DRAFT

TECHNICAL POSITION

ON

POSTCLOSURE SEALS IN AN UNSATURATED MEDIUM

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1.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission's (NRC's) "Generic Technical Position on Borehole and Shaft Sealing of High-Level Nuclear Waste Repositories" (NRC, 1986) focuses mainly on issues related to repositories in saturated media. However, the Department of Energy (DOE) is currently investigating the unsaturated Yucca Mountain site for detailed characterization. Although the guidance in the existing generic technical position (GTP) is also applicable to repositories in unsaturated media, DOE's current design concepts include a combination of sealing and drainage, and the NRC staff position on this concept is not adequately discussed in that GTP. Therefore, additional guidance is needed to clarify the NRC staff position on sealing and drainage for a repository in an unsaturated medium. The purpose of this technical position is to provide guidance with respect to sealing concepts as described in recent DOE publications (Case and Kelsall, 1987; Fernandez, 1985; Fernandez and Freshley, 1984; Fernandez et al., 1987).

In evaluating the need for seals in an unsaturated medium, the principal design goals should be to (1) prevent significant amounts of surface or ground water from reaching emplaced waste and (2) prevent significant amounts of gaseous radionuclides from escaping through shafts, ramps, and boreholes to the accessible environment. The seal requirements can be reduced in part by: (1) limiting the amount of surface water that may enter boreholes, shafts, and ramps; (2) selecting borehole, shaft, and ramp locations and orientations that provide long flow paths from the emplaced waste to the accessible environment above the repository; and (3) maintaining a sufficient rate of drainage below the repository horizon level so that water can percolate down through the rock mass without contacting waste packages. Seals for shafts and boreholes must be designed so that they do not become pathways that compromise the geologic repository's ability to meet the performance objectives.

Provisions for rapid drainage of uncontaminated water through the repository horizon can reduce the risk of water contacting waste packages. However, such a drainage scheme can also provide pathways for rapid flow of contaminated water to the accessible environment. The seals and drainage design should ensure that drainage pathways for uncontaminated water would not enhance flow of contaminated water toward the water table. The effects of intrinsic anisotropy in rock mass hydraulic conductivity and thermally driven lateral water or vapor flow should be considered in the evaluations of drainage pathways.

A successful design goal should determine what mechanism, or combination of mechanisms, of sealing and drainage would demonstrate compliance with long-term performance requirements with respect to both anticipated and unanticipated processes and events. The role and contribution of factors affecting the performance of the seal system should be assessed. The assessment should consider (1) the potential for water contacting the waste packages and the consequent release of radionuclides to the accessible environment and (2) the escape of gaseous radionuclides through the shafts and boreholes to the accessible environment. If drainage is to be incorporated as a basic strategy to preclude water inflow to the emplaced waste, then the uncertainties in

predicting and extrapolating the long-term behavior of the contributing factors (e.g., infiltration and effectiveness of drainage) should be considered in evaluating the post-closure performance of seals and the drainage system.

In establishing the NRC staff positions presented in this document, the staff has recognized that large uncertainties are likely to persist in evaluating the longevity and long-term effectiveness of seals and drainage for the postclosure period. In view of these uncertainties, the staff considers it prudent to minimize the need for seals wherever feasible. These considerations suggest that the number of surface openings be limited, and their locations be selected to discourage infiltration of surface water.

This technical position provides guidance regarding design considerations for seals of shafts, ramps, boreholes, and the underground facility. It should be noted that the criteria for seals given in Part 60 of Title 10 of the Code of Federal Regulations (10 CFR Part 60) do not specifically mention seals in ramps and the underground facility. However, because the seals and drainage design in ramps and the underground facility could also affect the overall system performance of the geologic repository, it is reasonable to apply the same guidance to these seals and drainage designs.

This technical position takes into account site characterization and performance confirmation testing, including the need for starting in situ seal testing during site characterization and for confirming the adequacy of seal and drainage concepts, emplacement methods, and material compatibility. In addition, this technical position emphasizes the need for considering the effects of seals and/or drainage design on meeting the overall system performance requirements.

