DOE is expected to make substantial progress in resolving these and other related technical uncertainties through the conduct of site characterization and waste-package programs. DOE is expected to collect extensive data regarding the waste package environment, the waste-package materials of choice, and the interactions between the waste-package and the environment. As such, the staff concludes that there is a low risk of noncompliance with most of the waste package design criteria described above.

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

The staff considers that there may be a high potential risk of non-compliance with 10 CFR 60.135 because, for the Yucca Mountain site, there are several Key Technical Uncertainties. Therefore, predictions of the releases of radionuclides from waste packages, and the EBS, may vary widely and may lead to unwarranted conclusions concerning compliance with the EBS performance objectives. The staff believes that the risk of non-compliance due to the following Key Technical Uncertainties is sufficient that a Detailed Safety Review supported by analyses is justified.

Key Technical Uncertainty Topic: Prediction of Thermomechanical Effects on the Performance of Waste Packages and the Engineered Barrier System (EBS)

Description of Uncertainty: Heat from emplaced waste packages will induce mechanical stresses in the waste package, the emplacement borehole, backfill, and other features of the underground facility. These thermomechanical stresses may result in the degradation of repository host rock, backfill, or EBS components. Stresses may also be induced by impingement of repository materials on the waste

package. It will be difficult to quantify these stresses and even more difficult to predict the resultant consequences. The heat released will also result in elevated temperatures of the waste package material and other EBS components for hundreds to thousands of years. These elevated temperatures may result in transformations of metallic phases or other unexpected behavior of the waste package material or other EBS components (Manaktala and Interrante, 1990).

There is also high risk that some significant degradation modes due to thermomechanical effects will not be identified or will be erroneously deemed insignificant or incredible.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: Impingement of the waste package by repository materials may: (1) rupture the waste package, resulting in loss of containment; or (2) contribute to local acceleration of waste package degradation, resulting in loss of containment or an unpredictable release rate. For waste package materials and other EBS components, phase transformations or property changes of the waste package material and the other EBS components, due to long-term exposure to elevated temperatures, may result in the waste packages or EBS components being more susceptible to penetration by corrosion or mechanical forces.

In conducting a degradation analysis of a system, such as the EBS, for which there is no precedent, it is difficult to provide reasonable assurance that the degradation modes due to thermomechanical effects have been adequately considered.

Description of Resolution Difficulty: DOE is expected to make substantial progress in resolving this Key Technical Uncertainty and has recognized the need for obtaining information on thermomechanical effects on waste packages and the EBS (see DOE, 1988, pp. 8.3.4.2-27, 8.3.4.2-28, and 8.3.5.10-72). However, it is likely that considerable lack of data will exist and that DOE will use engineering judgement and expert opinion to resolve this lack of data.

Key Technical Uncertainty Topic: Prediction of Environmental Effects on the Performance of Waste Packages and the Engineered Barrier System (EBS)

Description of Uncertainty: The environment of the waste package and the EBS is expected to change with time. Methodologies for predicting the changing environment are not currently available to the extent necessary to predict effects on long-term performance of the waste package or the EBS.

To predict the long-term performance of waste packages for containment and the EBS for gradual release, it will be necessary to understand the waste package and EBS environments at the time of emplacement, as well as changes in the environments with time. The areas most likely to contribute to uncertainty in service life prediction are: (1) geochemistry (water chemistry, pH, Eh, rock chemistry, and trapped, dissolved, or circulating gases); (2) radiation and radiolysis; (3) microbial effects; and (4) synergistic effects.

In addition to the above, there are other environmental concerns which may influence the response of the waste packages and EBS. These concerns fall broadly into the following classifications: (1) hydrology and climatology; (2) geology; (3) tectonics (including repeated dynamic motions); and (4) waste package internal corrosion.

There is also high risk that some significant degradation modes due to environmental effects will not be identified or will be erroneously deemed insignificant or incredible.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: The radioactive contents of the waste package provide a unique environment that could interact with and change the existing repository near-field environment, as well as the materials that comprise the waste package itself. The interactions could possibly lead to new degradation modes or an acceleration in the rates of degradation observed in the absence of a radiation field, and the ability of the waste package and EBS to contain high-level waste could be compromised as a result. Synergistic effects of two or more of these factors could lead to more severe environmental effects than consideration of the environmental factors separately (Manaktala and Interrante, 1990).

