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U.S. DEPARTMENT OF ENERGY (DOE) REVIEW OF U.S. NUCLEAR REGULATORY COMMISSION'S (NRC) REPOSITORY DESIGN AND THERMAL-MECHANICAL EFFECTS ISSUE RESOLUTION STATUS REPORT, REVISION 2

DOE has reviewed Revision 2 of the Issue Resolution Status Report (IRSR) on the Key Technical Issue of Repository Design and Thermal-Mechanical Effects. The enclosed comments are directed primarily at the acceptance criteria for the subissues associated with repository design and thermal-mechanical effects and related discussions of the technical bases supporting those criteria.

In general, DOE agrees with the risk-informed performance-based approach that the NRC staff has adopted in its development of the proposed 10 CFR Part 63. However, we are concerned that some of the discussions in the subject IRSR contain implicit or explicit requirements beyond those in the acceptance criteria. A number of these requirements and some of the acceptance criteria themselves appear to be more prescriptive than is the intent of the performance-based proposed 10 CFR Part 63. They appear to remove the flexibility contained in the proposed regulation and are not linked clearly to repository performance. These concerns are discussed in our comments.

DOE appreciates the opportunity to review the IRSRs and provide comments for your consideration. The enclosure contains both technical and editorial/information comments. We request that our comments be considered in the preparation of the next revision of the IRSR.

If you or your staff have any questions regarding our comments, please contact Paul Harrington at (702) 794-5415 or Carol Hanlon at (702) 794-1324.

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OL&RC:DWK-0824

Enclosure:
Comments on Issue Resolution Status Report,
Revision 2 Key Technical Issue: Repository
Design and Thermal-Mechanical Effects

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Rec'd from
NMSS 1/23/02

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COMMENTS ON ISSUE RESOLUTION STATUS REPORT, REVISION 2, KEY TECHNICAL ISSUE: REPOSITORY DESIGN AND THERMAL-MECHANICAL EFFECTS

Comments

1. Section 4.3.3.1, Page 28, Acceptance Criterion 8: The acceptance criterion states:

   "Both drift- and repository-scale models of the underground facility are used in TM [Thermal Mechanical] analyses to establish the intensity and distribution of ground movement (rock deformations, collapse, and other changes that may affect the integrity or geometrical configuration of openings within the underground facility). The number and variety of models permit the examination of conditions along drift-parallel and drift-normal directions."

   DOE suggests the words "as needed consistent with the design concept" be added to the end of the first sentence of this criterion. This change would remove a mandate to develop repository-scale models if they are not needed. To date, DOE has not identified problems that require a full-scale repository model. IRSR Section 5.3.1.8 points out that DOE has not conducted repository-scale design calculations to establish the intensity and distribution of ground movement and synergistic effect on stability of the emplacement drifts in the area of high to low rock quality transition and has not performed bounding calculations to account for the potential effects. However, drift-scale models have been developed that represent the range of expected repository conditions, and modeling has been developed to examine limiting or bounding conditions (CRWMS M&O 1999a, Section 3.3). This issue was discussed during an Appendix 7 meeting on November 17 and 18, 1999, and the following points were made.

   a. Rock temperatures along the drift change so gradually that drift-parallel analyses are not needed (CRWMS M&O 1999a, Table I-7).

   b. For the new (very large) drift spacing, drift-scale analyses show that repository-scale analyses are not needed to capture effects normal to the drifts and are probably not needed to capture the effects of thermal loading sequence. (CRWMS M&O 1999a, Section 3.3)

   c. The design for the worst case rock properties can be extended through any transition of rock qualities so that repository-scale analyses will not be needed for the transition situation. (CRWMS M&O 2000, Section 4.1.6 and Tables 4-5a, 4-5b, and 6-2).

   DOE strategy is based on the premise that understanding rock mass behavior in the proximity of the openings provides vital information needed to interpret processes occurring around the openings and pillars separating adjacent openings (near-field phenomena). DOE considers that edge phenomena can be dealt with effectively by adjusting drift ventilation and the spacing of canisters, thus moderating the edge temperature effects (CRWMS M&O 1999b, Section 6.2 and Figures 4.1 and 6.4). Therefore, DOE has no current plans to develop repository-scale models. However, we will continue to evaluate the need for additional work in this and other areas as our knowledge about the site continues to increase. If the need arises, we will modify our plans accordingly.