This technical position does not explicitly address the implications of potential changes in water level during the postclosure period. However, it is expected that sealing performance analyses and requirements will include adequate consideration of credible future tectonic, geologic, geomorphological, and geochemical processes and events that could affect seal performance.

Technical positions describe and make available to the public criteria for methods acceptable to the NRC staff for implementing specific parts of the Commission's regulations or otherwise provide guidance to the DOE. Technical positions are not substitutes for regulations, and compliance with them is not required. Methods and solutions not in accordance with criteria set out in the position will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission.

2.0 REGULATORY FRAMEWORK

The applicable regulations in 10 CFR Part 60 are stated below, and the text of these regulations is provided in Appendix B of this document.

10 CFR 60.112 addresses the requirements for the selection of the geologic setting and design of the engineered barrier system and the shafts, boreholes, and their seals to meet the overall system performance objectives for the geologic repository after permanent closure with respect to both anticipated and unanticipated processes and events.

10 CFR 60.21(c)(1)(ii)(D) requires the DOE to assess the effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation.

10 CFR 60.152 requires the DOE to implement a quality assurance program based on the criteria of Appendix B to 10 CFR Part 50 as applicable. If seals are determined to be important to waste isolation, then the seals and the activities which affect their performance should be covered by the quality assurance program.

10 CFR 60.134(a) provides the general criterion for design of seals for shafts and boreholes, and 10 CFR 60.134(b) addresses the selection of materials and placement methods for seals.

10 CFR 60.15 addresses the site characterization requirements.

10 CFR 60.140, 60.141, and 60.142 address the general requirements, confirmation of geotechnical and design parameters and design testing, respectively, pertaining to the performance confirmation program.

3.0 TECHNICAL POSITIONS

3.1 Design Considerations

(1) Measures should be established to document that the applicable NRC regulatory requirements relevant tc seal design, materials selection, and placement methods have been adequately translated into design bases, specifications, drawings, procedures, and instructions.

(2) The shaft and ramp designs should specify appropriate construction controls to limit the lateral extent and degree of damage to the rock mass surrounding the shafts and ramps.

(3) The seals and drainage system for water potentially entering into and around the shafts and/or ramps should be designed so as to limit inflow into the waste emplacement area of the geologic repository and to minimize the chance of water contacting the waste.

(4) The design of shaft and/or ramp liners should consider the effects of those liners on postclosure seal performance. If part or all of a liner is to be removed when the geologic repository is closed permanently, the possibility that such removal might create water and gaseous pathways should be examined and the effect on postclosure seal performance should be evaluated. If the liner is to be left in place, the effects of the potential degradation and disintegration of the liner during the postclosure period should be factored into the design.

(5) Seal materials and placement methods should be designed to be geochemically compatible with the host rock and its environment. Seals should be analyzed

(e.g., through modeling and accelerated testing) for long-term compatibility that is consistent with overall system performance requirements.

(6) All exploratory boreholes drilled for site characterization should be sealed. If any of the boreholes are not to be sealed, the possibility that they might become pathways for water infiltration and for gaseous releases should be analyzed to demonstrate that the performance objectives can be met.

(7) The seals for exploratory boreholes and test holes drilled from shafts, ramps, the underground facility and test areas should be planned, designed, and analyzed to the same standards as the exploratory surface boreholes.

(8) The design of seals for the underground facility should consider the consequences of their partial and/or complete failure during the post-closure period. Alternatively, reasonable assurance should be provided that the seals will perform satisfactorily for the 10,000 years specified for meeting the performance objectives for the geologic repository .

3.2 Site Characterization Considerations

(1) The shafts and/or ramps should be located so as to limit the potential infiltration of surface water through and around the shaft and ramp openings.

(2) The number of exploratory boreholes should be limited to the extent practicable to meet site characterization and waste isolation needs. The proximity to the planned waste emplacement areas should be considered in determining the locations of boreholes. Planning of borehole depths should take into consideration the potential adverse effects of inflow of water to waste emplacement areas, of gaseous releases, and of outflow of contaminated water to the accessible environment.