As one example of environmental effects, heat from emplaced waste packages will alter the immediate environment of the waste package and the EBS by increasing the temperature and evaporating and driving away moisture. A heat pipe effect may result whereby moisture near the emplacement borehole is evaporated and driven away to the geologic setting, where it may condense and return with a different chemical composition (Buscheck and Nitao, 1993; Pruess and Tsang, 1993). This might affect the ability to meet the long-term performance objectives of containment and gradual release as well as the overall performance objective.

The borehole host rock may deteriorate due to the cumulative effect of seismic motions, such as those associated with weapons testing, in conjunction with *in situ* and thermally induced stresses.

In conducting a degradation analysis of a system, such as the EBS, for which there is no precedent, it is difficult to provide reasonable assurance that the degradation modes due to environmental effects have been adequately considered.

Description of Resolution Difficulty: DOE's site characterization program should provide extensive data on the environment at Yucca Mountain and DOE's Engineered Barrier System program should provide extensive data on the EBS and its effect on the near-field environment. However, it is likely that considerable lack of data will exist and that DOE will use engineering judgement and expert opinion to resolve this lack of data.

Key Technical Uncertainty Topic: Prediction of Criticality Events in Waste Packages

Description of Uncertainty: There is considerable uncertainty about the long-term performance of the criticality control measures that will be incorporated into the waste package. The criticality control materials now used in spent fuel transportation casks or storage racks have only been demonstrated to be effective over relatively short periods of time. The staff is concerned that, subsequent to the period of waste package containment, the criticality control structure and features of the waste package design will degrade before the spent fuel assemblies lose their integrity and structure. This would leave the affected waste packages vulnerable to a criticality event and concomitant loss of waste package integrity and release of radionuclides.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: A criticality event could result in the loss of waste package integrity and the release of the radionuclides from the waste package during the containment period and the release of radionuclides from the EBS during the post-containment period.

Description of Resolution Difficulty: There is uncertainty about whether the state of the art exists to design waste package criticality control features which will retain their functional capability for 10,000 years in a repository environment. This resolution difficulty may be exacerbated by the fact that DOE has the responsibility for packaging and disposing of highly-enriched spent fuel assemblies from defense-related activities.

DOE has recently expressed interest in the universal container system (UCS) concept. The use of the UCS concept might make criticality control even more difficult to resolve, in view of the UCS functional requirements for storage, transportation, and disposal. Designing for long-term integrity of criticality measures which must also perform to meet transportation needs is highly uncertain. Also, the large number of fuel rods in close proximity within a UCS container makes criticality control more difficult.

Key Technical Uncertainty Topic: Prediction of Release Path Parameters (such as the Size, Shape, and Distribution of Penetrations of Waste Packages) due to Thermomechanical, Environmental, or Criticality Effects

Description of Uncertainty: For any particular waste package degradation mode, it will be difficult to accurately predict release path parameters (such as the size, shape, and distribution of the resulting waste package penetrations) as functions of time and simplifying assumptions will probably be required.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: If the release path parameters (such as the size, shape, and distribution of the waste package penetrations) are underestimated, the predicted releases of radionuclides from the waste package during the containment period and from the EBS during the post-containment period will also be underestimated.

Description of Resolution Difficulty: It is expected that DOE will make substantial progress in resolving this technical uncertainty by analytical studies and experimental testing. However, it is not likely that this uncertainty will be fully resolved.

Most existing analytical models that are used to analyze waste package degradations predict only the onset of waste package penetration and do not predict the release path parameters (such as size, shape, and distribution of the perforations or flaws). It is anticipated that DOE will develop analytical models that will predict release path parameters (such as the size, shape, and distribution of penetrations of the waste packages). However, such analytical models will likely contain simplifying assumptions, which may carry with them large uncertainty.

Key Technical Uncertainty Topic: Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the Engineered Barrier System during the Post-Containment Period.

