

COMPLIANCE DETERMINATION STRATEGY

RRT 3.2.2.10 POTENTIALLY ADVERSE CONDITIONS: COMPLEX ENGINEERING MEASURES

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(c)(20)

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)

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 topic is related to radiological safety, retrievability, 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). It concerns a potentially adverse condition regarding complex engineering measures and focuses on two issues: (1) rock and groundwater conditions at Yucca Mountain that would require complex engineering measures in the design and construction of the underground facility; or (2) complex engineering measures in the sealing of boreholes and shafts (including ramps). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with the above cited regulations using this Review Plan.

The geologic conditions of the Yucca Mountain site are to be investigated as part of the site characterization program in order to understand the effect of such conditions on the pre-closure features of repository design, construction and operation (including waste retrievability). The rule does not specify what types or kinds of engineering measures could be regarded as "complex," and thus a potentially adverse condition (PAC); nor does the rule define what complex engineering measures are. However, for the purpose of the license application review, the staff considers the term "complex engineering measures" to refer to those specific engineering solutions, applied to mitigate certain rock or groundwater conditions, for which there is little or no engineering experience. Because of the lack of experience in applying such solutions and the uncertainty attendant thereto, advanced testing or research

and development might be needed to confirm the adequacy of a proposed design solution and reduce the uncertainty associated with the performance, with "reasonable assurance," prior to the receipt of a license to receive and/or emplace waste. A review type higher than a Type 3 would be needed only in those instances for which there might not be "reasonable assurance" that a proposed engineering measure would not compensate for or remediate certain rock or groundwater conditions, or that methods and approaches do not exist to properly characterize (in the manner described in 10 CFR 60.21(c)(1)(ii)(B)) the rock or groundwater conditions.

Based on our current knowledge, rock and/or groundwater conditions expected to be present at the Yucca Mountain site would not require complex measures in the design and construction of the geologic repository operations area, or in the characterization of the *in-situ* rock or groundwater conditions. With regard to rock conditions, the repository block will be located in the Topopah Springs welded tuff unit, in which underground excavations are expected to remain stable throughout the repository operational period, with adequate reinforcement and periodic maintenance. Even so, this repository host rock will likely have been subject to some faulting and fracturing due to active faulting within the Basin and Range. It is likely that certain regions within the repository block will have a higher degree of fracturing than other areas. Depending on the strike and dip of fractures and/or joints, direction of the principal *in-situ* stresses, as well as thermal stresses induced by the emplaced wastes, certain orientations of the excavations will be inherently more stable and require less complex engineering measures, in the form of support, reinforcement, and maintenance than others. Also, due to the fact that mechanical excavation of the entire underground facility may be difficult with any mechanical excavator other than tunnel boring machines, due to the high compressive strength of the welded tuff, it is probable that drill and blast methods may be utilized for smaller emplacement drifts, creating an additional zone of fracturing around the tunnel.

With regard to groundwater conditions, the repository horizon has been chosen in the unsaturated zone well above the groundwater table, the minimum distance to the saturated zone being approximately 200 meters. However, perched water zones are a possibility in the nonwelded units above the proposed repository at Yucca Mountain. This is due to the current knowledge that these nonwelded units have a smaller mean pore size, which could create a capillary barrier and create zones of perched water.

As regards the need for the use of complex engineering measures in the sealing of boreholes, shafts, and ramps, DOE indicated in its 1988 Site Characterization Plan (SCP) that coring and drilling operations would have a potentially adverse impact on the site. However, DOE rationalized that sealing of these features would not represent a significant engineering challenge because seals were not needed to meet the performance objectives (see DOE, 1988b), although it is not clear whether DOE, in its SCP, considered sealing the underground facility against gaseous releases. In its Site Characterization Analysis, the staff noted that DOE had provided no information or analysis to support the basis for this conclusion (see NRC, 1989, p. 4-62).

For example, in the case of exploratory boreholes currently in place, many are either obstructed by previously used drilling equipment (tubing, screens, debris, etc.), existing seals, or collapsed borehole walls (see Jarrell, 1991). Before these boreholes can be properly sealed, the obstructions must be cleared, and it is the staff's experience that the clearing and re-drilling of existing boreholes may complicate any sealing procedure. In over-coring or re-drilling an existing borehole, it is possible to deviate from the existing borehole path, thus producing a new pathway that must be sealed. DOE recognizes the existence of these complications in its borehole seal program and expects that it may have to modify or "fine-tune" its sealing plan for each individual borehole depending on the nature of the

obstruction and its success in removing the obstruction (see Jarrell, 1991). The same may be true for shafts and ramps where sealing plans may need to be "fine-tuned" to account for the *in-situ* conditions encountered.