(3) All site characterization activities, including those related to borehole and shaft seals, should be planned and implemented so as not to compromise the isolation capability of the site.

3.3 Performance Confirmation Considerations

(1) Data on the performance of seals for boreholes, shafts, ramps, and the underground facility should be collected using tests, experiments, and analytical methods before the license application is submitted.

(2) The program for testing the adequacy of the seals and drainage should include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to demonstrate the adequacy of the design, materials, and placement methods.

(3) If, on the basis of the measurements and observations made during the performance confirmation program (including data obtained during the site characterization program), it is not possible to ensure the effectiveness of the seals and drainage the need for modification of the design should be determined and design changes should be implemented, as needed.

3.4 Performance Analysis Considerations

(1) A methodology should be developed for predicting the long-term behavior of the seals and drainage as designed, including the environmental, thermal, and geochemical effects. The methodology should be used for evaluating the overall system performance during the postclosure period with respect to both anticipated and unanticipated processes and events. Uncertainties in predicting and extrapolating the long-term behavior of the components affecting seal performance should be considered.

(2) Engineering analysis of seals (including backfill and settlement plugs) should be performed with respect to the potential for both water inflow and gaseous outflow. The analysis should account for possible long-term settlement of shaft backfill and piping (channel flow) along the boundary between the liner and backfill and other potential flow paths.

(3) The potential adverse effects of the deteriorated liner and/or grout materials on drainage should be considered in evaluating the effectiveness of drainage and the consequent effect on seal performance during the postclosure period.

(4) The analysis of overall system performance should consider the possible consequences of partial or complete failure of seals and/or drainage over 10,000 years. Alternatively, reasonable assurance should be provided by tests, experimental results, and/or analyses that seals will remain effective during the postclosure period.

4.0 DISCUSSION

The following discussion parallels the list of technical positions given in Section 3.0.

4.1 Design Considerations

(1) DOE should evaluate site sealing to determine if it is important to waste isolation and if the seals should be placed on the DOE Q-list. The NRC staff position on an acceptable method for determining Q-list items is given in NUREG-1318, "Technical Position on Items and Activities in the High-Level Geologic Repository Program Subject to Quality Assurance Requirements" (NRC, 1988). If DOE determines that the seals for shafts, ramps, boreholes, and the underground facility are important to waste isolation, then it should include them on the Q-list. If seals are included on the Q-list, then DOE should ensure that all activities associated with the seals are covered by an adequate quality assurance plan.

The overall systematic design and approval process for the seals should consider the 10 CFR Part 60 requirements that deal with site characterization and long-term isolation. The process should establish a link between the NRC regulatory requirements and seal design. As a part of the process, the applicable 10 CFR Part 60 requirements dealing with seal design, materials selection, and placement methods should be identified. There should be clear and systematic documentation of how each relevant 10 CFR Part 60 requirement is translated into design bases, specifications,

drawings, procedures, and instructions. Those aspects of seal design that may affect waste isolation should be translated into requirements that consider the need to meet the performance objectives for the geologic repository over 10,000 years. In addition, a verification process should ensure that the 10 CFR 60 requirements are incorporated into the various stages of design.

(2) The method of constructing the openings and the care taken while implementing the selected construction procedures may influence the need for sealing. Therefore, to the extent necessary to meet the design objectives, the selected method of construction should be specified so that the lateral extent and degree of damage to the rock mass surrounding the shaft and ramp openings are limited. If the selected construction methods can cause excessive damage to the rock surrounding the openings, the sealing of these damaged zones should be considered and their long-term effects should be analyzed to demonstrate compliance with the performance objectives.