Description of Uncertainty: Large uncertainties exist in estimating the quantities of gaseous radionuclides which may be generated from the waste forms and which would be released from penetrated waste packages. It is also uncertain whether, for gaseous radionuclides, the regulatory requirements regarding containment (10 CFR 60.113(a)(1)(ii)(A)) and gradual release (10 CFR 60.113(a)(1)(ii)(B)) are attainable.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: The inventory of carbon-14 in spent fuel can vary considerably and is largely dependent on nitrogen impurities in the fuel and fuel assembly hardware (Van Konynenburg et al., 1987). DOE believes that the proposed EPA release limit in 40 CFR Part 191 and the 10 CFR 60.113 annual release rate limit from the engineered barrier system for carbon-14 are too restrictive (Park and Pflum, 1990).

Description of Resolution Difficulty: While DOE has developed a program in the 1988 Site Characterization Plan for the conduct of research on spent fuel, the research performed to date to address potential carbon-14 and other gaseous radionuclide problems appears to be inadequate. The lack of adequate information related to this issue makes it difficult to determine whether a significant compliance problem will arise for the release of carbon-14 and other gaseous radionuclides from the waste packages or the engineered barrier system.

Key Technical Uncertainty Topic: Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the Engineered Barrier System during the Post-Containment Period.

Description of Uncertainty: Two significant mechanisms for the release of non-gaseous radionuclides from penetrated waste packages and the engineered barrier system will be: (1) diffusion; and (2) convective transport by air or water. Estimating the diffusion of radionuclides from a penetrated waste package or from the engineered barrier system will likely be difficult and require the use of simplifying assumptions of uncertain accuracy. Estimating the flow rate of air or water through the waste package or the engineered barrier system will also likely be difficult and require the use of simplifying assumptions of uncertain accuracy. Furthermore, even if the flow rate of air or water effluent streams could be accurately estimated, the concentration of the individual radionuclide species in these effluent streams will likely be uncertain.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: Release rates of non-gaseous radionuclides can be significant from waste packages that have been penetrated. Releases through small apertures and cracks in a waste package could affect compliance with the EBS performance objectives (Chambre et al., 1986).

Description of Resolution Difficulty: The calculation of diffusion or fluid flow of non-gaseous radionuclides when a large number of perforations coexist on a waste package, is difficult and simplifying assumptions are necessary (Chambre et al., 1986; Pescatore and Sastre, 1987). Considerable uncertainties currently exist (and are likely to persist) in modelling the dissolution of radionuclides in air and water effluent streams (Apted et al., 1990). For example, there is uncertainty in determining which solubility-limiting solids will form and the characteristics of these solids.

Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations (Type 5) Rationale:

The staff considers that there may be the highest potential risk of non-compliance with this regulatory requirement because, for the Yucca Mountain site, the following Key Technical Uncertainty is the most difficult to resolve. There might be a high risk of non-compliance with the performance objectives specified below because very little can be done to reduce the risk, or compensate for the risk using, for example, favorable site conditions or engineered features. The potential for alternate data collection strategy, interpretation, and extrapolation of collected data by the license applicant and subsequent high risk of non-compliance in light of this Key Technical Uncertainty requires a detailed safety review supported by independent tests, analyses, or other investigations.

Key Technical Uncertainty Topic: Extrapolation of Short-Term Laboratory and Prototype Test Results to Predict Long-Term Performance of Waste packages and Engineered Barrier Systems

Description of Uncertainty: The length of time specified in the regulations for containment by the waste package (300 to 1,000 years) and for gradual release from the EBS (following the containment period) exceeds the functional times commonly required in engineering design and also far exceeds the functional times that will be available for the testing and analysis of materials. Also, the large number of waste packages (45,000 to 80,000) expected to be emplaced at the geologic repository implies that scaling up from laboratory and prototype tests to the size of the repository is a unique endeavor. After the repository is closed and sealed, the waste package will be inaccessible during the required containment and isolation periods, which will be up to thousands of years. Therefore, a determination of reasonable assurance for containment and subsequent gradual release must come from a very high level of confidence in a scientific understanding of the effects of time and the environment on a repository system composed of a large number of waste packages (Manaktala and Interrante, 1990). The reference material for the waste package, as described in the 1988 Site Characterization Plan (DOE, 1988, p. 7-25), is a stainless steel, and such steels have been in existence for less than 100 years. By the end of FY 93, DOE is expected to identify the specific material for the waste package along with further design details. The specific alloy chosen for the waste package material is expected to be one which, like the stainless steel reference material identified early in the process, has a short service and experience history. Also, for such a material, natural analogs may not exist. Even for materials (e.g., iron and copper) for which human experience reaches thousands of years, there are considerable uncertainties in translating that experience to repository relevant conditions.

