2/15

COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN No. 4.4 ASSESSMENT OF COMPLIANCE WITH DESIGN CRITERIA FOR THE UNDERGROUND FACILITY—PROGRESS REPORT

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3/15

CONTENTS

CONTENTS (Cont'd)

5/15

CONTENTS (Cont'd)

Section Page

6/15

CONTENTS (Cont'd)

COMPLIANCE DETERMINATION METHOD FOR REVIEW PLAN No. 4.4 ASSESSMENT OF COMPLIANCE WITH DESIGN CRITERIA FOR THE UNDERGROUND FACILITY—PROGRESS REPORT

3.2.24 Safety Review of 10 CFR 60.133(f)

The scope of this part of the Safety Review is focused on the design and analysis of the proposed excavation methods for the underground facility. The determination of compliance with 10 CFR 60.133(f) is based on the demonstration that the design of the underground facility incorporates excavation methods that will limit the potential for creating preferential pathways for groundwater to contact the waste packages or for radionuclides to migrate to the accessible environment by minimizing and controlling potential damage, fractures, and displacement around the openings. This section is concentrated on three methods of excavation: drill-and-blast, tunnel-boring machine (TBM), and roadheader. These methods are currently being considered by the U.S. Department of Energy (DOE) for developing the underground openings.

3.2.24.1 Review of Site Characteristics, Processes, and Events

The Nuclear Regulatory Commission (NRC) staff shall review the DOE designs to determine if the pertinent site characteristics are adequately and appropriately considered in the design and analysis of the excavation methods for the underground facility. This review shall be performed by considering site characteristics used in the DOE design. The relevant site characteristics include the following (the license application (LA) sections providing the source of the information are presented in brackets).

- Potential for perched water formation [3.2.2.12]
- Mechanical properties and hydrological conditions of the host rocks [3.1.2, 3.1.3, 3.2.1.14, 3.2.2.2, 3.2.2.4 and 3.2.3.2]
- Fractures and faults information [3.1.1]

3.2.24.2 Review of Design Basis, Requirements and Technical Specifications Relevant to Excavation Methods for the Underground Facility

For each type of excavation method, there probably are several combinations of excavation parameters that can limit the potential for damaging the surrounding rock mass. The design criteria for each set of excavation parameters (such as blasting parameters) depend largely on the geological and hydrological conditions at specific locations, the surrounding structures, and the size and shape of the opening to be excavated. As a result of changing geological and hydrological conditions, excavation parameters are likely to vary from one location to another. Some acceptance criteria given below are therefore intended to be general to allow for flexibility of the designs, to account for the intrinsic variability of the site, and to cover a wide range of the technical requirements and limitations of the specific locations and of the nearby engineering and geologic structures. The evaluation conducted by the reviewers shall be based mainly on their field experience in rock excavation and underground construction, and on their knowledge and skill in advanced geomechanics, particularly in rock fragmentation, tool-rock interaction, dynamic wave propagation, and fracture mechanics. The NRC staff shall review the design basis and design requirements for the excavation methods and parameters to determine if the following acceptance criteria are met.

8/15

- The relevant site characteristics data (e.g., mechanical properties of rock mass, intact rock, and discontinuities, inclusions, infiltration, perched water zones, moisture contents, *in situ* stresses, etc.) (West et al., 1981) are used in developing the design basis and excavation methods. For instance, the design and application of the excavation methods consider the intrinsic variability of the rock conditions (e.g., variations of the rock mass strength, intact strength, joint strength, joint intensity, joint stiffness, etc.). Local *in situ* stress states measured or calculated for the rock units are considered in the design and application of the excavation methods, for each orientation, geometry, and depth of the openings.

- The DOE describes how the technical specifications of the TBM are derived. These include, for example, type, arrangement, and configuration of cutters (e.g., disc, drag, and roller cutters); advance rate; thrust capacity; energy; stroke; rotation speed; weight; dimension; minimum turn radius; maneuverability; launch chamber dimension; and opening size range.

- The DOE describes how technical specifications of the roadheader machine(s) have been derived. These include, for example, number and length of cutting booms, cutting principles (i.e., ripping or milling), type of cutting picks, advance rate, thrust capacity, energy, pick cutting forces, rotation speed, weight, dimension, automatic or computer-controlled guidance system, and maneuverability.

- Justifications for technical specifications are focused on limiting the potential for damage (i.e., fracturing, failure, joint slip or separation, etc.) of the surrounding rock mass.

- The design and selection of TBM and roadheader and their cutting and boring parameters are supported by sufficient performance history and records, in terms of limiting the potential damage to the surrounding rock, in similar geological conditions.

- If drill-and-blast methods are used, the blasting scheme(s) include controlled blasting, line drilling, presplitting (preshearing), perimeter blasting, cushion blasting, and delay detonation.

- The proposed excavation methods provide for installation of rock supports and/or liners within the allowable standup period of the openings (if needed).

- The design requirements for the accuracy of blast-hole drilling are consistent with those suggested by Holmberg (1982).

- The blast design takes into consideration the impact of ground (blast) vibration on the nearby support systems, nearby fault zones, and surrounding rock. The blasting is designed such that the ground vibration (peak particle velocity) limits the impact on the performance and integrity of the previously installed support systems and does not induce movement of fault zones and surrounding rock mass. Calculations and measurement plans identify the characteristics of blasting vibration (i.e., ground motion, wavelength, peak particle velocity and frequency) (Dowding, 1992). The design allows for incorporation of the results of the previous blasting into the subsequent blast design.

- The proposed blasting cut designs [e.g., burn, wedge, fan, or drag designs (Whittaker and Frith, 1990)] are suitable for the rock conditions and for the size and shape of the opening to be excavated.