(3) The seals and drainage system should be designed so that water entering the shafts and ramps and the damaged zone around the openings would have a limited adverse effect on the isolation of the waste in the repository. One way to meet this design criterion could be to provide for a long-term drainage system that would allow the water to drain away before it entered the waste emplacement area. Drainage through the rock mass may initially be sufficient to prevent an adverse effect on waste isolation. To assess if the drainage will remain sufficient to meet the long-term design criteria, the drainage capacity over an extended period should be evaluated. Experimental as well as analytical methods should be used to assess the long-term effectiveness of the drainage system in meeting the design criteria.

(4) The shaft and ramp liners can significantly affect the overall effectiveness of the seal system. This potential must be sufficiently evaluated and accounted for in assessing the long-term performance of the seal system. If part or all of a liner is to be removed at permanent closure, then the effect of such removal should be assessed. The liner-removal process can result in damage of the rock around the shaft and ramp wall. Also, liner removal could change stresses in the shaft and ramp walls and could increase the shaft and ramp closure. The effects of liner removal should be considered in the determination of the rate of drainage with time and the potential for creating water and gaseous pathways.

If the liners are to be left in place at permanent closure, the compatibility of liner material with any water with which it might come in contact should be evaluated because of the potential for dissolution of the material and redeposition in rock pores during the postclosure period. Consideration should be given to the possibility that the liners could: (a) degrade and disintegrate with time; (b) cause minerals to redeposit in rock pores with time and contribute to the clogging of the drainage through the rock mass and fractures; and (c) deteriorate and cause additional closure of shaft and ramp walls, thereby creating rock movements that could cause the creation of additional flow paths for water inflow and gaseous outflow. Such recurrence should be considered when evaluating the role of liners in regard to seal performance. It is desirable that the selection of any emplaced materials, such as cement, aggregates, and

rock reinforcement components, be based, in part, on chemical compatibility during the postclosure period.

(5) Selection of the seal materials and placement methods is an integral part of the seal design. For the seals to be effective, it is essential that seal materials are geochemically compatible with the host rock environment and that placement methods are specifically selected for the conditions encountered in the seal placement environment. The compatibility of the seal material with the host rock should be analyzed over the long period of time for which the repository performance has to be evaluated. 10 CFR 60.134(b) requires that the materials and placement methods for seals be selected to reduce, to the extent practicable (a) the potential for creating a preferential pathway for groundwater to contact the waste packages or (b) radionuclide migration through existing pathways. Accordingly, the selected seal materials and placement methods should contribute to the overall performance of the seals in reducing the potential for water contacting waste and for gaseous outflow. The analysis should consider uncertainties with respect to the behavior and compatibility of seal and host rock materials.

(6) In view of the potential significance of the boreholes because of their large number, proximity to waste emplacement areas, and depths, all boreholes should be sealed to provide a margin of safety in regard to the postclosure performance of the repository system. If any of the planned or existing boreholes will not be sealed, the effect of these boreholes on the long-term waste isolation capability of the site should be evaluated. The analysis should consider the possibility that the unsealed boreholes could become pathways for water inflow and/or for gaseous outflow. The analysis should consider the uncertainties regarding potential future natural processes and events and should demonstrate that the design objectives can be met if the identified boreholes are not sealed.

(7) The exploratory shafts and underground test areas may become part of the final repository. As part of the exploration and testing process, a large number of vertical and horizontal holes may be drilled from within the shafts and test areas. Since most of the exploratory holes and test holes are likely to be in areas that may become a part of the repository, they could affect the waste isolation capability of the site. Therefore, these holes should also be sealed. If it is considered desirable that some of the boreholes not be sealed to facilitate drainage of the uncontaminated water, it should be demonstrated that these holes cannot compromise the waste isolation capability of the site by facilitating outflow of contaminated water. The staff believes that in view of the potential significance of these holes if they should be located in a part of the future repository, their seal design should be planned and analyzed to the same standards as the exploratory surface boreholes.

(8) Seals in the underground facility should meet standards similar to those specified for borehole and shaft seals. For an underground facility developed in unsaturated media, the design of seals may include methods for plugging the surface and underground openings to prevent water inflow or methods for encouraging the drainage of water through the host rock. The design of seals may incorporate a combination of these two design methods. If seal performance is relied on for an extended period,

reasonable assurance must be provided that the longevity of the seal material is adequate to meet the performance requirements.