Performance Objectives at Risk: 10 CFR 60.113(a)(1)

Explanation of Nature of Risk: For some material degradation modes, the rate of degradation decreases with time. For example, in general corrosion, insoluble corrosion products or other protective films are often formed which tend to diminish the corrosion rate. For these degradation modes, extrapolation of short-term data and analyses to long times will be conservative. However, there are many other degradation modes (e.g., crevice corrosion, pitting corrosion, stress-corrosion cracking and waste-form dissolution) in which there is an initial incubation period in which little or no degradation occurs, followed by rapidly increasing degradation. For these degradation modes, there is the highest risk that extrapolation of results from short-term tests and analyses will not provide reasonable assurance of complying with the EBS performance objectives of substantially complete containment and gradual release.

Description of Resolution Difficulty: Closure of this issue will be difficult because, currently, there is no accepted, rational scientific method for extrapolating relatively short-term data and experience to the long performance periods required for a geological repository. Such a method is needed to provide reasonable assurance that all significant waste package degradation modes have been identified and that predictions of waste package degradation rates will not underestimate the actual degradation rates. However, there can be no assurance that such a method will be available at the time that this safety review is performed. Accordingly, it is expected that a significant amount of expert judgement will be used by DOE in extrapolating short-term data and analysis. These extrapolations by DOE are likely to be highly controversial.

REVIEW STRATEGY:

Acceptance Review:

In conducting the *Acceptance Review* of the assessment of the U.S. Department of Energy's waste package design (including waste package components), the reviewer should determine if the information present in the license application and its references for determining compliance with the applicable regulatory requirements is complete in technical breadth and depth as identified in Section 5.2 of the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)." The descriptions provided in Section 5.1 ("Description of the Engineered Barrier Systems and Components that Provide a Barrier Between the Waste and the Geologic Setting) of the license application will form the basis for the *Safety Review* of the information contained in Section 5.2 of the license application. Thus, the review of the information contained in Section 5.1 will be performed in parallel with the review of the information contained in Section 5.2. Therefore, during the *Acceptance Review* of Section 5.2, the reviewer should determine whether or not all appropriate waste package information necessary for the staff to conduct a *Safety Review* of the design has been provided, as described in Section 5.1, and that the information is both internally consistent, and consistent from section-to-section.

The reviewer should determine whether or not all appropriate information necessary for the staff to review the demonstration of compliance with the applicable regulatory requirements is presented such that the assessments required by the regulatory requirements associated with total system and subsystem performance objectives or other technical criteria can be performed. The reviewer should also determine whether or not the information in the license application is presented in such a manner that the assumptions, data, and logic leading to a demonstration of compliance with the applicable regulatory requirements are clear and do not require the reviewer to conduct extensive analyses or literature searches. Finally, the reviewer should also determine whether or not controversial information and appropriate alternative interpretations and models have been acceptably described and considered.

Finally, the reviewer should determine if DOE has either resolved all the NRC staff objections that apply to this requirement or provided all the information requested in Section 1.6.2 of the FCRG, for unresolved objections. The reviewer should evaluate the effects of any unresolved objections, both individually and in combination with others, on: (1) the reviewer's ability to conduct a meaningful and timely review; and (2) the Commission's ability to make a decision regarding construction authorization within the three-year statutory period.

Safety Review:

This regulatory requirement topic is limited to assessment of compliance of the waste package (and its components) with the pertinent 10 CFR Part 60 design criteria. It is not concerned with assessment of compliance of the EBS (exclusive of the waste package and its components), with other pertinent 10 CFR Part 60 design criteria and performance objectives. The review of the EBS, from the post-closure perspective, is the subject of the review called for in Section 5.3 ("Assessment of Compliance with the Design Criteria for the Engineered Barrier System") of the license application and its attendant review plan. Finally, the confirmation of the waste package design described by the U.S. Department of Energy (DOE) in this section of the license application will be the subject of a performance confirmation program described in Section 8.3 ("Performance Confirmation Program for the Engineered Barrier System") of the license application and its attendant review plan.