DOE recommends that the criterion be reworded consistent with the idea that "drift-scale *and/or* [emphasis added] repository-scale models ...." Such wording would be consistent with the performance-based flexibility of proposed 10 CFR Part 63.

2. When NRC refers to analyses that it has conducted, more information on data inputs and assumptions would be valuable to assist DOE's understanding and evaluation of the results provided. For example:

   a. It would be helpful if Figure 16 of the IRSR (Page 68) and the text describing this figure contained or referenced a more complete listing of input parameters used (for example, inputs for joint strength and deformability). Access to the input parameter data would allow DOE to consider those data in future analyses of ground support.

   b. In the discussion of the Site-Scale Continuum Model on Pages 32 and 33, Item (1), a significant inelastic response is predicted in pillar centers due to using non-degraded Young's modulus with degraded strength parameters and stiff drift support. For most materials, Young's modulus decreases as strength decreases. Any data the NRC has indicating otherwise would be appreciated.

   c. Figure 4, Page 56, includes Curves Y3, F2, and C2, described as having *Q* values reduced to 10 % of the current values (in the descriptive material included as part of the Figure caption). This reduction is also discussed in the IRSR, Page 32. This means a *Q* of 4.1 would be reduced to 0.41. Such extreme reductions appear unusual. If data indicate that such reductions in Q could occur, DOE requests reference to or identification of the data for consideration in future analyses of ground support.

   d. Section 4.3.4.2, Page 40: The IRSR notes results from studies by the Center for Nuclear Waste Regulatory Analysis for rock masses that are "weaker and have a higher thermal expansion coefficient (Figures 13 and 14)." DOE requests that the strength and expansion coefficient data used by NRC be specified for DOE's consideration in future ground control analyses.

3. Section 4.3.3.2, Page 31, Paragraphs 2 and 3: The IRSR states that the rock mass friction angles predicted by DOE in *Confirmation of Empirical Design Methodologies* (IRSR Reference CRWMS M&O 1997a) are 57° and 58° . It notes an apparent conflict with the values predicted by NRC (28° to 35°) based on the method described in *Practical Estimates of Rock Mass Strength* (IRSR Reference Hoek and Brown 1997).

   DOE believes that its approach is consistent with the reference cited by the NRC and that the apparent discrepancy is due to the range of the confining pressures used for the curve-fit of the non-linear Hoek and Brown curve to the linear Mohr-Coulomb criterion. The source referenced by the NRC, *Practical Estimates of Rock Mass Strength* (IRSR Reference Hoek and Brown 1997), correctly identifies that "...for values of σ'_n of less than 5 MPa, the straight line, constant C' and ϕ' method overestimates the available shear strength of the rock mass by increasingly significant amounts as σ'_n approaches zero. Under such circumstances, it would be prudent to use values of C' and ϕ' based on the tangent to the shear strength curve in the range of σ'_n values applying in practice." In-situ stresses at Yucca Mountain are relatively low, in the range 1 to 3 MPa (SNL 1996). Radial stress is zero on the excavation surface and remains small in the vicinity of the excavation profile. The range of confining, or normal stresses, is in the lower non-linear portion of the Mohr-Coulomb failure envelope. DOE utilizes practices recommended by Hoek and Brown 1997, whereby stability analyses typically use a low cohesion and moderately high friction angle.

DOE suggests that utilizing low ϕ, as predicted by the NRC may result in a design that is excessively conservative. DOE believes that using a lower range of normal stress is appropriate (see Figure 1), and friction angles of 57° to 58° are considered more representative of actual conditions observed in the Exploratory Studies Facility and Enhanced Characterization of the Repository Block Cross Drift where the rock mass cohesion of the TSw2 geologic unit is in the range of 1.9 to 3.9 MPa. Figure 1, below, identifies a single tangent point or solution for the low stress range of σ_1 – vs – σ_3 values (where σ_1 and σ_3 are maximum and minimum principal stresses) calculated using the Hoek-Brown failure criterion (e.g., IRSR references Hoek, 1994; Hoek and Brown, 1997). Multiple tangents are used to determine the range of c and ϕ that best describes the linear fit for this section of the curve. Based on tests conducted on core specimens collected from boreholes along the alignment of the ESF North Ramp and Main Drift, the friction angles ranged from 46 to 58° (IRSR reference CRWMS M&O, 1997h, Table 5-32).