However, it should be noted that boreholes, shafts, and ramps may have an effect on the overall repository performance because they might act as conduits for enhanced water infiltration (leading to waste package corrosion), liquid radionuclide transport, and gas transport to the surface. The nature of the risk associated with these features as potential conduits and the adequacy of seals as barriers depends on the degree to which DOE determines the overall contribution of seals to geologic repository performance. Accordingly, the staff's strategy is to address the technical uncertainty related to seal design in its review of Section 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps") of the license application and its attendant review plan, and the technical uncertainties related to the contribution of seals to geologic repository performance in Chapter 6.0 ("Overall System Performance Assessment") of the license application and its attendant review plans. Despite these potential technical uncertainties, though, the staff believes that methods are currently available to characterize *in-situ* rock or groundwater conditions, and that there is sufficient engineering experience to review DOE's design solutions to those *in-situ* rock or groundwater conditions that might affect the sealing of boreholes, shafts, and ramps, and thus a Type 3 review would be adequate.

In summary, a Type 3 review is based on the following assumptions:

- (1) methods and approaches are available to identify and define the *in-situ* rock and groundwater conditions at Yucca Mountain in order to understand the nature of any "complex" design requirements, if any;
- (2) sufficient engineering expertise exists to review DOE's design solutions to those *in-situ* rock and groundwater conditions encountered that might affect the sealing of boreholes, shafts, and ramps;
- (3) an evaluation of the adequacy of seal design and performance for boreholes, shafts, and ramps will be treated in other sections of the license application;
- (4) DOE's performance confirmation program will confirm the design and performance assumptions related to seals; and
- (5) underground excavations at the Yucca Mountain site will be maintained to ensure stability throughout the period of repository operations.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of this potentially adverse condition (PAC), the reviewer should determine if the information presented in the license application and its references for demonstrating compliance with the applicable regulatory requirements is complete in technical breadth and depth as identified in the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)." The reviewer should determine whether all appropriate information necessary for the staff to review this potentially adverse condition is presented such that the assessments

required by the Review Plans associated with total system and subsystem performance objectives can be performed.

The reviewer should determine whether 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 regulatory requirements are clear and do not require the reviewer to conduct extensive independent analyses or literature searches. The reviewer should also determine whether controversial information and appropriate alternative interpretations and models have been acceptably described and considered.

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

Safety Review:

Following the Acceptance Review, the first step in the NRC review will be to evaluate DOE's analyses to determine if the following basic review assumptions have been met. They are:

- (1) methods and approaches are available to identify and define the *in-situ* rock and groundwater conditions at Yucca Mountain in order to understand the nature of any "complex" design requirements, if any;
- (2) sufficient engineering expertise exists to review DOE's design solutions to those *in-situ* rock and groundwater conditions encountered that might affect the sealing of boreholes, shafts, and ramps;
- (3) an evaluation of the adequacy of seal design and the contribution of boreholes, shafts, and ramps seals to repository performance will be treated in Section 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps") and Chapter 6.0 ("Overall System Performance Assessment,") respectively, of the license application and its attendant review plans;
- (4) DOE will describe a performance confirmation program, in Section 8.2 ("Performance Confirmation for Structures, Systems, and Components of the GROA") of the license application, to confirm the design and performance assumptions related to seals; and
- (5) DOE's design of the GROA, including those plans for its construction and operation, will assure that underground excavations at the Yucca Mountain site will be maintained in stable condition throughout the pre-closure period.

If the above assumptions are met, the staff review will follow the review strategy described here. If these assumptions are not met, the staff review may require a different review strategy for evaluating DOE's demonstration of compliance with the applicable regulatory requirements. It is expected, however, that any deviation from these assumptions will be known well in advance of the time of license application submittal, and this strategy shall be revised in accordance with such new information as it becomes available to the staff.

In conducting the Safety Review, the reviewer will, at a minimum, determine the adequacy of the data and analyses presented in the license application to support DOE's demonstrations regarding 10 CFR 60.122(c)(20). Specifically, DOE will need to: (1) provide information to determine whether and to what degree evidence of the PAC is present; (2) provide information to determine to what degree this PAC is present, but undetected; (3) assure the sufficiency of the lateral and vertical extent of the data collection; and (4) evaluate the information presented in support of Items (1) and (2), with assumptions and analysis methods that adequately describe the presence (or absence) of the PAC and ranges of relevant parameters. The specific aspects of the license application on which the reviewer will focus are described 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) the results of site characterization studies, including laboratory and field measurements of the geomechanical and hydrologic properties of the repository block, as well as *in-situ* measurements, to show that the rock and groundwater conditions at the site have been adequately investigated and evaluated;
- (2) analyses showing that any engineering measures to be employed at the geologic repository are consistent with standard engineering practice and thus not considered to be "complex"¹; and
- (3) a conservative evaluation showing that the rock and groundwater conditions representative of the site and their effect on geologic repository design, construction, operation, and performance can be addressed by engineering measures, or compensated for by other favorable conditions.²

If these analyses and evaluations are not complete, the reviewer will have to assess their potential impacts with respect to this PAC.³ Modifications to the Review Strategy and the Review Methods may be needed. The nature of such modifications will have to be determined based on the judgment of the staff. If the assumptions are met, the review will proceed as outlined. Examples of the specific review activities include the following.

