COMPLIANCE DETERMINATION STRATEGY

RRT 5.4 ASSESSMENT OF COMPLIANCE WITH THE ENGINEERED BARRIER SYSTEM PERFORMANCE OBJECTIVES

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.113(a)(1)
10 CFR 60.113(b)

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 Other Investigations (Type 5)

RATIONALE FOR TYPES OF REVIEW:

Acceptance Review (Type 1) Rationale:

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

Safety Review (Type 3) Rationale:

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

The Engineered Barrier System (EBS) performance objectives (10 CFR 60.113(a)(1)) stipulate that the EBS shall be designed so that, assuming anticipated processes and events, containment of high-level waste within the waste packages shall be substantially complete during the containment period and that any release of radionuclides from the EBS shall be a gradual process which results in small fractional releases to the geologic setting over long times. To comply with these performance objectives, DOE is expected to develop extensive data to characterize the EBS and the environment that the EBS will experience. DOE's compliance demonstration methods are expected to be based

largely on predictive mathematical models of varying complexity and credibility and on subjective information obtained through expert elicitation.

DOE's analyses of engineered barriers should include a comparative evaluation of alternatives to the major EBS design features, with particular attention to the alternatives that would provide longer radionuclide containment and isolation. To support this comparative evaluation, there should be data from field tests, *in situ* tests, and laboratory tests.

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

The staff considers that there may be a high potential risk of non-compliance with the regulatory requirements set forth in 10 CFR 60.113(a)(1) 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 possible 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 possible 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 of waste packages incorporating a large number of spent fuel assemblies in close proximity to one another. Designing for long-term integrity of criticality measures which must also perform to meet transportation needs is highly uncertain.

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 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 release path parameters (such as the 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 distributions of penetrations of the waste packages). However, such analytical models will likely contain simplifying assumptions.

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 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 in light of this Key Technical Uncertainty and subsequent high risk of non-compliance 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 compliance with the Engineered Barrier System (EBS) performance objectives, 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 5.4 of the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG). The reviewer should determine whether or not all appropriate information necessary for the

staff to review the demonstration of compliance with the EBS performance objectives 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 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 requirement are clear and do not require the reviewer to conduct extensive analyses or literature searches. 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 consideration of assessment of compliance with the subsystem performance objectives for the EBS. It is not concerned with assessment of compliance with the design criteria for either the EBS and its components (including the waste packages) or with the postclosure design features of the underground facility. These topics are covered in sections 5.2 and 5.3 of the license application and the attendant review plans.

In conducting the Safety Review, the reviewers will, as a minimum, determine the adequacy of the data and analyses presented in the license application to determine DOE's compliance with § 60.113(a)(1). The specific aspects of the license application on which the reviewer will focus are described below as well as in the FCRG, and the *Acceptance Criteria* will be identified in Section 3.0 of this Review Plan.

The Safety Review will assess whether the waste packages provide substantially complete containment (with reasonable assurance) and whether the waste packages and the other components of the EBS meet the gradual release requirement (with reasonable assurance). The staff's objectives in the Safety Review are 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 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 specified below); and (4) determine whether the use of expert opinion (if used) was appropriate.

In general, the reviewers will assess the adequacy and completeness of DOE's analyses of the design of the waste packages and the EBS with respect to the performance objectives for containment and gradual release from the EBS. The Safety Review will determine whether or not DOE's assessment shows that all anticipated processes and events have been considered and analyzed. For disposal in the repository domain, the Safety Review will also determine whether or not DOE's assessment shows that both the partial and complete filling with groundwater of available void space in the underground facility have been considered and analyzed, per 10 CFR 60.113(a)(1)(i)(B).

The Safety Review will also determine whether or not DOE's assessment shows that: (1) all the favorable conditions and potentially adverse conditions, that are characteristic of the site, have been considered in the demonstration for the EBS performance objectives expressed in § 60.113(a)(1); and (2) the assumptions made in examining each potentially adverse condition are not likely to underestimate the effects of that condition on the EBS performance objectives expressed in § 60.113(a)(1). Only anticipated processes and events will be considered in the assessment. [For disposal in the repository domain, both partial and complete filling with groundwater of available void space in the underground facility should also be appropriately considered and analyzed, per 10 CFR 60.113(a)(1)(i)(B).]

In order to conduct an effective review, the reviewer will rely on staff expertise and independently-acquired knowledge, information and data such as the results of research activities being conducted by the NRC Office of Nuclear Regulatory Research, in addition to that provided by the DOE in its license application. Therefore, it is incumbent upon each reviewer to have acquired a body of knowledge regarding critical considerations in anticipation of conducting the safety review to ensure that the information provided is sufficient to resolve concerns. At a minimum, each reviewer must be familiar with the experiments and analysis on EBS concepts sponsored by DOE (e.g., Chambre *et al.*, 1986; Van Konynenburg *et al.*, 1986; Mallet, 1986; Liebetrau *et al.*, 1987; Zwahlen *et al.*, 1989; Apted *et al.*, 1990; Light *et al.*, 1990; Sadeghi *et al.*, 1990; Wilson, 1990; Zwahlen *et al.*, 1990; Farmer *et al.*, 1991; Lee *et al.*, 1991; Lee and Choi, 1991; Leider *et al.*, 1991; Pescatore and Sullivan, 1991; and Ueng and O'Connell, 1992) and NRC (e.g., Interrante *et al.*, 1987a, 1987b, 1988a, 1988b, 1989, 1990, 1991, and 1993; Manaktala and Interrante, 1990; Wu *et al.*, 1990; Nataraja and Brandshaug, 1992: and Sridhar *et al.*, 1993), and more current works as they become available.