- Data from *in situ* assessment of damaged rock or permeability increase zones caused by the selected methods are used to adjust or modify the excavating parameters to decrease the rock damage for the subsequent excavations when appropriate. Methods for such *in situ* measurements are consistent with applicable industry standards, guidelines, and practices [e.g., ASTM D 4879 (1989) for fracture mapping, and ASTM D 4630 (1986) and ASTM D 4631 (1986) for *in situ* permeability measurements].

- Exploratory Studies Facility (ESF) construction experience is utilized for establishing the excavation parameters. For the TBM, these data are used to modify, where applicable, type, arrangement, and configuration of cutters, advance rate, stroke, thrust capacity, and rotation speed. For the roadheader, these data are used to modify type of cutting picks, advance rate, thrust capacity, energy pick force, and rotation speed.

- The proposed roadheader machine is equipped with an automatic guidance or computer-controlled system to minimize the overbreak and damage of the surrounding rock (Whittaker and Frith, 1990).

3.2.24.3 Review of Analyses, Design Processes, and Methodologies Relevant to Excavation Methods for Underground Facility

The staff shall review the design processes, methodologies, and calculations to determine if the following acceptance criteria are met.

- The design basis and design requirements identified in Subsection 3.2.24.2 are factored into the design processes, methodologies, and calculations of the excavation parameters.

- The design processes, methodologies, and calculations of the blasting parameters take into consideration the potential modes of failure including cracking, joint slipping, joint separation, fracture propagation, and overbreak rock zone. For the TBM and roadheader, the joint slipping and separation, and allowable standup period of the opening, are taken into consideration.

- Methods for calculation and/or numerical prediction of the stress redistribution for each step of sequential excavation (i.e., full face cutting and bench cutting) are consistent with the industry practices (e.g., Hoek and Brown, 1980).

- The DOE provides a detailed blasting procedure and calculation of charge, peak particle velocity, and energy for each type of opening. These details include, for example, diameter, length, orientation, spacing and number of fired holes and burn holes; layouts (vertical and horizontal cross sections) of blast holes with respect to the opening size and shape to be excavated; type, depth, and amount of charges, caps, and stemming; types and velocity of detonation; number of blast rounds; drilling methods; methods for loading charges and stemming; methods for firing; densities of explosives; powder factor and distribution; method(s) for primary rock supports; and method(s) for debris clearance. Detailed calculations for the proposed blast designs should be consistent with those developed by Langefors and Kihlstrom (1978) and Gregory (1973). Where applicable and appropriate, well established guidelines, industry practices, research results, and case studies are used in supporting the analyses of the drilling and blasting parameters. Potentially applicable literature includes, for example, Dowding and Aimone (1992), Dowding (1985), E.I. du

10/15

Pont de Nemours & Co. (1988), Dick et al. (1983), Langefors and Kihlstrom (1978), Atlas Powder Co. (1987), and Holmberg (1982).

- Where applicable and appropriate, well established guidelines, industry practices, research results, and case studies are used in supporting the calculations and analyses of the excavation parameters. Potentially applicable guidelines for selection and design of excavation parameters for openings in rock include those given by Whittaker and Frith (1990), McFeat-Smith (1982), Breeds and Conway (1992), Wahlstrom (1973), Megaw and Bartlett (1983), Bickel and Kuesel (1982), Hood and Roxborough (1992), and Brennan (1985). Potentially applicable literature for roadheader machine excavation include Farmer and Garritty (1987), Hurt et al. (1982), Kogelmann (1988), McFeat-Smith (1977), McFeat-Smith and Fowell (1977), and Sandback (1985). Potentially applicable literature on TBM excavation include Whittaker and Frith (1990), Howarth (1987), Lislerud (1988), Thon (1983), McFeat-Smith (1982; 1987), and Synder (1989).

3.2.24.4 Selected Focused Safety Review

The NRC staff shall perform focused reviews on representative design samples, calculations, and analyses to determine if the items of Subsections 3.2.22.1, 3.2.22.2, and 3.2.22.3 have been implemented properly. Specific acceptance criteria include, but may not be limited to, the following.

- Rock characteristics, hydrological conditions, faults and fractures information, and perched water formations were used appropriately to develop design basis and design requirements.
- Design bases and requirements are appropriately considered in the design processes, methodologies, and calculations of the excavation parameters.
- Input data for analyses and design calculation are consistent with those used to develop the design basis and design requirements.
- The design methods are correctly applied and calculations are carried out correctly, to include correct interpretation of design charts, curves, tables, etc.
- Interpretation of the analysis results is correct and conservative, and the results support the design and selection of excavation parameters for the underground openings.

3.3 Rationale for Review Procedures and Acceptance Criteria

3.3.24 Rationale for Safety Review of 10 CFR 60.133(f)

Design and operation of the drill-and-blast, TBM, and roadheader methods addressed in Section 3.2.24 have been well established in the underground mining and construction industry. The analyses and calculations of the excavation parameters identified by the acceptance criteria are consistent with the industry guidelines (West, 1988; Whittaker and Frith, 1990). Conservative use of these techniques will limit rock damage.

11/15

4.0 IMPLEMENTATION

4.1 Review Responsibilities

TBD.

4.2 Interfaces

4.2.1 Input Information

TBD.

4.2.2 Output Information

TBD.

12/15

5.0 EXAMPLE EVALUATION FINDINGS

5.2 Findings for Compliance Reviews

5.2.22 Finding for 10 CFR 60.133(f)

The NRC staff finds that the design, selection, and analysis of the proposed excavation methods have (have not) been acceptably described, and that there is (is not) reasonable assurance that 10 CFR 60.133(f) will be met for the design of the underground facility to incorporate excavation methods that
will limit the potential for creating preferential pathways for groundwater to contact the waste packages or for radionuclides to migrate to the accessible environment.

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