In general, the reviewer should assess the adequacy and completeness of DOE's demonstration of compliance with the waste package design criteria. The specific aspects of the license application on which the reviewer will focus are discussed in the FCRG and 10 CFR 60.135 and 60.131(b)(7), and the acceptance criteria are identified in Section 3.0 of this Review Plan.

The reviewer's objectives during the *Safety Review* of this regulatory requirement topic are the following:

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

(2) conduct a preliminary review of the data base used for demonstrating compliance with the applicable regulatory requirements to determine which parts of the data are most uncertain or that may be incomplete;

(3) determine whether portions of the data and/or analyses submitted should be subjected to further detailed review (in addition to those areas requiring detailed *Safety Reviews* which may arise in the future); and

(4) determine whether any use of expert opinion was appropriate.

In conducting the *Safety Review*, the reviewer should determine if the information presented in the license application and its references are an acceptable demonstration of compliance with all applicable regulatory requirements. At a minimum, the reviewer should determine the adequacy of the data and analyses that are presented in the license application as DOE's supporting information concerning its demonstration that its design for the waste package (and its components) meets those design criteria specified in 10 CFR 60.131 and 60.135, as appropriate. The review should include consideration of the information that has been presented for those waste forms specified in Section 2.5 ("Radioactive Material Description") of the license application for disposal at the geologic repository,[1] and evaluation of the contribution of those waste forms to meeting the post-closure performance objectives. Pertinent design criteria chosen by DOE should also be reviewed for

[1] Spent nuclear fuel and high-level radioactive waste are the predominant waste forms expected for disposal although other waste forms, such as low-level, greater-than-class-C, or transuranic radioactive wastes, might possibly be disposed of at the geologic repository.

adequacy. The reviewer should determine whether or not DOE has demonstrated that the design bases for the post-closure features of the waste package take into account the results of DOE's site characterization activities. The specific aspects of the license application on which the reviewer will focus are described in the FCRG and below, and the *Acceptance Criteria* are identified in Section 3.0 of this review plan.

In conducting the Safety Review, the staff will determine if DOE has submitted the following:

(1) a description and discussion of the waste package design including (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission; (ii) the design bases and the relation of the design bases to the principal design criteria; (iii) information relative to materials of construction (including types, grades, approximate dimensions, methods of fabrication); and (iv) codes and standards that DOE proposes to apply to the design and construction of the waste package.

(2) a description and analysis of the design and performance requirements for structures and components of the waste package which are important to safety. This analysis should consider the margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin.

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

(4) an identification of those structures and components of the waste package which require research and development to confirm the adequacy of design. For structures and components important to safety and for the engineered barriers important to waste isolation, DOE should provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

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

(1) an assessment evaluating the effectiveness of engineered and natural barriers,including barriers that may not be themselves a part of the geological repository operations areas, against the release of radioactive material to the environment. The analysis should also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(2) an analysis of the performance of the major design structures and components, to identify those that are important to safety. For the purposes of this analysis, it should be assumed that operations at the geologic repository operations area (GROA) will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the license application.

(3) an explanation of measures used to support the models used to perform the assessments required in Items (1)-(3) above. Analyses and models that will be used to predict future conditions and changes should be supported by using an appropriate combination of such methods as field tests, *in situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

For the information described in Item (3), the following should be reviewed for completeness and adequacy:

(a) variability and uncertainty of data and resultant propagation of errors in models or analyses for which such data was used;

(b) discussions of data representativeness, including uncertainties associated with extrapolation of data;

(c) documentation and validation of models and analyses;

(d) identification of, and justification for, assumptions used in models and analyses;

(e) input and output data and interpretations of the data with the basis for interpretation; and

(f) the role of expert judgment, if used, in models and analyses.

Models and analyses used by the DOE to predict post-closure behavior of the waste package and its components should be reviewed for completeness and adequacy. These analyses should include the following:

(1) identification and evaluation of design parameters used to meet design criteria;

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

(3) descriptions of models and analyses used to predict future conditions and changes in post-closure features of waste package model parameters; and

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

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

In order to conduct an effective review, the reviewer should rely on various sources (e.g., staff expertise and independently acquired knowledge, information, and data such as the results of research activities being conducted by the NRC's Office of Nuclear Regulatory Research. These sources are to supplement the information provided by the DOE in its license application. The reviewer should

also have available specific pertinent documents that were commissioned by the NRC, DOE, or others. Specifically, the reviewer will need to (1) understand and evaluate DOE's compliance demonstration logic, (2) conduct a preliminary review of the data base used for compliance demonstration to determine which parts of the data are more uncertain or incomplete, (3) determine whether portions of the data and/or analyses submitted should be subjected to further detailed review (in addition to those areas requiring a *Detailed Safety Review*, as specified below), and (4) determine if relevant use of expert opinion was appropriate.