If percolation through host rock is relied on to drain the water out of the repository, large uncertainties exist regarding the system's ability to remain functional for 10,000 years. Therefore, the analysis of the overall system performance should consider the possible consequences of a partial and/or total failure of the underground facility seals and drainage during the 10,000 years. Alternatively, reasonable assurance should be provided using experimental results and/or analysis that the underground facility seals and drainage will remain effective.

4.2 Site Characterization Considerations

(1) The locations of the shafts and ramps can be a key factor in determining the long-term infiltration potential through and around the shaft and ramp openings. Reasonable and conservative estimates of flooding, infiltration, sheet flow, and other potential water intrusions should be made taking into account climatic changes with respect to additional rainfall and the potential for surface erosion. It should be noted that uncertainties will always exist in these estimates. A prudent means of arriving at reasonable locations of shafts and ramps is to consider these uncertainties and, whenever possible, locate the openings where there is little potential for future infiltration into and around the openings.

(2) The number of exploratory boreholes, their proximity to the future waste emplacement areas, and their depths with respect to the repository level as well as the groundwater table are all important considerations in evaluating the seal design for these boreholes. 10 CFR 60.15(d)(2) requires that the number of exploratory boreholes and shafts be limited to the extent practicable consistent with obtaining the information needed for site characterization. Since openings from the ground surface may, if not properly sealed, affect the isolation capability of the site, only the number of boreholes required for obtaining information needed for site characterization should be planned.

If the boreholes are to be located close to the future emplacement area, they can affect the waste isolation capability of the site. 10 CFR 60.15(d)(3) requires that, to the extent practical, exploratory boreholes in the geologic repository operations area be located where shafts are planned for underground facility construction and operation or where large unexcavated pillars are planned. Accordingly, the locations of boreholes should be considered with regard to their proximity to the planned waste emplacement areas and should be planned and coordinated with the design and construction of the geologic repository operations area.

Boreholes that penetrate below the repository horizon can create flow paths for water from the waste emplacement area to the groundwater table. Similarly, shallow holes, if interconnected through existing faults and fractures, can provide pathways for gaseous releases from waste emplacement areas to the ground surface. Therefore, in planning the depths of boreholes, the potential effects of inflow of water, gaseous releases, and outflow of contaminated water through these pathways should be considered.

(3) Subpart F to 10 CFR Part 60 requires that a program of seal design testing should be started during site characterization and should continue until permanent closure. The test program should include verification of the adequacy of the seal design, materials, and placement methods and should be initiated as early as practicable. 10 CFR 60.15(d)(1) requires that the investigations to obtain the required information be conducted in a manner so as to limit adverse effects on the long-term performance of the geologic repository to the extent practicable. Therefore, seal testing activities should be planned and implemented so as not to compromise the isolation capability of the site.

4.3 Performance Confirmation Considerations

(1) Preliminary results from seal and drainage testing should be available when the license application is submitted. At that time, the performance of seals and drainage system during the postclosure period will have to be extrapolated from the results of testing that has been completed. Therefore, considerable data should be obtained by that time, so that a reasonable estimate of the effectiveness of the seal design during the postclosure period can be made.

The data available when the license application is submitted are likely to reduce uncertainties in predicting the performance of seals during the postclosure period. Significant amounts and good quality of test data at that stage can lead to fewer uncertainties and accordingly can help the Commission find reasonable assurance that the performance objectives will be met.

Before proceeding with sealing operations on boreholes, shafts, ramps and/or the underground facility, the effectiveness of the proposed seals should be evaluated using test results and/or analytical procedures. This evaluation should provide reasonable assurance that the proposed seals will function as designed for the intended period in the anticipated range of seal environments.

(2) 10 CFR 60.140(c) requires that the evaluation program to determine the adequacy of seal design, material selection, and placement methods include in situ monitoring, laboratory and field testing, and in situ experiments, as appropriate. For the test program to be valid and directly applicable to the assessment of the long-term performance of seals, it is essential that it be conducted for the range of environmental conditions that are anticipated in the repository during the postclosure period. Both laboratory and field testing may be necessary to simulate the range of anticipated repository conditions.