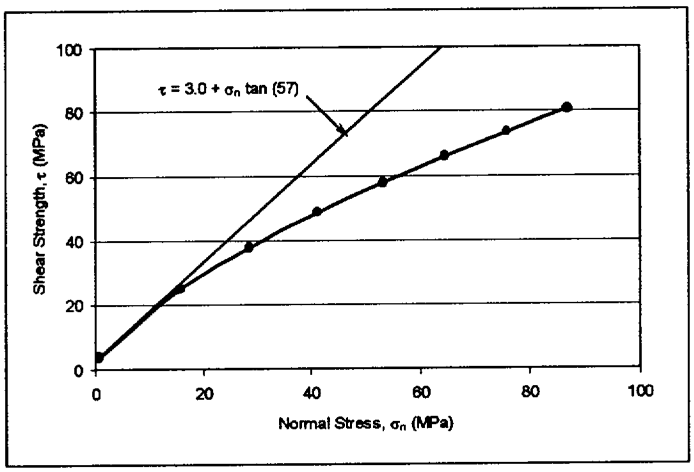

Figure 1. Shear Strength Curve Based on the Hoek and Brown (1997) Approach (GSI=62, σ_{ci}=167.9 MPa, m_i=19.68)

Based on the discussion provided above, DOE recommends that the current IRSR narrative discussion (Section 4.3.3.2, Page 31, Paragraphs 2 and 3) be replaced with the following:

> The values for the rock-mass strength parameters c and ϕ currently proposed for YM (CRWMS M&O, 1997a) were estimated by fitting straight lines to sets of σ_1 – vs – σ_3 values (where σ_1 and σ_3 are maximum and minimum principal stresses) calculated using the Hoek-Brown failure criterion (e.g., Hoek, 1994; Hoek and Brown, 1997).
>
> The procedure presented by Hoek and Brown (1997) for estimating c and ϕ is based on the GSI index. The values of this index can be determined through geologic mapping of the rock mass following guidelines described by Hoek and Brown (1997) or estimated through correlations with Q or RMR. The values of c and ϕ obtained using this procedure (Ofoegbu, 1999) with the TSw2 section of the ESF Q data (Figure 2) are given as functions of Q in Figure 4. The figure shows ϕ varying from about 28° to about 35° as Q varies from about 0.73 to about 13.6. These values of ϕ are much smaller than the DOE values presented previously. The difference between the CRWMS M&O (1997a) ϕ values of 57-58°and the values in Figure 4 (28-35°) for the same range of Q values is quite significant in

predicting the mechanical behavior of the rock mass in the vicinity of the proposed waste-emplacement openings (e.g., see the numerical-model results discussed presently).

The practice of using values of c and ϕ based on the tangent to the shear strength curve in the range of normal stress values is recommended by Hoek and Brown (1997) because of the low normal, or radial stress around the opening. The range of radial stresses around the opening is in the lower non-linear portion of the Mohr-Coulomb failure envelope, where the method of using a constant c and ϕ from the broader range of normal stresses overestimates the available shear strength of the rock mass at the vicinity of the tunnel opening. Friction angles of 57 to 58° are considered to be more representative of actual conditions observed in the Exploratory Studies Facility and Enhanced Characterization of the Repository Block Cross Drift, where the rock mass cohesion of the TSw2 geologic unit is calculated in the range of 1.9 to 3.9 MPa.

4. Section 4.3.4.2, Page 46, Failure Criterion: The IRSR appears to be excessively conservative. It states, "If the impact stress calculated using Eq. (6) induces a total strain at the contact of impact exceeding 2-percent (Timoshenko, 1956), the WPs [waste packages] are assumed to be ruptured. This assumption should provide a conservative approach for estimating failure of WPs." The cited reference (IRSR Reference Timoshenko 1956) provides this information for mild steel in order to give an example for the behavior of ductile materials after the yield limit is exceeded. The subject source does not indicate failure at 2% strain for mild steels.

   More extensive research in literature of mild (low-carbon) steel shows that a typical range of minimum ductility is 23% to 30% elongation in a 50 mm specimen (ASMI 1990, Page 389). The current waste package outer shell material is Alloy 22, which has 45% elongation before failure (ASTM 1998). Therefore, DOE believes that the 2% strain assumption is extremely conservative, and this failure criterion is inappropriate for the existing waste package design. DOE suggests that NRC reconsider this failure criterion and that the IRSR be revised accordingly.