It should be noted that 10 CFR 60.113(b) provides for alternate radionuclide release rates and/or waste package containment periods. Should DOE implement this provision, the reviewers will, as a minimum, determine the adequacy of the data and analyses presented in the license application to determine DOE's compliance with any alternate radionuclide release rates and /or waste package containment periods proposed. Accordingly, the *Review Strategy* described above would still apply.

Detailed Safety Review Supported by Analyses (Type 4):

A Detailed Safety Review and Analysis will be needed for evaluation of the Key Technical Uncertainties related to: (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) release path parameters (such as the 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 Engineered Barrier System during the post-containment period; and (6) the releases of non-gaseous radionuclides from waste packages during the containment period and from the Engineered Barrier System during the post-containment period. This review will make use of data, models, analyses, and methodologies developed by DOE and/or other parties and reviewed and found acceptable by the staff. This will ensure that DOE has adequately demonstrated Items (1)-(4), listed in the previous section ("Safety Review", paragraph 3). Probability and uncertainty analyses will be used to identify critical parameters whose associated uncertainties contribute in a major way to demonstration of compliance with the performance objectives. Activities performed in this Detailed Safety Review will help to

ensure that DOE has adequately addressed and resolved these Key Technical Uncertainties so that they do not lead to non-compliance with the EBS performance objectives.

The Detailed Safety Review of the Key Technical Uncertainty related to thermomechanical effects will require the staff to examine closely the data, analyses, and assumptions used by DOE to analyze thermomechanical effects on the waste packages and the EBS. The staff must determine whether or not all reasonable thermomechanical effects have been considered by DOE and that the models used by DOE are not likely to underestimate the consequences of the thermomechanical effects on the structural integrity of the waste packages and the EBS. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

The Detailed Safety Review of the Key Technical Uncertainty related to environmental effects will require the staff to examine closely the data, analyses, and assumptions used by DOE to analyze environmental effects on waste packages and the EBS. The staff must determine whether or not all reasonable environmental effects have been considered by DOE and that the models used by DOE are not likely to underestimate the consequences of the environmental effects on the structural integrity of the waste packages and the EBS. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

The Detailed Safety Review of the Key Technical Uncertainty related to criticality events in waste packages will require the staff to examine closely the data, analyses, and assumptions used by DOE to predict criticality events. The staff must determine whether or not the models used by DOE are not likely to underestimate the probability of a criticality event. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

The Detailed Safety Review of the Key Technical Uncertainty related to release path parameters (such as the size, shape, and distribution of penetrations of waste packages) due to thermomechanical, environmental, or criticality effects will require the staff to examine closely the data, analyses, and assumptions used by DOE to predict the penetrations of waste packages due to those effects. The staff must determine whether or not the models used by DOE are not likely to underestimate the penetrations of waste packages. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

The Detailed Safety Review of the Key Technical Uncertainty related to releases of gaseous radionuclides from waste packages during the containment period and from the Engineered Barrier System during the post-containment period will require the staff to examine closely the data, analyses, and assumptions used by DOE to predict the transient generation and release of gaseous radionuclides. The staff must determine whether or not the models used by DOE are not likely to underestimate the quantities of gaseous radionuclides generated and released. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

The Detailed Safety Review of the Key Technical Uncertainty related to releases of non-gaseous radionuclides from waste packages during the containment period and from the Engineered Barrier System during the post-containment period will require the staff to examine closely the data, analyses, and assumptions used by DOE to predict the release rates of non-gaseous radionuclides through

penetrated waste packages and the subsequent transport of non-gaseous radionuclides to the boundaries of the Engineered Barrier System. The staff must determine whether or not the models used by DOE are not likely to underestimate the release rates of non-gaseous radionuclides. Detailed reviews will be supported by the staff's own analyses including the use of data and analytical models not considered by DOE, if appropriate.

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

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 waste packages and engineered barrier systems. This will ensure that DOE has adequately demonstrated Items (1)-(4) listed in "Safety Review," paragraph 3.

In order to evaluate this Key Technical Uncertainty, the staff must review the waste package and EBS degradation modes considered by DOE to determine whether anticipated processes and events will not result in any credible degradation modes not analyzed by DOE. In conducting this review, each reviewer must have developed an understanding of the credible degradation modes that have been identified in DOE studies (e.g., Farmer *et al.*, 1991) and in NRC and other independent studies (e.g., Manaktala and Interrante, 1990).

The staff must also review DOE's data extrapolation procedures to ensure that these procedures are supported by the appropriately conservative mechanistic models of the long-term performance of the waste package. If DOE proposes to use natural analogs as part of these data extrapolation procedures, the staff must determine whether the data and conclusions based on the analogs are not likely to result in non-compliance with the EBS performance objectives. In conducting this review, the staff must have developed an understanding of the degradation mechanisms that have been identified in DOE studies (e.g., Farmer *et al.*, 1991) and in independent NRC studies (e.g., The Integrated Waste Package Experiments Project).

Finally, the staff must review DOE's formal procedures for the elicitation of expert judgement, if used, to ensure that the use of the data and conclusions generated are not likely to result in non-compliance with the EBS performance objectives. In conducting this review, the staff must have developed an understanding of formal elicitation procedures that have been successfully used to address other complex technical issues (e.g., NRC, 1990).

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Date of Analysis: July 26, 1993

APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(1)(ii)(C)
10 CFR 60.21(c)(1)(ii)(D)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.113(a)(1)
10 CFR 60.113(b)

Type 3:

10 CFR 60.113(a)(1)
10 CFR 60.113(b)

Type 4:

10 CFR 60.113(a)(1)
10 CFR 60.113(b)

Type 5:

10 CFR 60.113(a)(1)
10 CFR 60.113(b)

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