The reviewer should assess DOE's descriptions, laboratory and *in-situ* experiments, and analysis of rock conditions, as well as an evaluation of their predictability throughout the repository block, to ensure that the underground facility can be designed and constructed without compromising the performance

¹ For exploratory boreholes, the reviewer should determine if DOE has included a description of the condition of each borehole along with documentation regarding the nature and extent of any obstruction (e.g., collapsed borehole walls, previously existing seals, or unrecovered drilling equipment), the depth at which the obstruction occurs along with an estimation of its extent, and the difficulties, if any, expected in removing the obstruction and emplacing a seal.

² The review of how favorable conditions and other PACs, together with the engineered barrier system, contribute to meeting the performance objectives relating to the isolation of waste will be addressed in Section 3.2.5 ("Assessment of Compliance with Criteria for Combinations of Favorable Conditions and Potentially Adverse Conditions") of the license application and its attendant review plan.

³ It is possible that additional information may be needed to confirm repository designs or conditions, or evaluate alternatives to repository design. DOE should include a plan and a schedule for providing this information as part of its plan for design described in Chapter 4.0 ("Geologic Repository Operations Area") of the license application.

objectives. In addition, the reviewer should assess DOE's evaluation of the rock conditions on subsequent engineering measures to seal portions of the underground facility as well as shafts and ramps.

The reviewer should, in general, evaluate DOE's site characterization studies (DOE, 1988a) to determine the presence or absence of such features. If perched water zones are shown to be present, the reviewer should assess whether DOE can adequately account for them in the design and construction of the underground facility or that their effect can be compensated for by other favorable conditions so as to meet the performance objectives.

With regard to the placement of seals in exploratory boreholes, shafts, and ramps, it should be noted that the review of the design and an evaluation of their adequacy will be treated in Section 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps") and Chapter 6.0 ("Overall System Performance Assessment"), respectively, of the license application and its attendant review plans.

DOE will also need to provide an explanation of the measures used to support the analyses used to assess the need for complex engineering measures. Analyses and models that will be used to predict the need for complex engineering measures shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests that are representative of field conditions, monitoring data, and natural analog studies.

In conducting the aforementioned evaluations, the reviewer should determine whether DOE uses: (1) analyses that are sensitive to evidence of the PAC; and (2) assumptions which are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations regarding the need for complex engineering measures, both within the controlled area and outside the controlled area, as necessary, in the manner defined in 10 CFR 60.21(c)(1)(ii)(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's Office of Nuclear Regulatory Research, in addition to that provided by the DOE in its license application. The reviewer should be able to identify those variables that may significantly influence the final design and construction of the repository, and also identify the structures, systems, and components that might require research and development to confirm the adequacy of their designs, and reduce any uncertainty associated with their performance. 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 to ensure that this potentially adverse condition related to complex engineering measures in the design, construction, and sealing of the underground facility, as presented in the license application, is sufficient in scope and depth.

RATIONALE FOR REVIEW STRATEGY (OPTIONAL):

Not Applicable.

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APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(c)(20)

Type 3:

10 CFR 60.122(c)(20)

REFERENCES:

Fernandez, J.A. "Sealing Concepts and Design Approach," Presentation to the Nuclear Waste Technical Review Board Panel on Structural Geology and Geoengineering. November 12, 1991, Seattle, Washington, 18 p. [Unpublished; prepared by Sandia National Laboratories]

Jarrell, M.D., "Technology to seal Exploratory Boreholes," Presentation to the Nuclear Waste Technical Review Board Panel on Structural Geology and Geoengineering. November 12, 1991, Seattle, Washington, 15 p. [Unpublished; prepared by the IT Corporation.]

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research.

Nuclear Regulatory Commission, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada," Office of Nuclear Material Safety and Safeguards, NUREG-1347, August 1989.

U.S. Department of Energy, Chapter 8.3.1.2, "Geohydrology," in "Site Characterization Plan , Yucca Mountain Site, Nevada Research and Development Area," Office of Civilian Radioactive Waste Management, DOE/RW-0199, Vol. 4, Part B, December 1988a.

U.S. Department of Energy, Chapter 8.3.3, "Seal Program," in "Site Characterization Plan , Yucca Mountain Site, Nevada Research and Development Area," Office of Civilian Radioactive Waste Management, DOE/RW-0199, Vol. 6, Part B, December 1988b.