5. Section 4.3.4.2, Page 44, Impact Load and Stress Calculations: The IRSR outlines a method of calculation for predicting impact loads and stress calculations on waste packages that appears to be excessively conservative. The report states, "...(ii) the deformation of waste packages is directly proportional to the magnitude of the dynamically applied force." The approach to the solution of impact loads on the waste package should address three different sources of nonlinearities: (a) contact between the impacting object and the waste package outer shell, (b) geometric nonlinearities due to large deformations, and (c) material nonlinearities due to change in the slope of the curve in the stress-strain diagram. DOE considers the finite element method to be the appropriate way of handling these nonlinearities based on state of the art engineering solutions.

   Commercially available finite element codes have the capability of solving nonlinear problems by making use of "contact elements" for the first type of nonlinearities described above. They also include Newton-Raphson time integration method, in which the stiffness matrix is updated at every equilibrium iteration in order to account for the change in geometry and subsequent change in stiffness. Finally, stress-strain curves can be explicitly defined in order to account for the nonlinear behavior of materials.

Therefore, DOE suggests that the IRSR reconsider the approach used by DOE as more appropriate for a prediction of impact loads and stress calculations on the waste package shell.

Editorial / Information Comments

1. Section 3.2.1, Page 6, Paragraph 2: The IRSR states that new administrative procedures are being developed to replace the existing QAP procedures. The replacement procedures were implemented in June 1999.

2. Section 4.3.3.2: In reference to the statements in the IRSR of uncertain behavior of heated concrete (Pages 35 through 37) and most specifically related to the discussion of degradation in the form of creep-induced cracking (Page 36), it should be noted that, after two years of heating concrete lining in the drift scale test, no cracking or deformation has been detected at temperatures of about 180°C. Monitoring is continuing. (See Comment 4, below).

3. Section 4.3.3.2: The discussion in the IRSR, Section 4.3.3.2 (Pages 32 and 33), is not applicable to DOE's current repository design concepts. The current concepts are based on thermal criteria that restrict intermediate pillar temperatures to sub-boiling so that no more than 50 % of a pillar is ever above boiling. This will be achieved by waste blending to maintain a reduced line load and by increasing the center-to-center pillar dimension from 28m to 81m.

4. Section 4.3.3.2, Page 35: The discussion on "Temperature and Time Effects on Concrete" has been substantially affected by current repository design concepts that eliminate use of concrete liners and invert structures. These concepts also limit the use of cementitious materials in the emplacement drifts to rockbolt grout. This effectively reduces the volume of concrete/grout previously estimated by a factor of 25.

5. Section 4.3.4.2, Page 40, Possibility of Simultaneous Rockfall and Vertical Extent of Potential Rockfall: In the IRSR, a 100 MTU/acre thermal loading density is referenced as basis for Figures 11 and 12. DOE's current thermal loading density is planned to be 60 MTU/acre or less.

6. Section 4.1.5.2, Page 20, Acceptance Criterion 12: The IRSR expresses the concern and states that "This indication that the design uses the earlier assumption...shows a potential loss of control with respect to changes in, and evaluation of, design inputs." DOE provides the following update related to actions taken to address the NRC's concerns regarding control of changes to an original design and proper documentation of such changes.

   S. Brocoum letter to C. William Reamer of August 10, 1999, provided information identifying action, taken to date related to the concern. The assessment (Self-Assessment Report SA-R&L/EA-99-003) identified in that letter has since been completed and identified additional examples of similar problems. Deficiency Report LVMO-00-D-010 was issued identifying the problem and assuring that it is addressed under the corrective action program. The deficiency report is pending implementation of corrective action.

References

ASMI (ASM International) 1990. Metals Handbook Tenth Edition, Volume 1, *Properties and Selection: Irons, Steels, and High-Performance Alloys*. Materials Park, Ohio: ASM International. TIC: 241248

ASTM (American Society for Testing and Materials) 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip*. ASTM B575-97. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816

CRWMS (Civilian Radioactive Waste Management System) M&O (Management and Operating Contractor) 1997. *Yucca Mountain Site Geotechnical Report*. B00000000-01717-5705-00043 REV 01. Las Vegas, Nevada: CRWMS M&O. ACCs: MOL.19971017.0736 and MOL.19971017.0737.

SNL (Sandia National Laboratory) 1996. *Hydraulic Fracturing Stress Measurements in Test Hole ESF-AOD-HDFR#1, Thermal Test Facility, Exploratory Studies Facility at Yucca Mountain.* Albuquerque, New Mexico: SNL. TDIF: 305878. DTN: SNF37100195002.001. ACC: MOL.19970717.0008.