(3) 10 CFR 60.141(d) requires that the measurements and observations made during the construction and operation of the repository be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or construction method should be determined. If the effectiveness of the seals and drainage system cannot be ensured, either the design of the seals and drainage system should be modified, or it should be demonstrated that the overall

performance requirements can be met without taking into consideration the long-term effectiveness of seals.

4.4 Performance Analysis Considerations

(1) Tests to determine the adequacy of the seal and drainage design can be conducted only for a limited time. Therefore, a methodology should be developed for predicting the long-term behavior of the seals and drainage as designed including the environmental, thermal, and geochemical effects with respect to both anticipated and unanticipated processes and events.

Confirmation testing of seal performance should continue until permanent closure. Therefore, additional data should become available from the time the license application is submitted until permanent closure. These data can be used to verify the applicability of the methodology developed in the license application for predicting the long-term behavior of the seals and drainage system as designed. However, despite the availability of performance confirmation data, considerable uncertainties are likely to exist in extrapolating these data for the postclosure period. It is essential that sufficient conservatism is used in the seal and drainage design for shafts, ramps, boreholes, and the underground facility to allow for these potential uncertainties.

(2) The performance requirements for the seals and drainage system for shafts, ramps, boreholes, and the underground facility are all to be governed by the requirements for meeting the performance objectives of 10 CFR 60.112. These requirements state that the shafts, the boreholes, and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to the Environmental Protection Agency standards with respect to both anticipated and unanticipated processes and events. The environmental standards for radioactivity expected to be established by the Environmental Protection Agency require engineering analysis of seals with respect to the potential for both water inflow and gaseous outflow.

At permanent closure, the shafts may be backfilled with crushed tuff or some other suitable material. Settlement plugs also may be used to reduce backfill settlement. The behavior of the shaft backfill as well as the settlement plugs during the postclosure period may be important in regard to the potential for both water inflow and gaseous outflow.

The plugs are likely to deteriorate with time and, therefore, the effect of this disintegration on the performance of seals and the drainage system should be taken into account. The backfill is also likely to settle with time. Channeled flow paths could be created within the shaft backfill and act as preferential pathways for both water inflow and gaseous outflow. Such pathways could also be created at the interface of the shaft wall and the backfill. The effects of such phenomena should be taken into consideration when evaluating the effect of backfill on the performance of seals and the overall postclosure performance of the repository.

(3) In some areas of the ramps, diversion structures such as dams may be installed to guide the water flow on the floor of the ramps. Also, seals may be installed in the shaft and ramp walls and other faces to plug up

the damaged areas to prevent the inflow of water. These seal components are likely to shrink and/or disintegrate with time and should only be relied on for long-term performance to the extent that their long-term properties can be determined. Furthermore, the disintegration of dams and other seal components could have detrimental effects on the performance of the drainage system. The effects of such seal disintegration during the postclosure period should be considered in evaluating the drainage potential of the rock. Finally, these effects should be considered in the overall system performance analysis of the geologic repository after permanent closure.

(4) Uncertainties exist with respect to the seals remaining functional throughout the time specified to meet the repository performance objectives. The uncertainties include potential shrinkage of the seal material, deterioration and degradation of the material, performance of the seals in a heated environment, and future tectonic events that might affect borehole seal performance. Therefore, seal effectiveness should only be relied on if a comprehensive analysis of the future environment and changes at seal locations confirms with reasonable assurance that the required seal performance can be obtained. With this need for conservatism in the design and analysis, the staff believes that the analysis of the overall system performance should consider the possible consequences if seals became partially or completely ineffective during the period following permanent closure. Alternatively, reasonable assurance should be provided using experimental data and/or analysis results that the seals would remain effective during the postclosure period.