The reviewer should also use any additional data and knowledge that can refine the assessment of compliance with the design criteria for the waste package, and should perform, as necessary, additional analyses to confirm the resolution capabilities of the methodologies. It is incumbent upon the reviewer to have acquired a body of knowledge regarding these and other critical considerations in anticipation of conducting the review, so as to ensure that the assessment of compliance with the design criteria for the post-closure features of the underground facility is sufficient, in scope and depth, to provide the information required to resolve the concerns.

At the reviewer's discretion, independent analyses of results of DOE's models or analyses may be performed, using data, descriptions, and models provided by DOE. Alternatively, when deemed appropriate, simple confirmatory calculations may be performed using appropriate procedures.

To conduct a successful *Safety Review*, the reviewer may choose to refer to additional information and analyses contained in other sections of the license application. These license application sections are listed in Table 5.2-1.

Detailed Safety Review Supported by Analyses:

A *Detailed Safety Review and Analysis* will be needed for evaluation of the Key Technical Uncertainties related to the prediction of the following: (1) thermomechanical effects on the waste packages and the EBS; (2) environmental effects on the waste packages and EBS; (3) criticality events in waste packages; (4) the release path parameters (such as size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects; (5) the releases of gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period; and (6) the releases of non-gaseous radionuclides from waste packages during the containment period and from the EBS during the post-containment period. These KTUs are the same as those identified in Review Plan 5.4 ("Assessment of Compliance with the Engineered Barrier System Performance Objectives") and the evaluation of these Key Technical Uncertainties will be addressed in Review Plan 5.4 of the License Application Review Plan.

Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations:

A *Detailed Safety Review, Independent Staff Modeling, and the use of the Results of Staff Investigations* will be needed for the Key Technical Uncertainty related to the extrapolation of short-term laboratory and prototype test results to predict long-term performance of containers and EBS. The evaluation of these Key Technical Uncertainties will be addressed in Review Plan 5.4 ("Assessment of Compliance with the Engineered Barrier System Performance Objectives") of the License Application Review Plan.

However, it should be noted that the design information and analyses submitted in this section of the license application will form the basis for the *Compliance Reviews* of information contained in Section 5.4 of the license application. Therefore, during the *Compliance Reviews* of Section 5.2, the reviewer should determine that the appropriate descriptive information, necessary for the staff to conduct the *Safety Reviews*, described above, has been provided, and that the information is both internally consistent, and consistent from section to section.

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Date of Analysis: 7/21/93

APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(E)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.21(c)(2)
10 CFR 60.21(c)(3)
10 CFR 60.21(c)(6)
10 CFR 60.21(c)(14)
10 CFR 60.131(b)(7)
10 CFR 60.135

Type 3:

10 CFR 60.131(b)(7)
10 CFR 60.135

Type 4:

10 CFR 60.135

Type 5:

10 CFR 60.135

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TABLE 5.2-1. Sections of the License Application that may support the "Review of Assessment of Compliance with the Design Criteria for the Waste package and its Components" section of the License Application.

License Application Section	SECTION TITLE
2.5	Radioactive Material
3.1	Description of Individual Systems and Characteristics of the Site:
3.1.5	Integrated Natural System Response to the Maximum Design Thermal Loading
4.1	Description of the GROA Structures, Systems, and Components:
4.1.3	Underground Facility
4.4	Assessment of Compliance with Design Criteria for the Underground Facility
5.1	Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting
5.3	Assessment of Compliance with the Design Criteria for the Engineered Barrier System
5.4	Assessment of Compliance with the Engineered Barrier System Performance Objectives
6.1	Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
6.2	Assessment of Compliance with the Individual Protection Requirements
6.3	Assessment of Compliance with the Groundwater Protection Requirements