There are bound to be uncertainties associated with the prediction of the long-term performance of the seals and drainage behavior during the post closure period. These uncertainties should be accounted for in evaluating the postclosure performance of the seals and drainage behavior and their role in meeting the overall system performance requirements for the repository.

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APPENDIX A: GLOSSARY*

"Accessible environment" means: (1) The atmosphere, (2) the land surface, (3) surface water, (4) oceans, and (5) the portion of the lithosphere that is outside the controlled area.

"Barrier" means any material or structure that prevents or substantially delays movement of water or radionuclides.

"Engineered barrier system" means the waste packages and the underground facility.

"Geologic repository" means a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. A geologic repository includes: (1) The geologic repository operations area, and (2) the portion of the geologic setting that provides isolation of the radioactive waste.

"Isolation" means inhibiting the transport of radioactive material so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

"Performance confirmation" means the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met.

"Underground facility" means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

For definitions of other relevant terms, see 10 CFR 60.2.

*Source: 10 CFR 60.2, "Definitions"

APPENDIX B: APPLICABLE 10 CFR Part 60 REGULATIONS

The technical rule 10 CFR Part 60 requires that the Department of Energy (DOE) design seals to meet the following requirements:

- §60.112 Overall system performance objective for the geologic repository after permanent closure

  The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

- 60.21 Content of [license] application

  §60.21(c)(1)(ii) The assessment [of the site] shall contain:

  (D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall 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.

- §60.134 Design of seals for shafts and boreholes

  (a) General design criterion: Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives over the period following permanent closure.

  (b) Selection of materials and placement methods: Materials and placement methods for seals shall be selected to reduce, to the extent practicable, (1) the potential for creating a preferential pathway for groundwater to contact the waste packages or (2) radionuclide migration through existing pathways.

10 CFR 60.15 addresses the site characterization plan requirements. 10 CFR 60.140, 60.141, and 60.142 address the site characterization requirements for the performance confirmation program.

- §60.15 Site Characterization

  (d) The program of site characterization shall be conducted in accordance with the following:

(1) Investigations to obtain the required information shall be conducted in such a manner as to limit adverse effects on the long-term performance of the geologic repository to the extent practical.

(2) The number of exploratory boreholes and shafts shall be limited to the extent practical consistent with obtaining the information needed for site characterization.

(3) To the extent practical, exploratory boreholes and shafts in the geologic repository operations area shall be located where shafts are planned for underground facility construction and operation or where large unexcavated pillars are planned.

(4) Subsurface exploratory drilling, excavation, and in situ testing before and during construction shall be planned and coordinated with geologic repository operations area design and construction.

§60.140 General requirements

(b) The [performance confirmation] program shall have been started during site characterization and it will continue until permanent closure.

(c) The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as may be appropriate to accomplish the objective as stated above.

(d) The program shall be implemented so that:

(1) It does not adversely affect the ability of the natural and engineered elements of the geologic repository to meet the performance objectives.

§60.141 Confirmation of geotechnical and design parameters

(d) These measurements and observations shall be compared with the original design bases and assumptions. If significant differences exist between the measurements and observations and the original design bases and assumptions, the need for modifications to the design or in construction methods shall be determined and these differences and the recommended changes reported to the Commission.

§60.142 Design testing

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full scale operation proceeds to seal boreholes and shafts.

If seals are included on DOE's Q-list, then 10 CFR 60.152 requires the DOE to design seals to meet the following requirements:

- 10 CFR Part 50, Appendix B, Criterion III, "Design Control"

  Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in § 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions. These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled. Measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of the structures, systems and components.

  Measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.

  The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. The verifying or checking process shall be performed by individuals or groups other than those who performed the original design, but who may be from the same organization. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualifications testing of a prototype unit under the most adverse design conditions. Design control measures shall be applied to items such as the following: reactor physics, stress, thermal, hydraulic, and accident analyses; compatibility of materials; accessibility for inservice inspection, maintenance, and repair; and delineation of acceptance criteria for inspections and tests.

  Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design and be approved by the organization that performed the original design unless the applicant designates another responsible organization.